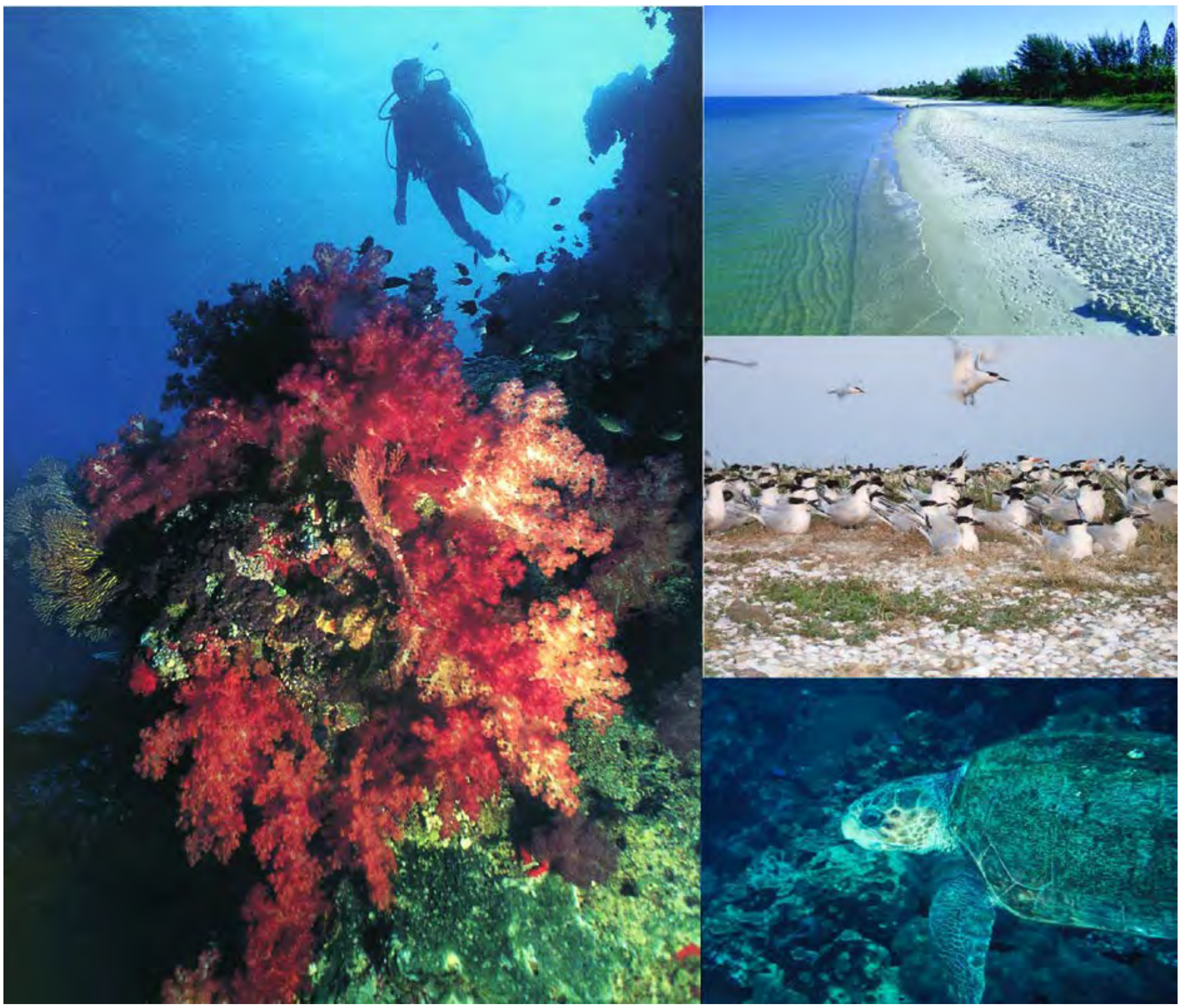
OCS Report
BOEM 2021-015

Biological Environmental Background Report for the Gulf of Mexico OCS Region



Estimated Lead Agency Total Costs
Associated with Developing
and Producing this Report:
$106,000

U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico Regional Office

BOEM
Bureau of Ocean Energy Management

OCS Report
BOEM 2021-15

Outer Continental Shelf

Biological Environmental Background Report for the Gulf of Mexico OCS Region

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Published by

U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico Regional Office

New Orleans
February 2021

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1 INTRODUCTION

1.1 PURPOSE

The mission of the Bureau of Ocean Energy Management (BOEM) is to manage development of U.S. Outer Continental Shelf (OCS) energy and mineral resources in an environmentally and economically responsible way. BOEM oversees the development of conventional (i.e., oil and gas) and renewable energy on the OCS, as well as manages access to marine mineral resources on the OCS (e.g., sand and gravel). The U.S. Department of the Interior regulates the Gulf of Mexico (GOM) OCS, which delegated this region to BOEM's New Orleans Office and the Bureau of Safety and Environmental Enforcement (BSEE).

This document compiles information that describes the biological resources of the GOM region and then explores these resources' vulnerability to BOEM-regulated activities associated with the exploration and development of oil and gas, marine minerals, and renewable energy. This background report may inform future internal and external efforts to describe GOM habitats and associated biological resources. This document will also inform future potential impact assessments of BOEM's programmatic activities prepared under the National Environmental Policy Act (NEPA). BOEM intends to use this document to inform future outreach processes with other Federal agencies and Tribal governments. Importantly, this document does not replace the NEPA process or obligations to consult. BOEM will only use this document as a more in-depth and technical reference resource for public NEPA documents.

Chapter 2 of this document describes the environmental setting of the GOM, including a discussion of the geology, physical oceanography, and other major drivers that shape the GOM ecosystem. **Chapter 3** includes a characterization of the biological resources of the GOM. These biological resources include coastal, pelagic, and benthic habitats and associated communities, followed by the individual organism groups of fish and invertebrates, sea turtles, marine mammals, and birds.

The vulnerability assessment (**Chapter 4**) evaluates the reasonably-foreseeable routine and accidental impact-producing factors (IPFs) from BOEM-regulated activities. A vulnerability assessment is conducted for each biological resource represented in the GOM. An IPF is the outcome of a proposed BOEM-regulated activity that can potentially impact a resource. For a list of IPFs included in this analysis, refer to **Chapter 4**. Routine activities generally occur on a regular basis and are the expected result of BOEM-regulated activity or associated actions. Accidental events do not occur on a regular basis during a BOEM-regulated activity and are unintentional by nature (e.g., spills of fuel, crude oil, or other chemicals resulting from accidents [less than 10,000 barrels], weather events, and collisions). Vessel strikes and trash and unintentional releases of marine debris are also considered accidental events.

This analysis does not asses the vulnerabilities to catastrophic events. Catastrophic oil spills such as the *Deepwater Horizon* explosion, oil spill, and response are not considered reasonably foreseeable accidental events and are not considered in this document. This document also does not include an analysis of vulnerabilities to other stressors or activities not regulated by BOEM, such as fishing, climate change, or coastal development.

Where appropriate, this document discusses most animal or plant types at a general level. Specific species are mentioned using their common names, when relevant; particularly protected species; and important fisheries species. **Appendix B** provides a list of common and scientific (or Latin) names of species mentioned in this document.

1.2 GEOGRAPHIC AND ADMINISTRATIVE SETTING

The GOM region comprises 1,630 miles (mi) (2,623 kilometers [km]) of coastline, spanning from the southern tip of Texas east across Louisiana, Mississippi, Alabama, and Florida to the Florida Keys. BOEM has designated three administrative units (i.e., planning areas) within the GOM (**Figure 1-1**): the Eastern Planning Area (EPA); Central Planning Area (CPA); and the Western Planning Area (WPA).

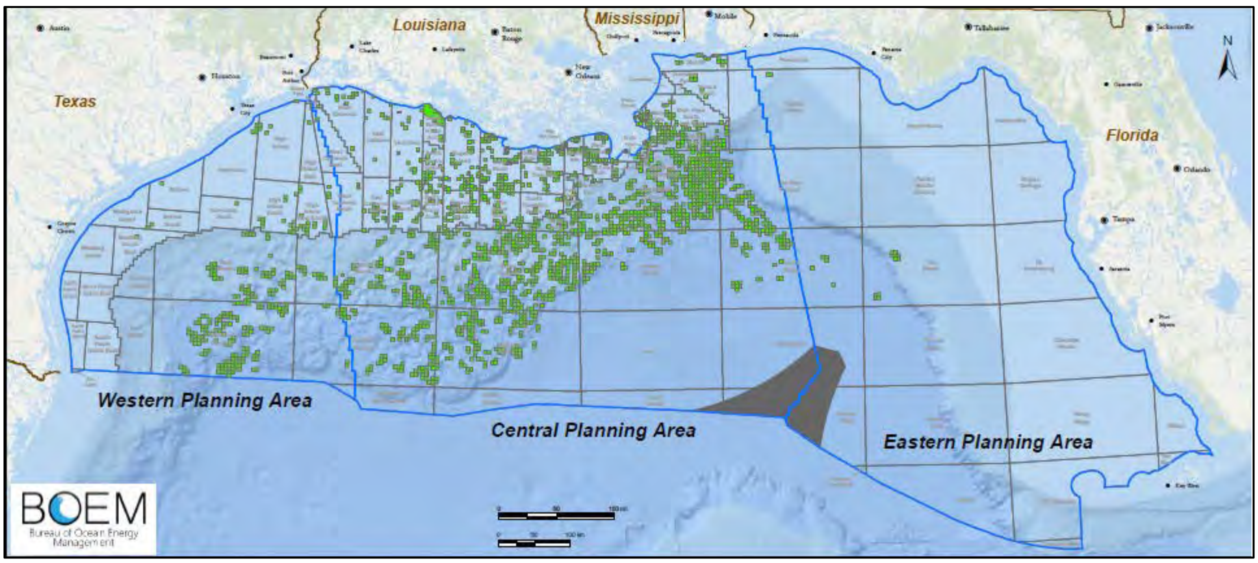

Figure 1-1. Map of BOEM Leasing and Planning Areas in the Northern Gulf of Mexico, December 2020. (Green boxes indicate blocks with active leases.)

As of December 2020, there are 2,259 active oil and gas leases in the GOM region, with 1,961 in the CPA, 280 in the WPA, and 18 in the EPA (BOEM 2020b). Only a fraction of these active leases has produced oil or gas, and there are no producing leases in the EPA. A portion of the CPA and most of the EPA is under restriction until 2022 as part of the Gulf of Mexico Energy Security Act of 2006. The area restricted is that portion of the EPA within 125 mi (201 km) of Florida, all areas in the GOM east of the Military Mission Line (86º 41' W. longitude), and the CPA portion that is within 100 mi (161 km) of Florida. The CPA and WPA remain the Nation’s primary offshore source of oil and gas, generating roughly 97 percent of all OCS oil and gas production. BOEM leases sand and gravel resources from the Gulf of Mexico OCS for shore protection, beach nourishment, and barrier island restoration. While BOEM anticipates future development of renewable energy in the Gulf of Mexico OCS, there is currently no renewable energy activity in the GOM region.

2 ENVIRONMENTAL SETTING

Large marine ecosystems (LMEs) are geopolitical regional units identified for the conservation of living marine, habitat, and socioeconomic resources. The LMEs are typically large areas of ocean space characterized by distinct hydrographic regimes, submarine topography, productivity, and trophically dependent populations (Sherman and Alexander 1986). Most marine economic activities (e.g., fishing, shipping, mineral extraction, etc.) takes place within LMEs; thus, these are subject to competing management, economic, and political interests (Wang 2004). The GOM in its entirety, including coastal zones, is identified as an LME under the jurisdiction of three countries: the United States (2/3 control); Mexico (1/3 control); and Cuba (marginal control). In the U.S., Federal agencies with management responsibilities in the GOM include the National Oceanic and Atmospheric Administration (NOAA), the National Marine Fisheries Service (NMFS), BOEM, BSEE, the U.S. Fish and Wildlife Service (FWS), the U.S. Geological Service (USGS), the National Park Service (NPS), the U.S. Department of Defense (DOD), the U.S. Environmental Protection Service (USEPA), the Gulf States Fisheries Management Commission[1], and the Marine Mammal Commission.

Primary management issues within LMEs include fisheries management, the protection of endangered species, pollution mitigation, the reduction of environmental stressors, and habitat restoration (Sherman 1991). Major ecosystem services (i.e., positive benefits provided by ecosystems to humans) managed within the context of the Gulf of Mexico LME include recreational and commercial fisheries, oil and gas production, and tourism. Primary anthropogenic stressors in the Gulf of Mexico LME include overfishing, pollution, eutrophication, habitat degradation and loss, hypoxic zones, coastal development, waste dumping, aerosol contaminants, and oil spills. Natural stressors include variable hydrographic processes, seasonal tropical storms, and terrestrial freshwater runoff. Compound stressors include natural hazards and climate change (Sherman and Duda 1999; Schirripa et al. 2013; Álvarez Torres et al. 2017).

Ecosystems within the context of an LME are comprised of interconnected ecologic, economic, and societal components. The LMEs have several key features. They are distinguishable from each other based on biophysical attributes and location. The LMEs include both living organisms and their abiotic environment (i.e., habitat). Resident organisms interact with each other through fluxes of energy and organic and inorganic material. Finally, LMEs have a dynamic structure that changes over time (Wang 2004).

An ecosystem-based approach towards an LME analysis and management recognizes that biological systems are dynamic. Organisms, populations, and communities within an LME cannot be separately analyzed from their environment. Further, human populations and the built environment are integrated within the LME (Yáñez-Arancibia and Day 2004). There are seven distinct geographic ecosystems in the northern GOM within the littoral zone of the LME, including the Lower Rio Grande, Texas Gulf Coast, Lower Mississippi River, Central Gulf, Florida Panhandle, North Florida, and South

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[1] The Gulf States Fisheries Management Commission is an organization of the five Gulf Coast States – Texas, Louisiana, Mississippi, Alabama, and Florida – whose coastal waters are the Gulf of Mexico. The compact was authorized by Congress under Public Law 81-66.

Florida (FWS 1995). Subregions within these ecosystems can be defined by discrete interactions between geologic, geomorphologic, oceanographic, and climatic regimes, as well as their coastal drainage systems, vegetation, fauna, estuary-shelf interactions, and human populations. In the GOM, subregions include marine-dominated semiarid lagoon-estuarine systems[2], non-river-dominated intermediate systems[3], river-dominated systems[4], marine dominated karstic systems[5], and coral reefs (Yáñez-Arancibia et al., 2013).

The biological components of the Gulf of Mexico LME are discussed in detail in this chapter. They are described within the context of three habitat regimes, i.e., coastal, pelagic, and benthic. These biological components are categorized by organism or community type, including fish and invertebrates (**Chapter 3.5**), sea turtles (**Chapter 3.6**), marine mammals (**Chapter 3.7**), and birds (**Chapter 3.8**). The Gulf of Mexico LME provides critical habitats for several ESA-listed species (**Figure 2-1**), which are discussed in their respective biological resource chapters. Organisms that do not fall into one of these categories are discussed in context of their relevant habitat(s) and include coastal communities (**Chapters 3.1 and 3.2**), pelagic communities (**Chapter 3.3**), and benthic communities (**Chapter 3.4**). The following subsections describe the physical and hydrographical regime of the Gulf of Mexico LME and the primary production that supports the resident biological community.

[2] Characteristics include low freshwater inflow, seagrasses, dwarf mangroves, salinity near or at that of the Gulf of Mexico, and low variability (Yáñez-Arancibia et al. 2013).

[3] Characteristics include salinity controlled by multiple factors, variability at annual time scales, and similar river and tidal flows (Yáñez-Arancibia et al. 2013).

[4] Characteristics include high freshwater inflow, the presence of an estuarine plume, broad coastal wetlands, and low to medium salinity variability at annual time scales (Yáñez-Arancibia et al. 2013).

[5] Characteristics include significant ground water discharge, dwarf and well-developed mangroves, and well-developed seagrasses (Yáñez-Arancibia et al. 2013).

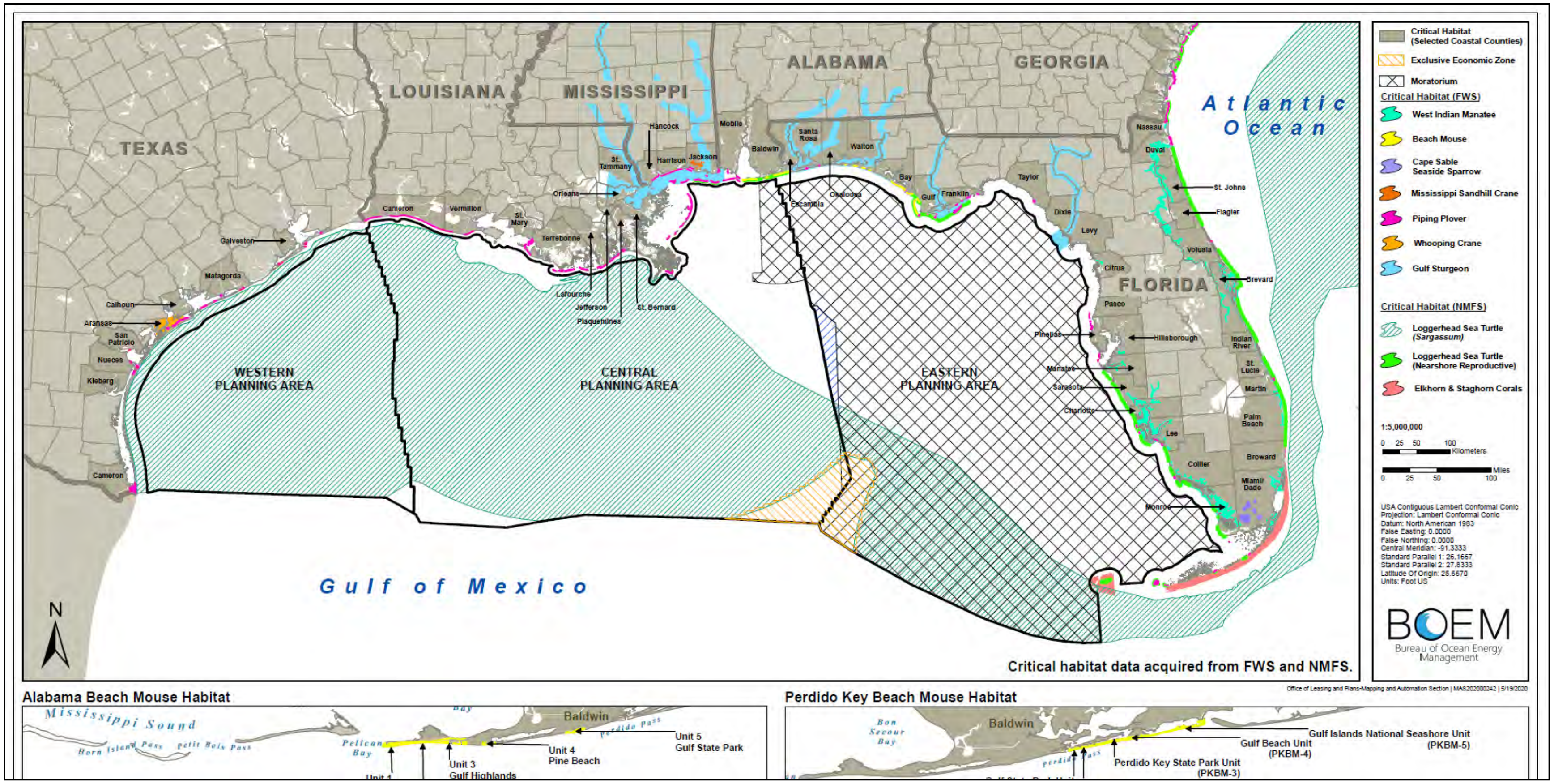

Figure 2-1. ESA-Listed Speciwes' Critical Habitat in the Gulf of Mexico Region.

2.1 GEOPHYSICAL SETTING

2.1.1 Surficial Geology

The GOM is a semi-enclosed basin with a surface area of more than 1.5 million km^2 (580,000 mi^2), maximum east-west dimension of 1573 km (977 mi), and maximum north-south dimension of 900 km (559 mi). The shallow OCS is generally less than 200 meters (m) (656 feet [ft]) in depth, is narrow and terrigenous in the west and moderately broad and terrigenous in the north, and has a wide carbonate platform in the east (i.e., the Florida platform). Approximately 32 percent of the GOM is continental shelf, 41 percent is continental slope (200-3,000 m [656-9,843 ft]), and 24 percent is abyssal plain (3,000+ m [9,843+ ft]). The deepest area is located within the Sigsbee Deep abyssal plain (3,800 m [12,467 ft]) (Darnell 2015; **Figure 2-2**).

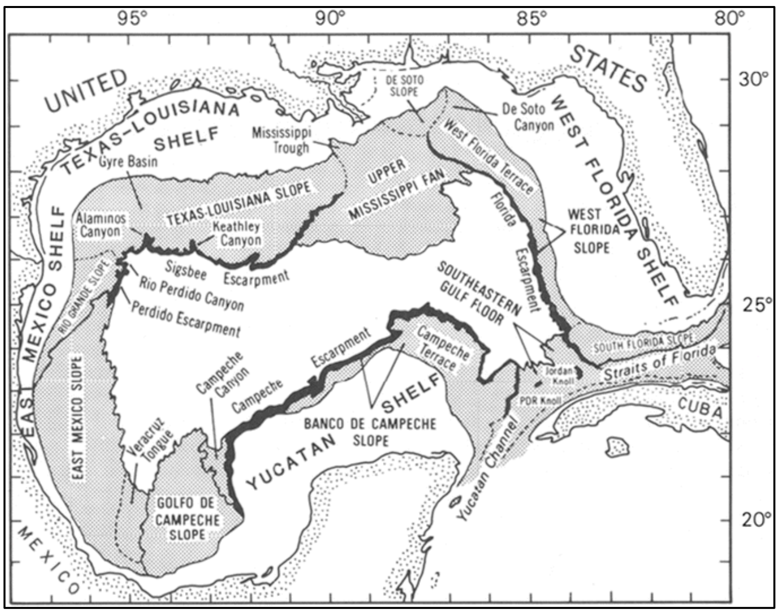

Figure 2-2. Physiographic Setting of the Gulf of Mexico. Physiographic map showing the major provinces of the Gulf of Mexico (from Martin and Bouma 1978). AAPG [1978], reprinted by permission of the AAPG whose permission is required for further use.

For biological communities and habitat, the definition of shallow water versus deep water is dependent upon local hydrography, sediment load, light penetration, organisms present, and community structure. In general, shallow water is defined as less than 300-m (980-ft) water depth and deep water as greater than 300-m (980-ft) water depth.

Sediments in the Gulf of Mexico basin and their distribution are derived from terrigenous sediments in the north and west, and carbonates that originate on the Florida platform. Sediment transport and distribution in the Gulf of Mexico basin are primarily due to waves, tides, and currents in shallow waters and gravity flow[6] in deep waters. The deep environments are dominated by a mixture of terrigenous and biogenic mud. Areas bounded by rivers receive the most sediment. The Mississippi River Delta plume covers over 37,500 km^2 (14,500 mi^2) of the continental shelf and carries approximately 550 million metric tons (500 million tons) of sediment into the GOM. The continental shelf in the western GOM off Texas receives little modern sediment.

The structure of the continental margins is the result of tectonic activity related to salt movement, reef growth, bottom currents, and sedimentation. The northern GOM is divided into two physiographic and sedimentary provinces by the De Soto Canyon, separating the limestone Florida platform in the east and the clastic embayments of the north and west (Antoine et al. 1974). Physiographic subprovinces include the Texas-Louisiana Shelf, the Texas-Louisiana Slope, the Rio Grande Slope, the Mississippi Fan, the Sigsbee Escarpment, the Sigsbee Plain, the Mississippi-Alabama-Florida Shelf, the Mississippi-Alabama-Florida Slope, the Florida Terrace, the Florida Escarpment, and the Florida Plain. Overall, sediment supply exceeds the subsidence rate, resulting in progradation of the shelf margin (Martin 1978; Ewing and Galloway 2019). Other prominent canyons include the Mississippi Trough, Green Canyon, and Keathley Canyon.

Warm, tropical waters enter the GOM between the Yucatan Channel and Cuba, circulate through the basin clockwise in the Loop Current (refer to **Chapter 2.1.2** for more information), and exit via the Florida Straits where they form the Gulf Stream. The Mississippi River dominates the terrestrial drainage system in the north, wherein two-thirds of the U.S. watershed drain into the GOM.

2.1.2 Physical Oceanography

Currents

Loop Current

The Loop Current, the dominant circulation feature in the GOM, enters through the Yucatan Channel and exits through the Florida Straits (refer to **Figure 3-1**). The sill depth at the Florida Straits is about 700 m (2,300 ft); the effective sill depth at the Yucatan Channel is nearly 2,000 m (6,560 ft) (Badan et al. 2005). Water masses in the Atlantic Ocean and Caribbean Sea that occur at greater depths cannot enter the GOM. The Loop Current is part of the western boundary current system of the North Atlantic. This is the principal current and source of energy for the circulation in the GOM. The Loop Current has a mean area of 142,000 km^2 (35 million acres) (Hamilton et al. 2000). It may be confined to the southeastern GOM but it can extend well into the northeastern or north-central GOM, with intrusions of Loop Current water northward and on to the West Florida Shelf (Vukovich 2005). Closed rings of clockwise-rotating (i.e., anticyclonic) water, called Loop Current eddies (LCEs), separate from the Loop Current at intervals of 5-19 months (Vukovich 2005). These LCEs are also called warm-core eddies because they surround a central core of warm Loop Current water. The Loop

[6] Sediment gravity flow is a type of sediment transport. It is a mixture of water and sediment particles where gravity acting on sediment particles moves the fluid. This is a common type of sediment transport in the deep waters of the Gulf of Mexico continental slope.

Current usually penetrates about as far north as 27°N. latitude just prior to shedding an LCE (Vukovich 2005).

Currents associated with the Loop Current and its eddies extend to at least depths of 700 m (2,300 ft), the sill depth of the Florida Straits; and geostrophic shear is observed to extend to the sill depth of the Yucatan Channel. These features may have surface speeds of 150-200 centimeters/second (cm/s) (59-79 inches/second [in/s]) or more; speeds of 10 cm/s (4 in/s) are not uncommon at a depth of 500 m (1,640 ft) (Cooper et al. 1990). The average diameter of warm-core eddies is about 200 km (124 mi), and they may be as large as 400 km (249 mi) in diameter. Warm-core eddies can have life spans of 1 year or more (Elliot 1982); therefore, their effects can persist at one location for long periods—weeks or even months (e.g., Nowlin et al. 1998). After separation from the Loop Current, these eddies often translate westward across the GOM at a speed of about 5 km/day (3 mi/day) (range 1-20 km/day [0.6-12.4 mi/day]). The LCEs decay and generate secondary cyclones and anticyclones (SAIC 1989) by interactions with boundaries, ring shedding, and ring-ring interactions. Consequently, the GOM is typically populated with numerous eddies, which are interacting with one another and with the margins (SAIC 1989; Hamilton and Lee 2005).

Cold-core cyclonic (counter-clockwise rotating) eddies have been observed in the GOM. These cyclones are often cold-core eddies because they surround a central core of seawater that is cooler and fresher than adjacent waters. Cyclonic circulation is associated with upwelling, which brings cooler, deeper water towards the surface. A cyclone will form north of an LCE encountering northern GOM bathymetry because of off-shelf advection (Frolov et al. 2004). Cyclones are also associated with the Loop Current (Schmitz 2005). Small cyclonic eddies around 50-100 km (31-62 mi) in diameter have been observed over the continental slope off Louisiana (Hamilton 1992). These eddies can persist for 6 months or longer and are relatively stationary.

Near the bottom of the Loop Current, velocities are low and uniform in the vertical although with bottom intensification, a characteristic of Topographic Rossby Waves (TRWs). This indicates that the Loop Current is a source of the TRWs, which are a major component of deep circulation below 1,000 m (3,281 ft) in this part of the GOM (Sturges et al. 1993; SAIC 1989; Hamilton 1990). Exchange of surface and deep water occurs with descent of surface water beneath the Loop Current in the eastern GOM and with the ascent of deep water in the northwestern GOM where LCEs spin down (Welsh and Inoue 2000). The Sturges et al. (1993) model suggests a surprisingly complex circulation pattern beneath LCE's, with vortex-like and wave-like features that interact with the bottom topography (Welsh and Inoue 2000). These model findings are consistent with Hamilton's (1990) interpretation of observations. Occasionally, currents have been directly measured at abyssal depths exceeding 3,000 m (9,843 ft) in the GOM. The major low-frequency fluctuations in velocity of these currents in the bottom 1,000-2,000 m (3,281-6,562 ft) of the water column have the characteristics of TRWs. These long waves have wavelengths of 150-250 km (93-155 mi), periods greater than 10 days, and group velocities estimated at 9 km/day (5.6 mi/day). They are characterized by columnar motions that are intensified near the seafloor. They move westward at higher group velocities than the translation velocity of 3-6 km/day (2-4 mi/day) that is typical of anticyclonic eddies. The Loop Current and LCEs are thought to be major sources of these westward propagating TRWs (Hamilton 1990; Oey and Zhang

2004). These TRWs transition from short to longer period in going from east to west over the GOM basin, probably because of bottom slope and regional bathymetric conditions (Donohue et al. 2008).

