US Army Corps
of Engineers ®
Galveston District

Appendix C

Magnuson-Stevens Fishery Conservation and Management Act Compliance

(Essential Fish Habitat Assessment)

for

Coastal Texas Protection and Restoration Study

October 2020

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

October 2020

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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
HSC	Houston Ship Channel
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 Refuges
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

Congress enacted amendments to the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (PL 94-265) in 1996 that established procedures for identifying essential fish habitat (EFH) and required interagency coordination to further the conservation of federally managed fisheries. Rules published by the National Marine Fisheries Service (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 abovementioned act and identifies consultation requirements.

In accordance with the MSFCMA and NMFS consultation guidelines, this EFH assessment has been prepared to document the effects of the recommended plan on EFH. The level of detail in this EFH assessment is commensurate with the complexity and magnitude of the potential adverse effects of the recommended plan considering the available information at the time of preparation of this assessment. Additional consultation with NMFS will occur once more detailed designs are available, as described further in section 1.1 of this assessment.

1.1 PROJECT BACKGROUND

The Coastal Texas Protection and Restoration Study (the Study) Draft Feasibility Report and Environmental Impact Statement (DFR &EIS) is examining coastal storm risk management (CSRM) and ecosystem restoration (ER) opportunities within 18 counties of the Texas Gulf coast (Figure 1). The study area consists of the entire Texas Gulf Coast from the Sabine River to the Rio Grande, and includes the Gulf and tidal waters, barrier islands, estuaries, coastal wetlands, river and streams and adjacent areas that make up the interrelated ecosystem along the coast. Along the Texas coast, vital resources critical to the economic and environmental welfare of the Nation are at risk from coastal storm damage. Without a comprehensive plan to protect, restore, and maintain a robust coastal ecosystem and reduce the risks of storm damage to industries and businesses critical to the Nation’s economy and security, the area will continue to be at risk from coastal storms. The health and safety of Texas coastal communities will also continue to suffer without a comprehensive plan. Therefore this Study seeks to develop a comprehensive plan along the Texas coast to protect the coast from coastal erosion, relative sea level rise (RSLR), coastal storm surge, habitat loss, and water quality degradation.

Figure 1. Coastal Texas Study Area

Currently, the Coastal Texas Study has completed the Agency Decision Milestone (ADM) meeting phase of the USACE Specific, Measurable, Attainable, Risk Informed, Timely (SMART) Civil Works planning process, where a plan has been recommended by the USACE vertical chain of command. At this stage of the planning, the major components of the plan have been identified and evaluated at a higher level of analysis. 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 RP, 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 location 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 RP, it is anticipated that the design of proposed structures will result in equal or lesser environmental impacts.

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 an

EIS to determine the feasibility of implementing the Coastal Texas Study. Because of the uncertainty and complexity of a number of the potential solutions to the problems, the Study employs a tiered NEPA compliance approach, in accordance with the Council on Environmental Quality's (CEQ's) Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR 1500—1508, specifically 1502.20). Under this structure, rather than preparing a single definitive EIS as the basis for approving the entire project, the USACE will conduct two or more rounds – or "tiers" – of environmental review. For projects as large and complex as the Study, this approach has been found to better support disclosure of potential environmental impacts for the entire project at the initial phase. Subsequent NEPA documents are then able to present more thorough assessments of impacts and mitigation need as the proposed solutions are refined and more detailed information becomes available in future phases of the project. This tiered approach also provides for a timely response to issues that arise from specific, proposed actions and supports forward progress toward completion of the overall study.

A Tier One assessment analyzes the project on a broad scale, while taking into account the full range of potential effects to both the human and natural environments from potentially implementing proposed solutions. The purpose of the Tier One EIS is to present the information considered to selected a preferred alternative, describe the comprehensive list of measures, and identify data gaps and future plans to supplement the data needed to better understand the direct, indirect, and cumulative effects of the proposed solutions.

Once refinements and additional information is gathered, USACE will shift to a Tier Two assessment, which involves preparation of one or more additional NEPA documents (either an EIS or Environmental Assessment) that build off the original EIS to examine individual components of the Recommended Plan in greater detail. Whether an EIS or EA is developed will be dependent on the significance of impacts anticipated from the action. In either situation, Tier Two assessments will comply with CEQ Regulations, including providing for additional public review periods and resource agency coordination. The Tier Two document would disclose site specific impacts to the proposed solution and identify the avoidance, minimization, and compensatory mitigation efforts to lessen adverse effects.

1.2 RECOMMENDED PLAN

The Recommended Plan includes a combination of ER and CSRM features that function as a system to reduce the risk of coastal storm damages to natural and built infrastructure and to restore degraded coastal ecosystems through a comprehensive approach employing multiple lines of defense. Focused on redundancy and robustness, the proposed system provides increased resiliency along the Bay and is adaptable to future conditions, including relative sea level change. The Recommended Plan can be broken into three groupings: a Coastwide ER plan, a lower Texas coast CSRM plan, and an upper Texas coast CSRM plan.

Coastwide ER Plan: A Coastwide ER plan was formulated to restore degraded ecosystems that buffer communities and industry on the Texas coast from erosion, subsidence, and storm losses. A variety of measures have been developed for the study area, including construction of breakwaters, marsh restoration, island restoration, oyster reef restoration and creation, dune and beach restoration, and hydrologic reconnections. Figure 2 shows the location of the ER measures and the following describes what each measure includes:

- Bolivar Peninsula and West Bay Gulf Intracoastal Waterway (GIWW) Shoreline and Island Protection (G-28):
    - Shoreline protection and restoration through the nourishment of 664 acres of eroding and degrading marshes and construction of 40.4 miles of breakwaters along unprotected segments of the GIWW on Bolivar Peninsula and along the north shore of West Bay,
    - Restoration of 326 acres (approximately 5 miles) of an island that protected the GIWW and mainland in West Bay, and
    - Addition of oyster cultch to encourage creation of 18.0 acres (26,280 linear feet) oyster reef on the bayside of the restored island in West Bay.
- Follets Island Gulf Beach and Dune Restoration (B-2)
    - Restoration of 10.1 miles (1,113.8 acres) of beach and dune complex on Gulf shorelines of Follets Island in Brazoria County.
- West Bay and Brazoria GIWW Shoreline Protection (B-12)
    - Shoreline protection and restoration through nourishment of 551 acres of eroding and degrading marshes and construction of about 40 miles breakwaters along unprotected segments of the GIWW in Brazoria County,
    - Construction of about 3.2 miles of rock breakwaters along western shorelines of West Bay and Cow Trap lakes, and
    - Addition of oyster cultch to encourage creation of 3,708 linear feet of oyster reef along the eastern shorelines of Oyster Lake.
- East Matagorda Bay Shoreline Protection (M-8)
    - Shoreline protection and restoration through the nourishment 236.5 acres of eroding and degrading marshes and construction of 12.4 miles of breakwaters along unprotected segments of the GIWW near Big Boggy National Wildlife Refuge (NWR) and eastward to the end of East Matagorda Bay,
    - Restoration of 96 acres (3.5 miles) of island that protects shorelines directly in front of Big Boggy NWR, and

  - Addition of oyster cultch to encourage creation of 3.7 miles of oyster reef along the bayside shorelines of the restored island.
- Keller Bay Restoration (CA-5)
  - Construction of 3.8 miles of rock breakwaters along the shorelines of Keller Bay in order to protect submerged aquatic vegetation (SAV), and
  - Construction of 2.3 miles of oyster reef along the western shorelines of Sand Point in Lavaca Bay by installation of reef balls in nearshore waters.
- Powderhorn Shoreline Protection and Wetland Restoration (CA-6)
  - Shoreline protection and restoration through the nourishment of 529 acres of eroding and degrading marshes and construction of 5.0 miles of breakwaters along shorelines fronting portions of Indianola, the Powderhorn Lake estuary, and Texas Parks and Wildlife Department (TPWD) Powderhorn Ranch.
- Redfish Bay Protection and Enhancement (SP-1)
  - Construction of 7.4 miles of rock breakwaters along the unprotected segments of the GIWW along the backside of Redfish Bay and on the bayside of the restored islands
  - Restoration of 391.4 acres of islands including Dagger, Ransom, and Stedman islands in Redfish Bay, and
  - Addition of oyster cultch to encourage creation of 1.4 miles of oyster reef between the breakwaters and island complex to allow for additional protection of the Redfish Bay Complex and SAV.
- W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration
  - Restoration of the hydrologic connection between Brazos Santiago Pass and the Port Mansfield Channel by dredging 6.9 miles of the Port Mansfield Channel, providing 112,864.1 acres of hydrologic restoration in the Lower Laguna Madre,
  - 9.5 miles of beach nourishment along the Gulf shoreline north of the Port Mansfield Channel using beach quality sand from the dredging of Port Mansfield Channel, and
  - Protection and restoration of Mansfield Island with construction of a 0.7 mile rock breakwater and placement of sediment from the Port Mansfield Channel to create 27.8 acres of island surface at an elevation of 7.5 feet (NAVD 88).