Deepwater Currents

In general, past observations of currents in the deepwater GOM have revealed decreases in current speed with depth. During late 1999, a limited number of high-speed current events, at times approaching 100 cm/s (39 in/s), were observed at depths exceeding 1,500 m (4,921 m) in the northern GOM (Hamilton and Lugo-Fernandez 2001; Hamilton et al. 2003). Furrows oriented nearly parallel to depth contours have been observed recently in the region of 90°W. longitude just off the Sigsbee Escarpment and near the Bryant Fan, south of Bryant Canyon, from 91° to 92.5°W. longitude. Depths in those regions range from 2,000 to 3,000 m (6,562 to 9,843 ft). It is hypothesized that near-bottom speeds of currents responsible for the furrows that are closest to shore might be 50 cm/s (20 in/s), possibly in excess of 100 cm/s (39 in/s), and that these currents may be oriented along isobaths and increase in strength toward the escarpment. These currents might be sporadic or quasi-permanent. Mean deep flow (~2,000 m [~6,562 ft]) around the edges of the GOM circulates in a cyclonic (i.e., counterclockwise) direction (Sturges et al. 2004). A net counterclockwise circulation pattern was also observed at about 900-m (2,953-ft) depth around the borders of the GOM (Weatherly 2004). In deep water, several oil and gas operators have observed very high-speed currents in the upper portions of the water column. These high-speed currents can last as long as a day. Such currents may have vertical extents of less than 100 m (328 ft), and they generally occur within the depth range of 100-300 m (328-984 ft) in total water depths of 700 m (2,297 ft) or less over the upper continental slope. Maximum speeds exceeding 150 cm/s (59 in/s) have been reported. The mechanisms by which these currents are generated may include motions derived from the Loop Current and associated eddies. These motions may be due to eddy-eddy or slope-shelf/eddy interaction, internal and inertial wave motions, instabilities along eddy frontal boundaries, and biases in the data record related to instrument limitations (DiMarco et al. 2004).

The major large-scale permanent circulation feature present in the western and central GOM is an anticyclonic (clockwise-rotating) feature oriented about ENE-WSW with its western extent near 24°N. latitude off Mexico. There has been debate regarding the mechanism for this anticyclonic circulation and the possible associated western boundary current along the coast of Mexico. Elliott (1982) attributed LCEs as the primary source of energy for the feature, but Sturges et al. (1993) argued that wind stress curl over the western GOM is adequate to drive an anticyclonic circulation with a western boundary current. Sturges et al. (1993) found annual variability in the wind stress curl corresponding to the strongest observed boundary current in July and the weakest in October. Based on ship-drift data, Sturges et al. (1993) reported that the maximum northward surface speeds in the western boundary current were 25-30 cm/s (10-12 in/s) in July and about 5 cm/s (2 in/s) in October; the northward transport was estimated to vary from 2.5 to 7.5 m^3/s. Sturges et al. (1993) reasoned that the contribution of LCEs to driving this anticyclonic feature must be relatively small. Others have attributed the presence of a northward flow along the western GOM boundary to ring-slope-ring interactions (Vidal et al. 1999).

In deepwater regions of the GOM, clearly episodic wind events can cause major currents in the deep waters of the GOM. The initial currents give rise to inertial oscillations with decreasing amplitudes, which last for up to about 10 days and are superimposed on longer period signals.

On-Shelf Processes

Cold fronts, as well as diurnal and seasonal cycles of heat flux at the air and sea interface, affect near-surface water temperatures. However, although water at depths greater than about 100 m (328 ft) remains unaffected by surface boundary heat flux. Water temperature is greater than air temperature at the air and sea interface during all seasons. Frontal passages over the region can cause changes in temperature and velocity structure in the upper layers, specifically increasing current speeds and variability. These fronts tend to occur with frequencies from 3 to 10 days (weatherband frequency). In the winter, the shelf water is nearly homogeneous due to wind stirring and cooling by fronts and winter storms.

Continental shelf waves may propagate along the continental slopes of the GOM. These are long waves like TRWs, but their energy is concentrated along a sloping bottom with shallow water to the right of the direction of propagation, and because of this constraint, they are effectively “trapped” by the sloping bottom topography. Cold water from deeper off-shelf regions moves onto and off the continental shelf by cross-shelf flow associated with upwelling and downwelling processes.

A class of energetic surface currents previously unreported in the GOM were found over the Texas and Louisiana shelves during the Texas-Louisiana Shelf Circulation and Transport Process (LATEX) program of the early 1990s (Nowlin et al. 1998). July 1992 observations in 200-m (656-ft) water depth offshore of Louisiana were of maximum amplitudes of 40-60 cm/s (16-27 in/s) at a depth of 12 m (39 ft) during conditions of light winds. The period of diminished amplitudes followed an atmospheric frontal passage. These are near-circular, clockwise-rotating oscillations with a period near 24 hours. They seem to be an illustration of thermally induced cycling (DiMarco et al. 2000) in which high-amplitude rotary currents can exist in thin mixed layers typical of summer. By contrast, December 1992 measurements evidence no such behavior. Many examples of such currents, in phase at distinct locations, exist for the Texas-Louisiana shelf and, by implication, farther offshore. Currents at a depth of 1 m (3 ft) have been observed to reach 100 cm/s (40 in/s).

Inner-shelf currents on the Louisiana-Texas continental shelf flow in the downcoast (south or west) direction during non-summer months, reversing to upcoast flow in the summer (Cochrane and Kelly 1986; Nowlin et al. 2005). Modeling results show that the spring and fall reversals in alongshore flow can be accounted for by local wind stress alone (Current 1996). Monthly averaged alongshore currents on the outer shelf are upcoast in the mean but showed no coherent pattern in the annual signal. These currents were not often in the same alongshore direction at different outer-shelf locations (Nowlin et al. 1998). Mean cross-shelf geostrophic transport observed at the Louisiana-Texas shelf break was offshore during the winter (particularly in the upper 70 m [230 ft] of the water column) and onshore during the summer (Current and Wiseman 2000).

Circulation on the continental shelf in the northeastern GOM has been observed to follow a cyclonic pattern, with westward alongshore currents prevailing on the inner and middle shelf and opposing alongshore flow over the outer shelf and slope (Brooks 1991). Inner shelf currents are primarily wind driven and are also influenced by river outflow and buoyancy forcing from water discharged by the Mississippi, Apalachicola, Tombigbee, Alabama, and other rivers in the region. Cold water from deeper off-shelf regions moves on and off the continental shelf by cross-shelf flow associated with upwelling and downwelling processes. Upwelling of nutrient rich, cold water onto the shelf in 1998 was correlated with hypoxia, anoxia, and mass mortalities of fishes and invertebrates in the region, although causation has not been established (Collard and Lugo-Fernandez 1999).

Mean circulation on the West Florida inner shelf tends to be along the coast towards the southeast during the winter and reverses to be along the coast towards the northwest during the summer. These seasonal means in flow direction are because of the influence of seasonal local winds and heat flux forcing. Midshelf flow (around the 50-m [164-ft] isobath) can be in the opposite direction from inner shelf flow on the broad, gently sloping West Florida shelf because of the partial closure imposed by the Florida Keys to the south. The outer shelf is an area of transition between deepwater currents over the continental slope and the shelf regime. The nearshore regions are influenced by freshwater outflow from rivers and estuaries. Mississippi River water is advected onto the West Florida shelf at times in spring and summer because of strong currents along the shelf break. Freshwater from the Mississippi River is sometimes entrained by the Loop Current as well (Weisberg et al. 2005).

Water mass property extremes are closely associated with specific density surfaces. Summer heating and stratification affect continental shelf waters in the GOM. Salinity is generally lower nearshore, although freshwater from the Mississippi River and other rivers occasionally moves into outer shelf waters. Freshwater intrusions further lower the salinity after local storms. Subsurface waters derive from outside the GOM and enter from the Caribbean Sea through the Yucatan Channel. Below about 1,800 m (5,906 ft), horizontal distributions of temperature and salinity within the GOM are essentially uniform (Nowlin 1972).

Tropical Storms

Tropical cyclones that affect the Gulf of Mexico originate over the equatorial portions of the Atlantic Ocean, the Caribbean Sea, and the GOM. Tropical cyclones occur most frequently between June and November. Based on 50 years of data, there are about 9.6 storms per year with about 5.9 of those becoming hurricanes in the Atlantic Ocean. Data from 1950 to 2000 show that 79 percent of these storms, or 4.7 storms per year, will affect the GOM (Klotzbach and Gray 2005). The Yucatan Channel is the main entrance of Atlantic storms into the GOM, and a reduced translation speed over GOM waters leads to longer residence times in this basin.

Tropical cyclones, especially hurricanes, and extra tropical cyclones can result in extreme waves and cause currents with speeds of 100-150 cm/s (40-59 in/s) over the continental shelves. Brooks (1983; 1984) measured the effects of such phenomena down to depths of 700 m (2,297 ft) over the continental slope in the northwestern GOM. Hurricanes can trigger a series of internal waves with near inertial period. Waves as high as 28 m (91 ft) were measured under Hurricane Ivan (Wang et al. 2005). Tropical cyclones may develop or migrate into the GOM during the warmer months. These storms may affect any area of the GOM and substantially alter the local wind circulation around them.

Primary Production

Phytoplankton, photosynthetic and typically unicellular organisms, are the primary fixers of organic matter that support the Gulf of Mexico LME. They produce the bulk of organic matter in marine ecosystems. Key physical and chemical variables of phytoplankton growth include nutrient (e.g., nitrate, phosphate, and silicate) supply and composition, irradiance/turbidity, temperature, salinity, mixed layer depth, stability/stratification, and horizontal and vertical advection and diffusion. These in turn affect key ecologic variables including biomass (e.g., pigment and carbon), growth rates, loss rates (e.g., death, grazing, sinking, and advection), photosynthetic parameters, and phytoplankton community composition.

Nitrate is the primary limiting nutrient followed by phosphate in the GOM (Rowe 2017). Ninety percent of the water and most of the terrestrial-sourced nitrate and phosphate into the GOM comes from the Mississippi and Atchafalaya Rivers. Seasonal variability in river flow causes significant fluctuations in nutrient flux (Zhao and Quigg 2014), with peak nutrient input generally occurring in the spring (Lohrenz et al. 1997). The nutrient-rich Mississippi River plume in the north-central GOM is an area of considerable new primary production, with productivity greatest in the low salinity surface layer. The upper 10 m (33 ft) of the plume may account for up to 11 percent of the total surface productivity in the GOM (Wawrick et al. 2003).

While growth-limiting nutrients are primarily sourced from rivers, most of the nutrient flow into the GOM enters and exits via the Florida Straits (Turner and Rabalais 2019). In addition to nutrient flux from the Mississippi and Atchafalaya Rivers, primary productivity is affected by outflow from coastal lagoons and small rivers, cyclonic eddies along the continental margins, and wind-driven upwelling (summarized in Müller-Karger et al. 1991).

Primary productivity varies in the GOM, from eutrophic coastal and estuarine waters to the oligotrophic deep ocean. Production on the shelf off the Mississippi River and within estuaries is approximately 300 grams carbon per m^2/yr. On the shelf, at a distance from the Mississippi and Atchafalaya Rivers or where upwelling is sparse, production is approximately 200 grams carbon per m^2/yr. Production is much lower in the surface waters over the deep GOM basin. Therefore, primarily production in the GOM is dominated by processes along the margins of the GOM (Turner and Rabalais 2019). Hot spots of primary productivity characterized by relatively high biomass of phytoplankton, zooplankton, and micronekton do occur seaward of the shelf break due to freshwater entrainment, cross-isopycnal mixing, and mesoscale divergence (Biggs and Ressler 2001).

Physical and chemical processes in the GOM affect the LME on several spatial and temporal scales. For example, long-term changes in biologic processes such as seasonal variations in rates occur over relatively large spatial scales. Alternatively, areas of mixing can produce high biologic variability over smaller spatial scales in relatively short periods of time (days). Influential processes occur at larger scales including local (1-10 km; 1-6 mi), mesoscale (10-300 km; 6-186 mi), and synoptic (100-10,000 km; 186-6,214 mi). Local-scale processes include small river and estuarine outflow (e.g., Apalachicola River), wave effects on mixing, and nearshore (i.e., coastal) circulation features. Mesoscale processes include tidal mixing, upwelling, meteorological forcing (e.g., wind and cold storms), regional circulation, internal waves, topographic effects, larger rivers (e.g., Mississippi, Atchafalaya, and Mobile Rivers), fronts, and Loop Current circulation features. Synoptic-scale processes include seasonal variations in solar and atmospheric conditions and Loop Current excursions. The interaction of these numerous processes makes it difficult to understand the control of primary production, tease out trends, and relate to any species or habitat responses to such production (Lohrenz et al. 1999).

Climate Change and Ocean Acidification

The increasing concentration of greenhouse gases in the atmosphere is advancing planet-wide physical, chemical, and biological changes and substantially impacting the world's oceans and elsewhere. The three most impacting of these gases are carbon dioxide, methane, and nitrous oxide. Broadly, possible impacts include temperature and rainfall changes; rising sea levels; and changes to ocean conditions, such as ocean circulation patterns and storm frequency (IPCC 2014). These changes may affect marine GOM ecosystems by increasing the vertical stratification of the water column, shifting prey distribution, impacting competition, and generally impacting species' ranges (Learmonth et al. 2006). Such modifications could result in ecosystem regime shifts as the productivity of the regional ecosystem undergoes various downstream changes related to nutrient inputs and coastal ocean processes (Doney et al. 2012).

Climate change can influence weather patterns, with predicted increase in the frequency and intensity of storms (IPCC, 2014). In the GOM, high-intensity storms coupled with the highest rates of sea level rise in the United States (Lindsey 2020) contribute to coastal flooding and erosion, damage coastal infrastructure, and degrade coastal habitats. Fragile marine ecosystems like coral reefs are directly damaged by such storms, while other sensitive areas like seagrass beds may experience indirect impacts from increased water turbidity and nutrient runoff. Storm impacts on coastal communities will be exacerbated if shoreline vegetation is lost.

Warming ocean and coastal temperatures can push species to the edge of their optimal temperature ranges. The collective range shifts by individual species could result in broad changes to marine ecosystems, with unpredictable consequences (Doney et al. 2012; Karnauskas et al. 2015). A poleward shift in certain species' ranges is predicted. Warmer ocean temperatures have caused severe bleaching in reef-building corals, and this is expected to continue in future years (IPCC 2014). Zooplankton may serve as "beacons of climate change" because they are short-lived and particularly sensitive to changes in water temperature, making them tightly coupled to environmental changes (Richardson 2008). Warming waters can affect the timing of annual events such as plankton blooms, migration, and reproduction in some species, potentially disrupting predator-prey relationships, with cascading effects throughout the food web (Ullah et al. 2018). Climate change models show a higher likelihood of extinction of local species by 2050, with species invasion and replacements, also occurring but less prominent (Cheung et al. 2009).

Additional carbon dioxide in the Earth's atmosphere also changes ocean chemistry, affecting marine life. As seawater absorbs carbon dioxide, it becomes more acidic, a phenomenon known as "ocean acidification." The skeletons and shells of some organisms, including crustaceans, foraminiferans, and coccolithophores, are made from calcium carbonate, which dissolves in acid. Increased seawater acidity makes it more difficult for these organisms to build and maintain their shells and exoskeletons, and may have potential impacts on individuals and populations (Doney et al. 2009; Fabry et al. 2008). Raised acidity is also a challenge for both shallow and deepwater coral species by decreasing calcification rates or even dissolving exoskeletons (Doney et al. 2009; Thresher et al. 2015). Ocean acidification can also affect the growth and physiology of fishes at different life-history stages. Larval stages may be the most vulnerable (Llopiz et al. 2014), but it is not well understood whether fish can adapt to new environmental conditions (Ishimatsu et al. 2008). Finally, not only will ocean acidification affect the success of some species, it will also impact oceanic carbon sequestration, as some calcifying plankton play a crucial role in the global carbon cycle (Hoffman and Schellnhuber 2009). Changes to the global carbon cycle could lead to additional impacts on habitats and food webs, potentially triggering larger-scale ecosystem responses.

All of the climate change-related impacts described above can have cascading effects on marine ecosystems because they may act additively or synergistically with other stressors, including those introduced by oil and gas activities (Doney et al. 2012). In the open waters of the GOM, sea surface temperature, sea surface height anomalies, and wind speeds have gradually increased over a 20-year period, but primary productivity has not changed (Muller-Karger et al. 2015). During a similar time period, Muhling et al. (2012) reported an increase in numbers and kinds of fish larvae collected from Gulf of Mexico OCS waters, but model projections based on the temperature tolerance of bluefin tuna suggest that as water temperatures increase, spawn intensity should decrease (Muhling et al. 2012). These mixed results suggest that the long-term effects of rising sea surface temperatures on plankton and larval fishes will be species-specific, making it difficult to predict overall trends. Some predict that climate change will cause large-scale redistribution of global fishing catch and alter coastal economies (Cheung et al. 2010). The collective range shifts by individual species could result in broad changes to marine ecosystems, with unpredictable consequences (Doney et al. 2012; Karnauskas et al. 2015).

3 RESOURCE DESCRIPTIONS

3.1 INTRODUCTION

Chapter 3 describes the biological resources of the GOM region. Each chapter provides information about the ecology, status, and trends of a given biological resource. In this document, most animal or plant types are discussed at a general level where appropriate. Specific species are mentioned when relevant, especially those that have a protected status or are commercially important. In these cases, their common name is used in the main body of the text. Refer to **Appendix B** for a table of common and scientific names of organisms that appear in the text, as well as any relevant protective status.

3.2 COASTAL COMMUNITIES

The U.S. coastline in the GOM comprises more than 750 bays, estuaries, and sub-estuary systems (USEPA 2012; **Figure 3-1**). These coastal and estuarine habitats provide critical nursery grounds and adult habitat for numerous species of fish and invertebrates, while seagrass beds provide foraging habitat for sea turtles and manatees. Most of the GOM coastal waters are designated as essential fish habitat (EFH; refer to **Chapter 3.5**).

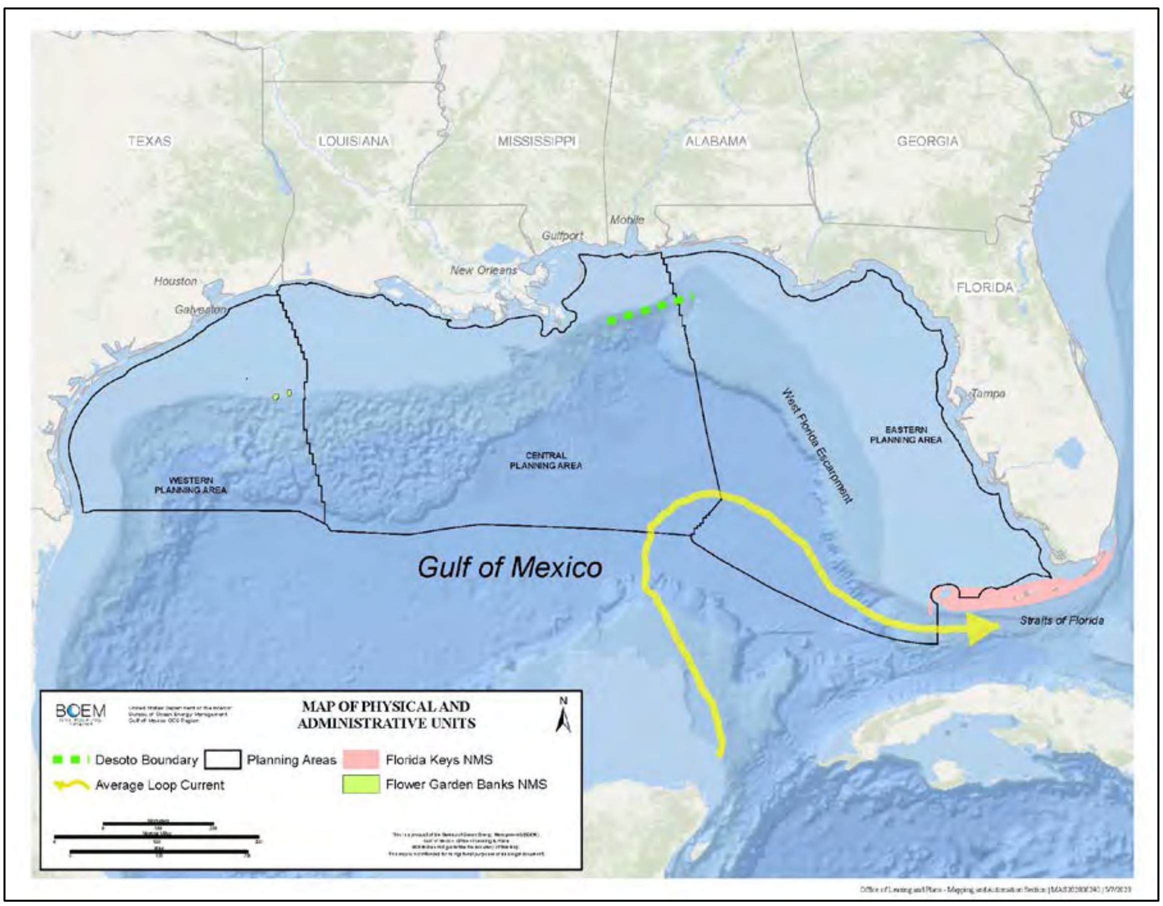

Figure 3-1. Map of Physical and Administrative Units of the Gulf of Mexico Region.

Coastal habitats in the northern GOM include marshes (i.e., salt, brackish, and fresh), forested wetlands, estuaries, beaches, and dunes. Saltwater marshes, saltwater mangrove swamps, and non-vegetated areas (e.g., sand bars, mudflats, and shoals) are the most common GOM coastal habitats (Dahl and Stedman 2013). The primary physical oceanography factors that influence coastal environments are temperature, salinity, dissolved oxygen, chlorophyll content, nutrients, potential of hydrogen (pH), oxidation reduction potential (Eh), pathogens, transparency (i.e., water clarity, turbidity, and suspended matter), and contaminant concentrations (e.g., heavy metals, hydrocarbons, and other organic compounds).

The Mississippi River is another defining feature of the GOM coastline in the CPA. Prior to the extensive leveeing and other controls, the lower Mississippi River used to shift its course to the GOM roughly every thousand years, seeking the most direct path to the sea while building a new deltaic lobe. The current lobe is known as the birdfoot of Balize delta. Older, historic lobes have shaped the Louisiana coast and contributed to the extensive coastal wetland system (Coleman et al. 1988). The Louisiana coastal area (USACE 2004) experiences relatively high rates of subsidence due to these delta-building and abandonment dynamics when compared to more stable coastal areas in the EPA and WPA. The shifting nature of the Mississippi River can be a driving feature of the habitats nearby (e.g., wetlands and estuaries).

3.2.1 Estuaries

Estuaries are typically semi-enclosed areas where marine saltwater is diluted by freshwater and where salinity may vary widely from day to day. The freshwater input (e.g., bayou, stream, or river) delivers sediment and nutrients that result in turbid, productive environments. Estuaries include many important habitat types (e.g., wetlands, seagrasses, and mudflats) and are frequently areas with high biomass. However, these environments can also have high energetic costs for resident organisms due to fluctuating conditions. Estuaries may be subject to extreme tidal exchange, strong currents, water-column stratification, and/or rapid fluctuations in dissolved oxygen.

Coastal and estuarine habitats are home to a diverse array of marine fish and invertebrates, including some protected species (**Chapter 3.5**). The coastal GOM waters are enriched by organic material exported from the estuaries and rivers that empty into the GOM and support high fish biomass. Many of the fishes and invertebrates found in mid- or near-shelf waters are dependent upon or opportunistically make use of estuaries at some point in their life cycle. For example, estuaries provide nursery habitat for Gulf menhaden, spotted sea trout, blue crab, brown shrimp, and gag. The eastern oyster is an example of a species that both benefits from the environmental conditions in estuarine habitat and serves as an important substrate. Bull sharks opportunistically make use of estuarine habitat and are common in estuaries and coastal waters. Critical habitat for the Endangered Species Act (ESA)-listed smalltooth sawfish occurs in the nearshore waters of the EPA (**Chapter 3.5**). The ESA-listed Gulf sturgeon has designated critical habitat in select rivers and coasts of Louisiana, Mississippi, Alabama, and Florida.

The coastal and estuarine habitats of the northern GOM support a variety of coastal and marine birds. Wetland and coastal habitats provide key foraging and resting areas for more than 400 species of birds (FWS 2013c). The northern GOM coastal areas provide essential wintering habitat for many species, such as the white pelican, common loon, and a variety of waterfowl and shorebirds. Portions of the shoreline in the northern GOM have been designated as critical habitat for wintering ESA-listed piping plovers. Some ESA-listed species, such as the Cape Sable seaside sparrow, may spend all their life stages in coastal marshes.

3.2.2 Wetlands

Wetlands occur along the coastal GOM areas, with the highest density occurring in Louisiana and southern Florida (Dahl and Stedman 2013). Coastal wetlands are complex systems that provide many essential functions. Coastal wetlands serve as a front line of defense against storm surge and a buffer against sea-level rise. High organic productivity and efficient nutrient recycling are characteristic of coastal wetlands. Wetland corridors provide habitat for a large and diverse group of resident plants, invertebrates, fishes, reptiles, birds, and mammals. Marsh environments are particularly vital nursery grounds for many economically important fish and shellfish juveniles. As "living filters," wetlands improve water quality by removing pollutants and nutrients, as well as trapping sediments. Furthermore, coastal wetlands provide direct human value by minimizing upland erosion, protecting property and infrastructure, and supporting the tourism, hunting, and fishing sectors of the economy.

Natural and anthropogenic stressors have contributed to a long-term trend of wetland loss in the coastal GOM. These losses are attributed to the effects of severe coastal storms, natural and induced land subsidence, sea-level rise, and the construction of levees and other water management measures along the Mississippi River. Artificial flood controls (e.g., levees) have reduced the natural riverine input to most of the GOM, resulting in a decrease in the sediment loads and nutrients needed for wetland survival (Kesel 1989; Ko and Day 2004). Additionally, the creation of channels and canals (often as a result of oil and gas industry activity) can lead to saltwater intrusion, which can destroy freshwater marshes (Ko and Day 2004).

Marsh erosion, in conjunction with natural subsidence of the uncompacted deltaic sediments in the region, contributes to some to the highest rates of relative sea-level rise in the U.S. (NOAA 2020). Sea-level rise results in marshland conversion to open water at staggering rates (see below). In some areas of the GOM, artificial hydrologic modifications and coastal development impede the ability of wetlands to migrate inland. This "coastal squeeze" (Doody 2004) contributes to an overall loss of intertidal coastal habitat in the region. The nutria, native to South America, was introduced to the Gulf Coast in the 1940s via the fur trade, and now occurs in all five Gulf Coast States. These rodents graze on wetland vegetation and exacerbate ongoing erosion, land loss, and saltwater intrusion.

In coastal Louisiana and Texas, oil, gas, and groundwater extractions have contributed to subsidence and relative sea-level rise (Dahl and Stedman 2013). Infrastructure development for offshore oil and gas activities (e.g., the construction of canals through wetlands) may also contribute to coastal land loss (Turner 1987; Turner and Cahoon 1987a, 1987b, 1987c; Ko and Day 2004; USACE 2004). An estimated 15,000 km (9,321 mi) of oil and gas pipelines cross Louisiana wetlands and approximately 50,000 oil and gas production facilities are located in coastal Louisiana (USACE 2004).

Recent evaluations of wetland trends in the U.S. from 2004 to 2009 indicated that the GOM region experienced a downward trend in coastal and intertidal wetland acreage. The GOM coastal region represents 99 percent of all intertidal, coastal wetland losses across the three coastal regions of the conterminous U.S. The wetland loss trends for each Gulf Coast State are discussed below, and these patterns are depicted in **Figure 3-2**.