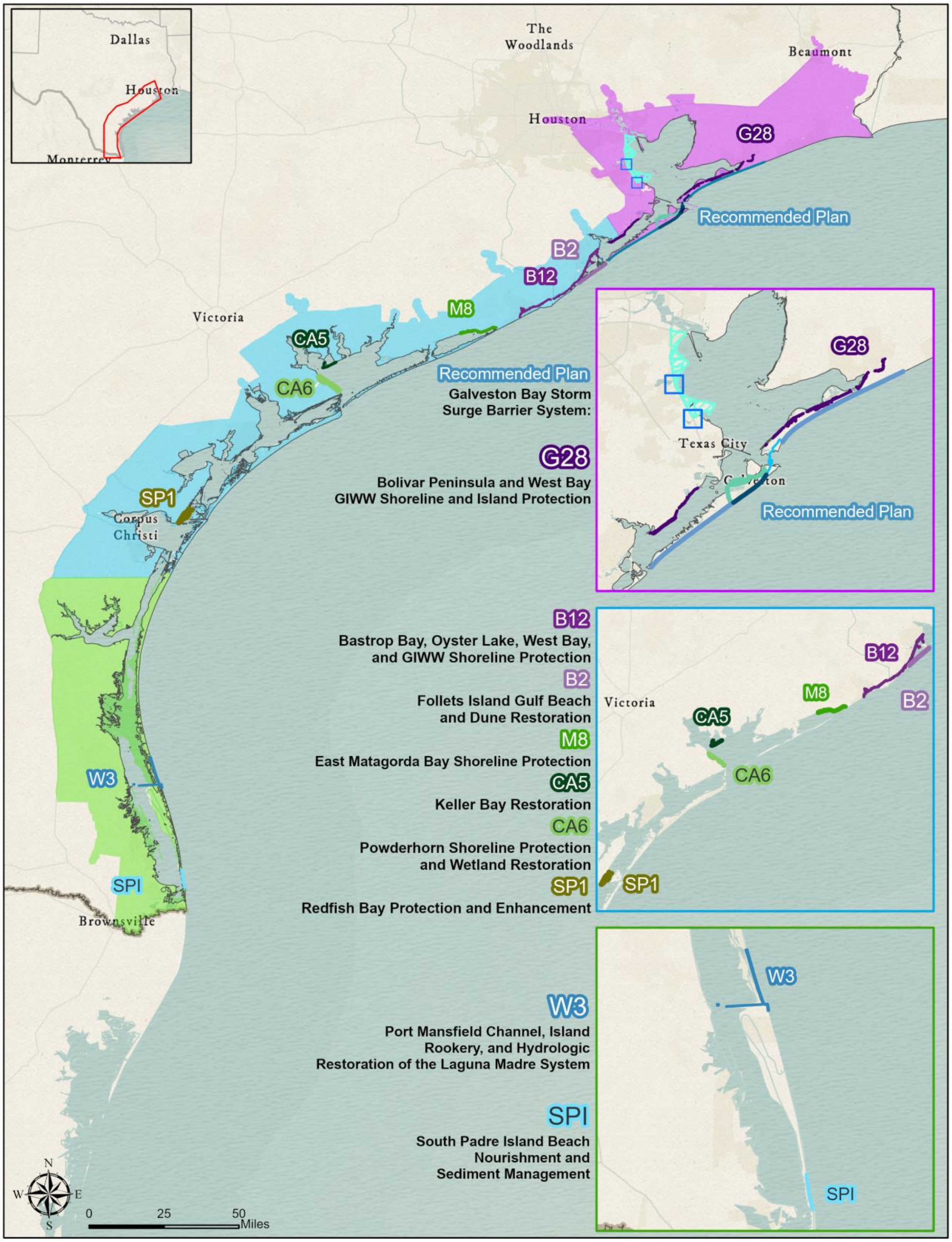

Figure 2. Coastwide ER Measures of the Recommended Plan

Lower Texas Coast Plan: The lower Texas coast component of the recommended plan includes 2.9 miles of beach nourishment at South Padre Island to be completed on a 10-year cycle for the authorized project life of 50 years (Figure 3).

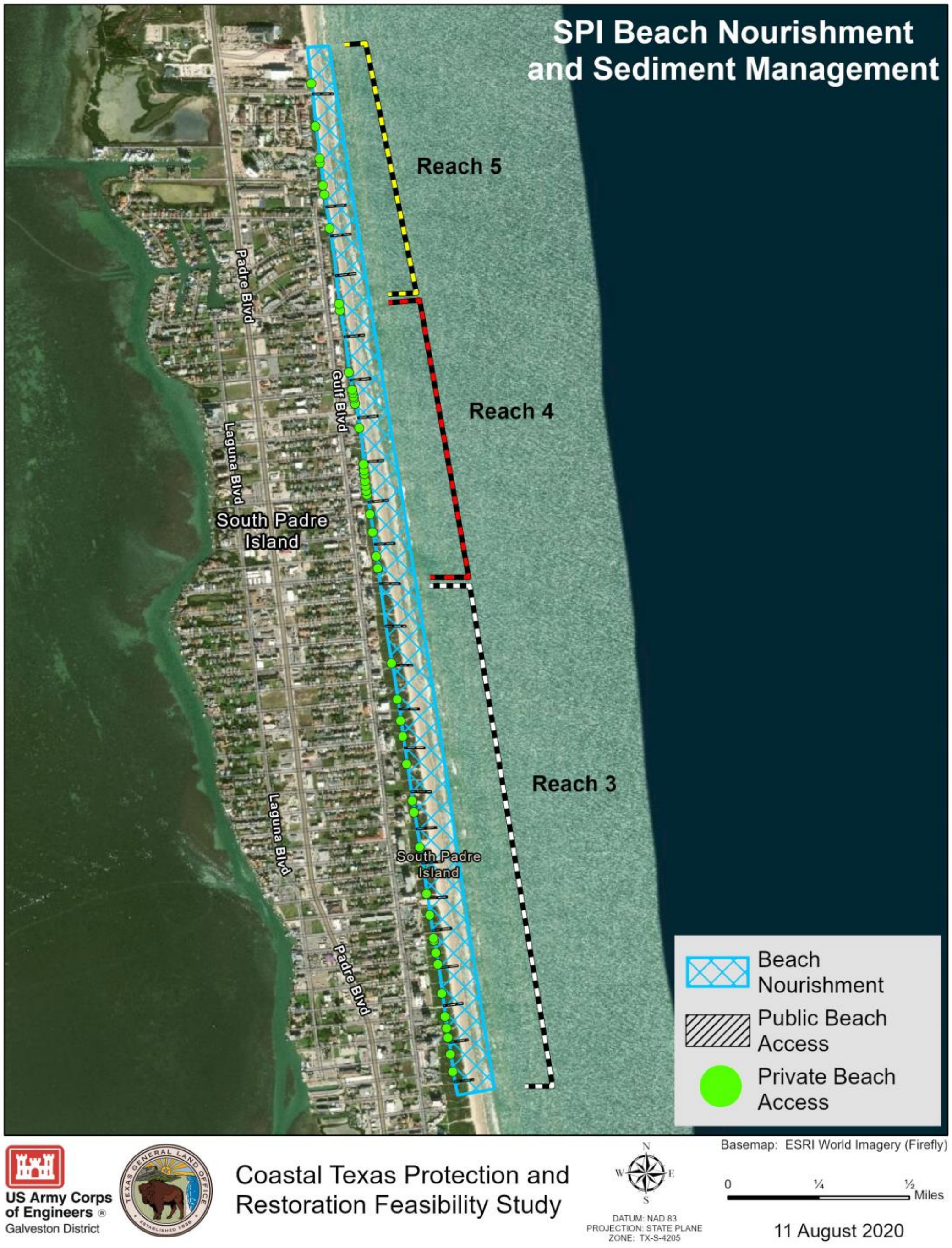

Figure 3.South Padre Island CSRM

Upper Texas Coast Plan: The upper Texas coast component of the recommended plan includes a multiple-lines-of-defense system known as the Galveston Bay Storm Surge Barrier System. The system is designed to provide a resilient, redundant, and robust solution to reduce risks to communities, industry, and natural ecosystems from coastal storm surge. The system includes a Gulf line of defense which separates the Galveston Bay system from the Gulf of Mexico to reduce storm surge volumes entering the Bay system. It also includes Bay defenses which enable the system to manage residual risk from waters already in Galveston Bay. Figure 4 shows the spatial relationship between the Gulf and Bay lines of defense. Measures which make up the system include:

- The Bolivar Roads Gate System, across the entrance to the Houston Ship Channel, between Bolivar Peninsula and Galveston Island (Figure 5);
- 43 miles of beach and dune improvements on Bolivar Peninsula and West Galveston Island that work with the Bolivar Roads Gate System to form a continuous line of defense against Gulf of Mexico surge, preventing or reducing storm surge volumes that would enter the Bay system (Figure 5);
- Improvements to the existing 10-mile Seawall on Galveston Island to complete the continuous line of defense against Gulf surge (Figure 5);
- An 15.8-mile Galveston Ring Barrier System (GRBS) that impedes Bay waters from flooding neighborhoods, businesses, and critical health facilities within the City of Galveston;
- 2 surge gates on the west perimeter of Galveston Bay (at Clear Lake and Dickinson Bay) that reduce surge volumes that push into neighborhoods around the critical industrial facilities that line Galveston Bay; and
- Complementary nonstructural measures, such as home elevations or floodproofing, to further reduce Bay-surge risks along the western perimeter of Galveston Bay.

Within the recommended plan, it has been determined that several features, identified as “actionable” measures, have a sufficient level of site-specific detail to fully understand the context and intensity of the anticipated impacts of the feature. Therefore, the EIS has incorporated a site-specific Tier Two analysis for some features for which the measures would be fully compliant with NEPA and all environmental laws and regulations, including MSFCMA. Feature identified as “Tier One” measures will require separate independent NEPA analysis at which time additional EFH consultation would occur to ensure full compliance with MSFCMA once the impacts are fully understood. Table 1 shows which measures are actionable and which are not.

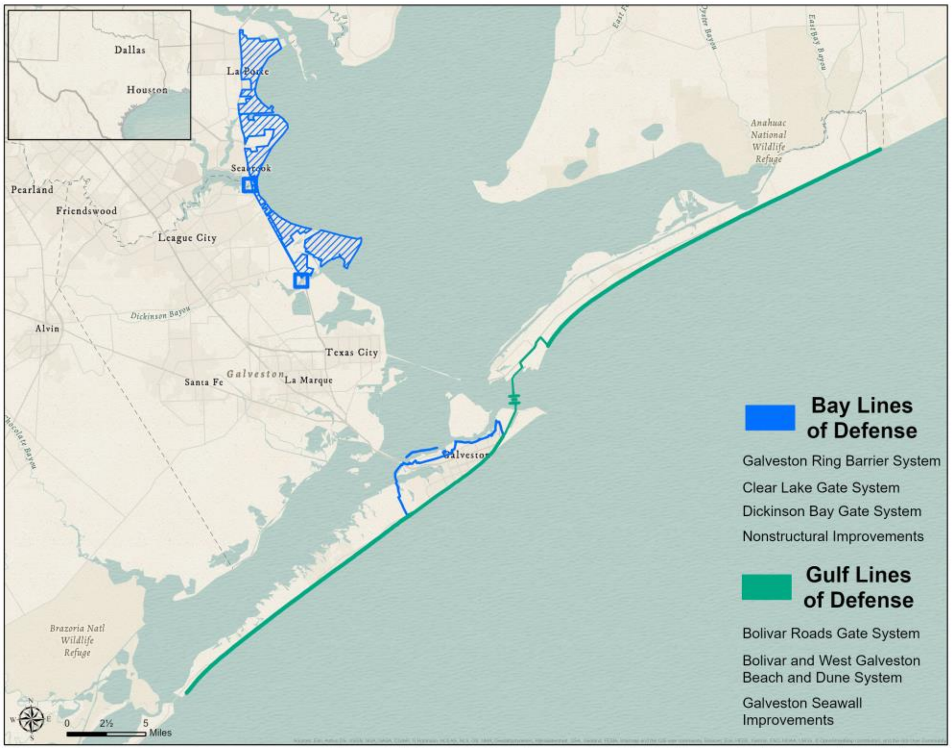

Figure 4. Galveston Bay Storm Surge Barrier System

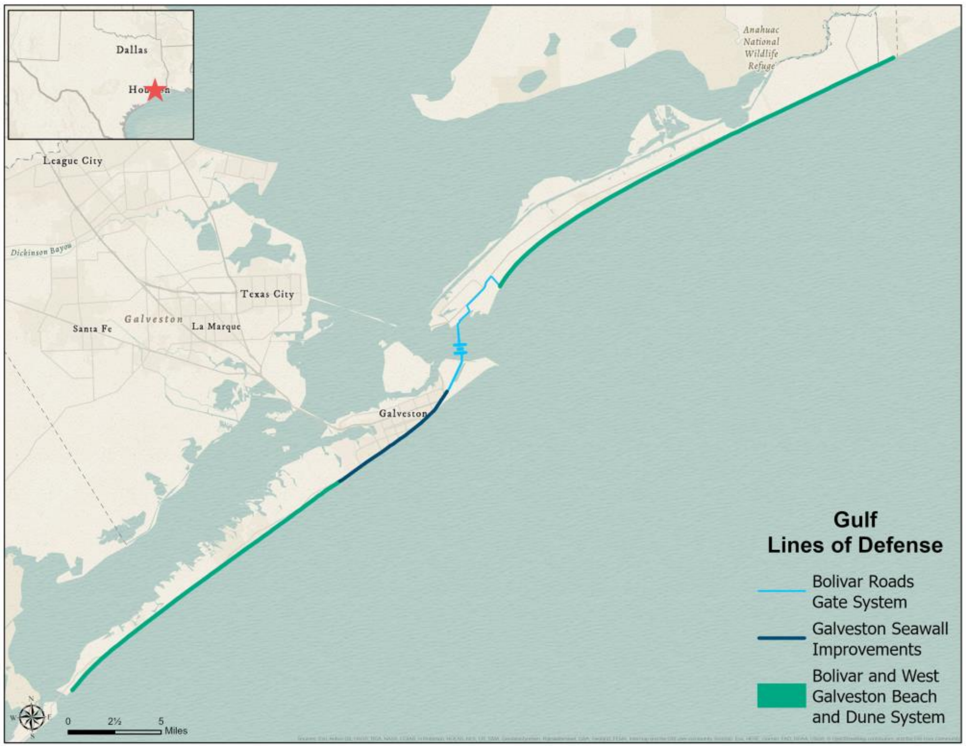

Figure 5. Gulf Lines of Defense of the Galveston Bay Storm Surge Barrier System

Table 1. Actionable and Tier One Measures of the Recommended Plan

Recommended Plan Component	**Actionable**[*]	**Tier One**[+]
G-28 – Bolivar Peninsula and West Bay GIWW Shoreline and Island Protection	X	
B-2 – Follets Island Gulf Beach and Dune Restoration		X
B-12 – West Bay and Brazoria GIWW Shoreline Protection	X	
CA-5 – Keller Bay Restoration	X	
CA-6 – Powderhorn Shoreline Protection and Wetland Restoration	X	
M-8 – East Matagorda Bay Shoreline Protection	X	
SP-1 – Redfish Bay Protection and Enhancement	X	
W-3 – Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	X	
South Padre Island Beach Nourishment	X	
Bolivar Roads Gate System		X
Bolivar and West Galveston Beach and Dune System		X
Galveston Seawall Improvements		X
Galveston Ring Barrier System		X
Clear Lake Surge Gate		X
Dickinson Surge Gate		X
Non-structural Measures		X

[*] Tier 2 NEPA, no additional EFH consultation anticipated

[+] Tier 1 NEPA, Requires additional NEPA and MSFCMA Consultation

2.0 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).

2.1 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. 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.

2.1.1 Recreational and Commercial Fisheries

Table 2 provides a list of representative commercial and recreational fish species 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 2. Representative Recreational and Commercial Fish and Shellfish Species Known to Occur in the Project Areas

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

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

[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 2.2, is provided in the following sections. Table 3 provides the life stage relative abundance of these species. These estuarine-dependent species serve as prey for other fisheries managed under the GMFMC.

Table 3. Life Stage Relative Abundance of Representative Recreational and Commercial Shellfish in the Project Areas

Species	Bay System with Project Area Locations				
	Galveston Bay	**Brazos River**	**Matagorda Bay**	**Corpus Christi Bay**	**Laguna Madre**
Eastern oyster	all life stages abundant to highly abundant year-round	N/D	all life stages common year-round	all life stages common year-round	rare
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	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	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
	year-round				
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

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) provides growth rates 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.

Oysters can filter water 1,500 times the volume of their body per hour, which in turn influences water clarity and phytoplankton abundance (Powell et al., 1992a; Lester and Gonzalez, 2011). 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 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 (Pattillo et al., 1997; Lassuy, 1983a). 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) (Pattillo et al., 1997; Nelson et al., 1992).

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 is 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 (Pattillo et al., 1997; Lee et al., 1980). Juveniles begin leaving seagrass in late summer, congregating with adults around nearshore reefs as they mature (Pattillo et al., 1997; Jennings, 1985). Adults also use oyster reefs, shallow muddy bottoms, marshes, piers and rocks, and over 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 seagrass (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. Juvenile spotted seatrout feed on zooplankton as larvae, 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 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 (Pattillo et al., 1997; Lassuy, 1983b). Adults have seasonal migrations moving between estuarine waters typically in the summer and 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) (Pattillo et al., 1997; Nelson et al., 1992). 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) (Pattillo et al., 1997; Nelson et al., 1992). Larval black drum occurs 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, mud, and oyster reefs year-round (Pattillo et al., 1997; Sutter et al., 1986; Nelson et al., 1992).

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 (Pattillo et al., 1997; Daniels, 2000). 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 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 (Pattillo et al., 1997; Reagan and Wingo, 1985; Nelson et al., 1992). Within the project areas, Southern Flounder may occur in the tidally influenced emergent wetlands and within or adjacent to open-water areas.

2.2 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 4 lists the species that NMFS and the GMFMC identify in the study project area as having 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. Additionally, portions of the study area are in marine waters and include the marine water column and unconsolidated marine water bottoms.

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 are 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 4. Species Identified with 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
Bignose Shark	*Carcharhinus altimus*	X		
Whale Shark	*Rhincodon typus*	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

Common Name*	**Species Name***	**Coastal Region**		
		Upper	**Mid**	**Lower**
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
Swordfish	*Xiphius gladius*	X		
Blue marlin	*Makaira nigricans*			X
Atlantic yellowfin tuna	*Thunnus albacares*	X		

Source: NMFS (2009); NOAA (2013, 2016).

* Species according to Page et al. (2013).

2.2.1 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). 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

Table 5. Species Adult and Juvenile Presence the Project Area for Essential Fish Habitat

Common/Scientific Name*	**Galveston Bay**		**Brazos River**		**Matagorda Bay**		**Corpus Christi/ Upper Laguna Madre**		**Lower Laguna Madre**		**Marine**	
	Juvenile	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**
Brown shrimp (*Farfantepenaeus aztecus*)	abundant year-round major nursery area	common Apr–Oct	not present		common to highly abundant year-round major nursery area	common to highly abundant Apr–July	not present		not present		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	not present		not present		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 rare to not present Dec–Jan nursery area	abundant March common Apr–June, Aug–Nov	not present		not present		not present	present year-round spawning March–October
Blacknose shark (Carcharhinus acronotus)	not present		not present		not 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*)	present	not present	not present		present	not present	not present		not present		present	
Silky shark (*Carcharhinus falciformis*)	not present		not present		not present		not present		present		present	
Finetooth shark (*Carcharhinus isodon*)	not present		not present		not present		not present		not present		present	
Bull shark (*Carcharhinus leucas*)	common Mar–Nov	not present	present		present	not present	not present		not present		present	
Blacktip shark (*Carcharhinus limbatus*)	present	not present	not present		present	not present	not present		not present		present	

Common/Scientific Name*	**Galveston Bay**		**Brazos River**		**Matagorda Bay**		**Corpus Christi/ Upper Laguna Madre**		**Lower Laguna Madre**		**Marine**	
	Juvenile	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**
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	
Lemon shark (*Negaprion brevirostris*)	not present	present	not present		present		not present		not present		present	
Atlantic sharpnose shark (Rhizoprionodon terraenovae)	present		not present		present		not present		not present		present	
Scalloped hammerhead shark (*Sphyrna lewini*)	present	not present	not present		present	not present	not present		not present		present	
Great hammerhead shark (*Sphyrna mokarran*)	not present		not present		not present		not present		not present		present	
Bonnethead shark (*Sphyrna tiburo*)	present	not present	not present		present		not present		not present		present	
Bignose shark (*Carcharhinus altimus*)	not present		not present		not present		not present		not present		not present	present
Whale shark (*Rhincodon typus*)	not present		not present		not present		not present		not present		not present	present
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		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

Common/Scientific Name*	**Galveston Bay**		**Brazos River**		**Matagorda Bay**		**Corpus Christi/ Upper Laguna Madre**		**Lower Laguna Madre**		**Marine**	
	Juvenile	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**
Dolphin (*Coryphaena hippurus*)	not present		not present		not present		not present		not present		present year-round	
Greater amberjack (*Seriola dumerili*)	not present		not present		not present		not present		not present		present year-round	adult and spawning area year-round
Lesser amberjack (*Seriola fasciata*)	not present		not present		not present		not present		not present		not present	present
Red snapper (*Lutjanus campechanus*)	nursery area year-round	not present	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 area year-round	not present		nursery area	major adult area year-round	not present		not present		not present	major adult area year-round spawn June–August
Lane snapper (*Lutjanus synagris*)	nursery area	not present	nursery area	not present	nursery area	not present	not present		not present		nursery area	adult and spawning area year-round
Vermilion snapper (*Rhomboplites aurorubens*)	not present		not present		not present		not present		not present		nursery area	not present
Red drum (*Sciaenops ocellatus*)	common year-round nursery area	present year-round	common year-round nursery area	common year-round	nursery area year-round	common year-round	not present		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	nursery area year-round	present year-round	not present		not present		not present		nursery area year-round	present year-round spawning area May–Nov

Common/Scientific Name*	Galveston Bay		Brazos River		Matagorda Bay		Corpus Christi/ Upper Laguna Madre		Lower Laguna Madre		Marine	
	Juvenile	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**	**Juvenile**	**Adult**
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	not present		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	
Swordfish (*Xiphias gladius*)	not present		not present		not present		not present		not present		not present	present year-round spawn Apr-Aug
Atlantic yellowfin tuna (*Thunnus albacares*)	not present		not present		not present		not present		not present		not present	present year-round spawn May-Aug

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

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 or shell substrates associated with plant-water interface (Rakocinski et al., 1992; Baltz et al., 1993; Peterson and Turner, 1994; GMFMC, 2004). 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 to 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 but graze on algae and detritus (Pattillo et al., 1997; Lassuy, 1983c).

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) (Pattillo et al., 1997; Lassuy, 1983c). 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 with 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 course 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).