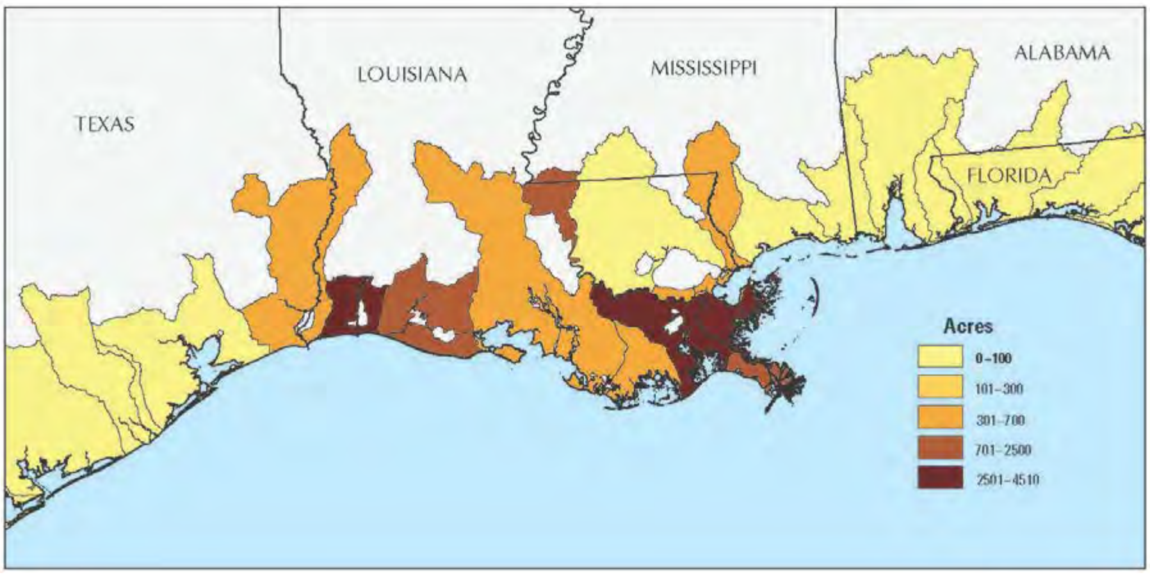

Figure 3-2. Upper Gulf of Mexico Showing the Magnitude of Saltwater Wetland Loss to Open Water, 2004 to 2009 (from Dahl and Stedman 2013).

An estimated 3.9 million acres (ac) (1.6 hectares [ha]) of wetlands existed on the Texas coast in 1992. Approximately 1.7 million ac (687,966 ha) or 52 percent of the freshwater wetlands in coastal Texas were classified as farmed wetlands used to cultivate rice and other agricultural uses (Moulton et al. 1997). The greatest losses were of freshwater emergent and forested wetlands (Moulton et al. 1997). The primary cause was faulting and land subsidence due to the withdrawal of underground water and onshore oil and gas, which has resulted in the submergence of marshes (Moulton et al. 1997).

Coastal Louisiana contains about 37 percent of the estuarine herbaceous marshes in the conterminous U.S. and supports the largest commercial fishery in the lower 48 States. Since the 1930s, Louisiana has lost approximately 4,877 km^2 (1,883 mi^2) of land (Couvillion et al. 2011). These wetlands account for about 90 percent of the total coastal wetland loss in the continental U.S., with a current loss rate of 16.57 mi^2/yr (42.9 km^2/yr) (Couvillion et al. 2011). This rate is an improvement from the 42 mi^2/yr (108.8 km^2/yr) rate experienced during the late 1960s. Ninety-five percent of this loss is due to continual loss of land through subsidence, saltwater intrusion, and other factors. Separating the causes of such land loss is difficult, but one study estimated that the total of direct and indirect impacts from OCS oil- and gas-related activities from 1955 to 1978 accounted for an 8 to 17 percent of Louisiana's total wetland loss (Turner and Cahoon 1987a, 1987b, 1987c).

Both Mississippi and Alabama have estuarine intertidal emergent habitats that include salt marsh, as well as intertidal forested/shrub that can include mangroves and salt-tolerant shrubs. In 1999, Mississippi had approximately 64,000 ac (25,900 ha) of vegetated coastal wetlands (State of Mississippi, Dept. of Marine Resources 1999). Estuarine wetlands are common in Mississippi and include marshes, mud flats, and forested wetlands. The estuarine marshes around Mississippi Sound and associated bays occur in discontinuous bands. The most extensive coastal wetland areas in Mississippi occur in the eastern Pearl River Delta near the Louisiana/Mississippi border and in the Pascagoula River Delta area near the Mississippi/Alabama border (State of Mississippi, Dept. of Marine Resources 1999; Wallace 1996; Couvillion et al. 2011). Most coastal wetlands in Alabama occur on the Mobile River Delta or along the northern Mississippi Sound. While Alabama's historic coastal wetland loss was considerable, the areal extent changed very little between 1974 and 2010 (Ellis et al. 2011).

Florida wetlands, at one time estimated to encompass over 20 million ac (8.1 million ha), have been converted through draining, dredging, filling, and flooding, until by 1996, approximately 11.4 million ac (4.6 million ha) remained (Dahl 2005). Wetland loss rates in Florida, as high as 72,000 ac/yr (29,137 ha/yr) from the mid-1950s to the mid-1970s, declined to 5,000 ac/yr (2,023 ha/yr) from 1985 to 1996 (nearly 80% rate decline) due to increased regulations and the elimination of incentives for wetland drainage. Florida's coastal zone contained approximately 21 percent of the estuarine and marine wetlands of the conterminous U.S. and 92 percent of estuarine shrub wetlands in 1996.

Wetland loss across the Gulf Coast States is expected to continue. Coastal and estuarine habitat acreage will likely continue to decline, particularly in Louisiana, due to global sea-level rise and subsidence. Also, offshore hypoxia has persisted for years (varying in intensity and size) and is expected to remain for decades to come, with varying effects on the coastal ecosystem. The shoreline surrounding the Mississippi River Delta is also expected to continue to erode, as agricultural, residential, and commercial development persists (Boesch et al. 1994b; Day et al. 2000, 2001). Erosion of shorelines, storm intensification, and coastal flooding due to climate change may continue to affect coastal wetlands in the GOM. Any stressors that lead to the degradation or loss of key habitat areas for estuarine fish, shellfish, and birds will likely put additional stress on these species.

In recognition of these ongoing and projected patterns of coastal land loss, several programs have been established for the conservation, protection, and preservation of coastal areas. In response to Hurricanes Katrina and Rita, as well as other events, Federal, State, and local agencies are engaged in ongoing efforts to restore and protect the Gulf Coast's natural and human environment. Louisiana's Coastal Protection and Restoration Authority has secured roughly $21.4 billion in State and Federal funding for protection and restoration projects and benefitted over 18,234 ha (46,058 ac) of coastal habitat. Some of these restoration efforts use sand dredged from the OCS through BOEM's Marine Minerals Program. The Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act (RESTORE Act), passed in 2012, dedicates administrative and civil penalties from the *Deepwater Horizon* oil spill to be used for the restoration and protection of the Gulf Coast region. It also established Centers of Excellence for science, technology, and monitoring. Collectively these efforts are making some headway at restoring coastal habitats and may be reducing rates of coastal land loss. However, currently, these efforts are not sufficient to reverse the current and projected trends for land loss along the Gulf Coast.

3.2.3 Mangroves

Mangrove swamp habitat, a type of coastal wetland, can be found from Texas to Florida along the northern GOM. Mangrove swamps are named after the dominant vegetation, the salt-tolerant mangrove tree. In the continental U.S., only three species of mangrove exist: red, black, and white mangroves. Florida's southwest coast supports one of the world's most extensive mangrove swamps. Mangroves provide habitat for a wide diversity of animals, including fish, oysters, shrimp, and other invertebrates, which subsequently support wading birds, pelicans, and the ESA-listed American crocodile. Mangroves stabilize shorelines and serve as storm buffers. Mangroves trap fine substrates and reduce turbidity by filtering upland runoff and trapping waterborne sediments and debris.

3.2.4 Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) is a vital component of coastal aquatic ecosystems, with at least 26 species of SAV growing in the northern GOM (Carter et al. 2011; Heck et al. 2011). The SAV are defined as the collection of benthic plants (e.g., seagrasses) that settle and grow in marine and/or estuarine waters but that do not emerge above the water's surface. Distribution and composition of the species present depend on an interrelationship among several environmental factors, including water temperature, depth, turbidity, salinity, turbulence, and substrate suitability (Kemp 1989; Onuf 1996; Short et al. 2001). In high salinity waters, SAV are marine seagrasses that generally occur in relatively shallow and clear protected waters with substrates firm enough to enable colonization on the seafloor (Short et al. 2001). For estuarine waters where the salinity varies with tidal stage and location, there is a wider range of SAV species. For example, at lower salinities species such as water celery and water nymph may dominate (Carter et al. 2009; Handley et al. 2007). Typical mesohaline species found in the GOM region include wigeon grass, shoal grass, pond weed, and turtle grass (Handley et al. 2007; Cho and May 2008; Merino et al. 2009; Carter et al. 2009). In higher salinity estuarine waters, star grass, wigeon grass, shoal grass, manatee grass, and turtle grass are typical SAV species (Carter et al. 2009; Merino et al. 2009).

The SAV provides several vital ecological functions, including foraging material for grazers, habitat for marine life, and essential nursery grounds for numerous commercially important fish and invertebrate species. The SAV habitats are important in carbon sequestration, nutrient cycling, and sediment stabilization (Heck et al. 2003; Duarte et al. 2005; Orth et al. 2006; Frankovich et al. 2011). The SAV also provides shelter and protection for many species from predation. Further, SAV provides food resources for associated infauna species, nekton, and other megaherbivores and overwintering waterfowl (Rozas and Odum 1988; Rooker et al. 1998; Castellanos and Rozas 2001; Heck et al. 2003; Orth et al. 2006; Maiaro 2007). One of the more critical functions of SAV systems is the transfer of primary production from epiphytic algae into the ecosystem via grazing of those epiphytes by secondary consumers; however, without grazers, excessive epiphyte growth can become a hindrance to growth (Howard and Short 1986; Bologna and Heck 1999; Heck et al. 2006).

According to the most recent and comprehensive data available, an estimated 1.25 million ac (500,000 ha) of SAV beds exist in exposed, shallow coastal/nearshore waters and embayments of the GOM; over 80 percent of these beds are in Florida Bay and Florida coastal waters (calculated from Handley et al. 2007). In the northern GOM from south Texas to Mobile Bay, Alabama, marine SAV occur in relatively small beds behind barrier islands in bays, lagoons, and coastal waters, while freshwater SAV occurs in the upper regions of estuaries and rivers (Onuf 1996; Castellanos and Rozas 2001; Handley et al. 2007). Elevated nutrient concentrations, declining water quality, and sedimentation from natural and anthropogenic events are common and are a significant cause of seagrass declines worldwide (Orth et al. 2006; Carlson and Madley 2007; Waycott et al. 2009). In the northern GOM, SAV coverage has decreased from the bays of Texas to the GOM shores of Florida (Handley et al. 2007). While declines have been documented for different species in different areas, it is difficult to estimate rates of decline because of the fluctuation of biomass among the different species seasonally and annually.

3.2.5 Beaches and Barrier Islands

Barrier islands are present along more than half of the United States GOM coastline (BOEM 2015) and protect the mainland from shoreline erosion by reducing wave action (Morton 2003b). Barrier islands serve as critical stopover areas for numerous migrating birds as well as important habitat for nesting and wintering birds (**Chapter 3.8**). Barrier islands also provide habitat for sand-dwelling crustaceans (e.g., mole crabs, ghost shrimp, and clams) and burrowing small mammals (e.g., beach mice and rabbits) (Britton and Morton 1989).

Beaches in the GOM also provide important nesting habitat for several species of sea turtles (**Chapter 3.6**), including Kemp's ridley, loggerhead, green, leatherback, and hawksbill sea turtles (Valverde and Holzward 2017). Critical habitat on beaches and in coastal waters has been designated for the loggerhead sea turtle in Florida, Alabama, and Mississippi.

The increasing intensity and frequency of hurricanes in the GOM has greatly impacted the system of protective barrier islands, beaches, and dunes and associated wetlands along the Gulf Coast. The GOM shorelines have lost existing beach dunes and have experienced a decrease in beach ridge elevations, and barrier islands and wetlands have lost acreage to wave erosion due to hurricanes. As a result of decreased dune and barrier island elevations, as well as associated marshes and backshore and foreshore wetlands, the inland coasts and wetlands are more vulnerable to future hurricanes and wind-driven tidal or storm events.

Beach Mice

Beach mice are restricted to the coastal barrier sand dunes along coastal Alabama and the Florida panhandle, and are nocturnal herbivores that forage on sea oats and beachgrass, occasionally consuming invertebrates (Ehrhart 1978; Moyers 1996). Optimal overall beach mouse habitat is currently thought to be comprised of a heterogeneous mix of interconnected habitats including frontal dunes, scrub (tertiary) dunes farther inland, and interdunal areas between these dune habitats. Beach mice dig burrows mainly in the frontal dunes and interior scrub dunes where the vegetation provides suitable cover for avoiding predators, storing food, and providing cover during the day and during inclement weather conditions.

The following four subspecies of beach mouse occupy restricted habitats in the mature coastal dunes: the Alabama beach mouse; the Perdido Key beach mouse; the Choctawhatchee beach mouse; and the St. Andrew beach mouse. Critical habitat for the four subspecies of beach mouse extend from Baldwin County, Alabama, to Gulf County, Florida. These four subspecies of beach mice are similar in appearance but can be identified by pelage color and location (Bowen 1968). Habitat loss from non-BOEM-regulated-activities (e.g., beachfront development) and predation have the greatest impacts to beach mice. Populations of the listed subspecies have fallen to levels approaching extinction. However, due to the dynamic nature of mouse populations that fluctuate with environmental conditions, abundance estimates are unreliable. Trends in populations are determined using percent area occupied, with ongoing monitoring efforts for each of the beach mouse subspecies.

3.2.6 Coastal Coral Reefs

The GOM shallow-water reefs occupy roughly 1,019 mi^2 (2,640 km^2) of the entire GOM (<0.2% of the area), with the largest distribution along the Florida coast (Tunnell et al. 2007). The GOM shallow-water coral reefs are less abundant than other areas (e.g., the Caribbean) but are widely distributed from the Florida Keys to the Flower Garden Banks (located 70-115 mi [113-185 km] off the coast of Texas and Louisiana). Coral reefs are widely recognized as important marine ecosystems; the inherent structure of coral reefs leads to high productivity and biodiversity. Corals and the reefs they form provide key ecosystem functions, including coastal protection from storms and erosion, habitat, and spawning and nursery grounds for numerous fishes, as well as human ecosystem functions like tourism, fishing and recreation, and even a source of new medicines.

Corals in the GOM that are protected under the ESA include those listed in **Appendix B**. Distribution of those listed species within the U.S. Exclusive Economic Zone ranges from Florida to the Flower Garden Banks National Marine Sanctuary and the U.S. territories of Puerto Rico, U.S. Virgin Islands, and Navassa Island. Critical habitat was designated for the elkhorn and staghorn coral species by NMFS in 2008 and includes four counties in Florida (i.e., Palm Beach, Broward, Miami-Dade, and Monroe Counties), as well as the U.S. territories of the U.S. Virgin Islands (i.e., St. John/St. Thomas and St. Croix), and Puerto Rico (*Federal Register* 2008). Elkhorn and staghorn corals are one of the most important coral species in the Caribbean and can form dense groups, or thickets, in very shallow waters. Their global population was decimated by disease in the early 1980s to the point that only 3 percent of the former abundances of elkhorn and staghorn exists today (NOAA

Fisheries 2020c, 2020i). The boulder star coral is native to the Caribbean, GOM, Bahamas, and Bermuda. This species colonizes in massive clumps (sometimes in plates) and is vulnerable to threats because of its small population size (NOAA Fisheries 2020b). The lobed star coral is one of the most abundant coral species in the Caribbean and grows into varying shapes depending on light conditions (NOAA Fisheries 2020e). The mountainous star coral is also native to the Caribbean and the GOM (NOAA Fisheries 2020f). All five ESA-listed shallow-water GOM corals are threatened by ocean warming, ocean acidification, unsustainable fisheries, and pollution (NOAA Fisheries 2020b, 2020c, 2020e, 2020f, 2020i). Shallow-water GOM coral reefs face decline due to habitat destruction, turbidity, and sedimentation as well (Schutte et al. 2010, Jones et al. 2015).

3.2.7 Coastal Ocean Acidification

Compared to other regions, the pH of the coastal GOM waters has not yet decreased significantly. It is expected that the GOM will not experience acidified coastal waters until after 2099 (Ekstrom et al. 2015). However, the eastern oyster is vulnerable to changes in pH (Beniash et al. 2010; Tomanek et al. 2011; Boulais et al. 2017). Hypoxia and riverine input, both major factors in the coastal waters of the GOM, exacerbate local ocean acidification (Melzner et al. 2013; Ekstrom et al. 2015) and may contribute to lower pH values in the GOM in the near future.

3.3 Pelagic Habitats and Communities

This chapter describes the physical and chemical characteristics of pelagic habitats in the GOM and its influence on their associated communities. The pelagic zone (i.e., habitat) encompasses the entire water column from the surface of the water column down to the greatest depths (excluding the seafloor); pelagic communities include all swimming and floating organisms. Although the pelagic zone is overwhelmingly large in extent and volume, the animals found within the various pelagic habitats are not randomly distributed (Hobday et al. 2011). The relationships of pelagic communities to pelagic habitat are complex and frequently tied to physical and chemical attributes that vary seasonally and annually. These relationships can also be influenced by significant environmental events (e.g., tropical storms and freshwater inputs) and in some cases by the presence of anthropogenic and/or renewable energy structures and vessel activity, such as oil and gas infrastructure, maritime operations, military activities, commercial fishing, and recreational boating activities. Some pelagic habitats (e.g., deep sea) are more static and less susceptible to large-scale variations.

The pelagic zone is divided into two provinces: neritic and oceanic (**Figure 3-3**). Coastal and estuarine waters are considered part of the neritic province and span from the coast to the continental shelf break (328-656 ft; 100-200 m). The oceanic province begins at the shelf break, continuing out into the open ocean.

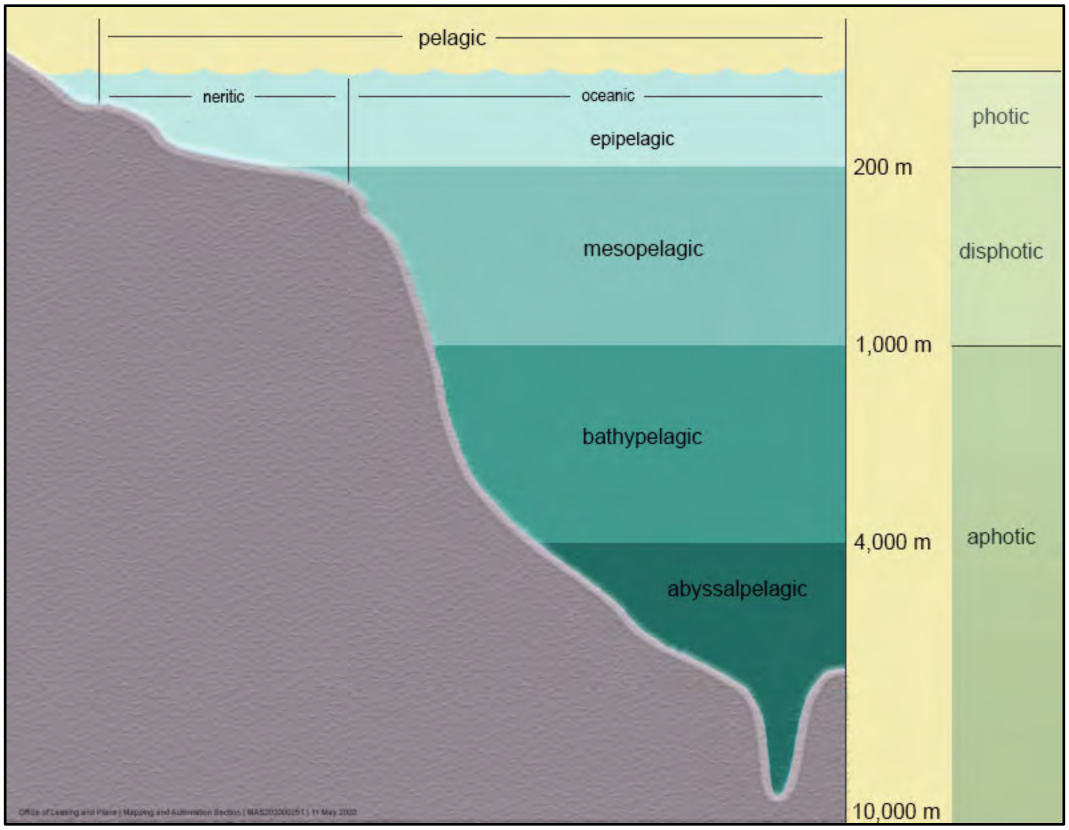

Figure 3-3. Subdivisions of the Pelagic Zone.

3.3.1 Neritic Province

The neritic province encompasses all waters from the intertidal zone (waters between high and low tide) to the continental shelf break and contains only epipelagic waters (0-656 ft; 0-200 m). For the purposes of this document, pelagic waters are considered to start at the 20-m (66-ft) isobath; therefore, not all the neritic province is included in this analysis (refer to **Chapter 3.2**). The neritic province is entirely penetrated by sunlight, allowing for organisms (i.e., marine algae, dinoflagellates, and seagrasses) to photosynthesize. These photosynthetic organisms are the primary producers of their ecosystems, forming the base of marine food webs. The neritic zone receives ample amounts of nutrients from both land-based inputs (e.g., watersheds and associated outflows like major rivers, creeks, and groundwater) and deepwater, nutrient-rich upwelling events (refer to **Chapter 2**). Wide temperature and salinity ranges occur throughout this zone, accommodating a variety of animal life. As a result, the neritic zone is highly productive and rich with biodiversity, supporting many commercial and recreational fisheries and ecotourism operations. Further, the neritic zone houses some of the oceans most complex habitats, including coral reefs, seagrass beds, and oyster reefs (refer to **Chapter 3.2**). For more information on benthic habitats and associated communities in the neritic province, please refer to **Chapter 3.3**. Similarly, refer to the chapters on fish and invertebrate resources (**Chapter 3.5**), sea turtles (**Chapter 3.6**), marine mammals (**Chapter 3.7**), and birds (**Chapter 3.8**) for descriptions of the fauna that are commonly found utilizing these habitats. In addition to sunlight, pelagic habitats and communities in the northern GOM are highly influenced by freshwater inputs (e.g., Mississippi River), as well as a complex network of oil and gas infrastructure (e.g., platforms).

3.3.1.1 Mississippi River Delta

The Mississippi River Delta is one of the most dominant features influencing GOM pelagic habitats and communities. The Mississippi River Delta's freshwater input into the GOM occurs mainly from the Mississippi and Atchafalaya Rivers. The input of freshwater, nutrients, and suspended sediments creates a highly productive environment by altering both biological and physical dynamics over the continental shelf (Grimes 2001). The nutrients introduced into the environment (e.g., phosphorus, nitrogen, and silica) start a chain reaction in which the populations of primary producers (i.e., phytoplankton) increases significantly, directly and indirectly providing food for consumers at all levels of the food chain. The Mississippi River Delta also creates frontal zones, water column stratification, and the transport and retention of fish larvae (Grimes 2001). The creation of a frontal zone occurs when less dense river water from the Mississippi River Delta meets dense seawater from the continental shelf, which has particular influence on pelagic habitats. Researchers have found higher concentrations of phytoplankton, copepods, and fish larvae along frontal zones when compared to waters east or west of the Mississippi River Delta, potentially indicating the influence that frontal zones have on the reproductive success of local pelagic species (Lohrenz et al. 1990; Dagg and Whitledge 1991; Govoni et al. 1989). Research has also highlighted the role frontal zones play in the development of sea turtles due to the increased food availability (Carr 1987).

Although the influx of nutrients into neritic pelagic waters can be beneficial to many organisms, it can also cause extensive areas of hypoxia in the summer (**Figure 3-4**), with varying impacts to pelagic habitats and associated communities. Hypoxia is generally defined as water with dissolved oxygen concentrations less than 2.8 mg O_2/L (Diaz and Rosenberg 1995). This phenomenon occurs when nitrogen from the Mississippi River Delta and other land-based sources stimulates an increase in phytoplankton populations, which then supports bacteria production and grazing by zooplankters (e.g., protozoa, gelatinous organisms, and copepods) (Dagg and Breed 2003). Portions of the organic waste from these organisms and uneaten phytoplankton eventually sink to the bottom where it begins to decompose, which requires consuming oxygen. This process is exacerbated by water stratification, which occurs when freshwater from the Mississippi River Delta remains above denser seawater. Water stratification inhibits the mixing of oxygenated surface waters with oxygen-poor bottom waters, keeping oxygen-depleted waters close to the seafloor where immobile, benthic organisms (e.g., oysters and barnacles) are particularly vulnerable.

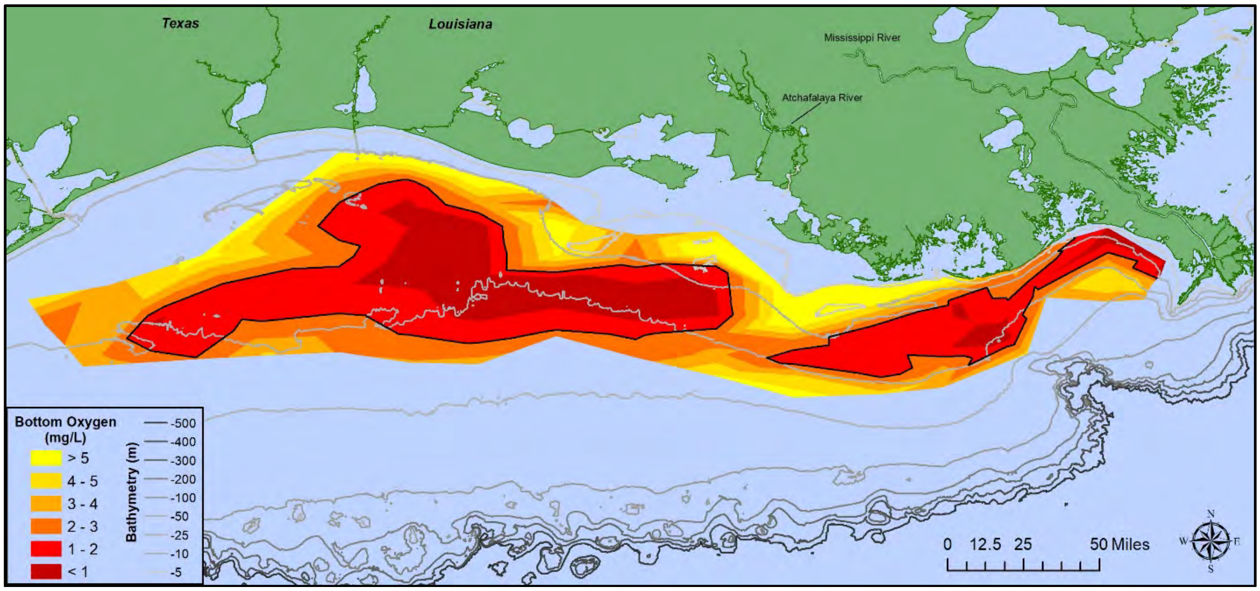

Figure 3-4. Map Depicting the 2019 Hypoxic Zone in the Northern GOM. Source: N.N. Rabalais and R.E. Turner, Louisiana State University, Louisiana University Marine Consortium. Funding: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Studies, www.gulfhypoxia.net.

Free-swimming pelagic organisms are generally less susceptible to hypoxia than benthic organisms as they can detect and actively avoid hypoxic waters (Howell and Simpson 1994). For example, aerial surveys conducted by Craig et al. (2001) indicated that loggerhead and Kemp's ridley sea turtles appeared to alter their habitat usage to avoid hypoxic bottom waters in Mississippi, Alabama, and Texas where they normally feed on benthic invertebrates (Shaver 1991; Plotkin et al. 1993). Similarly, Zhang et al. (2009) observed low fish biomass in hypoxic waters, with fish tending to aggregate horizontally at the edges of hypoxic areas and directly above severely hypoxic bottom waters. Laboratory and field testing have demonstrated profound negative effects of hypoxia on fish reproduction and development (Wu 2009), and some mobile pelagic species may be more vulnerable than others. For example, Gulf menhaden comprised 72 percent of the total biomass killed over a 55-year period along the Texas coastline, which was largely attributed to hypoxia (Thronson and Quigg 2008). Overall, the effects of hypoxia on pelagic habitats is stratified and seasonal, correlating with oxygen depleted waters present in the lower water column, particularly during summer months. The negative effects on pelagic species appear to be species-specific with many showing behavioral alterations to avoid less favorable environmental conditions.

3.3.1.2 Anthropogenic Structures and Activities

Various anthropogenic structures and activities in the neritic province become habitats of their own as well as community influences within pelagic ecosystems. For example, sounds from anthropogenic sources have added an abiotic component to the ambient pelagic soundscape, which is the combination of biological, physical, and human-centered sounds. The introduction of anthropogenic sounds into the pelagic soundscape may result in a multitude of negative effects such as the masking of biologically significant sounds. For more information on the possible effects that sound has on pelagic habitats and communities, refer to **Chapter 4.3.2**. Another example includes the commercial shrimp trawling alteration of bottlenose dolphin feeding behavior (Lorenz 2015) as well pelagic fishes (e.g., sharks, blackfin tuna, and yellowfin tuna), which are known to forage on the bycatch thrown overboard.

Oil- and gas-related infrastructure in the coastal northern GOM (e.g., platforms in coastal waters) has altered pelagic habitats by creating vertical structure throughout the water column in an environment that otherwise would have none. Further, infrastructure occurs where the water bottom is comprised mostly of soft sediments, creating opportunities for hard bottom habitats to exist. For more information on the possible effects that offshore habitat modification has on pelagic habitats, refer to **Chapter 4.3.5**. These structures attract several types of fauna, including sea turtles, marine mammals, and seabirds, likely by providing foraging opportunities (Lohoefener et al. 1990; Gitschlag et al. 1997; Ronconi et al. 2015; Todd et al. 2020).

Fish and invertebrates are also attracted to structural habitats. The large-scale introduction of platforms in the neritic northern GOM waters has created a network of artificial reefs that attract and enhance the production of pelagic species of fish (Franks 2000). One study found indirect evidence of the potential spawning, nursery, and recruitment habitat provided by platforms in the northern GOM (Shaw et al. 2002). Moreover, the predominant taxa of post-larval and juvenile fishes collected down current of platforms are primarily represented by pelagic species and pre-settlement stages of soft-bottom taxa, which may be taking advantage of the elevated zooplankton and ichthyofauna concentrations near the platforms (Shaw et al. 2002). These organisms are likely attracted to the light field from the platforms (Shaw et al. 2002).

3.3.2 Oceanic Province

The oceanic province includes all waters beyond the continental shelf and, because of its vast depths, it has different zones based on both sunlight (i.e., light zones) and habitat (i.e., oceanic province habitat zones) (**Figure 3-3**). The lights zones of the oceanic province include the photic (with sunlight), dysphotic (little to no light or perpetual twilight), and aphotic (no light) zones. The amount of sunlight penetrating the depths highly influences the nature of animals found within the different oceanic subdivisions, and it is a major limiting factor on the distribution and behavior of ocean plants and animals. For example, animals in the photic zone can rely on energy produced from primary production while organisms in the deep sea rely on sinking organic matter or other adaptations to obtain food (e.g., chemosynthesis). **Table 3-1** includes the water depths associated with these layers as well as the oceanic habitat zones.

Table 3-1. Light Zone Water Depths Compared to Oceanic Province Habitat Zone Water Depths.

Light Zone	Water Depth ft (m)	Habitat Zone
Photic	0-656 (0-200)	Epipelagic
Disphotic	656-3,280 (200-1,000)	Mesopelagic
Aphotic	>3,280 (1,000)	Bathypelagic Abyssopelagic Hadalpelagic

There are five habitat zones determined by depth (**Figure 3-3**); however, these depths and the number of zones can change based on physiographic or ecological principles (Priede 2017). Generally, the different zones are the epipelagic, mesopelagic, bathypelagic, abyssopelagic, and hadalpelagic zone (Webb 2019). Sigsbee Deep, located in the west-central GOM, is the deepest water bottom (12,631 ft; 3,850 m) in the GOM (Darnell and Defenbaugh 1990). As such, the GOM has no hadalpelagic waters; therefore, it will not be further discussed. Cold temperatures, which can near freezing in the abyssopelagic zone, as well as intense water pressures, also influence the types of organisms and associated adaptations found within the pelagic habitat zones of the oceanic province.

3.3.2.1 Epipelagic Zone

The uppermost habitat zone in the oceanic province is the epipelagic zone. In the GOM, the temperatures of epipelagic sea-surface waters vary seasonally and can rise above 90°F (32°C) during the summer. This zone is entirely within the photic zone, allowing for photosynthesis by phytoplankton (e.g., diatoms) and other primary producers (e.g., autotrophic dinoflagellates). However, unlike the sunlit waters of the neritic province, oceanic epipelagic waters are generally nutrient-poor in comparison. This is due to their distance from shore and the rapid utilization of available nutrients by photosynthetic organisms in neritic waters (Webb 2019). Consequently, primary producers present in the oceanic province rely heavily on atmospheric deposition of nutrients such as soil dust from deserts and other terrestrial habitats (Jickells and Moore 2015).

Nutrients can also enter this zone by other means. Oceanographic research in the northern GOM has indicated that there are seasonal “hot spots” of phytoplankton and zooplankton in oceanic epipelagic waters. The convergence of the Loop Current with coastal waters in the GOM causes both upwelling and cross-shelf transport of nutrient-rich Mississippi River Delta waters through entrainment in meso-scale eddies (refer to **Figure 3-1**) south of the Mississippi outflow, south of the Louisiana/Texas shelf, and in the northwest and northeast corners of the GOM (Ohlmann et al. 2001; Morey 2003). Phytoplankton present in this zone as a result of nutrient availability from upwelling, entrainment in meso-scale eddies, or atmospheric deposition are eventually consumed by primary consumers (i.e., zooplankton). The zooplankton (e.g., heterotrophic dinoflagellates, foramnifera, copepods, and larval fish) are then food sources for higher trophic organisms.

Higher trophic-level organisms that primarily occur in oceanic epipelagic waters rarely encounter the coastline or the seafloor. Prey is generally scarce, and most forage over long distances. Many are generally large in size and highly migratory, with some making cross-basin or even trans-ocean migrations. They include Atlantic tunas, swordfish, sharks, and billfish and are federally managed in cooperation with international governments (NMFS 2006). Epipelagic fish in the oceanic province can be described as having low biodiversity compared to neritic fishes, and they generally comprise the highest trophic levels, whereas reef-associated fish have the widest trophic level distributions (Chen 2017). Therefore, on average, an epipelagic fish is either a tertiary consumer (i.e., a carnivore eating another carnivore) or an apex predator (i.e., an animal that is at the top of the food chain with few predators).

Other animals utilizing the epipelagic zone include marine mammals (**Chapter 3.7**), sea turtles (**Chapter 3.6**), seabirds (**Chapter 3.8**), and deep-sea fish (**Chapter 3.5**). The GOM epipelagic waters support a diversity of marine mammal species by potentially supplying a large number of ecological niches (Baumgartner et al. 2000) created by a variety of available habitat (e.g., canyons) and prey (e.g., mesopelagic organisms). Although specific prey species for most oceanic cetaceans is unknown, many likely feed on cephalopods and epi- and mesopelagic fishes (Davis et al. 1998). Post-hatchling and juvenile sea turtles, as well as foraging seabirds, are also found in epipelagic waters in association with floating *Sargassum* habitats (refer to **Chapter 3.6**) (Haney 1986; Carr 1987; Witherington et al. 2012; Moser and Lee 2012). Additionally, seabirds occupy epipelagic waters while diving for prey or roosting on the ocean surface, usually during their spring and fall trans-Gulf migration periods.

Many epipelagic species utilize deeper habitat zones during the day for a variety of reasons, including foraging, shelter from predation, or thermoregulation. Bluefin tuna tagged with internal satellite tags were recorded in depths over 1,640 ft (500 m) in the GOM (Teo et al. 2007). Smaller, unidentified tuna species have also been documented in deep-sea (328-1,969 ft; 100-600 m) habitats in the northern GOM (Benfield and Kupchik 2017). Aside from fish, sperm whales have been recorded with towed hydrophone arrays making dives in excess of 1,640 ft (500 m) (Thode et al. 2002) and have even been observed with remotely operated vehicles diving on foraging trips as far down as 5,696 ft (1,736 m) in the northern GOM (Benfield and Kupchik 2017).

3.3.2.2 Sargassum

Due to the depths of the oceanic province and its distance from shore, there is a lack of natural structural habitat. However, in the GOM a unique floating habitat ubiquitous in the oceanic epipelagic zone is *Sargassum*. *Sargassum* are pelagic species of free-floating, brown macroalgae that float in generally large mats, or "floating islands." These mats can be up to dozens of meters long and in diameter. *Sargassum* provides an otherwise nonexistent essential habitat for several purposes and for numerous species (**Table 3-2**). For example, flyingfish, which are an important epipelagic prey species, attach their eggs directly to the *Sargassum* and their young use it for refuge (Dooley 1972). *Sargassum* habitat has also been identified as potential forging grounds for some marine mammals, particularly in frontal zones, and is likely an important nursery habitat for post-hatching and juvenile sea turtles (Laffoley et al. 2011; Witherington et al. 2012).

Table 3-2. *Sargassum* Mats – Ecosystem Functions and Associated Animals.

Ecosystem Function	Associated Fauna	
Nursery habitat	Billfish	Jacks*[†]
	Dolphinfish	Sea turtles
	Driftfish	Swordfish**
	Filefish	Triggerfish
	Flying fish	Tunas
Feeding grounds for juvenile and adult commercially and recreationally valuable fish	Amberjacks	Mackerels
	Billfish[†]	Mahi-mahi
	Dolphinfish[†]	Tunas[†]
	Jacks[†]	Wahoo
Sole habitat	*Sargassum* swimming crab	
	Sargassum nudibranch	
	Slender *Sargassum* shrimp	
	Sargassum frogfish	

Sources: Dooley 1972, Lafolley et al. 2011, and Witherington et al. 2012.
*Juvenile and sub-adults.
**Juveniles.
†*Sargassum* serves multiple functions.

Gower and King (2009) found a seasonal pattern with satellite imagery in which *Sargassum* originates in the northwestern GOM in the spring of each year, forming long, narrow meandering slicks. The *Sargassum* is then advected out of the GOM into the Atlantic Ocean east of Cape Hatteras, North Carolina by July and finally moving into the northwest Bahamas by February of the following year. Once in the Atlantic, mats accumulate in the North Atlantic sub-tropical gyre and is referred to as the Sargasso Sea or the floating, golden rainforest of the Atlantic Ocean (Laffoley et al. 2011). As such, the protection of this habitat from anthropogenic threats (e.g., accidental oil or chemical spills) is important for epipelagic GOM organisms and *Sargassum*-associated communities in the Atlantic.

3.3.3 Deep-Sea Zones (Mesopelagic, Bathypelagic, and Abyssopelagic)

Deep-sea pelagic habitat zones are here defined as those deeper than 656 ft (200 m). These zones represent an enormous biovolume of space in which organisms can live (>billion/km^3) but are some of the least understood environments on the planet (Webb et al. 2010). However, technological advances have allowed scientists to further sample the deep sea, revealing a diverse and adapted ichthyofauna (Webb et al. 2010). Because of their vast depths, deep-sea zones are some of the most stable environments in the ocean versus shallower waters, which are subject to mixing from physical processes (e.g., storms, wind, and waves). This relative stability has resulted in unique habitats and allows scientists to delineate deep-sea zones based on physical attributes (e.g., depth and light availability) and associated biota. Together, these characteristics influence the types of organisms found in deep-sea pelagic ecosystems and their adaptations that allow them to inhabit these zones.

Stability in the deep sea may also contribute to increased vulnerability to chronic disturbances resulting from anthropogenic activities, including noise, sediment resuspension, introduction of toxins, overfishing, habitat disturbance, and others.

The deep-sea pelagic realm represents approximately 91 percent of the GOM's total volume and contains enormous taxonomical and functional diversity (Sutton et al. 2020). It is one of the four "hyper-diverse" mid-water ecosystems in the World Ocean due to the GOM's unique geography, the combination of tropical waters and winter cooling, and the presence of a large river system (Sutton et al. 2017, 2020). Much of what is known about the GOM's deep-sea pelagic ecosystems has come from the collection or observations of meso- and bathypelagic organisms (refer to **Chapter 3.5**).

3.3.3.1 Physical Environment and Biological Adaptations

All deep-sea pelagic habitats around the world have similar physical attributes that influence the types of organisms that reside within these zones and their adaptations for survival. One of the most influential physical characteristics shaping deep-sea communities is the amount of sunlight penetrating its depths. The mesopelagic zone receives little to no sunlight and is commonly referred to as the "twilight" zone as it lies between the photic zone and aphotic zone. Very little light is present in the uppermost layer (<1% of surface illumination) of the mesopelagic zone (Del Giorgio and Duarte 2002). However, there is enough sunlight to allow organisms to distinguish diurnal and nocturnal cycles (Sutton 2013). This light continues to fade until it completely dissipates near the border of the bathypelagic zone (**Figure 3-3**). Both the bathy- and abyssopelagic zones are completely devoid of light.

There are no photosynthetic organisms (e.g., marine plants or phytoplankton) living in the meso-, bathy-, and abyssopelagic zones because of the lack of penetrable sunlight. As such, many deep-sea organisms rely heavily on sinking organic matter from the epipelagic zone for energy. Much of this energy sinks to these depths in the form of "marine snow," which is organic detritus originating in the photic layer and which consists of phytoplankton blooms, fecal matter, and suspended sediments (Turner 2002). Episodic inputs of organic matter (e.g., carcasses of dead animals) also provide energy. For information on benthic communities associated with hydrothermal vents in the deep sea, refer to Chapter 3.4. Other deep-sea animals have developed combinations of physical and behavioral adaptions to cope with the relative scarcity of food. Many mesopelagic fishes have highly sensitive, specially adapted eyes that allow them to sufficiently see and hunt in low-light zones (Priede 2017). Many fish have also developed very large mouths, hinged jaws, and expandable stomachs to take advantage of a variety of prey sizes. In all deep-sea zones, many organisms have evolved the ability to emit light through bioluminescence (the biochemical emission of light) as a means of attracting prey, hunting prey without being seen (e.g., red bioluminescence in dragonfishes), avoiding predators, or communication (Partridge and Douglass 1995; Haddock et al. 2009).

The energy demands of deep-sea communities cannot be met by a reliance on particulate influx (e.g., marine snow and whale fall) alone (Bianchi et al. 2013). Therefore, nocturnal vertical migration is a prominent and important behavioral adaptation of meso- and bathypelagic organisms to the shortage of food availability in deep-sea habitats and represents the Earth's largest animal migration (Sutton 2013). Fish and invertebrates migrate into the epipelagic zone at night to feed, which is when the risk of predation is reduced. However, these migrations do make them susceptible to predation by some epipelagic predators (e.g., marine mammals, large epipelagic fish, and sea birds).

Temperature and pressure are also important physical influences on the biology of deep-sea inhabitants. Temperature decreases with depth, whereas pressure increases. A major thermocline exists in the mesopelagic zone with drastically falling temperatures. This temperature decrease generally stabilizes in the bathy- and abyssopelagic zones. For every 33 ft (10 m) the water pressure increases by 1 atmosphere (14.6 pounds per square inch; 6.6 kilograms per square centimeter), resulting in enormous pressures in the deep sea. These physical characteristics can influence biological adaptations often resulting in long-lived (>100 years in some species) organisms with slow metabolisms and "K" selected life history properties, including low fecundity and low intrinsic rates of population recovery (Pianka 1970; Roberts 2002; Priede 2017). As such, organisms living in deep-sea pelagic habitats are especially vulnerable to perturbations in their environments and overexploitation.

3.3.3.2 Deepwater Petroleum Structures

Recently, the GOM has experienced an increased emphasis on deepwater oil and gas exploration in water depths greater than 984 ft (300 m). As such, the presence of deepwater petroleum structures has become more commonplace in the GOM. The deepwater petroleum structures can include tension-leg platforms, compliant towers, spars, drillships, floating production storage and offload platforms, and other equipment. The deepwater petroleum structures can indirectly act as fish aggregating devices, which are known and used worldwide to attract large pelagic fishes, particularly tunas. Yellowfin tuna, bigeye tuna, and skipjack tuna are the most common species associated with fish aggregating devices, and aggregations have been reported at GOM deepwater petroleum structures (USGS and Florida Caribbean Science Center 2002). Other marine fauna (e.g., sea turtles and marine mammals) may also be attracted to deepwater petroleum structures. However, it is important to recognize there are currently few deepwater petroleum structures in the GOM and they are widely dispersed. As of April 19, 2020, there were 59 deepwater petroleum structures installed in water depths greater than 1,000 ft (305 m) (BSEE 2020). For more information on the possible effects that offshore habitat modification has on pelagic habitats, refer to **Chapter 4.3**.

3.4 Benthic Habitat and Communities

Benthic fauna inhabit the seafloor throughout the GOM at all water depths (**Figure 3-5**). These organisms interact with seafloor sediment through bioturbation, oxygenation, and cementation of the sediments. Sessile and mobile organisms that live on top of the sediment are called epifauna and include most megafaunal species. Organisms that live within the sediment are called endofauna or infauna and include macrofauna[7] and meiofauna[8]. Microbial communities and, within the photic zone,

[7] Organisms greater than 1 mm (0.04 in) in size.
[8] Organisms between 45 μm and 1 mm (0.00004 and 0.04 in) in size.

microalgae, macroalgae, and rooted vegetation also inhabit the seafloor. All benthic communities are trophically linked[9] and contribute significantly to global carbon cycling.

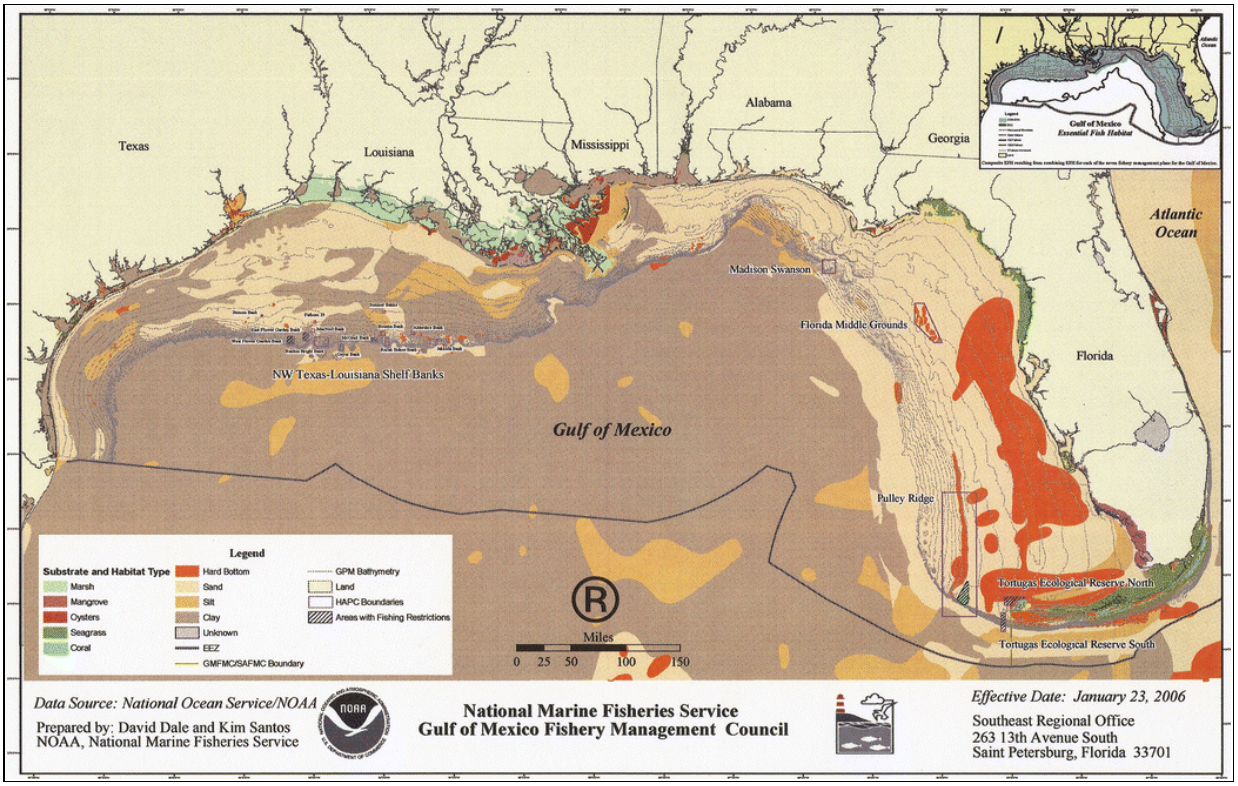

Figure 3-5. Benthic Habitat in the Gulf of Mexico. Benthic habitat distribution in the Gulf of Mexico (Rowe 2017 [modified from GMFMC 2004, 2005]). This figure is licensed under the terms of the Creative Commons Attribution-NonCommercial 2.5 International License (http://creativecommons.org/licenses/by-nc/2.5/).

Documented benthic ecosystems in the GOM discussed in this chapter include muddy soft bottom; oyster reefs; coral and sponge dominant banks; hydrocarbon seeps along the continental margin; and marine canyons, escarpments, and seamounts on the abyssal plain (Briones 2004). Coastal benthic habitats are discussed in **Chapter 3.2**.

Connectivity with areas adjacent to and within the GOM depends on pelagic larval transport by surface currents. Most GOM hard bottom benthic communities are diverse and characterized by high species richness and low abundance, while soft bottom communities are characterized by low species richness and high abundance. Suspension feeders are generally most abundant in high-energy environments, and deposit feeders are most abundant in low-energy environments in areas with fine-grained, muddy sediments (Snelgrove 1999).

Regular or chronic anthropogenic activities impact and influence the formation, composition, and persistence of benthic habitats and communities. Anthropogenic activities in the GOM region that

[9] A trophic linkage is an energetic pathway within a food web.

can alter the natural formation of benthic communities include terrestrial agriculture, hydrological control systems (e.g., river levee systems), coastal development, oil and gas infrastructure installation and use, bottom fishing, artificial reef installation, commercial shipping (e.g., ballast water discharge and shipwrecks), and dredging.

3.4.1 Shallow Water (<300 m; 980 ft)

3.4.1.1 Soft Bottom Communities

In the GOM, the OCS extends from below the low tide mark to the continental edge. Approximately 90 percent of the OCS can be defined as soft bottom. Up to 50 percent of the seafloor is muddy and more than 40 percent is sand with some gravel and shell.

Hydrographic processes structure the continental shelf ecosystem by transporting and distributing sediment and organic primary production from the coastal zone and water column. Recruitment of organisms to a particular area is linked to hydrological flow of energy and material. The largest inflow of material to the GOM basin is associated with mixing due to winter cold fronts, fluvial outflow, and coastal primary production. In the GOM, commercial bottom trawling significantly contributes to the rate of nutrient remineralization through mechanical turbation (Briones 2004).

The ratio of production to biomass is high compared with temperate and cold marine systems due to the high metabolic rates of organisms. Abundance, biomass, and community composition vary with distance offshore and the proximity to rivers, estuaries, bays, and lagoons, as well as fossil hydrocarbon expulsions and density of offshore oil and gas infrastructure (Briones 2004). Refer to **Chapter 3.5** for a discussion of fish and invertebrate biomass in the GOM.

On continental shelf soft bottom sediments, dominant components of the benthic community are invertebrates and demersal fishes. Six common and abundant phyla in benthic communities in the GOM include polychaete worms, pericaridean and decapod crustaceans, echinoderms, mollusks, nematodes, and hydroids (Briones 2004; Rowe 2017). Species richness is generally low compared to coastal ecological zones.

Sand shoals may represent “hotspots” of biodiversity in primarily soft bottom regions of the GOM and may provide refuge for benthic organisms during periods of hypoxic conditions (see below) (Dubois et al. 2009). On the Ship Shoal sand bank, high benthic microalgal biomass suggests that benthic primary production contributes to the local food web and is an important ecosystem component on GOM sand shoals (Grippo et al. 2009). Macrofaunal communities varies across shoals; sand percentage is the most influential environmental parameter (Dubois 2009; Gelpi 2012). Diversity and abundance increase with decreasing sediment grain size and increasing bottom water dissolved oxygen. The most common species on sand shoals are polychaetes and crustaceans (Dubois et al. 2009), and they serve as a spawning ground for blue crabs (Gelpi 2012).

The GOM annually develops an extensive seasonal hypoxic zone west of the Mississippi Delta during the late spring and summer. Hypoxic conditions are defined as water masses with dissolved oxygen concentrations lower than 2 milligrams per liter. In 2019, this “dead zone” measured ~18,000 km^2 (6,952 mi^2), the eighth largest on record (NOAA 2019). Hypoxic zones are caused by terrestrial runoff, nutrient-fed algal growth, and subsequent bacterial decomposition, resulting in near seafloor oxygen levels too low to sustain most marine life and causing habitat loss, sublethal stress, and/or death. The persistence of hypoxic zones leads to a metazoan community with anaerobic conditions that significantly change the benthic ecosystem. The extent of hypoxic zones varies over the course of their duration due to water column mixing by wind and storm events. In the GOM, the persistence of the hypoxic zone into the early fall depends on the breakdown of vertical stratification of the water column by winds from either tropical storms or cold fronts; they rarely persist into late fall or winter (Rabalais et al. 2002).

3.4.1.2 Hard Bottom Communities

Naturally occurring geological (exposed bedrock) or biogenic (authigenic carbonate relict reef) seafloor with measurable vertical relief serves as important habitat for a wide variety of sessile and mobile marine organisms in the GOM. Encrusting algae and sessile invertebrates such as corals, sponges, sea fans, sea whips, hydroids, anemones, ascidians, and bryozoans may recruit to and colonize these hard substrates, creating “live bottom” (Cummings et al. 1962). Corals and large sponges function as structural architects, adding complexity to the benthic habitat. This complex structure provides shelter to small fish and invertebrates, which in turn provide food for larger fishes, including many that form important commercial fisheries (Fraser and Sedberry 2008; Szedlmayer and Lee 2004; Gallaway et al. 2009; Johnston et al. 2015; Nash et al. 2013).

3.4.1.3 Defined Topographic Features

Defined topographic features or banks are a subset of live bottom habitats that are large enough to play an important ecological role in the GOM with high biomass, diversity, and abundance. They are created through bedrock uplift by underlying salt diapirs and the exposure of barrier islands. Alternatively, they may be formed from relict carbonate reef (Rezak and Bright 1981, 1976; Berryhill 1987). There are 38 defined topographic features with special protection from offshore commercial activities in the GOM: 22 in the WPA and 16 in the CPA. Zones of major reef-building activity include the following (Rezak et al. 1990):

- zones of major reef-building activity – *Diploria-Monastrea-Porites*, *Madracis* and Leafy Algae, *Stephanocoenia-Millepora*, and Algal Sponge;
- zone of minor reef-building activity – *Millepora*-Sponge;
- transitional zones – Antipatherian-dominant; and
- zone of no reef-building activity – Nepheloid.

Figure 3-6 illustrates the OCS lease blocks that contain defined topographic features in the GOM.

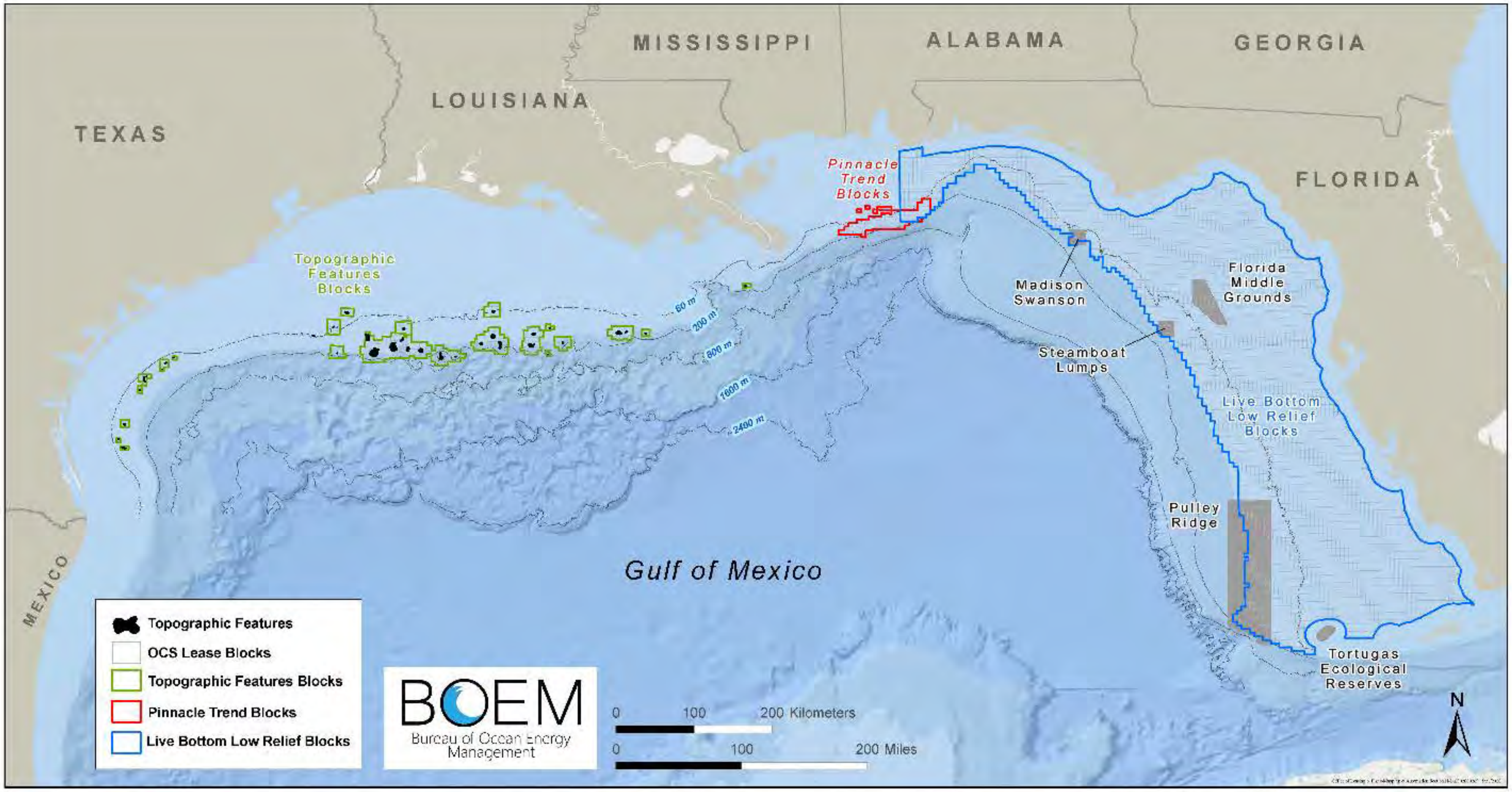

Figure 3-6. Gulf of Mexico OCS Blocks that Contain Defined Topographic Features.