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; Morgan et al., 2008; Driggers et al., 2007). 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 south Atlantic (Sulikowski et al., 2007; Morgan et al., 2008). 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) (NMFS, 2009; Bethea et al., 2008). 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 common 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 (Compagno, 1984; Burgess, 2009). Spinner sharks feed primarily on fish including sardines, herring, anchovies, catfish, mullet, bluefish, tunas, and jacks (Compagno, 1984; Burgess, 2009). Adult and juvenile spinner sharks are present 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. It 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 deepwater 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 occupying deeper waters further offshore. Silky sharks leave the nursery areas as subadults 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). Primarily a fish eater, 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, off beaches, and off 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 are capable of traveling great distances. They are the only species of shark that are 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 off 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 (Compagno, 1984; Burgess and Branstetter, 2009). This species is often confused with spinner sharks due to their unusual habitat 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 1,312 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 known sharks, among the slowest growing, and viviparous have a long gestation period (as long as 22 months) producing 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 (bearing live young) (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, being omnivorous 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 302 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 on 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 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 (Hoese and Moore, 1998; Cortés, 2009). 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 shelves 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 (Compagno, 1984; Baum et al., 2007). Adults feed on a variety of fish and cephalopods, while juveniles feed mainly on demersal fish, benthic reef fish, and crustaceans (Compagno, 1984; Baum et al., 2007). 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, semi-oceanic 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 latitudes 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 33 to 262 feet (Campagno, 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 require higher daily allocations 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).

Bignose Shark (*Carcharhinus altimus*)

Bignose sharks are a deepwater species that migrate diurnally between 30 and 430m. The species has a circumglobal distribution in warm and tropical seas on the continental shelf edges (Cavanagh et al., 2003). They reproduce once every two years with litters from one to thirteen, though their gestation period is unknown (Last and Stevens, 1994). Adult bignose sharks are present in the Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Whale Shark (*Rhincodon typus*)

Whale sharks are a circumglobal species found in mid-latitude warm temperate and tropical waters (Compagno, 2001). They tend to be solitary, though small aggregates have been noted on occasion (Meekan et al., 2006; Brooks et al., 2010). Whale sharks are filter feeders preying on planktonic organisms. Gravid females are rarely found in the wild, but have been seen in the Sea of Cortez area on multiple occasions (Rowat and Brooks, 2012). The largest recorded whale shark today was from a Taiwanese fishery in 1987 and measured 20m and weighed 34 tons (Chen et al., 1997). Whale sharks are present in the 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 656 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 (Garcia-Moliner and Eklund, 2004; Froese and Pauly, 2017). 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 (GMFMC, 2004). Spawning occurs in the Gulf from January to March

(Bertoncini et al., 2008). 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 (GMFMC, 2004; Bertoncini et al., 2008). Older juveniles move offshore in the fall to shallow reef habitat in depths of 3 to 165 feet. Adults prefer depths of 33 to 328 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 (GMFMC, 2004; Bertoncini et al., 2008). 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 are widely distributed throughout the Gulf found over ledges and high-relief rocky bottoms, congregating at depths of 40 to 240 feet in the Gulf (GMFMC, 2004; Rocha et al., 2008; Bates, 2016). 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 (GMFMC, 2004; Collette et al., 2015). 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 (GMFMC, 2004; Florida Museum of Natural History, 2017a). 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 279 feet. They travel together in small schools and exhibit north-south seasonal migrations (GMFMC, 2004; Collette et al., 2011). Multiple spawning events occur throughout the year in open water when temperatures rise above 69.8°F (GMFMC, 2004; Collette et al., 2011). Eggs and larvae are pelagic and commonly associated with *Sargassum*. Young billfishes often prey upon dolphin larvae and juveniles 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, juveniles on plankton and other small invertebrates (Florida Museum of Natural History, 2017). 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 427 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 1,968 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, postlarvae, 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 (GMFMC, 2004; Gallaway et al., 1999). Juvenile red snapper feed mainly on shrimp, but after age one, prey primarily on fish and squid (GMFMC, 2004; Moran, 1988; Anderson et al., 2015). 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. Postlarvae 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 (Pattillo et al., 1997; Lindeman et al., 2016a). 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). Adult lane snapper occur offshore in depths up to 430 feet near sand bottoms, natural channels, banks, and artificial and natural structures and remain in the same area their entire lives (GMFMC, 2004; 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). Spawning occurs in aggregations in Gulf waters from March through September (GMFMC, 2004; Florida Museum of Natural History, 2017c). 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 (GMFMC, 2004; Florida Museum of Natural History, 2017c). 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 demersal occurring found in waters 66 to 656 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., 2011; 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., 2011; Florida Museum of Natural History, 2017d). Sharks, billfishes, and 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 111 feet (Collette et al., 2011; 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 (GMFMC, 2004; Collette et al., 2011). 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., 2011). 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 33 to 115 feet throughout the coastal zone of the Gulf (GMFMC, 2004; Florida Museum of Natural History, 2017f). 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 in 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 (Pattillo et al., 1997; Collette et al., 2011). 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 131 feet (Collette et al., 2011; NMFS, 2009). They often occur in loose aggregations over a large area, occasionally forming small schools most likely by size (Collette et al., 2011). 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., 2011; 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., 2011; 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 and estuarine portions 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., 2011; 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 131 feet (Collette et al., 2011). 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 tuna-like fish, crustaceans, squid, and cephalopods (Collette et al., 2011; 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).

Swordfish (*Xiphias gladius)*

Swordfish are a highly migratory species that can be found in the temperate, tropical, and sometimes colder waters of the Atlantic, Indian, and Pacific Oceans, as well as the Gulf of Mexico. They spawn multiple times a year in the western North Atlantic, the Sargasso Sea and the Caribbean Sea producing up to 29 million eggs per brood. Their diet consists of a variety of fish and invertebrate species. Juvenile of the species are preyed upon by sharks and other large predatory fish, but adults do not appear to have any predators (NMFS, 2020a). Adult swordfish are found in the Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

Atlantic Yellowfin Tuna (*Thunnus albacares*)

Atlantic yellowfin tuna are a highly migratory species found in the tropical and subtropical oceans around the world. They are fast swimming pelagic fishes which prey on fish, squid, and crustaceans. They are in turn preyed upon by larger predatory fish species and sharks. The yellowfin tuna grows quickly and can reach up to 400 pounds over a life span of approximately seven years. Females spawn annually producing between one and four million eggs approximately every three days during the spawning season, May – August in the Gulf of Mexico and July to October in the Caribbean Sea (NMFS, 2020b). Adult yellowfin tuna are found in the Gulf portions of the study and project areas (Table 4) (NMFS, 2009; NOAA, 2016).

3.0 POTENTIAL IMPACTS TO EFH AND FEDERALLY-MANAGED SPECIES

The following section describes the potential direct and indirect impacts to the quality or quantity of EFH as a result of implementing the recommended plan. Adverse effects include direct and indirect physical, chemical, or biological alterations of habitat and the cumulative or synergistic consequences.

Actionable Measures are described first and are anticipated to occur if the action is implemented with reasonable certainty. Tier One measures are also briefly described; however, the impacts associated with these measures are highly uncertain and require additional investigation after more site-specific design level details are available at which time a separate EFH assessment detailing impacts would be prepared and provided to NMFS for consultation.

The Recommended Plan 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, bignose shark, whale shark, red grouper, cobia, dolphin, greater amberjack, red snapper, gray snapper, lane snapper, red snapper, little tunny, king mackerel, Spanish mackerel, sailfish, swordfish, Atlantic yellowfin tuna, 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 2.1.1.

Table 6 shows the cover types impacted during construction of the recommended plan components.

Table 6. Direct Impact to each Habitat Cover Type (acres)

Measure	Developed/ Upland[1]	Islands / Bird Rookeries	Palustrine Emergent Wetland[2]	Estuarine Emergent Wetland[3]	SAV	Oyster Reef	Open Water	Dune[4]	Supra-tidal[5]	Inter-tidal[6]	Total Acres
Actionable Measures											
G-28	105.7	23.5	--	513.7	--	--	735.9	--	--	--	1,212
B-12	41.1	--	--	427.0	1.0	0.7	405.6	--	--	--	859.2
M-8	240.4	2.6	--	29.3	15.2	--	112.3	--	--	--	415.8
CA-5	--	--	--	--	295.4	2.5	27.8	--	--	--	28.9
CA-6	6.8	--	--	244.4	4.0	21.2	283.8	--	--	--	457.2
SP-1	90.5	117.8	--	--	3,088.8	5.2	434.6	--	--	--	475
W-3	4.6	3.8	--	--	1.8	--	1,109.4	257.6	53.3	1.0	1,949.7
South Padre Island	4.6	--	--	--		--	358.5	0.5	2.1	0.1	365.8
Tier One Measures											
B-2	79.6	--	--	--	--	--	624.3	220.7	168.3	20.9	1,113.8
Coastal Barrier	1,520.9	--	128	134	--	6	161.6	--	--	--	1950.5

Source: NOAA (2017c, 2017d)

[1] Includes bare land, cultivated crops, deciduous forest, develop (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 gulf side and bayside of the barrier island.

3.1 ACTIONABLE MEASURES

3.1.1 Impacts Common to All Actionable Measures

Construction activities occurring in or near open water, including dredging activities, placement of sediment or hard material, and operation of vessels and equipment, is expected to temporarily impact Federally-managed species. The significance of direct effects resulting from construction of the actionable measures on Federally-species will depend on life stage and the usage of the project area. For example, it is more likely that eggs and larval fish will be affected to a greater extent than adults and juveniles, because the older life stages have greater swimming abilities and will be able to move away from construction activities. However, eggs and larvae of many species are widely distributed over the continental shelf, so the destruction of these life stages is not expected to cause significant impact to fish populations.

For all actionable measures, USACE has determined that construction of the actionable measure may have minor adverse effects on EFH of Federally-managed species, but the adverse effects will largely be temporary and localized within the footprints of the constructed feature. Long-term operation of the features are not expected to impact "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" to any appreciable extent over a significantly large area or over any significant period of time. Although construction of the project may impact individual fish, no adverse effects to the populations of Federally-managed species that inhabit any of the project areas are expected. Also, conversion of EFH habitat to non-EFH habitat is considered a long-term adverse impact to EFH habitat; however, the long-term benefit of protection of a significantly larger area of EFH habitat outweighs the minor loss. Because no significant adverse impacts are anticipated, no mitigation has been proposed.

Water Column

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; Wright, 1978; Wilber et al., 2005). The release of sediment in the form of a sediment plume is common when sediments are stirred up by vessels and equipment or when force is placed on soft bottoms. The sediment plume size and extent is dependent on the size of the particles and the direction and strength of the currents (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 (Newcombe and Jensen, 1996; Clarke and Wilber, 2000; 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; Wilber and Clarke, 2001; Newcombe and Jensen, 1996). 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; Wilber and Clark, 2001; Wilber et al., 2005; Newcombe and Jensen, 1996).