The topographic features blocks (green) include shelf-edge, midshelf, and South Texas banks. Other defined topographic features discussed in this chapter include the pinnacles trends offshore Mississippi and Alabama, the Florida Middle Grounds, and Pulley Ridge. Other identified topographic features illustrated here include Madison Swanson Bank, Steamboat Lumps, and the Tortugas Ecological Reserves, the latter outside of but potentially influenced by BOEM-permitted activity areas.

Figure 3-7 provides an example of the ecology and habitat description of topographic features at different depths; most banks contain only a few of the illustrated zones. There are three primary bank classifications in the northwest GOM: shelf-edge banks; midshelf banks; and South Texas banks.

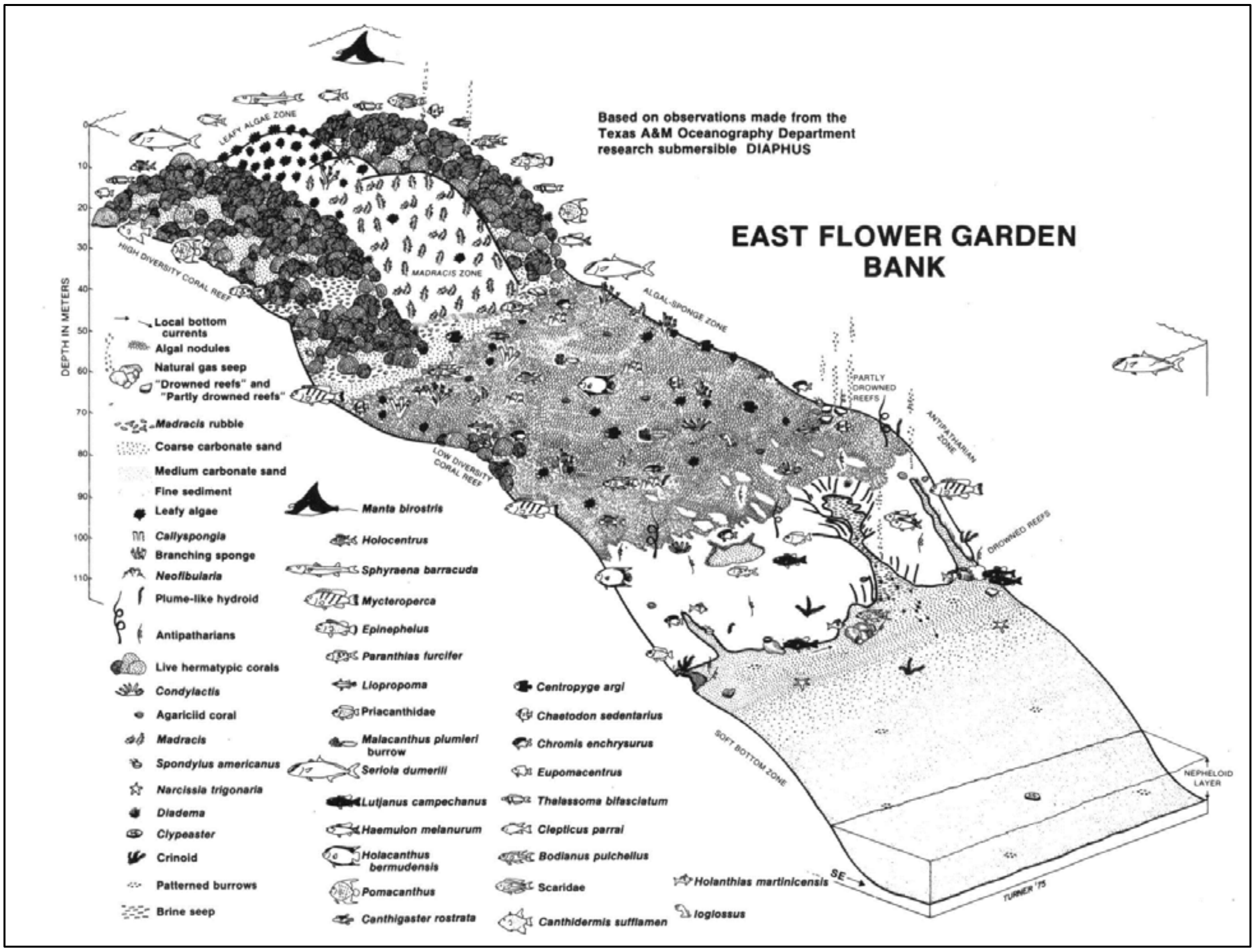

Figure 3-7. Ecological Representation of Common Features on GOM Banks and Reefs (Bright et al. 1985).

3.4.1.3.1 Shelf-edge Banks (Including the Flower Garden Banks)

Shelf-edge banks are located between 80 and 300 m (262 and 980 ft) (**Figure 3-8**) (Rezak et al. 1990). Shelf-edge banks have the greatest vertical relief of all bank types and exhibit the greatest range of habitat types (Rezak et al. 1983). They therefore contain the highest number of topographic feature zones. The best known and most studied of the shelf-edge banks are the Flower Garden

Banks, three of which (i.e., the East Flower Garden Bank, West Flower Garden Bank, and the midshelf bank Stetson Bank) comprise the Flower Garden Banks National Marine Sanctuary. They are the northernmost coral reefs in the continental United states, located approximately 200 km (120 mi) south of the Texas/Louisiana coast. The coral reefs at East and West Flower Garden Banks have been subject to annual monitoring since 1989 and at Stetson Bank since 1993.

The community structure on shelf-edge banks is dependent on the geological characteristics of the substrate, regional and local current regimes, winter temperature minima, river-influenced salinity and turbidity, depth of the bank crests, and depth and thickness of the nepheloid layer (Rezak et al. 1990). Loop Current rings and eddies that pass through the western GOM induce oxygen and nutrient enrichment, and cross-shelf water exchange with deep water regulating temperature, salinity, and larval dispersal within and between banks (Lugo-Fernandez 1998). The annual reproductive period coincides with the summer water temperature maximum in August or September (Hagman et al. 1998). Refer to **Chapter 2** for a discussion of the GOM large marine ecosystem.

The Flower Garden Banks contain all but the *Millepora*-Sponge zone. The coral caps are dominated by large boulder star and brain corals (*Montastreaea* spp., *Diploria strigosa*, and *Colpophyllia natans*) with 50-80 percent surface coverage. As global coral reef systems are in decline, the northwest GOM reef system may provide a refuge for Caribbean coral reefs and associated communities (Hickerson et al. 2012). Common sessile and mobile organisms on the coral caps of these banks include bacteria, algae, sponges, cnidarians, ctenophores, annelids, crustaceans, bryozoans, mollusks, echinoderms, tunicates, bony fishes, and cartilaginous fishes. The highest fish biomass and density is located directly adjacent to hard substrate (Langland 2015). Recent research suggests that the Flower Garden Banks could serve as nursery habitat for one or more Mobulid species (Stewart et al. 2018). Sea turtles, marine birds, and marine mammals also make regular use of the Flower Garden Banks. For a complete species list, refer to https://flowergarden.noaa.gov/about/specieslist.html. Below the coral cap, gorgonians and black corals dominate the benthic community.

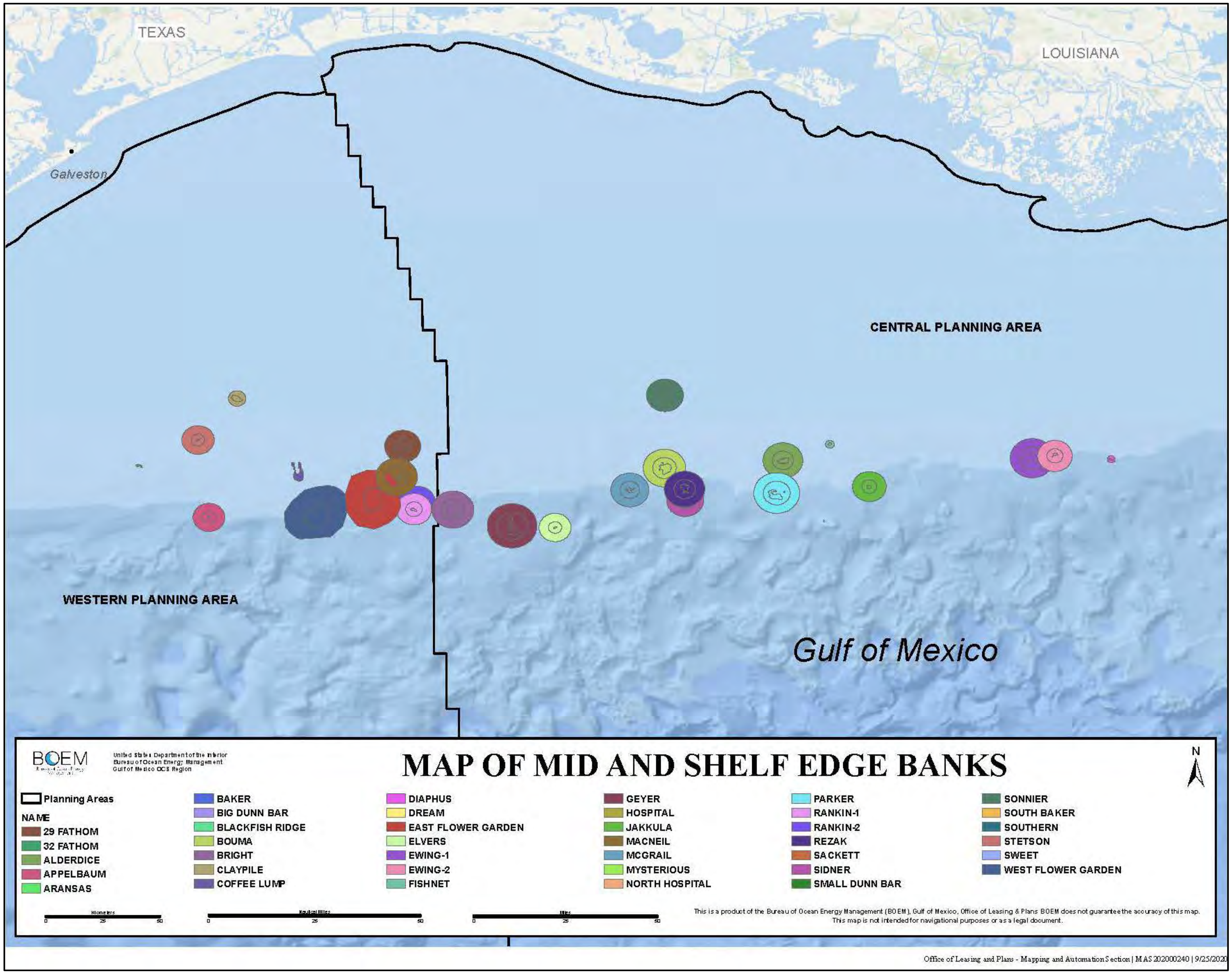

Figure 3-8. Shelf-edge and Midshelf Banks in the North and Northwestern Gulf of Mexico.

The midshelf banks are found in water depths less than 80 m (262 ft) and have a relief of 4-50 m (13-164 ft). Identified midshelf banks include 32 Fathom, Stetson, Claypile, Coffee Lump, Sonnier, and Fishnet. All are outcrops of bedded Tertiary limestones, sandstones, claystones, and siltstones associated with salt domes. Claypile, Sonnier, and Stetson Banks contain the *Millepora*-Sponge Zone. The crests of the other midshelf banks is within the Antipatharian Zone. The effects of the bottom nepheloid layer are more pronounced on midshelf banks than on shelf-edge banks, likely due to both shallower water depth and lower relief (Rezak et al. 1990).

Stetson Bank is incorporated into the Flower Garden Banks National Marine Sanctuary and is, therefore, the most studied and monitored of the midshelf banks. It contains claystone pinnacles running east-west for 457 m (1,500 ft), with a relief of on average of 17 m (55 ft) below the sea surface. The bank is dominated by sponges, algae, and *Millepora alcicornis*, with outcroppings of *Madracis decactis* and hermatypic corals (Hickerson et al. 2012). Since monitoring began at Stetson Bank in 1993, the benthic community has transitioned from a *Millepora*-sponge dominant community to an algal-sponge community (Nuttall et al. 2020).

3.4.1.3.2 South Texas Banks

The South Texas banks are primarily drowned Pleistocene coralgal reefs (**Figure 3-9**) (Berryhill et al. 1976; Bright and Rezak 1976). They are found at depths between 50 and 80 m (164 and 262 ft) and have relief up to 20 m (66 ft). They are located within a mid- to high-energy environment characterized by high turbidity and sedimentation.

The shallowest portions of all South Texas banks are occupied by community assemblages similar to the Antipatharian Zone found on midshelf banks (Rezak et al. 1990). The most well-studied of the South Texas banks is Southern Bank, located approximately 55 km (34 mi) east of Corpus Christi on the edge of the continental shelf with a maximum relief of 22 m (72 ft). Two hundred and sixty-nine species have been reported at Southern Bank, almost half are annelid worms, while 16 percent are polychaetes. Twelve percent of identified species are bony fishes. The lack of intensive benthic surveys makes it difficult to generalize about the community structure of the South Texas banks, but a survey of the existing literature (as of 2013) indicates that Annelida, Chordata, and Mullusca are the most common phyla (Nash et al. 2013).

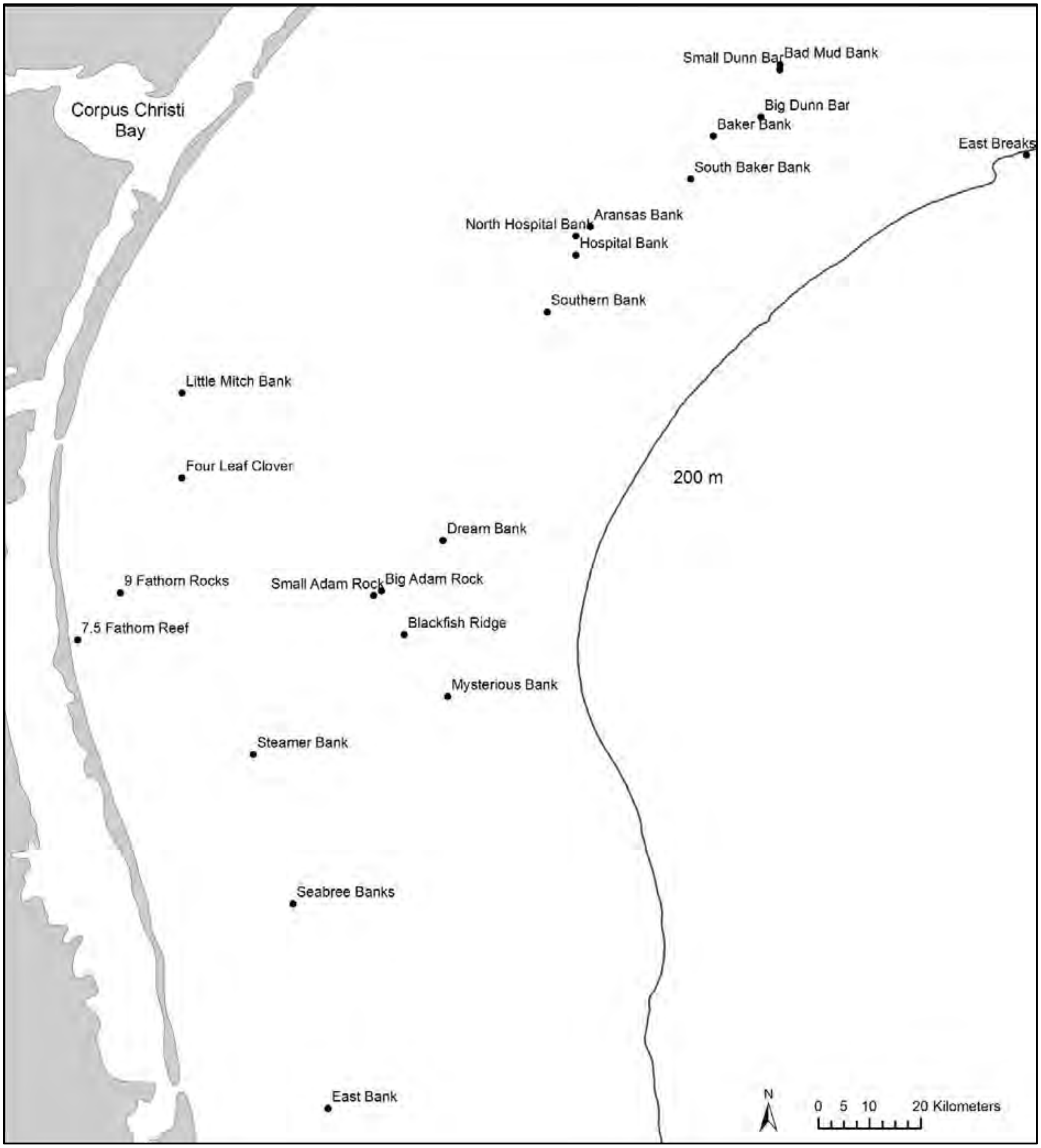

Figure 3-9. South Texas Banks (Nash et al. 2013).

3.4.1.3.3 Pinnacle Trend

The Pinnacle Trend is a band of high-relief carbonate mound features along the Mississippi-Alabama shelf edge between 68- and 101-m (223- and 331-ft) water depth. Average relief height is 9 m (30 ft), with some over 15 m (49 ft). Overall, Pinnacle Trend sites are dominated by the octocorals *Swiftia* sp., *Thesia nivea*, and *Hypnogorgia* sp. (Boland et al. 2017). The Pinnacle Trend is afforded special avoidance protection by BOEM with regard to OCS activities.

One well-studied Pinnacle Trend feature is known as 36 Fathom Ridge, which is approximately 250 m (820 ft) wide and extends north-south for 1,000 m (3,280 ft). 36 Fathom Ridge rises from 90- to 64-m (295- to 213-ft) water depth. Community structure on different parts of the feature is variable. Sessile organism density is dependent on the location, relief, and orientation of the substrate. At the base surface recruitment is low, likely due to surface erosion and sediment turbidity. The vertical walls are densely populated with *Rhizopsammia manuelensis*, which is the dominant species. Several species of soft corals (*Antipathes* spp., *Cirripathes luetkeni*, and *Ellisella* sp.), ahermatypic stony corals, and comatulid crinoids are present. Horizontal surfaces recruited the same community as the vertical walls; however, biotic cover is increased. Overall, the number of fish on these features appears to be low (Thompson et al. 1999). Since 2010, research has also been conducted on the Pinnacle Trend reefs Alabama Alps, Roughtongue, and Yellowtail (Boland et al. 2017).

Other morphologic configurations of hard bottom habitat east of the Mississippi River Delta include flat-top reefs, patch reefs, reef-like mounds, and isobath parallel ridges. Flat-top reefs are broad, approximately 1,000 m (3,280 ft) wide, 15 m (49 ft) in height, and steep-sided, located in the west-central GOM at approximately 80-m (262-ft) water depth. Patch reefs are mostly mushroom shaped and approximately 10 m (328 ft) across at the same depth range as flat-top reefs. Reef-like mounds are located along the western rim of De Soto Canyon, are about half the height of flat-top reefs, and are 10-70 m (33-230 ft) across. Isobath parallel ridges are up to 100 m (328 ft) wide and several kilometers long with seaward facing escarpments. Isobath parallel ridges are found in slightly shallower water than flat-top, patch, and reef-like mounds (summarized in Schroeder 2000).

3.4.1.4 Eastern GOM Coral Reef Systems

3.4.1.4.1 Florida Middle Ground

Hermatypic coral reefs form from the mid-shelf to the upper slope within the photic zone off the coast of Florida. The Florida Middle Ground is a complex of carbonate banks in approximately 45-m (148-ft) water depth, with approximately 12-15 m (39-49 ft) of relief. It trends north-northwest, parallel to the platform margin, and the trend is approximately 60 km (37 mi) by 15 km (9 mi). It was formed by a mix of carbonate production, climate and sea-level change, and physical oceanographic processes (Hine et al. 2008).

The flora and fauna of the Florida Middle Ground are eurythermic and are comprised of a mix of tropical and temperate species. Common tropical species include black spiny sea urchin, thorny oyster, fire coral, and fire worm. Recruitment of tropical species is from local sources and larval delivery via the Loop Current (Hine et al. 2008; Lee et al. 2002).

Octocorals are the most ubiquitous organisms on Florida Middle Ground reef structures. There are four primary faunal zones with characteristic coral assemblages (Grimm and Hopkins 1977): *Muricea-Dichocoenia-Porites* (26-28 m [85-92 ft]) upon horizontal platforms; *Dichocoenia-Madracis* (28-30 m [92-98 ft]) along the slope margins and horizontal platforms; *Millepora* (31-31 m [98-102 ft]) on the upper levels of the slope; and *Millepora-Madracis* (31-36 m [102-118 ft]) along middles and lower levels of the slope.

The five most abundant species are purple reef fish, yellow reef fish, slippery dick, stripped parrot fish, and cocoa damselfish (Coleman et al. 2005).

In the southeast corner of the northern GOM are other important coral reef bank systems. Along the south Florida margin are three small carbonate banks, which form the western extent of the rimmed margin and which defines the Florida Keys: Dry Tortugas; Tortugas Bank; and Riley's Hump. The Dry Tortugas supports sandy cays and shallow coral reefs.

3.4.1.4.2 Drowned Shoreline Reefs

Coral reefs are also found on drowned intact shoreline formed from rocky substrate and uncemented sediment (Locker et al. 1996). A prominent example off the coast of Florida in the GOM is Pulley Ridge, an approximately 300-km (186-mi) multiple ridge complex in approximately 65-m (213-ft) water depth. The southernmost 30 km (19 mi) contains submerged barrier island features with beach ridges, recurved spits, tidal inlets, cat's eye ponds, and a cuspate foreland. Geologically, Pulley Ridge is a young, slow-growing reef system (Hine et al. 2008). Pulley Ridge is the deepest, light-dependent coral reef on the U.S. continental shelf. The southern portion of Pulley Ridge supports a coralline algae-coral dominant reef. The northern portion of Pulley Ridge lacks the macroalgae found farther south and supports a heterotrophic, octocoral-dominant community.

In the aphotic zone, the west Florida slope also supports ahermatypic coral reef species at approximately 550 m (1805 ft) (Newton et al. 1987).

3.4.1.4.3 Stress and Mortality

Corals experience stress or mortality when water temperatures exceed or drop below tolerance ranges or when sufficient light is not present, due to depth change or water turbidity, for photosynthesis by symbiotic zooxanthellae to take place. Naturally occurring stressors to coral reef communities include hurricanes and strong storm events that cause direct physical damage and increased coastal runoff and invasive species, including the Indo-Pacific lionfish, which was first observed in the Flower Garden Banks National Marine Sanctuary in 2011. For example, in 2005, Stetson Bank was subject to a bleaching event following Hurricane Rita and increased nutrient loading from associated terrestrial runoff (DeBose et al. 2008). In 2016, there was a localized mortality event of the Flower Garden Banks. Research suggests that low oxygen concentrations (Johnston et al. 2019b) or higher water temperatures (Johnston et al. 2019a) in combination with other factors were the cause of this bleaching event. Genetic evidence from two endangered coral species (*Orbicella* spp.) at East Flower Garden Bank indicates that hyposaline surface conditions due to the passage of Hurricane Harvey in 2017 is linked to sublethal stress related to the redox state and mitochondrial function in benthic invertebrates (Wright et al. 2019).

Anthropogenic stressors include hook and line fishing, scuba diving, pollutant discharge, oil- and gas-related activities, and illegal fishing and anchoring (Hickerson et al. 2012).

3.4.1.5 Oyster Reefs

The eastern oyster is the dominant reef-building species in the northern GOM and is primarily found with shallow-water coastal estuarine areas. Maturation (>75 mm [2.95 in] shell height) typically occurs within 1 year of settlement. Oysters can form extensive reefs, isolated clusters, or, in southwest Florida, attach to the prop roots of mangroves. Ecosystem services provided by oyster reefs include

- providing a nursery, food, and habitat for recreationally and commercially important fish, crustaceans, and other invertebrates;
- providing a natural filter for phytoplankton, detritus, bacteria, and contaminants;
- preventing coastal erosion and boat wake mitigation; and
- acting as sentinels for environmental monitoring (Volety et al. 2014).

Reef characteristics such as adjacent habitat, connectivity, redundancy, complexity, and water quality affect associated oyster reef assemblages. A synthesis of occupancy studies identified overall 115 fish and 41 decapod crustacean species inhabiting oyster reefs in northern GOM estuaries (La Peyre et al. 2019). The cycle of oyster recruitment, growth, death, and degradation create a succession of available benthic habitat. Relict oyster reefs can create habitat that provide refuge from predation and substrate for egg-laying by mobile organisms (Tolley and Volety 2005).

Oyster reefs are sensitive to damage and impairment. In the Big Bend region of Florida, evidence suggests that the primary mechanisms for reef loss is reduced survival and recruitment due decreased freshwater inputs, which increase vulnerability to wave action and sea-level rise (Seavey et al. 2011). Aggregate analysis and in situ sampling of restoration sites in the north-central GOM indicate that 73 percent of restoration efforts produced at least one living oyster (La Peyre et al. 2014).

3.4.2 Deep Water (>300 m [980 ft])

3.4.2.1 Soft Bottom Communities

The deep sea is the largest ecosystem on the planet and within the GOM. It is generally oligotrophic compared to habitats at higher latitudes or those in areas of upwelling. The presence of different habitats and temporal variation in the deep sea, including within the GOM deep-sea basin, supports diversity (Ingels et al. 2016).

Soft bottom communities are composed of several size classes defined by required sampling regimes: microbiota (<1 μm [bacteria and archaea to 40 μm [protists]); meiofauna (>40 μm to 500 μm); macrofauna (250 μm to 500 μm); megafauna (>1 cm); and demersal fishes. Refer to Rowe (2017) for a discussion of size-class biomass and community structure. The richness of diversity of metazoan and microbial organisms is greater than all other biomes, with diversity in community composition controlled by surface water productivity and physical mixing (Rex and Etter 2010; Zinger et al. 2011).

The deep water of the GOM is divided into seven bathymetric zones, each with its own characteristic faunal assemblages:

- Shelf-Slope Transition Zone (150-450 m [492-1,476 ft]) – Demersal fish are dominant, many reaching their maximum populations. Asteroids, gastropods, and polychaetes are common.
- Archibenthal Zone, Horizon A (475-740 m [1,558-2,428 ft]) – Demersal fish are less abundant than in the Shelf-Slope Transition Zone but are a major constituent of the fauna, along with gastropods and polychaetes. Sea cucumbers are more numerous.
- Archibenthal Zone, Horizon B (775-950 m [2,543-3,117 ft]) – There is a major change in the number of species of demersal fish, asteroids, and echinoids, which reach maximum populations. Gastropods and polychaetes are numerous.
- Upper Abyssal Zone (1,000-2,000 m [3,281-6,562 ft]) – The number of fish species declines while the number of invertebrate species increases. Sea cucumbers and galatheid crabs are common.
- Mesoabyssal Zone (2,300-3,000 m [7,546-9,843 ft]) – Fish species are few. Echinoderms dominate the megafauna.
- Lower Abyssal Zone (3,200-3,800 m [10,499-12,468 ft]) – A large asteroid is the most common megafauna.
- Benthic Zone – This includes the seafloor and the water immediately above it. Characteristic fauna is dependent on environmental regime.

Macrofauna and megafauna appear to have a parabolic pattern of diversity along depth gradients, with the highest diversity present in intermediate depths (~2,000 m [~6,500 ft]), and diversity in community composition is likely related to productivity, competition, and predation relative to depth (Rex 1981). While the majority of corals in the GOM are found on hard substrate, sea pens, cup corals, and bamboo corals are found in soft bottom sediments, occasionally in high abundance over large areas (Gallaway et al. 1988; Rowe and Kennicutt 2009).

3.4.2.2 Hard Bottom Coral Communities

Hard substrate is found throughout the deep waters of the GOM and is comprised of either exposed bedrock or relict authigenic carbonate coral reef (Brooks et al. 2016). Both hard- and soft-bodied corals colonize deepwater substrate (**Figure 3-10**). Associated sessile and mobile benthic megafauna include sponges, anemones, echinoderms, crustaceans, and demersal fishes. Field data suggest that the extent of deepwater hard bottom habitat is large and that the diversity of corals and sponges is high (Boland et al. 2017).

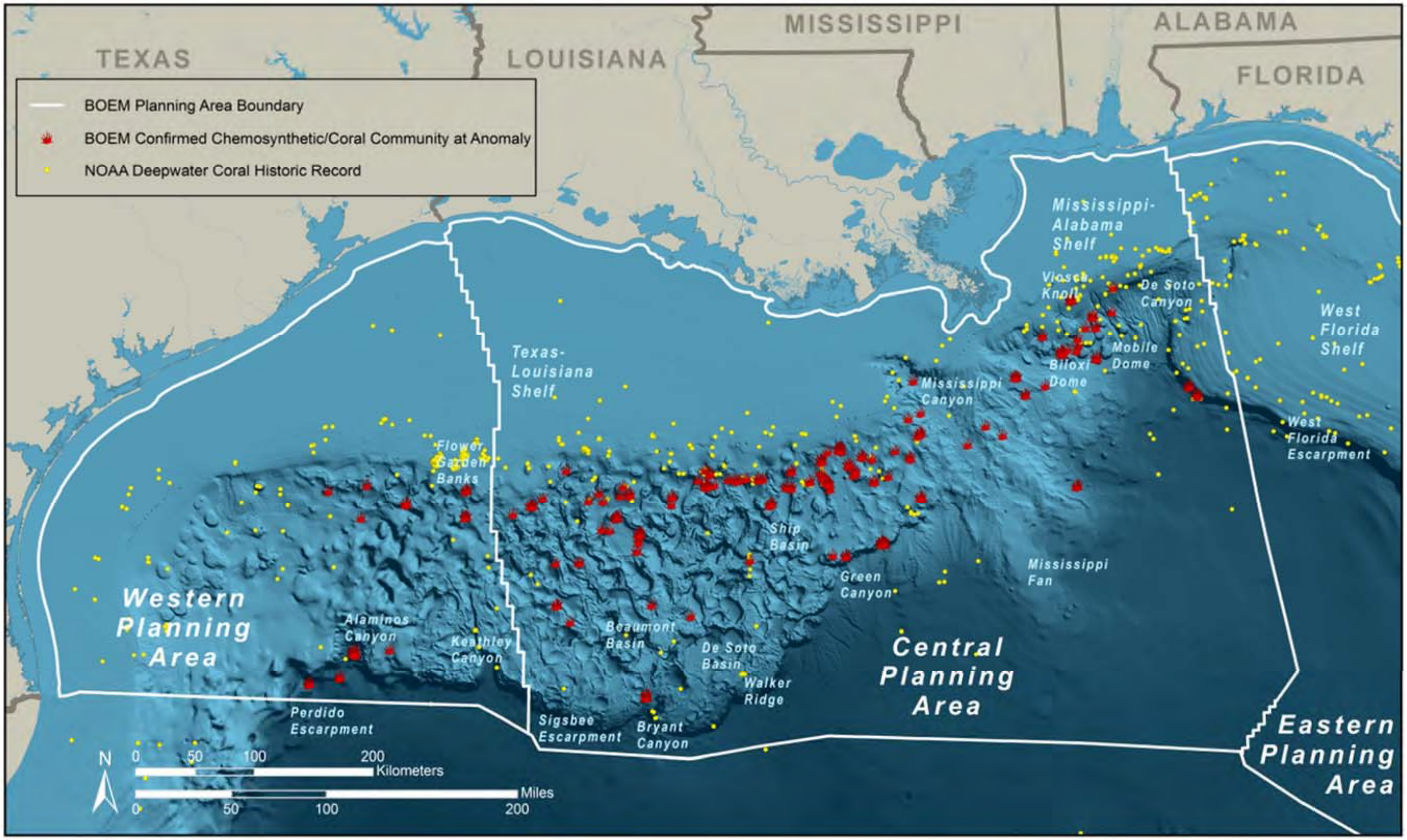

Figure 3-10. Estimated Distribution of Known Deepwater Benthic Communities in the Gulf of Mexico as of 2015.

Deepwater corals are invertebrates in the phylum Cnidaria and live at depths greater than 50 m (164 ft) up to 3,048 m (10,000 ft) where light is dim to non-existent. They are heterotrophic suspension feeders[10]; therefore, resource availability varies on small scales, even within or upon a single feature (Boland et al. 2017). For example, within De Soto Canyon, macrofauna abundance and species richness decreases and evenness increases with depth. Canyon wall abundances are higher than the canyon axis or adjacent slope, for which the differences may result from the entrainment of seasonal water masses. Variability in community composition may be due to the influence of hydrocarbon seeps within the canyon (Shantharam et al. 2020).

Deepwater corals grow relatively slowly compared to shallow-water species and may live to be hundreds to thousands of years old (NOAA 2014). Large, structure-forming deep corals generally prefer substrates with moderate to high relief including banks and mounds, and anthropogenic substrates such as shipwrecks and oil and gas infrastructure, which may be important for some species connectivity (Brooks et al. 2016; Boland et al. 2017). Some species of deepwater corals form large, three-dimensional reef structures. Structure-forming corals include branching scleractinian species, Antipatharians (black corals), and gorgonians (sea whips/sea fans). *Lophelia pertusa*, the most well-studied scleractinian coral, can form vast thickets covering over 1,000 m (3,280 ft) in surface extent and was observed forming large mounds with the black coral *Leiopathes glaberrima* at the Robert's Reef site (Lunden et al. 2013). The largest deepwater coral assemblage discovered (as of 2017) is located in Atwater Valley Block 357 at 1,050 m (3,445 ft) depth and is composed of the branching stony coral *Madrepora oculate* and large gorgonian octocorals *Paramuricea* spp., with many species of associated epifauna (Boland et al. 2017).

Deepwater coral reefs create microhabitats that enhance the structural complexity of the local environment, providing shelter, feeding sites, and nursery ground for several invertebrates and demersal fishes (Schroeder et al. 2005; Fisher et al. 2007; Fraser and Sedberry 2008; Sulak et al. 2008; Cordes et al. 2008; NOAA 2014; Hourigan 2014). Common associated species include golden crab; squat lobster; brittle stars; basket stars; barrelfish; wreckfish; snowy grouper; blackbelly rosefish; roughys; and thornyheads (Hourigan 2014).

Distribution of deepwater coral assemblages and associated species is influenced by depth, available substrate, and environmental conditions such as bottom currents. At least six different types of octocoral assemblages occur in the deep northwestern GOM and the West Florida Slope at depths of 250-2,500 m (820-8,200 ft). The black coral *Leiopathes* spp. appears broadly distributed across both regions. *Lophelia pertusa* is found primarily on the upper slope but has been reported as deep as 3,000 m (9,842 ft).

3.4.2.2.1 Chemosynthetic Communities

Cold seeps are areas of the ocean floor where high concentrations of oil or reduced chemicals including methane, sulphide, hydrogen, and iron II are expelled forming hydrocarbon or gas plumes. In the GOM, hydrocarbon seeps, the majority of which are gas prone, occur along the continental

[10] Most shallow-water corals derive energy from photosynthetic symbionts.

slope where hydrocarbons vertically migrate through fault systems, fractures along salt flanks, or other geological conduits to the seafloor. This fluid and gas migration is driven by salt diapirism, gravity compression, and disassociation of methane hydrates.

Cold seeps were first discovered in the GOM at the base of the Florida Escarpment in 1983 (Paull et al. 1984). Hydrocarbon seep ecosystems are composed of mosaic[11] habitats with a range of physio-chemical constraints for organisms including temperature, salinity, pH, oxygen, carbon dioxide, hydrogen sulfide, inorganic volatiles, hydrocarbon components, and heavy metals (Levin and Sibuet 2012). These habitats support chemosynthetic communities. Such communities on natural substrate typically occur in the GOM at water depths greater than 300 m (984 ft), at a temperature range of ~13˚C to 4˚C (~55˚F to 30˚F), with seafloor currents from 5-10 cm/s (2-4 in/s), and in locations with moderate hydrocarbon flow. The GOM seep communities tend to be large, up to several hundred meters across (MacDonald 1992). Over 330 chemosynthetic communities are confirmed in the GOM at depths ranging from 290 m (952 ft) (Roberts et al. 1990) to 2,750 m (9,022 ft) in Alaminos Canyon (Roberts et al. 2010) (**Table 3-1**).

Bacteria and Substrate Formation

At hydrocarbon seeps, microbial chemoautotrophic organisms oxidize methane and sulfides. Chemoautotrophic bacteria and archaea are also active within methane hydrate structures and may contribute to their stability (Lanoil et al. 2001). Respiration results in precipitation of authigenic calcium carbonate that forms hard substrate on the seafloor. The end-products of chemosynthesis sustain metabolically diverse microbial populations, which form bacterial mats that produce large amount of organic matter (MacDonald 2002). These mats are primarily composed of orange- or white-pigmented *Beggiatoa* spp., which serve as keystone members of the seep microbial community (Mills et al. 2004). Chemoautotrophic bacteria also occur as symbionts in several invertebrate species, including vestimentiferan tubeworms, mussels, and clams providing the bulk of the invertebrates' nutritional requirements. Results from stable isotope studies show that significant amounts of primary production are transferred to the surrounding deep-sea environment (MacDonald 2002).

Chemosynthetic Fauna

There are four general community types of chemosynthetic fauna – fauna for whom symbiotic microbes metabolize methane, sulphur compounds, or both – in the GOM: vestimentiferan tubeworms; mussels; epibenthic clams; and burrowing clams (MacDonald et al. 1990b). *Lemellibrachia* sp. is generally the more abundant tubeworm species at tubeworm-dominant sites and occur in clusters from a few individuals to large bushes up to 3 m (10 ft) in diameter. The largest communities may be up to 20 m (66 ft) in diameter. Bush Hill (MacDonald et al. 1989), located in Green Canyon Blocks 184 and 185, and Green Canyon Block 234 are both crests of salt diapirs and

[11] Mosaic habitats are different patch habitat types located within a defined area that allow for ecological exchange.

are well-known, tubeworm-dominant sites (MacDonald et al. 1990b). Individual tube worms can reach lengths of over 3 m (10 ft) and live for hundreds of years (Fisher et al. 1997).

Mytilid seep mussels are correlated with hydrocarbon seep sites where methane bubbles into the water column and at hypersaline brine pools (MacDonald et al. 1990b). At one such mussel-dominant brine pool site known as Mussel Beach in Green Canyon Block 228, mussels were observed in linear beds of 50 m^2 (538 ft^2) (MacDonald et al. 1990a). Mytilid mussels reach reproductive age relatively quickly, with growth rates slowing into adulthood (Fisher 1995). There is significant heterogeneity within and among seep-associated mussel beds with regard to age-class, growth characteristics, and organism density. Across sites, the mussels show differing levels of health, partly due to parasitic infestations (MacDonald 2002). Powell (1995) estimates that some clam and mussel communities at chemosynthetic sites have been present for between 500 and 4,000 years.

Chemosynthetic clam communities tend to be dispersed over large areas. Epibenthic and mobile Vesicomyid clams live on soft sediments and exhibit chemolithoautotrophic[12] utilization of sulfides. Aggregations of vesicomyid clams have been described on the Louisiana Slope (Rosman et al. 1987; Guinasso 1989 cited in MacDonald et al. (1990b). The chemosynthetic potential of Lucinid and Thyasirid burrowing clams is inferred from habitat and abundance. All species are identified with authigenic carbonates. Assemblages are often characterized by dead valves on the sediment surface and buried living organisms. Burrowing clams have been collected in box cores at up to 65-cm (26-in) water depth in sediment (MacDonald et al. 1990b).

Chemoautotrophic bacteria precipitate calcium carbonate that forms hard substrate on the sea floor, which subsequently may be colonized by sessile and benthic heterotrophic organisms. Common recruits on authigenic carbonate include a variety of mollusks, crustaceans, fish, and echinoderms (Carney 1994). Faunal biodiversity within a hydrocarbon seep site is generally low (Levin 2005) although variation between seep communities may be relatively high (Cordes et al. 2010). Communities are a mix of seep-endemic communities and those present in the surrounding environment; however, many species remain undescribed. Stable isotope signatures indicate that most seep-associated heterotrophic organisms may have a mixed seep-background detritus diet (MacDonald 2002).

Naturally occurring methane hydrates may influence the morphology and characteristics of chemosynthetic communities (Sassen 1998). The dynamics of hydrate alteration could play a major role in the release of hydrocarbon gases to fuel biogeochemical processes and influence community stability (MacDonald 1998). Precipitation of authigenic carbonates and geological instability may alter surface seepage patterns and available substrates; however, similar chemosynthetic communities typically reoccupy sites post event recovery (Powell 1995).

[12] A chemolithoautotroph is a chemosynthetic organism that obtains energy from the oxidation of inorganic compounds and uses carbon dioxide as its sole source of carbon for growth.

Chemosynthetic invertebrates also are found in association with shipwrecks in the GOM. Pre-20th century, the most commercially important bulk commodities shipped from the GOM over deep water were perishable, organic goods including cattle, indigo, and cochineal from New Spain and Mexico; cotton, sugar, and rice from the Mississippi Valley; and sugar, tobacco, and coffee from Cuba. The decomposition of these cargos within the vessels may provide a source of energy for the chemosynthetic organisms similar to the hydrocarbon seeps (Caporaso et al. 2018). For example, on the early 19th century Monterrey shipwrecks in the Keathley Canyon area, living chemosynthetic tube worms were located growing within the woody pulp of the hull and the remains of the cargo. A more recent example, on the early 20th century steam yacht *Anona*, which sank in 1944 in the Mississippi Canyon area, chemosynthetic tubeworms were found growing in boxes of potatoes within the hold.

3.5 Description of Fish and Invertebrate Resources

This chapter describes the fish and invertebrate communities present throughout the GOM. Further detail is provided for species of ecological and economical (commercial and/or recreational) significance. For the purposes of this document, these resources are divided into coastal and oceanic waters with subcategories used to distinguish zones. A detailed discussion of essential fish habitat (EFH) in the GOM, as well as threatened and endangered species is included in this chapter. Lastly, in each section an emphasis will be placed on the northern GOM, where BOEM's regulated OCS activities occur.

The GOM has a taxonomically and ecologically diverse assemblage of fishes and invertebrates due to its unique geologic, oceanographic, and hydrographic features (refer to **Chapter 2**). Felder and Camp (2009) reported that the GOM has a total of 1,541 fish species in 736 genera, 237 families, and 45 orders. Fifty-one of these species are sharks and 42 are comprised of rays and skates (Ward and Tunnell Jr. 2017). The invertebrate assemblages of the GOM are represented by well over 13,000 species in 46 phyla (Felder and Camp 2009). Some of the most diverse, ecologically, and economically significant of these phyla include the following:

- Annelida (segment worms);
- Crustacea (amphipods, copepods, crabs, shrimps, etc.);
- Cnidaria (corals, anemones, hydroids, jellyfish, etc.);
- Dinoflagellata (protists);
- Echinodermata (sea stars, sea cucumbers, sea urchins, sand dollars, brittle stars, etc.);
- Foramnifera (amoeboid protists);
- Mollusca (chitons, snails, bivalves, cephalopods, etc.); and
- Porifera (sponges).

Additionally, the numbers of described species for both fish and invertebrates in the GOM continues to increase overtime due to ongoing exploration of deep-sea mesopelagic, bathypelagic, and abyssopelagic ecosystems.

Similar to fishes found along the U.S. Atlantic Coast from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, northern GOM fishes are generally considered to be warm temperate (Carolinian) (Sherman et al. 1991). Conversely, the southerly waters of the continental shelf in the northern GOM contains tropical fish species, which can be found occupying hard bottom habitats (e.g., natural banks and artificial reefs). These species likely originated from the southern, tropical waters of the GOM and beyond, and were carried north via the Loop Current. Many of these tropical fishes and invertebrates, along with other endemic species are year-round residents in the northern GOM. Other large pelagic species found in the northern GOM (e.g., whale sharks, giant manta ray, and bluefin tuna) occur seasonally and are highly migratory. However, continued satellite tagging efforts in the northern GOM have indicated that some adult highly migratory species (e.g., blue marlin and yellowfin tuna) exhibit more residency than previously assumed (Weng et al. 2009; Kraus et al. 2011).

Fish and invertebrates in the GOM can vary spatiotemporally due to ontogenetic (i.e., development from egg to adult) shifts in habitat use. For example, movements can include cross-shelf migrations of larvae, juveniles, and adults to and from estuarine and coastal waters (e.g., penaeid shrimps and Gulf menhaden). For others, habitat shifts are predominantly food-driven, resulting in vertical migrations through the water column in search of prey — a behavior commonly observed in deep-sea fish and invertebrates (Hopkins and Baird 1985; Flock and Hopkins 1992; Salvanes and Kristofferson 2001). For highly migratory species, seasonal shifts in habitat use are correlated to reproduction and food availability. Less mobile species can include those attached to or primarily living in the benthos as adults and juveniles (e.g., sponges, corals, anemones, oysters, barnacles, blennies, and tilefish), and their larval stages are the only time when these animals are highly mobile. During this period, eggs and larvae are at the mercy of estuarine and oceanic currents (e.g., the Loop Current and associated spin-off eddies), topography, and wind, but they are not randomly distributed. For example, in the north-central GOM, adjacent to Mississippi River plume waters, the larvae of billfish and swordfish (Rooker et al. 2012), as well as phytoplankton, copepods, and other pelagic fish larvae (Lohrenz et al. 1990; Dagg and Whitledge 1991; Govoni et al. 1997), are found in higher densities within frontal zones proximal to the Loop Current. Further, variability in survival of pelagic eggs and larvae during transport are thought to be important determinants of future year-class strength (i.e., fish hatched during an annual spawning period) in adult fish and invertebrate populations (Doherty and Fowler 1994). These processes and life histories shape the unique and diverse fish and invertebrate assemblages that occupy the many GOM large marine ecosystem habitats.

3.5.1 Coastal Fish and Invertebrates

Coastal waters are those extending from inland estuaries seaward over the continental shelf. These waters are enriched by organic material exported from GOM estuaries and rivers, and they support the greatest biomass of the coastal and pelagic zones described. Many species in coastal waters exploit the entire water column, while others can be found primarily utilizing pelagic or benthic environments, although fish in both categories can, at times, be found utilizing both environments. As such, fish and invertebrate resources are subcategorized into coastal pelagics and coastal demersals (i.e., those primarily associated with the benthic environment).

3.5.1.1 Coastal Pelagics

In this chapter, fish and invertebrate resources primarily found associated with the coastal pelagic environment are described. Coastal pelagic refers to those species that inhabit sunlit waters from coastal or estuarine habitats to the continental shelf. These animals typically do not spend a substantial amount of time near the shore or the bottom. An exception is when juveniles recruit to inshore and nearshore nursery ground habitats. Certain species, such as Gulf menhaden, can be found nearshore as adults to filter feed in nutrient rich waters, but they are not necessarily associated with the benthic environment. The taxonomic groups listed in **Table 3-3**, although not exhaustive, can be considered coastal pelagic fish and invertebrates, a few of which will be discussed further (i.e., zooplankton, herrings, and sharks).

Table 3-3. Examples of Coastal Pelagic Fish and Invertebrate Taxa in the GOM.

Classification	Taxonomic Group	Common Name
Invertebrate	Annelida	worms
	Dinoflagellata	dinoflagellates
	Coelenterates	cnidarians and ctenophores
	Copepoda	copepods
	Decapodiformes	squids
Vertebrate	Engraulidae	anchovies
	Clupeidae	menhaden
	Scombridae	mackerels and tunas
	Mugilidae	mullets
	Elopidae	ladyfish
	Carangidae	jacks and scads
	Pomatomidae	bluefish
	Rachycentridae	cobia
	Carcarhinidae	requiem sharks
	Sphyrnidae	hammerhead sharks

Zooplankton

Plankton refers to all plants and animals that drift with the currents in marine and freshwater environments, and is divided into phytoplankton (i.e., plants) and zooplankton (i.e., animals). Zooplankton communities encompass animals who spend their entire lives living within the community of plankton (e.g., dinoflagellates and copepods), as well as the eggs and larvae of pelagic and demersal fish and invertebrates. Most of the eggs and larvae present within zooplankton communities will eventually recruit to other habitats (e.g., benthic, pelagic). There are an innumerable quantity of fish and invertebrate species inhabiting the GOM zooplankton communities. Three taxonomic groups will be described further, i.e., the Dinoflagellata, Copepoda, and larval fish and invertebrates. Each play important roles in marine food web dynamics and ecosystem functionality in coastal pelagic waters.

Dinoflagellates (i.e., Dinoflagellata) are an extremely diverse and ubiquitous phyla of protists that typically dominate plankton assemblages (Jeong et al. 2010). They are often mistakenly considered algae because they can harness sunlight and convert it into chemical energy, but they are in fact animals, and most survive by consuming organic sources of carbon (e.g., plant and/or animal matter). Some dinoflagellates form symbiotic relationships with corals (colloquially known as zooxanthellae), while others are parasitic to a variety of marine creatures, including other protists, copepods, cnidarians, crustaceans, and fish (Coats 1999). Other species can produce neurotoxins, causing the "red tide" phenomenon, paralytic shellfish poisoning, or ciguatera poisoning (Jeong et al. 2010). These events all have significant ecological and socioeconomic consequences in GOM coastal waters. The input of excess nutrients into coastal pelagic waters is thought to be a main driver in the increase of dinoflagellates during these events. Because both copepods and larval fish are known to consume dinoflagellates (Schultz and Kiørboe 2009; Sotecker and Govoni 1984), they can act as pathways for these toxins and other anthropogenic inputs (e.g., polycyclic aromatic hydrocarbons [PAHs]). Dinoflagellates are also an important prey item for other zooplankton community members, including copepods and larval fish.

Copepods (i.e., Copepoda) are small, aquatic crustaceans that are some of the most numerous metazoan groups in marine ecosystems (Turner 2004), and they play pivotal roles in marine food webs as predators, prey, and parasites. Many copepod taxa are parasitic, internally or externally infecting fishes and invertebrates. Others are considered to be predominately herbivorous or omnivorous (Kleppel 1993), feeding on detritus, marine plants (i.e., plankton), and other metazoans (e.g., dinoflagellates and other copepods), and they are particularly prevalent in coastal waters where nutrients from land-based inputs cause phytoplankton blooms. Copepods are prey for a plethora of adult and larval fishes and invertebrates, and their seasonal abundances in the northern GOM, as a response of Mississippi River plume waters in the spring and summer (Dagg and Whitledge 1991), likely play an important role in the reproductive strategies of fishes and invertebrates in the region.

Larval fish and invertebrates are another key component of coastal pelagic zooplankton communities in the GOM as they are predators of lower trophic-level organisms (e.g., plankton, dinoflagellates, and copepods) and are prey for many others (e.g., other larval fish and invertebrates, tunicates, and cnidarians). In the northern GOM, estuarine-dependent fish and invertebrates (e.g., blue crabs, penaeid shrimps, Atlantic croaker, spotted seatrout, and red drum) will typically spawn offshore in coastal waters, likely timing these events to facilitate the transport and retention of larvae into estuarine, nursery habitats (Lyczkowski-Shultz et al. 1990). In contrast, the larvae of many oceanic fish and invertebrates in the northern GOM can be found in association with convergence or frontal zones, which are largely created when freshwater from the Mississippi/Atchafalaya River systems encounters dense saltwater from the continental shelf, effectively concentrating phytoplankton, copepods, and larvae (Lohrenz et al. 1990; Dagg and Whitledge 1991; Govoni et al. 1989; Rooker et al. 2012). For more information, refer to **Chapter 3.3**.

Menhaden

Menhaden are small, planktivorous fish in the family Clupeidae, which are highly prevalent in the northern GOM, particularly off the coasts of Louisiana and Mississippi (Lassuy 1983; SEDAR 2011). They are described in detail in this section because they represent a taxa of small, schooling fishes that link lower trophic-level (e.g., plankton) and higher trophic-level (e.g., sharks) organisms. Menhaden likely influence the population dynamics of many predatory fish species in the northern GOM (e.g., blacktip sharks, king mackerels, Spanish mackerels, and red drum) (Sagarese et al., 2016; Chen 2017). Three species occur in the GOM: finescale; yellowfin; and Gulf menhaden. Gulf menhaden are numerically dominate compared to the other species and represent roughly 99 percent of the menhaden species captured commercially (Ahrenholz 1981). They are euryhaline, meaning they inhabit both nearshore marine and estuarine waters. Gulf menhaden are estuarine-dependent and their larvae are released offshore during spawning events between September to April (VanderKooy and Smith 2002), and eventually recruit to inshore nursery habitats (e.g., estuaries and rivers); they stay in these habitats until they reach adulthood and migrate back offshore. Females reach sexual maturity between 1 and 2 years old or when they reach an approximate fork length of 5.9 in (150 mm) (Lewis and Roithmayer 1981).

Coastal Pelagic Sharks

The GOM waters are home to a diverse assemblage of coastal pelagic sharks, with varying spatial and temporal distributions (e.g., there are variations in dominant species between the northern and southern regions). In the southern GOM, along southwest Florida, the most common coastal pelagic sharks encountered are bonnethead, blacktip, blacknose, and lemon sharks. In the northern GOM, populations are dominated by Atlantic sharpnose, followed by blacktip, finetooth, and bull sharks (Parsons and Hoffmayer 2007). Coastal sharks in the northern GOM are known to migrate from inshore to offshore waters due to more intense seasonal temperature variations (Parsons and Hoffmayer 2007; Hoffmayer et al. 2006; Chen 2017). These seasonal habitat shifts are not as likely in the southern GOM where seasonal temperature fluxes are generally less dramatic (Chen 2017). Some coastal pelagic sharks, like the sandbar shark, are known to leave the GOM and travel into the Atlantic (Parsons and Hoffmayer 2007). Young of the year and neonate shark species (e.g., Atlantic sharpnose, blacktip, finetooth, bull, scalloped hammerhead, spinner, and sandbar sharks) have been found inhabiting coastal habitats such as barrier islands, bays, and estuaries along the coasts of the northern GOM states from Texas to the Florida Panhandle, indicating their likely importance as nursery habitats (Carlson 1999; Neer and Thompson 2004; Parsons and Hoffmayer 2007; Froeschke et al. 2010).

Shark species in the GOM are separated into three management groups by the Gulf States Marine Fishery Management Council (GSMFC): (1) small coastal; (2) large coastal; (3) and pelagic. Small sharks include bonnetheads, sharpnose, blacknose, and finetooth sharks. Large sharks include blacktip, bull, great hammerhead, lemon, sandbar, scalloped hammerhead, silky, smooth hammerhead, spinner, and tiger sharks. Pelagic sharks include basking, bignose, bigeye sand tiger, Caribbean reef, Caribbean sharpnose, dusky, Galapagos, great white, narrowtooth, night, sand tiger, smalltail, and whale sharks; however, they are no longer included in the management groups because of low population biomass and poor stock conditions (i.e., overfished), which has resulted in them being listed as commercially and recreationally prohibited species.

Sharks are high trophic-level predators who play important roles in marine food webs. By exerting top-down control over prey species, they can significantly alter community structures (Heupel et al. 2014). Consequently, the large-scale removal of shark species, particularly large sharks, has been suggested to result in trophic cascades through top-down effects (Stevens et al. 2000; Myers et al. 2007). They are particularly vulnerable to overfishing due to aspects of their life histories, such as slow growth, late sexual maturation, and the production of a small number of offspring (e.g., between 1 and 300 offspring can be produced during a single reproduction event [Cortés 2000]).

3.5.1.2 Coastal Demersals

Coastal demersal fish and invertebrates refer to those species that inhabit coastal or estuarine waters extending from the nearshore to waters over the continental shelf. In contrast to coastal pelagics, species described here primarily utilize benthic substrates or are associated with structure (natural or man-made). The coastal waters of the northern GOM are comprised of mostly low-relief, soft bottom habitat, but benthic hard bottom and man-made topographic features are scattered throughout (refer to **Chapter 3.3**). Several trends exist of coastal demersal fish and invertebrates. Some species are primarily found over either soft or hard bottom habitats, whereas others can be found utilizing both (**Table 3-4**). Species attracted to structure, such as reef fish, can be found throughout the northern GOM in association with natural hard bottom substrates and artificial reefs. These assemblages include economically important reef fish such as snappers and groupers. A few ecologically and economically important representatives of coastal demersal fish and invertebrates will be discussed in more detail below.

Table 3-4. Fish and Invertebrate Taxa and Species Based on Coastal Benthic Habitat Types.

Coastal Habitat Type	Associated Fishes	Associated Invertebrates
Soft bottom	tilefishes, flatfishes	penaeid shrimps, mantis shrimps
Hard bottom	snappers, groupers, triggerfishes, jacks, angelfishes	soft and stony corals, brittle stars, stone crabs, lobsters
Both	drums, red grouper, spotted sea trout, red snapper	blue crab, octopus

Shellfish

Shellfish species (e.g., blue crab and penaeid shrimp) are coastal demersal species that are important both ecologically and economically. Ecologically they are important prey items for fish and invertebrates and some species, like the eastern oyster, create important benthic habitats (refer to **Chapter 3.2**). Many are economically valuable both commercially and recreationally, and the targeted fisheries include penaeid shrimp (i.e., brown, white, and pink), eastern oyster, and blue crab (**Figure 3-11**). Other, more moderately targeted species include the Atlantic seabob, Caribbean spiny lobster, rock shrimp, royal red shrimp, lesser blue crab, and Gulf stone crab.