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; Wilber and Clarke, 2001; Stern and Stickle, 1978). 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).

When conducting construction activities, TSS concentrations would be greater than 100 mg/L at the site of dredging or placement and would be expected to dissipate to less than 100 mg/L after the sediments in that area have not been disturbed for a period of time. Turbidities can be expected to return to near ambient conditions within a few hours after dredging ceases in a given area, thus, no long-term effects are anticipated. This conclusion is supported by modeling completed for the dredged material discharge in Laguna Madre, Texas, which concluded that impacts are 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 actionable measures of the recommended plan.

Also, activities that disturb sediments may reduce DO depending on the volume and duration of sediment resuspension, and the oxygen demand of the sediment. Fine sediments high in organic matter have greater potential oxygen demand than sandy sediments. DO reduction generally is associated with near bottom waters adjacent to the disturbance and decrease towards the surface and with increasing distance. The effct is anticipated to be temporary and localized in nature. The effects of temporary DO reduction on EFH-managed species may be negligible during winter-spring when DO levels are naturally high. However, similar reductions may result in temporary adverse effects in summer when DO is naturally lower. The potential to impact managed fishery species would depend on existing conditions and project-specific factors such as location, construction schedule, and impact duration. Avoidance displacement associated with project-related DO reduction could be locally adverse if spawning movements and/or recruitment of nursery areas were affected.

3.1.2 **Breakwaters**

All seven actionable ER measures would incorporate breakwaters features. Construction of breakwaters would permanently convert open water (combination of estuarine mud bottoms, Gulf waters, marsh edge, offshore, beach, coastal, and sand EFH) to rock which is not considered EFH. However, the loss of EFH would be offset by the long-term protection of valuable EFH habitats such as marsh, SAV, and oyster reef habitat from erosion, which then also maintains valuable nursery grounds for the many fish and shellfish species that live within those valuable EFH habitats. As well, the quality of EFH in the immediate vicinity would increase due to a decrease in long-term turbidity and suspended sediments from continual erosion and land loss.

As well, when breakwaters are placed in areas where the environments are predominantly soft sediments, it creates suitable habitat for marine organisms, which can settle and colonize on 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 when compared to natural shores (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. Based on the various research, it is reasonable to assume that constructed breakwaters would attract marine organisms and provide a greater ecological service than without the structure in place. If water quality is adequate, breakwaters could 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 rocky habitat that attracts fish and invertebrate communities.

Finfish could be directly affected by construction of the breakwaters. Individuals could be injured or killed through contact with the construction equipment or could be smothered under the breakwater material. In addition, construction activities, may change EFH species’ normal behaviors, such as foraging and hunting, as a result of noise and/or temporary, minor changes to water quality. The disturbance of sediment and placement of reef material is expected to result in increased turbidity and decreased DO during placement of material. Increased turbidity could cause gill clogging and reduce the foraging success of sight hunters. Reduced DO levels within the water column can stress aquatic organisms if the levels are low enough. Impairments to water quality are expected to be minor and temporary only lasting until all material is placed. Fish usage is expected to return to baseline conditions once construction is complete.

As well, the placement of material may reduce the population of prey species of Federally-managed species. Relatively non-motile benthos, such as polychaetes and mollusks would be lost during placement of the material; this may cause fish to move out of the project area until benthic communities recover. Recovery time of the benthos within the project area is expected to be between several months to several years.

3.1.3 Wetland and Marsh Restoration

Wetland and marsh restoration features would occur at four of the ER measures behind each of the constructed breakwater features. Construction activities using earthen materials to create marsh would bury existing EFH substrates and temporarily change environmental conditions, including: increased turbidity, total suspended sediments, and water temperatures and lower dissolved oxygen levels in the water column. However, the effects would be short-term and localized and the area would be expected to return to baseline conditions following completion of dredging and construction activities, except for in the marsh restoration units, in which a different EFH type would form.

Marsh restoration would convert open water and degraded marsh (combination of estuarine marsh and estuarine mud bottoms EFH) to estuarine marsh (marsh edge, submerged aquatic vegetation, marsh ponds, and inner marsh EFHs). Although EFH would be converted, resulting in loss of one EFH habitat type for another, once the marsh is functioning, the overall benefits outweigh the initial impacts. Wetlands and marshes provide numerous ecosystem services including providing 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). They provide important habitat and food for both recreational and commercial fish and shellfish spawning and growth and play an important role in estuarine chemical cycles (Minello, 1999; Yoskowitz et al., 2012; Schuster and Doerr, 2015). More fish and invertebrate species utilized 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 in the marsh. Minello et al. (1994) showed that creating marshes with these types of 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 approximately 2 years following marsh planting (Minello, 2000; Rozas et al., 2005). It is expected that the wetland and marsh restoration features would improve the fish and shellfish habitat in the areas compared to the No-Action Alternative.

Estuarine emergent wetland would be the primary type of EFH that would increase significantly at any of the restoration sites. This type of habitat would be created in shallow-open water areas and deteriorated marsh. Depending on the actionable measure, anywhere from 236.5 to 664 acres, for a total 1,980.5 acres of emergent marsh habitat would be restored. SAV is also expected to increase in parts of the restoration units; however, the increase is SAV would be limited by depth and turbidity, not seed source. Increase in those habitat types would benefit postlarval/juvenile and subadult brown shrimp; postlarval/juvenile and subadult white shrimp; and postlarval/juvenile red drum.

The creation of estuarine emergent wetlands would result in the loss of mud bottoms and estuarine water column as emergent marsh would replace those habitat types. Loss of mud bottom EFH could result in adverse impacts to subadult brown shrimp and postlarval/juvenile red drum. Although adverse impacts would occur to some types of EFH, more productive types of EFH (i.e. estuarine emergent wetlands) would be created and the loss would not contribute to regional population declines of the Federally-managed species.

3.1.4 Island Restoration

Island restoration features would occur at four of the ER measures. As a result of island restoration features, bay bottom habitat and open bay habitat would be permanently lost and converted to estuarine. Impacts associated with bay bottom habitat loss and temporary disturbances to the water column on estuarine habitat and fauna would be the same as those described above for the Storm surge barrier system open bay and bay bottom and would be expected to return to normal once construction 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.

3.1.5 Oyster Reef Creation

Oyster reef creation features would occur at five ER measures. Oyster cultch would be placed to construct four of the ER measures, CA-5 would be a reef constructed by placing reef balls in shallow water. The short- and long-term impacts of constructing oyster reefs would be similar to those described for the breakwaters, except that more productive EFH habitat would replace existing EFH habitats.

The conversion of shallow, sandy bottom habitat to hard reef habitat will be permanent in nature. However, the amount of sandy bottom that will be altered is relatively minor in comparison to the large areas of sandy seafloor that would remain available once construction is complete. As well, increasing habitat heterogeneity would have a long-term beneficial effect to EFH species and will far outweigh the effects that would result from the loss of sandy bottom habitat. The reef would increase productivity of the system and provide habitat for prey species, such as crustaceans, mollusks, worms, and fish. The hard reef structures would also increase shelter, cover, and foraging opportunities for EFH species, as well as attachment surfaces for benthic egg masses.

In the long-term, creation of oyster reefs is expected to protect restored islands, prevent breaching of islands and shorelines, and for SAV protection. Oyster reef creation is one type of living shoreline design that is an improvement over traditional armoring techniques (Schuster and Doerr, 2015). Oyster reefs have a positive benefit to the estuarine habitat and fauna by providing ecosystem services such as water filtration, 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 create protection to 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 together protecting nearby marsh habitat from erosion and accretion of sediments potentially allowing expansion of the marsh. SAV could also be created or protected through water quality improvement and sediment stabilization provided by the oyster habitat (Baggett et al., 2014).

3.1.6 Dune/Beach Restoration

W-3 and the South Padre Island Beach Nourishment and Sediment Management measure incorporate dune/beach restoration features. 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 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 Galveston Bay Storm Surge Barrier System open bay and bay bottom and would be expected to return to normal once construction is completed. Therefore, no long-term impacts to the aquatic community are anticipated as a result of dune/beach restoration features.

3.1.7 Hydrologic Restoration

No estuarine emergent wetlands, live hardbottoms, unconsolidated bottoms, or oyster reefs occur in Port Mansfield where dredging would occur; therefore there are no anticipated imapcts to these EFH areas.

The loss of material from subtidal flats and soft bottoms in the proposed dredging area would occur due to the removal of material from these habitats during construction. This action would negatively affect the EFH habitats by reducing available EFH. Most of the material removed considered beach compatible material and would be placed on the beach just north of Port Mansfield. Impacts of the placement of material are described in Section 3.1.6.

A change in the hydrologic regime as a consequence of altered bathymetry is expected and would contribute to an increase in tidal exchange within the Laguna Madre.

3.2 TIER ONE MEASURES

3.2.1 B-2 Follets Island Gulf Beach and Dune Restoration

Impacts from implementing this measure would be similar to those described for the actionable measures, specifically the Common to All Actionable Measures (Section 3.1.1) and Dune/Beach Restoration (Section 3.1.6).

3.2.2 Galveston Bay Storm Surge Barrier System

The design for the Galveston Bay Storm Surge Barrier System has been improved since the 2018 draft report. In 2019, the PDT hosted workshop where a team of surge barrier experts from around the world met in Galveston to consider the design for the system. The workshop concluded with several recommendations: only use gates that are currently in operation to reduce engineering challenges, incorporate multiple sector gates to improve resiliency, include small sector gates so that non-commercial vessel traffic doesn't have to use the same gates as the large commercial vessels. The Environmental Team discussed the 2018 designs with the agency review team and came up with some priorities to that were given to the Structural Team and they included, reducing the constriction on the channel as much as possible (allow the highest possible tidal exchange), minimize increased velocities in proximity to the structure, design the structures with the smallest footprint possible without jeopardizing the functioning of the structure, maintain shallow water exchange, and ensure that the sill does not create an abrupt change in elevation (ramp down).

The Structural Team took these recommendations and updated the design for the system. Some notable changes include the use of two 650-foot-wide sector gates instead of one larger gate, the inclusion of two 125-foot-wide sector gates to provide an alternative to the main channels that doesn't have a mast restriction, 300-foot wide vertical lift gates instead of 100-foot-wide gates to reduce construction, the incorporation of 16-foot-wide monolith gates with sill depth of -5-foot to provide shallow water exchange, and ramped sills. The new design reduced the channel constriction from 27.5% to between 7 and 10%.

3.2.2.1 Open Water Column

With the proposed Galveston Bay Storm Surge Barrier System, the Bolivar Roads Gate System, Clear Lake Gate System, Dickinson Bay Gate System, and the Galveston Ring Barrier System would impact a total of 167.6 acres of open-water habitat (Table 8). The majority would occur at Bolivar Roads, which would be covered by the support structures and gates. The current design of the Bolivar Roads Gate System indicates the support structures and gates would be 60 feet deep and 15 to 30 feet deep through the environmental gates. The Galveston Bay complex contains approximately 378,063 acres of open-bay habitat (Pulich, 2002). The 167.6 acres impacted is a very small fraction of the total available habitat within the entire Galveston Bay system.

Tidal Exchange/Amplitude and Velocities

The USACE Engineer Research and Development Center (ERDC) conducted 3D Adaptive Hydraulics (AdH) modeling for the Galveston Bay Storm Surge Barrier System for the 2018 design (McAlpin et al. 2019b) and updated it for the 2020 design. All model input conditions for this updated modeling match those for the present condition as referenced in McAlpin et al. 2019b. The updated AdH modeling showed that the 2020 design for the System would have lower changes to tidal prism, water velocities, and salinities in the Galveston Bay System. Using the present conditions (2019 water elevations/tides) with the 2020 Surge Barrier design, the model showed potential changes in tidal prism of 2.4-5.7% across all of the stations in Galveston Bay, which was equivalent to a 0.01-0.02 meter (0.4-0.8 inch) change (Lackey and McAlpin 2020).

The velocity magnitudes for the with-project condition do not vary greatly from the without-project condition at different locations in the bays (Figure 6 and Figure 7). The velocity magnitudes do drop at most locations for both surface and bottom but the reduction in the mean velocity magnitude is less than 0.1 m/s and more typically 0.05 m/s or less. Locations in West Bay and on the western perimeter of Galveston Bay show a slight increase in velocity magnitude for surface or bottom but, again, the change in the mean velocity magnitude is less than 0.1 m/s.

To analyze the hydrodynamics of the 2020 Galveston Bay Storm Surge Barrier System design at the barrier location, a new arc was located within the proposed location of the outbound 650-foot-wide sector gate. Instead of running the analysis for the full time series the researchers choose the strongest tide cycle that was observed in the two year analysis. The transition between low and high tide showed the greatest jump in predicted velocities through the navigation structure can reach 2 m/s (6.6 ft/s) in places. This could result in the formation of eddies on the backside of the structures, which may have impacts on navigation and could adversely impact organisms. The analysis does show that with this particularly strong tide cycle, once the transition period between low and high tide moves to the full incoming tide, the maximum velocities 0.75 m/s (2.5 ft/s) which was less than the 1.3 m/s (4.3 ft/s) seen in the without project condition during the tidal transition.

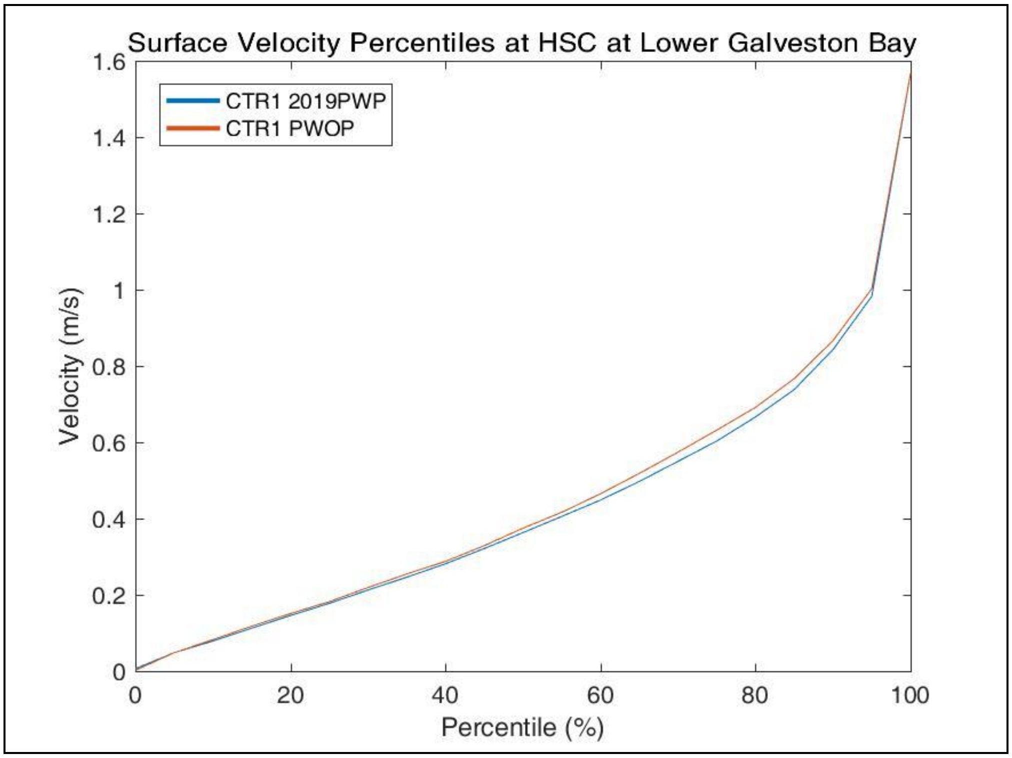

Figure 6. Surface Velocity Magnitude for the HSC at Lower Galveston Bay

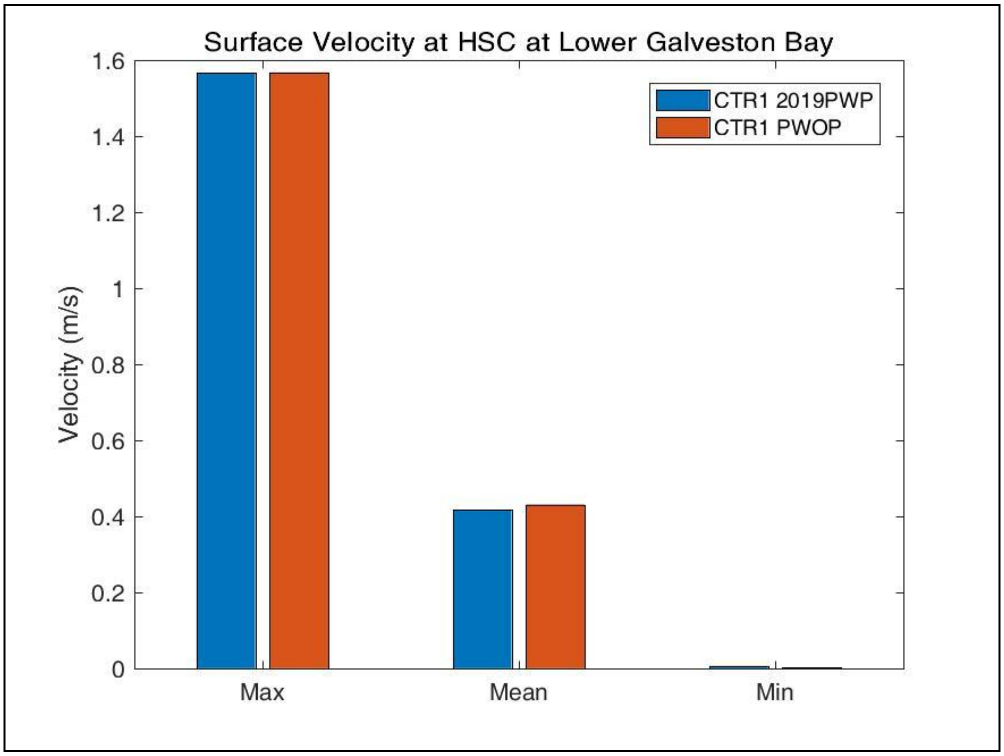

Figure 7. Maximum, Mean and Minimum Surface Velocity Magnitude at the Houston Ship Channel at Lower Galveston Bay

Eggs and larval stages of aquatic organisms can be affected by changes to tidal exchange/amplitude and velocities. These life stages are transported by currents, moving into the bay by the incoming tides. Larval forms of some species drop near the bottom on outgoing tides, particularly in the shallow areas of the nearshore to reduce transport out of the bay. Shallow water Environmental Gates (SWEG) along the shoreline of Bolivar Roads is 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 are presented in (pers. com. Rusty Swafford [NMFS], 2017). Table 9 describes the life stage relative abundance of these species in Galveston Bay and their migrations and movements.

With input from the resource agencies, the USACE used the Particle Tracking Model (PTM) to show indirect impacts, and the extent of those impacts, from constructing the storm surge barrier system at Bolivar Roads on the larval stages of the marine life that travel in and out of Galveston Bay. The PTM simulates the transport of particles, or local marine larval species, using environmental inputs such as circulation, salinity, currents, and water surface elevation from the 3D Adaptive Hydraulics Model and local marine species' transportation characteristics (e.g. bottom dwellers, top dwellers etc.). The particle movements represent a multitude of aquatic species including shrimp, blue crabs, and commercially and recreationally important finfish (e.g. spotted sea trout and flounder). Results showed that recruitment of larval species into the Bay were similar whether the proposed storm surge barrier system was implemented or not.

Table 7. Key Species Most Vulnerable to Flow Constrictions

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

Species	**Life Stage***	**Galveston Bay Abundance**	**Migrations and Movements**
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 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

Species	**Life Stage***	**Galveston Bay Abundance**	**Migrations and Movements**
	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

Species	Life Stage*	Galveston Bay Abundance	Migrations and Movements
			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

Salinity

The updated modeling also showed that the predicted changes in salinity using the present conditions with the 2020 Galveston Bay Storm Surge Barrier design, were almost identical near the HSC entrance, they begin to diverge further into the system at Mid Bay Marsh and Morgan’s Point. However, the change in the mean salinity between with and without project remains within 2 ppt and in most instances in the time series, the difference is less than 1 ppt for all of the stations across the bay.

Figure 8 shows the modeling results for the Morgan’s Point Station, which shows that even though there is some divergence, the salinities remain close. Figure 9 shows the average vertical salinity profile at the HSC at Morgan’s Point and while there is some divergence between the with and without project conditions, the differences are within 1 ppt.