Figure 3-11. Five Most Economically and Recreationally Valuable Shellfish Species in the Gulf of Mexico. These species include the blue crab (top left;(NOAA 2020b), eastern oyster (top right; (NOAA 2020a), brown shrimp (bottom left; (NOAA 2020e), white shrimp (bottom center;(NOAA 2020f), and pink shrimp (bottom right;(NOAA Fisheries 2020g).

All of the heavily targeted shellfish are dependent upon estuaries for some or all of their life cycles and can be characterized as r-selected species. R-selected species are those who produce many offspring, have low survival rates, reach sexual maturity quickly, and possess relatively short life spans. For example, under optimal conditions, eastern oysters in some GOM bays can become sexually mature just 4 weeks after settlement (VanderKooy 2012) and produce millions of eggs throughout a spawning season (i.e., spring, summer, and fall). Similarly, penaeid shrimps grow quickly, typically reaching sexual maturity after 2-3 months (Tunnell 2017). They can produce hundreds of thousands of eggs that can be released several times throughout a spawning season (March through September), and they typically live less than 2 years. The adaptations of these animals to produce such large quantities of eggs throughout a spawning season gives them an advantage in terms of resiliency to natural and human-caused perturbations versus slow-growing animals who produce only a few, well-developed offspring.

Commercially valuable shellfish species in the northern GOM face a multitude of natural and anthropogenic threats. Natural perturbations such as sea-level rise and tropical storms threaten coastal and estuarine habitats. Similarly, warming waters along coastlines are expected to affect the distribution of parasites, pathogens, and invasive species (Marcogliese 2008). Increases in human populations, particularly near coastlines, brings threats of ongoing development and habitat loss, freshwater input from diversions, overharvesting, and land/marine-based pollutants.

Red Drum

Red drum are an estuarine-dependent species of fish that is found throughout the GOM in coastal waters. They are an important secondary consumer in shallow, coastal habitats, assisting in the regulation of primary consumer populations, and they are important to coastal economies as they form a widely popular and lucrative recreational fishery. Red drum utilize a variety of demersal habitats throughout their lives (e.g., bays, artificial reefs, seagrass beds, estuarine passes, mud flats, coastal beaches, and nearshore shelf waters) (Chen 2017). Males and females typically form large spawning aggregations in estuarine passes where they release eggs and sperm into the water column. Female red drum can release up to 2 million eggs in a season (generally between August and October). The eggs hatch within 24-36 hours and are eventually carried via wind and tides into estuarine nursery grounds. Juveniles spend their early lives within estuaries feeding on a variety of small prey items including copepods, mysid shrimp, polychaetes, bivalves, and amphipods (Peters and McMichael 1987; Bass and Avault 1975). Adult red drum are generalists and have been found to forage on a variety of both fish and invertebrate prey such as mollusks, crabs, shrimp, menhaden, anchovies, pinfish, spot, and Atlantic croaker (Boothby and Avault 1971; Scharf and Schlight 2000). While growth rates and age at sexual maturity have been found to vary by location and sex, they can generally be described as growing quickly during their first few years then reaching a marked slowdown (Porch 2011). Recently, Bennetts et al. (2019) found an anomaly in red drum growth rates in the northern GOM, with both sexes reaching sexual maturity at around 3 years old.

Snappers

Snappers are in the family Lutjanidae and are comprised of 17 genera and about 100 species. In the GOM there are 16-17 species in six genera, many of which are targeted in both commercial and recreational fisheries (e.g., queen snapper, mutton snapper, cubera snapper, gray snapper, dog snapper, lane snapper, yellowtail snapper, vermilion snapper, and red snapper). Most are opportunistic carnivores and reef-dwelling as adults, with juveniles that settle into brackish mangrove estuaries (Chen 2017). Some regional variations exist; for example, juvenile gray snapper in western Florida have been found to primarily utilize seagrass beds as nursery grounds, while adults and subadults appear to largely associate with estuarine and channel habitats (Bortone and Williams 1986; Flaherty-Walia et al. 2015). Conversely, in the north-central GOM between Texas and Alabama, age-0 and age-1 red snapper juveniles prefer to settle over low-relief sand, shell rubble, and mud bottom substrates in nearshore waters (Rooker et al. 2004; Patterson et al. 2005; Wells et al. 2008), and adults eventually make their way to shelf waters in search of more complex habitats. Red snapper are arguably one of the most valuable and sought-after sport fish in the GOM because of their popularity as a food fish.

Red snappers can be found in coastal waters throughout the GOM and are particularly prevalent in the northern GOM from Texas to Florida. They grow rapidly in their first 10 years of life, reaching sexual maturity at relatively young ages (between 1 and 2 years) when considering their long lifespans (over 50 years) (Woods et al. 2003; Gallaway et al. 2009). Adults spawn offshore over the continental shelf and upper continental slope over sand and mud bottoms between April to May and September to October, with the highest abundances occurring in the northern GOM off central and western Louisiana (Collins et al. 2001; Chen 2017). Their larvae are planktonic and remain as ichthyofauna for approximately 30 days. Larvae transport to nearshore nursery habitats and can be highly influenced by topography (e.g., Mississippi River Delta, De Soto Canyon, and the Apalachicola Peninsula) and spin-off eddies associated with the Loop Current (Johnson and Perry 2020). Consequently, genetic studies have indicated the likelihood of metapopulations for the GOM red snapper stock with the general assumption being the existence of two primary sub-stocks within the region (an eastern and a western stock separated roughly by the Mississippi River) (SEDAR 2018).

The most recent stock assessment report (SEDAR 2018) indicated that red snapper are not overfished and that overfishing is not occurring, but it has not yet recovered to the Gulfwide rebuilding target. This is a sign that steps to manage overharvesting, which is the number one threat to red snapper populations in the GOM, are seeing evidence of success.

Groupers

Fishes of the family Serranidae (subfamily Epinephelinae) are found in both the tropical and subtropical GOM waters and consist of the commonly known groupers, rock hinds, and seabasses. They are slow-growing, late-maturing, long-lived demersal fish. Like snappers, groupers are structure orientated, generally associating with hard or rocky bottoms and reefs (both natural and man-made) (refer to **Chapter 3.4**). Groupers are typically solitary fish except for the formation of occasional spawning aggregations (Heemstra and Randall 1993). They are top-level predators in hard bottom, reef ecosystems feeding on a variety of prey items including fishes, crustaceans, and cephalopods (Heemstra and Randall 1993). Consequently, they play important roles in food web dynamics by enhancing complexity of the habitat and diversity of the communities in which they live.

Because of their popularity as food and a sport fish, both commercial and recreational fisheries exist, lending to their considerable economic value throughout the GOM. There are currently 15 species managed by the Gulf of Mexico Fishery Management Council, and they have been divided into shallow-water and deepwater grouper complexes (SEDAR 2006). Shallow-water groupers include red grouper, gag grouper, black grouper, scamp, yellowfin grouper, yellowmouth grouper, rock hind, and red hind. The deepwater groupers include snowy grouper, yellowedge grouper, speckled hind, warsaw grouper, and misty grouper. Both Nassau grouper and goliath grouper are managed separately and are prohibited from being harvested (Chen 2017). In the GOM, red grouper (**Figure 3-12**) are one of the most abundant and important commercial and recreational species.

Figure 3-12. Red Grouper (NOAA Fisheries 2020h).

Red grouper are distributed along the GOM continental shelf but are particularly abundant in the eastern GOM along the Florida shelf in depths of 10-400 ft (3-123 m) (Moe 1969; Johnson and Collins 1994). Like many other grouper species, they are protogynous hermaphrodites, meaning they begin their lives as females then transform into males once a certain size and/or age is reached (Jory and Iverson 1989). Unlike other grouper species, which typically form spawning aggregations, red grouper are unique in that they excavate depressions (or holes) in sandy bottom sediments (Wall et al. 2011). These “pockmarks” are used as home territories, primarily by males, where they will court and eventually spawn with females as they swim up into the water column (Scanlon et al. 2005; Wall et al. 2011). The maintenance of these holes involves the periodic clearing of sediment and debris. This exposes rocky substrate and allows for the settlement of sessile invertebrates, which may eventually create complex habitat for other economically important species such as Caribbean spiny lobster (Coleman et al. 2010). Thus, the red grouper may be of significant ecological importance to this region as a creator of additional habitat.

3.5.2 Oceanic Fish and Invertebrates

Oceanic waters are defined here as those waters seaward of the continental shelf, although oceanographic features and storms can cause these waters to intrude over the mid- or inner shelf. Just as oceanic waters can traverse the continental shelf so do oceanic-pelagic fauna, such as highly migratory species (e.g., tunas, oceanic sharks, billfish, and swordfish). Commercial longline catches, recreational fishing surveys, and a growing number of independent research efforts in deep-sea pelagic habitats inform much of what we know about the distribution and abundance of oceanic-pelagic species.

Oceanic-pelagic fish and invertebrates occur throughout the open ocean from the surface down to the vast depths of the abyssal plain. Water column structure is delineated by a variety of physical characteristics (i.e., depth, light penetration, turbidity, temperature, and pressure) and is the primary means of partitioning for distribution and abundance analyses. In general, these species recognize different water masses based upon physical and biological characteristics and have evolved various adaptations to survive in the habitats in which they are primarily found (**Table 3-5**). However, many of these organisms regularly traverse these boundaries in search of prey or refuge (e.g., nocturnal vertical migration in meso- and bathypelagic organisms). The following subcategories are used to distinguish among assemblages based on predominant depths inhabited in this chapter: epipelagic, which extends from the surface to a depth of 656 ft (200 m); mesopelagic, which extends from 656 to 3,281 ft (200 to 1,000 m); and bathypelagic, which includes depths greater than 3,281 ft (1,000 m). Knowledge of abyssopelagic assemblages and community structure in the GOM is limited and is not discussed in this chapter.

Table 3-5. Examples of Fish and Invertebrate Taxa and Species Based on Water Depths.

Water Column Zone	Water Depth	Associated Fishes	Associated Invertebrates
Epipelagic	Surface to 656 ft (200 m)	halfbeaks, flying fishes, early life stage driftfishes, yellowfin tuna, bluefin tuna, mahi mahi, swordfish, marlin, sailfish, giant manta ray, oceanic white tip shark, short fin mako shark, whale sharks	crustaceans (e.g., copepods), squids, chaetognaths, polychaete worms, pelagic octopus, gelatinous organisms (e.g., tunicates and ctenophores), pteropods
Mesopelagic	656-3,281 ft (200-1,000 m)	lanternfishes, bristlemouths, hachetfishes, dragonfishes, Atlantic angel shark, six gill sharks	crustaceans (e.g., amphipods, copepods, decapod shrimps, and ostracods), squids, pelagic octopus, gelatinous organisms (e.g., tunicates and cnidarians), pteropod and heteropod mollusks
Bathypelagic	>3,281 ft (1,000 m)	lanternfishes, bristlemouths, hachetfishes, anglerfish, dragonfishes, smooth-heads, fangtooths, whalefishes, cookie cutter shark, sleeper shark	crustaceans (e.g., decapod shrimps, *Lophogastrida* spp., mysids, amphipods, copepods, and ostracods), squids, gelatinous organisms (e.g., tunicates and cnidarians)

3.5.2.1 Epipelagics

Oceanic epipelagic species occur throughout the GOM, especially at or beyond the shelf edge. Epipelagics are reportedly associated with mesoscale hydrographic features such as frontal zones, meso-scale eddies, and discontinuities. Many of the oceanic fish and invertebrates in this subcategory are also associated with floating *Sargassum* and deepwater anthropogenic structures, which serve as foraging areas and nursery refugia (**Chapter 3.4**). Common species in this zone include halfbeaks, flying fish, early life stage driftfishes, and juvenile jack species that have limited connectivity with deeper waters. Several well-known highly migratory species are also epipelagic (**Table 3-5**), many of which are managed by NMFS' Highly Migratory Species Management Division and the International Commission for the Conservation of Atlantic Tunas. The lower section of the epipelagic zone has a distinct fauna, consisting of the poorly known oarfishes and its relatives, in addition to fishes with great depth ranges such as tunas and swordfishes (McEachran and Fechhelm 1998). Adult driftfishes are generally found at depths, bridging the lower epipelagic and upper mesopelagic zones. At night, the epipelagic zone receives an influx of animals from the meso- and bathypelagic depths, known as the "nyctoepipelagic" or diel vertical migratory fauna that come to feed (Sutton et al. 1998). Conversely, large epipelagic fish such as whale sharks (Tyminksi et al. 2015) and bluefin tuna (Teo et al. 2007) are known to vertically migrate down to the deep-sea zones (>200 m; 656 ft).

Tunas (Genus Thunnus)

Tunas of the family *Scombridae* are arguably one of the most ecologically important, widely occurring, and economically valuable oceanic-pelagic fishes in the GOM. They include bluefin tuna, yellowfin tuna, blackfin tuna, bigeye tuna, albacore tuna, little tunny, and skipjack. Yellowfin tuna are the most commercially and recreationally valuable tuna species in the GOM.

Like all tunas, yellowfin tuna can maintain a body temperature higher than that of surrounding water, allowing them to use their muscles more efficiently and therefore swim more quickly with little expenditure of energy. This makes them top-level predators in the GOM, particularly in the northern GOM where they are primarily captured (Teo and Block 2010). Although they have distinct spawning areas (i.e., Gulf of Guinea, southeastern Caribbean Sea, and GOM) and apparent heterogeneity in their distributions, they are currently considered to be a single stock for the entire Atlantic (ICCAT 2018). However, electronic tagging efforts in the northern GOM have shown that adult yellowfin tuna in the GOM may exhibit more retention (i.e., longer residence times) than previously assumed (Weng et al. 2009; Hoolihan et al. 2014; Franks et al. 2015), which may be related to the high productivity associated with the Mississippi River Delta and the extensive network of oil and gas structures.

In contrast to yellowfin tuna, bluefin tuna are true residents, with tagging studies indicating clear movements to and from the Atlantic and GOM (Block et al. 2005). They are the largest of the tuna species and an economically valuable sports and food fish worldwide. Genetic and tagging studies have indicated that two separate stocks in the Atlantic exist, and they are defined by their spawning grounds in the GOM (western stock) and Mediterranean Sea (eastern stock), respectively (Block et al. 2005; Boustany et al. 2008). In the northern GOM, the bluefin tuna spawning grounds are located far offshore in deep water, particularly in the waters west of the Loop Current, and spawning typically occurs from mid- to late May (Brothers et al. 1983; Block et al. 2005). Like yellowfin tuna, bluefin have been shown to use mesoscale oceanographic features (e.g., anti-cyclonic warm and cold core eddies) in the northern GOM as likely nursery habitats (Cornic et al. 2017), as well as other highly migratory species (e.g., billfish and swordfish) (Rooker et al. 2012).

Deep-Sea Fish and Invertebrates (Meso- and Bathypelagic Zones)

Much of what is known of deep-sea (over 200 m) meso- and bathypelagic fauna in the GOM comes from a combination of trawl surveys, ROV footage, and gut content analyses. These efforts have discovered assemblages of fish and invertebrates (**Figure 3-13**) that are so diverse and abundant, the GOM was recently classified as a unique biogeographic ecoregion in comparison to nearby oceanic regions such as the Caribbean and Sargasso Sea in the western Atlantic (Sutton et al. 2017). For example, deep-water pelagic surveys conducted since the *Deepwater Horizon* oil spill resulted in the collection of 794 mesopelagic and bathypelagic fish species, ranking the GOM as having one of the four most-speciose oceanic ichthyofaunas in the world (Sutton et al. 2017). Although it is not an exhaustive list, Table 3 in the Sutton et al. report includes many of the fish and invertebrate taxa that have been documented at various depths within the meso- and bathypelagic zones of the GOM.

Figure 3-13. Deep-sea Pelagic Fish and Invertebrates Captured during a DEEPEND Research Expedition in the Northern Gulf of Mexico. (©Danté Fenolio/DEEPEND; permission granted on April 22, 2020).

Fish in the deep sea tend to grow slowly and some can live to extraordinary ages, although aging has proven to be difficult, particularly for small, deep-sea pelagics (Calliet et al. 2001; Roberts 2002). Many deep-sea organisms are long-lived and tend to have a late age at maturity and low fecundity (Priede 2017). This may be facilitated by their slow metabolisms, which is typically an order of magnitude slower than fishes living in shallower habitats (Koslow 1997; Cailliet et al. 2001). Low metabolic rates in many deep-sea fishes may be an adaptation to the effects of increased pressure, low food supply, and low-light levels, which result in less energy demand in predator-prey behavioral interactions (Priede 2017). There is also a global trend of decreasing body size with depth in most fish and invertebrates, albeit with some exceptions (e.g., gigantism seen in some sharks and invertebrates), which may be an adaptation to low food supply (Van der Grient and Rogers 2015). Other notable physical adaptations include highly adapted eyes in many fish, cephalopods, and crustaceans, which allow them to see at any depth (Warrant and Locket 2003).

Contrary to previous thought, many of these species conduct major vertical migrations and are not necessarily confined to particular depth zones (Loeb 1986). For example, sampling in the GOM and several regions in the Atlantic revealed that, of the 234 fish species collected in the bathypelagic zone (>1,000 m; 3,281 ft), between 66 and 74 percent were also collected at shallower depths in the mesopelagic zone (<1,000 m; 3,281 ft) (Sutton 2013). However, there appears to be some taxa that are characteristic of certain zones and exhibit limited vertical migration (Sutton 2013). Some of the trends in physical and behavioral characteristics of these taxa are discussed below with specific examples of GOM fish and invertebrate species incorporated as appropriate.

3.5.3 Mesopelagics

Many of the fish and invertebrate species living primarily in the mesopelagic zone undergo diel vertical migrations to the epipelagic zone at night where they feed on plankton (Salvanes and Kristofferson 2001; Bianchi et al. 2013; Widder 2010). In the northern GOM, the majority of these organisms are located between 450 and 550 m (1,476 and 1,804 ft) during the day and rise to the surface at night to feed (Kaltenberg et al. 2007). In response, many epipelagial predators (e.g., fish, squids, night-foraging seabirds, and marine mammals) have adapted to take advantage of these migrations (Spies et al. 2016). Therefore, diel vertical migrations contribute to the transfer of energy from deep-sea ecosystems to surface waters and vice-versa. East of the Mississippi River, daily variability in diel vertical migrations intensify from autumn to spring, and the pattern changes in structure on the order of days to weeks in association with onshore and offshore currents, lunar variability, cloud cover, and the passage of harmful algal blooms (Parra et al. 2019).

In waters where the mesopelagic zone is subdivided into upper and lower zones (around 600-700 m; 1,967-2,297 ft), mesopelagic fishes inhabiting the upper zone tend to have reflective sides and large ventral photophores used to avoid predators (Denton et al. 1985). Fishes commonly collected in the upper mesopelagic zone include lanternfishes, bristlemouths (a.k.a. lightfishes), hatchetfishes, barricudinas, and small escolar (Sutton 2013). Fishes in the lower mesopelagic zone are generally less reflective, and this trend continues with depth. Commonly found species in the lower zone include dragonfishes, ridgeheads, deep-sea smelts, bristlemouths, lanternfish, hatchetfishes, and pelagic eels (Sutton 2013). The larvae of many of these taxa can be found in the upper 100 meters of the epipelagic zone (Sassa and Kawaguchi 2006; Hsieh et al. 2017) and in association with Loop Current frontal zones in the GOM (Richards et al. 1993).

Some of the most abundant and ecologically significant of these taxa in the GOM are the lanternfish (*Myctophidae*). They are one of the major migrating taxa between meso- and epipelagic zones and play important ecological roles as predators of zooplankton and as prey for a variety of predators in the epipelagic zone (Gartner 1993; Catul et al. 2011). They have a lifespan of approximately 1-5 years, which is relatively short compared to many demersal species (some recorded to live >100 years) (Priede 2017), and they produce relatively few eggs (100-2,000 per spawn) (Catul et al. 2011). In addition to fish, invertebrates of the mesopelagic zone also fulfill similar ecological roles.

There are many ecologically significant taxa of invertebrates present in the mesopelagic zone and, like fish, they also vertically migrate throughout the water column, contributing to the transfer of energy. They include many taxa of crustaceans (e.g., copepods, decapod shrimps, mysids, ostrocods, and amphipods), gelatinous organisms (e.g., tunicates, siphonophores, and ctenophores), cephalopods (e.g., squids and octopus), and polychaete worms (Spies et al. 2016). Cephalopods are particularly important in midwater ecosystems of the GOM as both predators and prey, and the majority of individuals inhabit the mesopelagic zone (Judkins and Vecchione 2020). They are known to be the primary prey of sperm whales in the GOM (Baumgartner et al. 2000) and likely other, lesser known oceanic-pelagic cetaceans. Through stable isotope stomach content analyses, McClain-Counts et al. (2017) have shown that invertebrates such as copepods and gelatinous prey (e.g., salps and pteropods) are important components of mesopelagic fish diets.

3.5.4 Bathypelagics

The bathypelagic zone is one of the largest and least understood biomes on the planet. It has no sunlight penetrating its depths, and there is a well-documented logarithmic decline of food energy with increasing depth (Haedrich 1996; Angel 1997; Sutton 2013). The sparseness of prey, increased water pressures, and absence of sunlight may all contribute to the general decrease in musculoskeletal robustness of fishes observed with increasing depth (Salvanes and Kristoffersen 2001). Other morphological adaptations include a reduction in relative eye size; the loss or reduction of photophores; a transition to black, brown, or red pigmentation versus silvery; and the reduction or loss of swimbladders (Marshall 1979; Sutton 2013). As a result of the environment and their adaptations, many fish in this zone have adopted “sit and wait” hunting strategies in which they use bioluminescent lures to attract prey and mates. Despite its extreme environmental characteristics, the upper bathypelagic waters are rich in biodiversity.

Midwater trawl surveys of bathypelagial organisms in the Atlantic Ocean have shown that depths around 1,000 m (3,281 ft), which is the border of the mesopelagic and bathypelagic zones, often contain the maximum species richness of both deep-pelagic and megabenthic fauna (Angel 1993). This finding was corroborated by a 1980s Minerals Management Service survey of deep-sea communities in the GOM (Pequegnat et al. 1983), where the mesopelagic zone exhibited an increasing fish diversity up to 3,117 ft (950 m), while fish diversity steadily decreased in the bathypelagic zone, with a drastic drop after 7,546 ft (2,300 m). More recent mid-water trawl surveys in the eastern GOM between 1,000 and 3,000 m (3,281 and 9,843 ft) have found that approximately 50 percent of the catch consisted of bristlemouth fishes, followed by Lophogastrid (17.3%) and decapod shrimps (17%) (Burghart et al. 2010). Gut contents analyses of these organisms revealed that both the bristlemouth fish and Lophogastrid shrimps primarily consumed smaller prey items like copepods and ostracods, whereas one family of decapod shrimps (Oplophoridae) primarily fed on relatively large fish (Burghart et al. 2010). In general, their findings suggest that there was little overlap in fish and invertebrate diets in the bathypelagic zone, with the majority showing a partitioning of food resources.

While many of the fish species present in the bathypelagic zone can also be found in the mesopelagic zone (i.e., lanternfishes, dragonfishes, hatchetfishes, and bristlemouths), there are still a unique assortment of fishes that are typically only found at these depths. In the GOM, these include ceratioid anglerfishes, whalefishes, and tubeshoulders (Tolley et al. 1989; Pietsch and Sutton 2015; Novotny 2018). Both anglerfishes and whalefishes have evolved extreme examples of sexual dimorphism, in which the female is extremely large in comparison to males (Pietsch and Sutton, 2015; Johnson et al. 2009). This may perhaps be an attempt to perpetuate their species' by investing the majority of their biomass in females, facilitating greater fecundity (Sutton 2013). Like the mesopelagic fishes, the larvae of many bathypelagic fishes can be found in surface waters (<200 m; 656 ft), where they have a higher likelihood of survival (Ahlstrom 1969).

Similar to fish, many of the same taxa of invertebrates are found in both the meso- and bathypelagic zones (i.e., crustaceans, cephalopods, gelatinous organisms, etc.). However, some taxa in this zone, such as species of lophogastrid, mysid, and decapod shrimps have a higher proportion of individuals that brood their eggs compared to mesopelagic populations (Burghart et al. 2007). This may be an adaptation to an environment in which pelagic larvae have less access to food and are not as likely to survive (Burghart et al. 2007). Although the highest number of individual cephalopods has been documented in the mesopelagic zone, 95 percent of oceanic cephalopod species in the northern GOM can be found spending a portion of their time migrating through or living within the upper bathypelagic zone (1,000-1,500 m; 3,281-4,921 ft) (Judkins and Vecchione 2020). Lastly, gelatinous zooplankton in the bathypelagic zone may play an important role in deep-sea ecology (Sutton 2013). In the eastern GOM, they have been found to be prey for decapod shrimps (Burghart et al. 2010) and are likely prey for other fauna in this zone (e.g., bathypelagic fishes).

3.5.5 Essential Fish Habitat and Threatened and Endangered Species

This chapter describes essential fish habitat (EFH), the process by which it is designated and currently managed. Additionally, threatened and endangered species of fish and invertebrates present in the GOM will be discussed, with an emphasis on the northern GOM.

3.5.5.1 Essential Fish Habitat

Fish and invertebrates such as white shrimp, Caribbean spiny lobster, bluefin tuna, great hammerheads, gag grouper, red snapper, and red drum are federally managed in the GOM. They all have portions of their range and associated habitats that have been recognized by Congress as "those waters necessary for spawning, breeding, feeding or growth to maturity" (16 U.S.C. §§ 1801 *et seq.;* NMFS 2007). As such, these habitats have been designated as EFH and given added protection through an amendment to the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §§ 1801 *et seq.;* NMFS 2007). In the GOM, the GSMFC and NMFS are responsible for EFH designation and management. To date, they have created EFH designations for red drum, reef fish (32 species), coastal migratory pelagic fishes (3 species), corals (2 classes), shrimps (4 species), spiny lobster, and highly migratory species (48 species). Collectively, the spatial extent of EFH designations in the GOM covers extensive areas, effectively encompassing all coastal estuaries and large portions of nearshore and offshore waters.

In addition to EFH, the GSMFC and NMFS are responsible for identifying habitat areas of particular concern, which are discrete subsets of EFH. These habitat designations are based on (1) the importance of the ecological function provided by the habitat; (2) the extent to which the habitat is sensitive to human-induced environmental degradation; (3) whether, and to what extent, development activities are, or will be, stressing the habitat type; or (4) the rarity of the habitat type. This designation does not give added protection for or restriction to an area, but it can help prioritize conservation efforts. Throughout the GOM, Habitat Areas of Particular Concern for corals have been identified and include a variety of ecologically diverse hardbottom habitats such as the East and West Flower Garden Banks in the northwest, the Florida Middle Grounds in the northeast, and Pulley Ride in the southern region near the Dry Tortugas. For more information on benthic habitats, refer to **Chapter 3.4**).

3.5.5.2 Threatened and Endangered Fish and Invertebrate Species

Several fish and invertebrate species occurring in the coastal and marine habitats of the GOM are listed as threatened or endangered under the ESA. Threatened species include the Gulf sturgeon, Nassau grouper, oceanic whitetip shark, giant manta ray, and several species of coral. The coral species listed under the ESA are discussed in **Chapter 3.2**. The smalltooth sawfish is the only endangered fish listed in the GOM to date.

3.5.5.3 Threatened Species

Gulf Sturgeon

Gulf sturgeon, a subspecies of the Atlantic sturgeon, were listed under the ESA in 1991. They are an anadromous fish, inhabiting coastal rivers from Louisiana to Florida during the warmer months and overwintering in estuaries, bays, and the GOM (*Federal Register* 2003). They have historically been subject to overfishing and suffered further declines due to habitat loss associated with the construction of water control structures such as dams and sills (*Federal Register* 2003). Their present range extends from Lake Pontchartrain in Louisiana to the Suwannee River in Florida.

Nassau Grouper

Nassau grouper are long-lived, moderately sized serranid fish that were listed as threatened under the ESA in 2016. They inhabit shallow coastal water habitats as juveniles and then migrate to deeper waters as adults and are generally associated with high-relief coral reefs or rocky substrates in clear waters. Their current distribution includes Bermuda and Florida, throughout the Bahamas and

Caribbean Sea (Heemstra and Randall 1993). They have been documented in the GOM but are generally replaced by red grouper in the eastern GOM in areas north of Key West and the Tortugas. They are considered rare or transient in the northwestern GOM along Texas, and a first sighting of a Nassau grouper was made in the Flower Garden Banks National Marine Sanctuary in September 2006 (Foley et al. 2007).