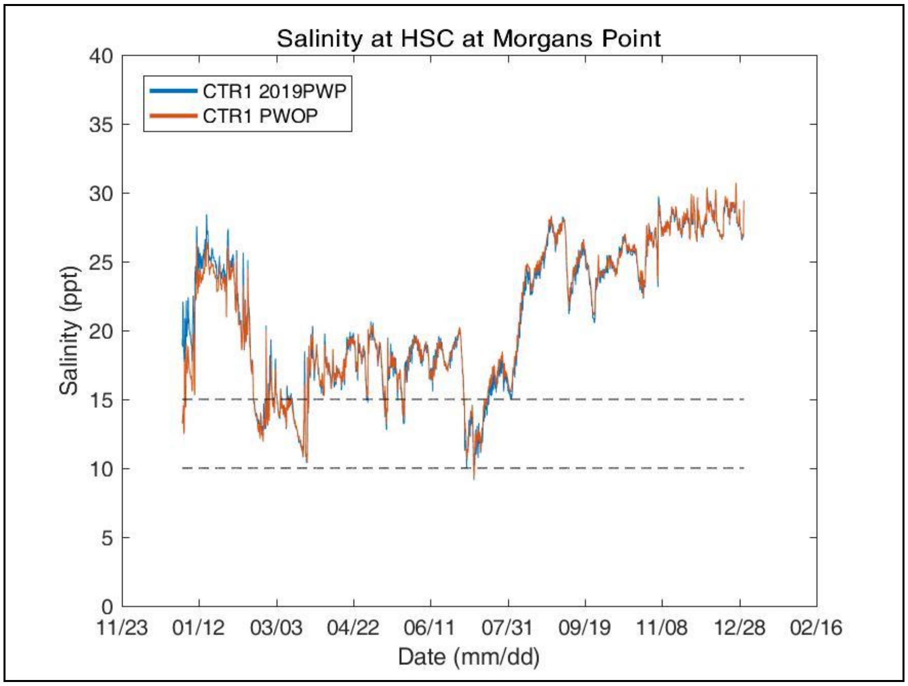

Figure 8. Salinity time history at Morgan’s Point within the Houston Ship Channel

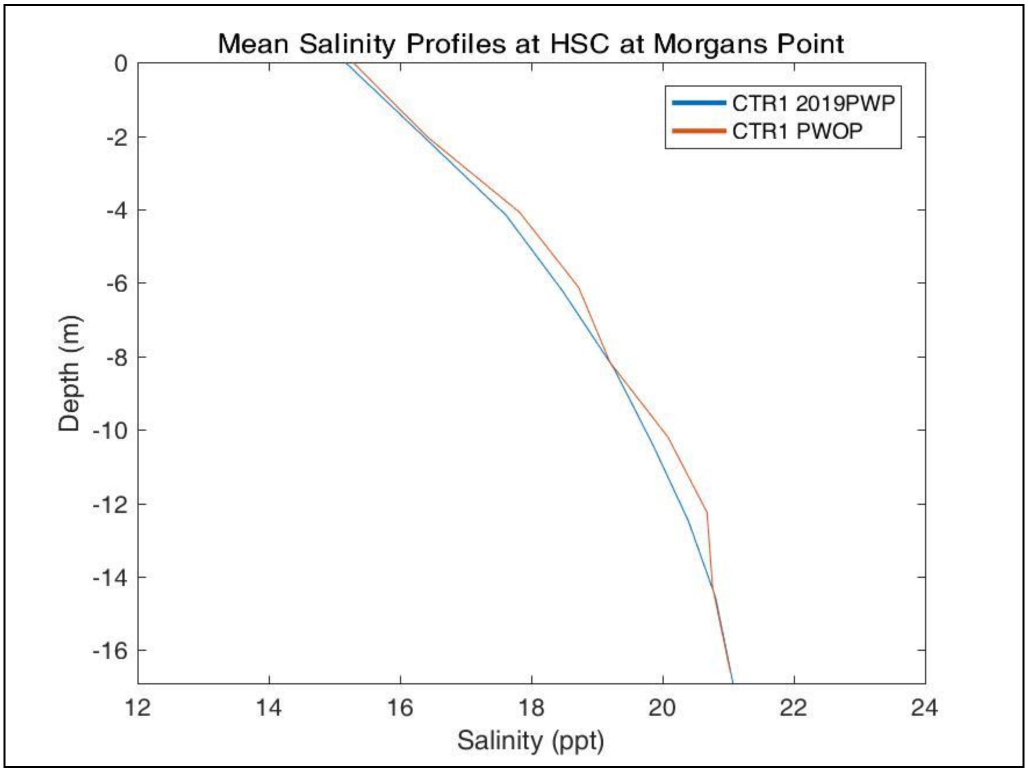

Figure 9. Vertical Salinity Profile at Morgan's Point in the Houston Ship Channel

A slight decrease in average salinity of between 1 and 2 ppt could be expected based on the estuarine modeling conducted by the USACE. 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.

3.2.2.2 Open-Bay Bottom

A total of 161.6 acres of bay bottom habitat would be permanently lost as a result of the storm surge barrier system at Bolivar Roads, Clear Lake, Dickinson Bay, and Offatts Bayou (Galveston Ring Barrier System) (Table 8). Of that loss, the majority would occur at Bolivar Roads, which would be covered by the islands, support structures and gates. As described in Section 4.2.2, the loss is a very small fraction of the total available habitat within the entire Galveston Bay system.

There would be direct impacts to benthic organisms, which would be buried or removed during construction of the Galveston Bay Storm Surge Barrier System. Excavation of sediments removes and buries benthic organisms, whereas placement of dredged material and structures smothers or buries benthic communities. Dredging and placement activities may cause ecological damage to benthic organisms due to ecosystem physical disturbance, mobilization of sediment contaminants making them more bio-available, and increasing concentrations of suspended sediments (Montagna et al., 1998). 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 and dredged material placement occurs through vertical migration of buried organisms through the dredged material, immigration of postlarval 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 et al., 2010; Bolam and Rees; 2003, Newell et al., 2004; Newell et al., 1998). Although changes in community structure, composition, and function may occur, these impacts would be temporary in some dredging and disposal areas (Bolam and Rees, 2003). Shallower, higher energy estuarine habitats can recover as fast as 1 to 10 months from perturbation, while deeper, more stable habitats can take up to 8 years to recover (Bolam et al., 2010; Bolam and Rees, 2003; Newell et al., 1998; Sheridan, 1999; Sheridan, 2004; Wilber et al., 2006; VanDerWal et al., 2011).

Maurer et al. (1986) demonstrated that many benthic organisms were able to migrate vertically through 35 inches of dredged material; however, the species present in early successional stages of recovery are not the same as those buried by the dredged material. Although vertical migration is possible, most organisms at the center of the disturbance do not survive, and survival was shown to increase as distance from the disturbance increased (Bolam and Rees, 2003; Maurer et al., 1986). The release of nutrients during dredging may also enhance species diversity and population densities of benthic organisms outside the immediate dredge placement area as long as the dredged material is not contaminated (Newell et al., 1998).

Dredged material for construction of the storm surge barrier system would either be used beneficially for construction of ER measures or put in approved placement areas. Thereby minimizing impacts to benthic communities and subsequent disturbance or loss of additional EFH habitat.

3.2.2.3 Oyster Reef

Oyster reefs are not mapped in the potential area of disturbance; however, oyster presence is possible. The PDT and interagency teams have noted that oysters occur in locations that have not been mapped by TPWD, for example in Offatts Bayou where the proposed Galveston Ring Barrier System would cross. Prior to construction, a survey would be completed to identify oyster reefs in the disturbance area. Project designs and construction actions would employ BMPs to avoid and minimize the impacts to oysters. For any disturbance that cannot be avoided, oyster mitigation would be completed to offset the loss. USACE will work with TPWD and other agencies as appropriate to identify an appropriate mitigation location, method of establishment, and monitoring program to ensure success.

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; Wilber and Clarke, 2001; Stern and Stickle, 1978). 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 or long-term operation of the storm surge barrier system would be temporary and localized.

The anticipated decrease in salinity is minimal (1-2 ppt) when compared to the fluctuations in the estuarine system and would not be expected to cause enough of a change in water quality to result in population losses of oysters. A decrease in salinity may actually be beneficial for limiting habitat suitability for oyster predators and pathogens, such as drills and Dermo, which tend to prefer 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 complex.

3.2.2.4 Offshore Sands

Under the Recommended Plan, 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 (Newcombe and Jensen, 1996; Clarke and Wilber, 2000). Benthic organisms would be buried, and survival would be low during placement of the construction dredged material over offshore sands. However, rapid recolonization would occur within months after the placement of dredge material (Bolam et al., 2010; Bolam and Rees, 2003; Newell et al., 1998; Sheridan, 1999; Wilber et al., 2006; VanDerWal et al., 2011). Section 4.2.1.3, above, provides a more-detailed discussion of impacts to benthic communities.

3.2.2.5 Estuarine Wetlands and Submerged Aquatic Vegetation

The proposed Galveston Bay Storm Surge Barrier System, including the Bolivar and West Galveston Beach and Dune System, the Dickinson Bay Gate System, the Clear Lake Gate System, the Bolivar Roads Gate System, and the Galveston Ring Barrier System are expected to have direct and indirect impacts to wetland and marsh habitats in the Galveston Bay region. Approximately 134 acres of estuarine wetlands are expected to be altered or potentially destroyed due to the construction of this measure. Construction of the Galveston Ring Barrier System on Galveston Island would require clearing, grubbing, levelling, and filling of wetland and marsh habitats. The potential for increased sedimentation and degraded water quality during construction could affect water quality and bury or damage adjacent vegetation in marshes landward of the structure. Any marshes on the interior of the ring barrier may be degraded or lost due to a loss of hydrologic connectivity. Additional modeling is required to fully understand the impacts of the ring barrier once more site-specific designs are developed.

The proposed beach and dune would 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. Over the long-term this would result in a beneficial impact by reducing the amount of marsh loss to RSLC and storm surge and maintaining valuable nursery habitat for Federally-managed species.

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).

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, protection from predators, and provide 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). 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).

The tidal amplitude reduction, as described above, would mean less marsh would be flooded, resulting in a loss of marsh surface area available for aquatic organisms to use as nursery habitat. Reduced access to marsh due to the tidal amplitude change was estimated for the Galveston Bay Storm Surge Barrier System. A tidal amplitude reduction of 0.5 foot, which is lower than the reduced tidal amplitude predicted by the AdH model (2.4-5.7% across all of the stations in Galveston Bay, which was equivalent to a 0.01-0.02 meter (0.4-0.8 inch) change [Lackey and McAlpin 2020]), was used to calculate the area of reduced marsh access. Although this is generally considered a very minimal change, the lack of topographic change in the area could result in a substantial area that would have a change in tidal frequency inundation. 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 should be noted that very few gate structures have been constructed in the world, and none this large; therefore, no studies have been conducted on the ecological impacts of gate structures of this size. There are many variables affecting the ecology of the Galveston Bay complex and exactly what impacts the structure could have on fisheries in the Galveston Bay complex is uncertain.

Following completion of the storm surge barrier structures across Bolivar Roads, the cross-sectional entrance into Galveston Bay would be constricted by less than 10 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. An analysis was conducted using the NOAA C-CAP 2010 landcover dataset for estuarine wetlands to estimate the potential area of affected wetland and marsh habitats within Galveston Bay as a result of the reduction in tidal amplitude. It is estimated that 6,887 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 mitigation plan has been developed that identifies potential mitigation sites. Additional investigation into marsh impacts is warranted once more site-specific designs are available. Once the investigations are complete, the mitigation plan would be updated to account for any change in the mitigation need.

4.0 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.

4.1.1 Actionable Measures

4.1.1.1 Direct Impacts

Construction of the Coastwide ER measures would result in a loss of open bay and bay bottom habitat and cause temporary disturbances to water column turbidity. Marsh creation and island restoration 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 of the bay. The created/restored marsh and island 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 species and red drum providing nursery and foraging habitat. In addition, it may also benefit other commercially and recreationally important species in those ER measure project areas. 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 than in open-water. (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).

4.1.1.2 Indirect Impacts

The Coastwide 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 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 lines of defense and Coastwide ER is intended to provide redundant and resilient levels of protection and restoration for both humans and Texas coastal ecosystems. When comparing the Coastwide 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.

4.1.2 **Tier One Measures**

4.1.2.1 Galveston Bay Storm Surge Barrier System

4.1.2.1.1 __Direct Impacts__

Estuarine wetland and SAV habitat occurs within the proposed project areas of the Recommended Plan (RP) and would be directly impacted by the proposed project. Dredged material for construction of the Storm surge barrier system would either be used beneficially for construction of Coastwide ER measures or put in approved placement areas. If used beneficially, this habitat may potentially be more productive than the open-water habitat that would be lost because of the RP.

Dredging and placement activities will directly impact the benthic environment; however, this 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 RP could temporarily reduce the quality of EFH in the vicinity of the project area, and some individual species may be displaced. The Galveston Bay Storm Surge Barrier System would result in permanent loss of 161.6 acres of open bay and bay bottom habitat for construction of the storm surge barrier system, with the majority 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 that could take estuarine habitats and fauna in those areas longer to recover to preconstruction activities. A portion of this bay bottom habitat would be converted to deeper habitat, 60 feet at the navigation gate and 20 to 40 feet through the Vertical lift gates, thus reducing the amount of food available to Federally-managed species.

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-related solids. 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 highly 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 these are 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 their mobility is limited and are more sensitive to suspended sediments (Newcombe and Jensen, 1996; Wilber and Clark, 2001; Stern and Stickle, 1978; Germano and Cary, 2005; 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 RP 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, would occur with dredging, filling, and placement activities; however, those impacts would be temporary and local. It is difficult to predict what impacts the storm surge barrier system could have during construction, because few similar gate structures have been constructed in the world. However, there should not 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.

4.1.2.1.2 <u>Indirect Impacts</u>

Indirect impacts of the RP from the Storm surge barrier system include long-term effects on prey for Federally managed species and on Federally-managed species themselves due to the reduced flow, reduced tidal amplitude, and periodic high velocities through the navigation and environmental gates that is expected. 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 RP. 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, Clear Lake, and Dickinson Bayassociated with the storm surge barriers, disturbances to the benthic environment will be short lived and impacts will be minimal.

With the Galveston Bay Storm Surge Barrier System in place, impacts to fish and shellfish with larval and juvenile stages that depend largely on passive transport could result from the indirect impacts. These impacts include losses resulting 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. Many of these species depending on passive transport of early life stages are important forage species for other species of fish, birds, and dolphins. These other species could experience indirect impacts resulting from reduced access to forage. It is difficult to predict what those impacts could be because few gate structures have been constructed in the world and no studies have been conducted on the ecological impacts these gate structures could cause. Therefore, the exact long-term impacts to the Galveston Bay complex are uncertain, and additional studies would be required to best predict the impacts the structure may cause.

4.2 CUMULATIVE IMPACTS

A cumulative impacts assessment takes into consideration the impact on the environment, which results from the incremental impact of the proposed action 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 proposed action, 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.

Positive environmental impacts would result from the RP Coastwide 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 RP Coastwide ER measures would result in the same benefits. The Coastwide ER measures would result in positive environmental impacts. Marsh nourishment efforts would complement current and future marsh restoration efforts by State, Federal, non-government organizations, and private entities. With regards to Coastwide ER measures, the cumulative effects of the RP would be beneficial when combined with other past, present, and reasonably foreseeable restoration actions around Galveston Bay.

For past, present, and reasonably foreseeable projects that have altered, or have the potential to alter, tidal dynamics or hydrosalinity gradients, there exists the potential for the RP to contribute to cumulative effects. For example, the Houston Ship Channel Expansion and Channel Improvement Project would slightly alter hydrosalinity gradients and may exacerbate any impacts that result from the Galveston Bay Storm Surge Barrier System measure 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 RP contributing to cumulative effects, Habitat Evaluation Procedure were applied to the future without-project and future with-project conditions to identify the potential changes to some species' habitats and appropriate mitigation was identified. Despite modeling efforts to identify potential changes from the RP, actual changes are hard to predict. Climate variability (e.g., drought and flood events) and RSLR also contribute to the uncertainties regarding the magnitude of

RP impacts, both positive and negative. Interagency coordination, regulatory compliance, mitigation, monitoring, and adaptive management strategies are intended to offset any detrimental impacts of the RP and further reduce or eliminate contributions to cumulative effects. When combined with past, present and reasonably foreseeable future impacts, as well as, modeling, and planning efforts, impacts of the RP would not be sufficient, to lead to significant degradation of the region's environment.

5.0 MITIGATION MEASURES

Compensatory mitigation is required for unavoidable impacts to the environment that are caused by the recommended plan. No mitigation is required for any of the actionable measures and B-2, since these measures are not expected to cause a net loss in habitat. The Coastwide ER features are being constructed with the intent of restoring, increasing, or creating higher quality habitats and to protect existing habitats from future degradation within the action areas. The South Padre Island Beach Nourishment is considered a CSRM feature, but is employing a nature-based method of shoreline protection which enhances the existing habitat so no unavoidable impacts are expected.

Implementation of the Galveston Bay Storm Surge Barrier System, however, is expected to have unavoidable adverse impacts as described in the previous sections. Impacted habitat types are estuarine emergent wetland, Palustrine emergent wetland, oyster reef and open bay bottom. A Draft Mitigation Plan, which is included as Appendix J of the EIS, details proposed plans to replace the lost functions and values of the impacted areas through restoration or enhancement activities that increase and/or improve the habitat functions and services within a mitigation site. Enhancement would involve implementing actions to improve already existing low-quality habitat. Restoration would involve creating a habitat type from open water or agricultural fields where none currently exists, but which historically occurred in the vicinity of the project area. The content and structure of the Draft Mitigation Plan were developed to meet the requirements for Regulatory Program compensatory mitigation plans in 33 CFR 332.4(c).

To address reduced tidal flow into the Galveston Bay from the proposed Bolivar Roads Gate System, the study team used Adaptive Hydraulics (AdH) modeling to predict any changes in the tidal prism and tidal amplitude and developed a spatial analysis using the NOAA Marsh Migration viewer outputs associated with a projected 1 ft. of rise in relative sea level. The study team addressed the permanent impacts to open bay bottom by the construction of the Bolivar Roads Gate System by working collaboratively with the resource agencies. They determined that mitigation for this can be satisfied through oyster reef creation and restoration by using Habitat Equivalency Analysis (HEA) though the USACE Institute for Water Resources (IWR) Planning Suite. In accordance with USACE planning policy, mitigation acreages were calculated by using USACE-certified species models to determine functional losses from impacts and functional gains (or “lift”) from mitigation.

Compensatory mitigation was formulated to occur within the same watershed as that of the impacts and to replace the functions and services of each habitat type with functions and services of the same habitat type. To be considered, mitigation measures were required to either restore or enhance the same habitat types that were impacted (e.g., “habitat type for habitat type”) with the construction of the Recommended Plan. As part of this study, preliminary design of the mitigation measures were completed by the study team, in close coordination with the resource agencies.

As summarized in Table 8, mitigation will be required for 881.6 AAHUs of direct and indirect impacts. The habitat type that would require the most mitigation, for direct and indirect impacts combined, is estuarine emergent wetland (59.5 AAHUs). Mitigation will replace the lost functions and values of the impacted environment through restoration and enhancement activities that increase and/or improve the habitat functions and services within a mitigation site.

Table 8. Impacts from Implementing the Galveston Bay Storm Surge Barrier System

Impact	**FWP Acreage**	**AAHUs**
Direct		
Palustrine Wetlands	-128	-11.8
Estuarine Wetlands	-134	-59.9
Open Bay Bottom	-161.6	-18.1
Oyster	-6	-2.8
Total Direct Impacts	-429.6	-92.6
Indirect		
Tidal Prism Change	-1,148	-789
Total Indirect Impacts	-1,148	-789
Total Impacts	1,577.6	-881.6

Potential locations for mitigation sites, as shown in Figure 10, have been developed with the interagency team but will be refined further during the PED phase. Ultimately, the final size of the mitigation measures (width, length etc.) may change. However, due to the conservative nature of engineering and economic assumptions used in the development of the Recommended Plan, it is anticipated that design refinements of the proposed structures will result in equal or lesser environmental impacts than currently estimated.

The mitigation plan (Appendix J) is tentative to give an idea of the potential mitigation need and to confirm that sufficient suitable sites exist to conduct mitigation if the project were to be considered further. The mitigation plan will be updated when the Tier Two documentation of the Galveston Bay Storm Surge Barrier System is completed. At that time, the impacts would be better understood based on site-specific designs. The mitigation amounts will change and are driven by the project refinement and more-detailed mitigation site planning.

Figure 10. Potential Mitigation Sites

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 actionable measures and B-2 of the Tier One measures of the recommended plan would provide an overall positive benefit to the ecosystem by increasing EFH habitat quality and quantity, while also protecting existing habitat from storm surge, tidal energies, and RSLC. These benefits outweigh the temporary adverse impacts caused by construction activities and over the long-term these measures would provide an overall benefit to the Texas coastal ecosystems.

The Galveston Bay Storm Surge Barrier System (Tier One) is expected to have adverse direct and indirect impacts, to EFH in the project area through loss of habitat and changes in habitat quality. The measures would result in permanent loss of estuarine water column, estuarine mud and sand bottoms, marine water column, and unconsolidated marine water bottoms. The measure may also have temporary and permanent impacts to estuarine shell substrate, estuarine emergent wetlands, seagrasses. Long-term effects on prey of Federally-managed species and on Federally-managed species themselves are anticipated due to the reduced flow, reduced tidal amplitude, and periodic high velocities through the navigation and environmental gates. These include a reduction in prey due to the mortality or displacement of benthic species associated with dredging, placement, and construction activities. The exact long-term impacts to the Galveston Bay complex are uncertain, and additional studies will be required to best predict the impacts the structure may cause. These would completed during the Tier Two analyses, at which time additional consultation with NMFS on EFH impacts would be sought to ensure compliance with MSFCM.

The Draft Feasibility Report and EIS serves to initiate EFH consultation under the MSFCMA for the actionable measures of the recommended plan. Prior to the release of the Final Feasibility Report and EIS, NMFS and GMFMC will have had an opportunity to provide comments on EFH impacts. Their comments will be incorporated into this report as warranted and a final concurrence letter from NMFS will be included as appendix to document their concerns, recommendations, and any mitigation or conservation measures they propose.

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