Oceanic Whitetip Shark

The oceanic whitetip shark is a large, pelagic requiem shark species that was listed as threatened under the ESA in 2018. It is broadly distributed globally in deep, open ocean habitats. They were once common but populations have decreased substantially over the years due to bycatch in longline fisheries and direct fisheries for the finfish trade. Like other sharks, oceanic whitetips are vulnerable to overexploitation because of their life histories, which are characterized by a late age at maturity and low fecundity (Musick et al. 2000). In the GOM, Baum and Myers (2004) have estimated that oceanic whitetip sharks have declined by over 99 percent between the 1950s and late 1990s.

Giant Manta Ray

The giant manta ray is the world's largest ray with a wingspan of up to 29 ft (8.8 m). They are slow-growing filter feeders that are globally distributed and highly migratory. However, tagging efforts in the southern GOM (i.e., Yucatan peninsula) have indicated that regional populations likely exist with a degree of site fidelity (Bennett et al. 2011; Graham et al. 2012). They have low fecundity, birthing only one or two live young every 1-2 years (Bennett et al. 2011). They are most often reported in coastal areas and continental shelves in association with seamounts and upwelling events (Anderson et al. 2011; Couturier et al. 2011). In the northwestern GOM, a prevalence of juvenile manta rays has been found at the Flower Garden Banks National Marine Sanctuary, suggesting that the banks may serve as nursery habitats for this species (Childs 2001; Stewart et al. 2018).

3.5.5.4 Endangered Species

Smalltooth Sawfish

Smalltooth sawfish belong to the subclass Elasmobranchii, which includes shark, skates, and rays. Although they more closely resemble sharks, they are rays as their gills and mouths are found on the underside of their bodies. Their name comes from their distinct rostrum, a long, flat snout resembling a saw. They live in shallow, tropical seas and estuaries. Historically they ranged from Texas to New York (*Federal Register* 2009); however, populations became so depleted they were listed as endangered under the ESA in 2003. Their decline is due to habitat loss and degradation, as well as being taken as bycatch in a variety of commercial and recreational fisheries. The most recent encounter data and research suggest that a resident, reproducing population of smalltooth sawfish only exists in southwest Florida (Simpfendorfer and Wiley 2005). As such, critical habitat designations for this species were created and include the Charlotte Harbor Estuary Unit and the Ten Thousand Islands/Everglades Unit.

3.6 SEA TURTLES

Five species of sea turtles occur in the GOM: the loggerhead turtle; green turtle; hawksbill turtle; Kemp's ridley turtle; and leatherback turtle. All are ESA-listed. The Northwest Atlantic Ocean Distinct Population Segment (DPS) of loggerhead turtle (**Figure 3-14**) and the North Atlantic DPS of green turtle are ESA-listed as threatened (*Federal Register* 2014). Hawksbill turtles, Kemp's ridley turtles, leatherback turtles, and breeding populations of green sea turtles in Florida are ESA-listed as endangered. Floating *Sargassum* patches in the CPA and WPA are federally designated under the ESA as critical habitat for loggerhead turtles (**Figure 3-14**) (**Chapter 3.3**). The FWS and NMFS share jurisdiction for sea turtles. The FWS has responsibility for monitoring and managing sea turtles on beaches (i.e., nesting turtles, eggs, and hatchlings), and NMFS has jurisdiction for sea turtles in the marine environment. More information on the description of sea turtles can be found in the 2018 FWS Biological Opinion (BiOp) (FWS 2018a). More information on the description of sea turtles can be found in the 2018 FWS Biological Opinion (BiOp) (FWS 2018a) and 2020 NMFS BiOp (NMFS 2020).

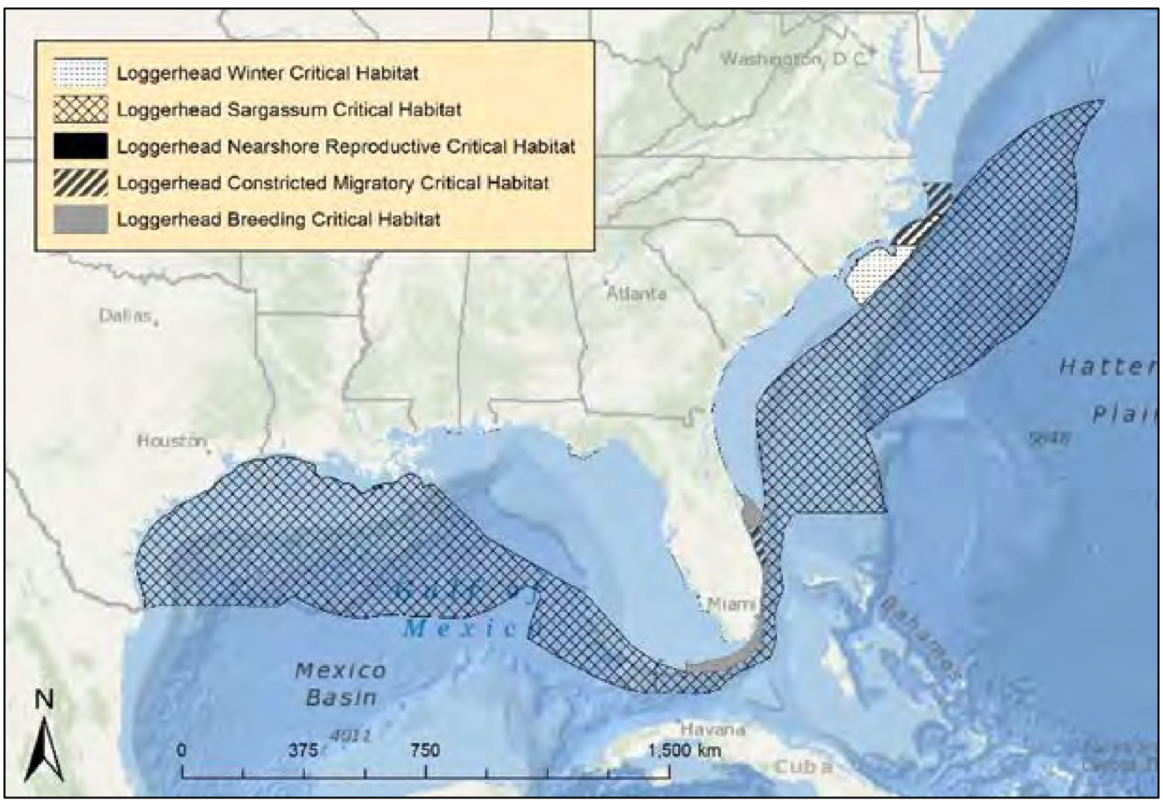

Figure 3-14. Loggerhead Turtle Critical Habitat. Map identifying the critical habitat for the Northwest Atlantic Ocean Distinct Population Segment of loggerhead turtle (NMFS 2018).

Loggerhead, green, hawksbill, Kemp's ridley, and leatherback turtles are all highly migratory. Individual animals migrate into nearshore waters as well as other areas of the North Atlantic Ocean, GOM, and Caribbean Sea. Important marine habitats for sea turtles in the Gulf of Mexico OCS include nesting beaches, estuaries and embayments, nearshore hard substrate areas, and the Gulf Stream (Valverde and Holzwart 2017). Barrier islands and mainland beaches in the GOM also provide important nesting habitat for sea turtles (Valverde and Holzwart 2017). These species rely on coastal (**Chapter 3.2**) and pelagic waters (**Chapter 3.3**) for foraging needs (Bjorndal 1997; Collard 1990; Fritts et al. 1983a, 1983b; Godley et al. 2008; NMFS and FWS 2015). For instance, seagrass beds provide foraging habitat for sea turtles (Ward 2017). *Sargassum* mats provide food and protection from predation for a wide spectrum of fauna, including juvenile sea turtles (Casazza and Ross 2008; Dooley 1972). The hatchlings of loggerhead, green, Kemp's ridley, and hawksbill sea turtles are thought to find *Sargassum* rafts when seeking frontal zones (predictable mesoscale [10s-100s km] regions of persistent frontal activity, i.e., Gulf Stream), then utilizing the habitat as foraging grounds and protection during their pelagic "lost years" (juvenile years in which turtle sightings are scarce) (Carr 1987; Coston-Clements et al. 1991; Witherington et al. 2012; Putman and Mansfield 2015). Most sea turtle species move geographically, either seasonally or between nesting activities.

3.6.1 Loggerhead Sea Turtle

Loggerhead turtles range from tropical to temperate regions globally, but the GOM is an important area for this species (**Figure 3-14**). Loggerheads are one of the most commonly occurring sea turtle species in the GOM. Critical habitat on beaches and in coastal waters has been designated for loggerheads in Florida, Alabama, and Mississippi. The EPA coastline represents 90 percent of the nesting habitat for the Northwest Atlantic subpopulation of loggerhead turtle (Ceriani and Meylan 2017). In the GOM, loggerhead turtles have been primarily sighted in waters above the continental shelf, although many surface sightings have occurred in the outer slope beyond the 3,281-ft (1,000-m) isobath. Sightings of loggerheads in waters above the continental slope suggest that they may be in transit through these waters to distant foraging sites or seeking warmer waters during the winter. Although loggerheads are widely distributed during summer and winter, their presence in surface waters above the slope is greater during winter (Mullin and Hoggard 2000). Adult loggerheads are known to make extensive migrations between foraging areas and nesting beaches. During non-nesting years, adult females from U.S. beaches are distributed in waters off the eastern U.S., GOM, Bahamas, Greater Antilles, and Yucatán (Conant et al. 2009).

Loggerheads mate in late March through early June in the southeastern U.S. The mean clutch size for loggerheads is 100-126 eggs per nest, with an average of 4.1 nests/nesting individuals per nesting season (NMFS 2013; Murphy and Hopkins 1984). The nesting migration for an individual female loggerhead is usually on an interval of 2-3 years, though it can vary from 1-7 years (Dodd 1988). In the western Atlantic, most loggerhead sea turtles concentrate their nesting in the north and south temperate zones and subtropics (NMFS and FWS 2007b). In the GOM, major nesting areas include some coastal beaches in Mississippi, Alabama, and Florida. Reproductive adult females return to their original hatching site to nest. Nesting data trends are declining in this species (*Federal Register* 2011; Witherington et al. 2009; Lamont et al. 2012). According to Ehrhart et al. (2003), the Peninsular Florida Recovery Unit (loggerheads originating from nesting beaches along the Florida-Georgia border through Pinellas County on the west coast of Florida, excluding the islands west of Key West, Florida [NMFS and FWS 2008]) represents approximately 87 percent of all nesting effort in the Northwest Atlantic Ocean DPS.

Juvenile developmental habitat is in the open ocean (NMFS and FWS 2007b). Offshore, they reside for months in the oceanic zone on *Sargassum* floats, generally along the Loop Current and the west coast of Florida. Somewhere between 7 and 12 years old, oceanic juveniles migrate to nearshore coastal areas to mature into adults (NMFS and FWS 2007b). These nearshore waters become important foraging and migratory habitat for juveniles and adults. Juveniles may also spend time in bays, sounds, and estuaries. Benthic immature loggerheads have been found from Cape Cod, Massachusetts, to southern Texas (NMFS and FWS 2007b). Benthic immature loggerheads foraging in northeastern U.S. waters are known to migrate southward in the fall as water temperatures cool (Morreale and Standora 1995) and migrate northward in spring. Juveniles are omnivorous and forage on crabs, mollusks, jellyfish, and vegetation at or near the surface (Dodd 1988). Subadult and adult loggerheads are primarily coastal and typically prey on benthic invertebrates, such as mollusks and decapod crustaceans in hard bottom habitats. McClellan and Read (2007) found that the shift from oceanic to neritic (i.e., coastal) waters is complex and reversible; some move into coastal waters and then return to the open ocean. Loggerheads originating from the western Atlantic nesting aggregations are believed to lead a pelagic existence in the North Atlantic gyre for as long as 7-12 years, though there is some variation in habitat use by individuals at all life stages.

A study by Garrison et al. (2020) found that loggerheads in the northern GOM were typically found in shallow water in late spring/early summer, then migrated into deeper water during fall and/or winter months. A broad range of habitats over the continental shelf serve as important foraging habitats for loggerheads, which are resident in limited areas for periods of several months, primarily during cooler water periods from fall through winter. The spatial and seasonal variation in loggerheads represents the shift in habitats and behavioral modes across seasons, with animals moving into deeper waters and spending progressively less time at the surface during cooler months (Garrison et al. 2020). The dive-surface behaviors for loggerheads indicated important seasonal, diurnal, and spatial effects on the time available at the surface.

3.6.2 Kemp's Ridley Sea Turtle

Kemp's ridley turtles are one of the most commonly occurring sea turtle species in the GOM, though internationally, they are considered the most endangered sea turtle species throughout its range. The Kemp's ridley turtle has a more restricted distribution through all of its life stages relative to other sea turtle species. Data suggest that Kemp's ridleys are found mainly in coastal GOM areas and the northwestern Atlantic Ocean; seawater temperature influences their distribution as this species is not cold water tolerant (Ogren 1989; Renaud 1995; Renaud and Williams 2005). Primary nesting sites in the U.S. for Kemp's ridleys are in the GOM. Nearshore GOM waters likely provide important developmental habitat for juveniles. Ogren (1989) suggested that the Gulf Coast, from Port Aransas, Texas, to Cedar Key, Florida, represents the primary habitat for subadult Kemp's ridleys in the northern GOM. Juvenile and subadult Kemp's ridleys have been found along the Eastern Seaboard of the U.S. (Epperly et al. 2007) and in the GOM (NMFS and FWS 2015). Atlantic juveniles and subadults travel northward with spring warming to feed in the productive, coastal waters of Georgia through New England, returning southward with the onset of winter to escape the cold (Ogren

1989; NMFS and FWS 2015). Along the Louisiana coast, immature Kemp's ridleys migrate to warmer nearshore waters during winter months (Coleman et al. 2016).

Kemp's ridleys nest in daytime aggregations (i.e., arribada) from April to July primarily at Rancho Nuevo, a stretch of beach in Mexico, Tamaulipas State (NMFS and FWS 2015). Hatchlings leave the nest at night and actively swim offshore into the anticyclonic Mexican Current and into the northern GOM. Re-migration of females to the nesting beach varies from annually to every 4 years, with a mean of 2 years (Turtle Expert Working Group 1998). The mean clutch size for Kemp's ridleys is 100 eggs per nest, with an average of 2.5 nests per female per season. Kemp's ridley nests have increased in recent years along the South Padre Island National Seashore in Texas (NPS 2018). In the GOM, juvenile/subadult Kemp's ridleys occupy shallow, coastal regions. Little is known of the movements of the post-hatching, planktonic stage within the GOM, although model predictions suggest that they mostly remain in waters offshore of Tamaulipas, Mexico (Putman et al. 2013). Studies have shown the post-hatchling pelagic stage varies from 1 to 4 years, and the benthic immature stage lasts 7 to 9 years (Schmid and Witzell 1997). Benthic immature turtles with an 8- to 24-in (20- to 60-cm) straight-line carapace length are found in nearshore coastal waters, including GOM and Atlantic estuaries. However, adult-sized individuals sometimes are found on the U.S. eastern seaboard.

The post-pelagic stages are commonly found dwelling over crab-rich sandy or muddy bottoms. Juveniles frequent bays, coastal lagoons, and river mouths. Adults are usually confined to the GOM, though occasionally swim into the Atlantic along the U.S. east coast. The age of sexual maturity is estimated to be 7-15 years (Turtle Expert Working Group 1998). Pelagic-stage, neonatal Kemp's ridleys presumably feed on available *Sargassum* and associated infauna or other epipelagic species found in the GOM (FWS 2015b). Stomach contents of Kemp's ridleys along the lower Texas coast consisted of a predominance of nearshore crabs and mollusks, as well as fish, shrimp, and other foods considered to be shrimp fishery discards (Shaver 1991).

A study by Garrison et al. (2020) found that dive-surface behaviors for Kemp's ridleys in the northern GOM indicated important seasonal, diurnal, and spatial effects on the time available at the surface. There was a significant interaction between season and day, indicating that the diurnal effects were different among the different seasons. Most notably, during the winter and spring, Kemp's ridleys spent a larger amount of time near the surface during daylight hours compared to night hours (Garrison et al. 2020). During the summer, the time at surface was the same for both day and night and was not significantly different during the fall.

3.6.3 Green Sea Turtle

Green turtles are found throughout the GOM (NMFS and FWS 2007a). Green sea turtle mating occurs in the waters off the nesting beaches, and nesting is typically associated with the female's hatching beach. The complete nesting range of the green sea turtle includes sandy beaches of mainland shores and barrier islands between Texas and North Carolina, and at the U.S. Virgin Islands and Puerto Rico (NMFS and FWS 1991). Principal U.S. nesting areas for green sea turtles are in eastern Florida (Ehrhart and Witherington 1992). Mean clutch size is highly variable among populations but averages about 110 eggs.

Hatchling green turtles swim offshore to areas of convergence zones characterized by driftlines and *Sargassum* patches (NMFS and FWS 2007a). The post-hatchlings are believed to remain tightly associated with these drift lines for several years, feeding close to the surface on a variety of pelagic plants and animals. The post-hatchling, pelagic-stage individuals are assumed to be omnivorous, but little data are available (NMFS and FWS 2007a). Once the juveniles reach a certain age and size range, they leave the pelagic habitat and travel to nearshore foraging grounds. Once they move to these nearshore benthic habitats, adult green turtles are almost exclusively herbivores, feeding on seagrass and algae (NMFS and FWS 2007a). Age at sexual maturity is estimated to be between 20 and 40 years. Adult females migrate from foraging areas to mainland or island nesting beaches and may travel hundreds or thousands of kilometers each way (NMFS and FWS 2007a). Foraging areas along the northern GOM include shallow, coastal waters with sufficient benthic vegetation such as seagrass.

3.6.4 Hawksbill Sea Turtle

In the continental U.S., hawksbill turtles have been documented along the east coast as far north as Massachusetts and in all Gulf Coast States, though they are found primarily along Florida and Texas. Hawksbills spend time in pelagic and coastal areas; this species is primarily tropical and subtropical (NOAA Fisheries 2020). Reproductive females undertake periodic (usually non-annual) migrations to their natal beach to nest. Movements of reproductive males are less understood, though they are presumed to involve migrations to the nesting beach or courtship stations along the migratory corridor. While nesting occurs along the beaches throughout the world’s oceans, with the most nesting occurring on beaches of the Caribbean Sea, hawksbill nesting on northern GOM beaches, including Florida, is rare (FWS 2015a; Mays and Shaver 1998). Females nest an average of 3-5 times per season, and the mean clutch size is 130 eggs (NMFS and FWS 2013a).

The life history of hawksbills consists of a pelagic stage that lasts from the time they leave the nesting beach as hatchlings until they are approximately 7-12 in (20-30 cm) in straight carapace length (Meylan 1988; Bell and Pike 2012), followed by a residency in developmental habitats (i.e., foraging areas where immature individuals reside and grow) in coastal waters. As with most sea turtle species, hatchlings and early juveniles are often found in association with oceanic *Sargassum* floats. As older juveniles, they move nearshore for feeding habitat and may associate with the same feeding locality for more than a decade (Musick and Limpus 1997). Adult foraging habitat, which may or may not overlap with developmental habitat, typically consists of coral reefs, although other hard bottom communities, and occasionally mangrove-fringed bays, may be occupied. Hawksbills show fidelity to their foraging areas over periods up to several years (van Dam and Diez 1998). Their diet is highly specialized and consists primarily of sponges and macroalgae (NMFS and FWS 2013a). The lack of sponge-covered reefs and the cold winters in the northern GOM may prevent hawksbills from establishing a substantial population in this area.

3.6.5 Leatherback Sea Turtle

Leatherback turtles, the largest and most pelagic of all sea turtles, have the widest-ranging distribution of any sea turtle. Leatherback distribution and nesting grounds are found in the waters of the Atlantic, Pacific, and Indian Oceans; the Caribbean Sea; and the GOM (NMFS and FWS 2013b). The leatherback is the most abundant sea turtle in waters over the northern GOM continental slope (Mullin and Hoggard 2000). Leatherbacks appear to use the continental shelf and slope habitats in the GOM (Collard and Ogren 1990). Mississippi Canyon to De Soto Canyon, especially near the shelf edge, appears to be an important habitat for leatherbacks in the northern GOM (Mullin and Hoggard 2000). Leatherbacks have been frequently sighted in the GOM during summer and winter (Mullin and Hoggard 2000). Leatherbacks are a long-lived species (over 30 years), with an estimated age of sexual maturity reported at about 3-19 years (Zug and Parham 1996). In the western Atlantic, female leatherbacks nest from the southeastern U.S. (east coast of Florida) to southern Brazil and from Mauritania to Angola in the eastern Atlantic Ocean (FWS 2015c; NMFS and FWS 2013b). They frequently nest with up to seven nests per year during a nesting season (March to July) and nest about every 2-3 years, although nesting is rare on GOM beaches (Florida Fish and Wildlife Conservation Commission 2020a). During each nesting, females may produce 100 or more eggs per clutch (Schulz 1975). The eggs require approximately 60 days of incubation.

Once the hatchlings emerge from the nest and leave the natal beach, very little is known about the juvenile life stage. While other sea turtle species remain in pelagic waters and *Sargassum*, there are no records to indicate this is consistent with leatherbacks. So little information is available about the early life history of leatherbacks that the period from hatching to approximately 10 years later, when females return to the nesting beach, is referred to as the “lost years” (Carr 1987). Information on those “lost years” would inform better management decisions; therefore, research is continuing to gain a better understanding of this life stage.

Adult leatherbacks forage in temperate and subpolar regions from 71° N. to 47° S. latitude in all oceans and undergo extensive migrations between 90° N. and 20° S. latitude to and from the tropical nesting beaches (NMFS and FWS 2013b). Leatherbacks forage widely throughout the water column from the surface to great depths throughout tropical and temperate oceans around the world. Their distribution appears to depend upon distribution of their prey, consisting mostly of jellyfish and other pelagic gelatinous organisms, such as tunicates (Eckert et al. 1989; Evans 2006). Adults have been tracked foraging in the GOM on the cannonball jellies and moon jellies (Evans 2006). Adult leatherbacks are deep divers, with estimated dives to depths over 3,281 ft (1,000 m), but they may come into shallow waters if there is an abundance of jellyfish (Eckert et al. 1989).

3.6.6 Threats to Sea Turtle Populations Unrelated to BOEM’s Activities

3.6.6.1 Noise and Bioacoustics

Sea turtle ears resemble those of most reptiles, though they have a few underwater specializations (Popper et al. 2014). They have no outer ear; the opening of their ear is covered by thick skin with a fatty layer underneath. As in marine mammals, this fatty layer helps conduct sound to the middle and inner ear. Bone-conducted hearing appears to be a reception mechanism for at least some of the sea turtle species, with the skull and shell acting as receiving structures (Lenhardt et al. 1983). Sea turtles are sensitive to acoustic pressure.

There is relatively little data on sea turtle hearing, though the current understanding is that their underwater hearing range is generally constrained to frequencies less than 2 kilohertz (kHz), with a narrower frequency range in air (Bartol et al. 1999; Piniak et al. 2012; Popper et al. 2014). A few preliminary investigations using adult green, loggerhead, and Kemp's ridley turtles suggest that they are most sensitive to low-frequency sounds (Ridgway et al. 1969; Lenhardt et al. 1983; Bartol et al. 1999). Compared to most fish and marine mammals, they have relatively low hearing sensitivity (Martin et al. 2012; Popper et al. 2014).

Sea turtles in the GOM planning areas are exposed to several sources of anthropogenic noise, including maritime activities, dredging, construction, mineral exploration in offshore areas, geophysical (seismic) surveys, sonars, explosions, and ocean research activities. Further, anthropogenic noise is generated by commercial and recreational vessels, aircraft, commercial sonar, military activities, and other human activities.

Vessel traffic is recognized as a major contributor to anthropogenic ocean noise, primarily in the low-frequency bands between 5 and 500 hertz (Hz). Marine vessel traffic adds noise to the marine environment, mostly from propeller cavitation. Over the last few decades, low-frequency ambient ocean noise has increased substantially due to a steady increase in shipping as vessels have become more numerous and of larger tonnage (Hildebrand 2009; McKenna et al. 2012). Shipping constitutes a major source of low-frequency sound in the ocean, particularly in the Northern Hemisphere, where the majority of vessel traffic occurs. The Popper et al. (2014) sound exposure guidelines were broad-ranging and provided nonquantified, generalized guidelines for shipping noise as a low risk of impairment, unless the turtle is in the near field range (within tens of meters), which would pose a moderate risk of temporary threshold shift that can recover over time. Faster, larger ships generally create more noise and lower-frequency sounds (less than 1 kHz), while smaller craft produce sounds in the mid frequencies (1-5 kHz). These ranges overlap with different animals' vocalizations and hearing ranges (McKenna et al. 2013). Mounting evidence indicates that noise in the marine environment could interfere with communication in sea turtles, a phenomenon called acoustic masking (Clark et al. 2009). The risk for noise to cause masking and behavior effects range from low to high depending on the location of the turtle relative to the noise (Popper et al. 2014). In addition to acoustic masking, elevated ocean noise levels can increase stress in sea turtles, which in turn can lower reproductive output and increase susceptibility to disease (Kight and Swaddle 2011).

Few studies have examined the role that acoustic cues play in the ecology of sea turtles (Mrosovsky 1972; Samuel et al. 2005; Nunny et al. 2008), and little is known about the extent to which the turtles depend upon their auditory environment. It is likely that sea turtles use acoustic signals from their environment as guideposts during migration and as a cue to identify their natal beaches (Lenhardt et al. 1983). Avoidance responses to seismic signals have been observed (e.g., Lenhardt 1994; Moein et al. 1995; McCauley et al. 2000; Weir 2007; DeRuiter and Doukara 2012); therefore, it is known that sea turtles can detect, respond to, and avoid low-frequency sound. Sea turtles appear to be low-frequency specialists, and thus the potential masking noises would fall within at least 50-1,000 Hz. However, there are no quantitative data demonstrating masking effects for sea turtles, and no noise exposure criteria have been developed for them officially by NOAA, though Popper et al. (2014) established acoustic thresholds for them. The impacts of increasing ambient noise are therefore expected to occur in the category of behavioral responses and possibly masking effects, rather than death, injury, or threshold shifts.

3.6.6.2 Coastal Development and Lighting

Coastal development, such as beach reclamation and dredging activities (Kildow et al. 2016; Sengupta et al. 2018), may degrade or destroy coastal sea turtle habitats. The construction of residential areas, industrial centers, ports, hotels, resorts, marinas, docks, seawalls, bridges, and roads and other infrastructure that occurs along the Gulf Coast (Kildow et al. 2016; Sengupta et al. 2018) may also degrade or destroy coastal sea turtle habitats. Coastal construction can indirectly degrade water quality by increased sedimentation, pollutant runoff, and potential discharges from construction vehicles. Further, coastal development can result in the displacement of sea turtles (Harewood and Horrocks 2008). Increasing coastal development, including artificial lighting from beachfront properties and other buildings, threatens nesting success and hatchling survival (Harewood and Horrocks 2008; Silva et al. 2017). Beachfront lighting can disorient nesting females and may result in failed nesting attempts (Harewood and Horrocks 2008). Beachfront lighting can also attract and disorient hatchlings when they emerge from the nest, leading them away from the water and towards roads and buildings where they may die from exposure, predators (Silva et al. 2017), or vehicles, or become trapped by obstacles.

3.6.6.3 Fisheries Interactions

Commercial fishing operations, such as shrimp trawl fisheries, often use equipment that may threaten sea turtles through entanglement or ingestion (Valverde and Holzwart 2017). For example, longline fishing practices, which typically target pelagic species, have been shown to unintentionally hook sea turtles, sometimes killing them. Similar to commercial fishing, recreational fishing also results in increased marine traffic. Fishing line and gear that is not disposed of properly can create hazards to sea turtles. Sea turtles may suffer injury and death from these and other types of marine debris, including those unrelated to fishing. Refer to **Chapter 4.1.8** for more discussion on the risks of marine debris to sea turtles.

Sea turtle bycatch occurs in the GOM, especially for the longline fishery, and can be driven by turtle density, fishing intensity, or both (Lewison et al. 2014). For example, the primary areas used by Kemp's ridleys (coastal waters less than 59 ft [18 m] in depth) overlap with the shrimp fishery (Renaud 1995; Shaver et al. 2013). A major source of mortality for loggerhead and Kemp's ridleys is capture and drowning in shrimp trawls (Caillouet et al. 1996; Epperly and Teas 2002; Shaver et al. 2013). Caillouet et al. (1996) found a significant positive correlation between turtle stranding rates and shrimp fishing intensity in the northwestern GOM. The Kemp's ridley population, because of its distribution and small numbers, is at the highest risk. Turtles may be accidentally caught and killed in finfish trawls, seines, gill nets, weirs, traps, longlines, and driftnets (Brady and Boreman 1994; Epperly and Teas 2002).

To reduce fishery impacts to turtles, NMFS has required the use of turtle excluder devices in southeast U.S. shrimp trawls since 1989 and has increased efforts over the years for adequate protection to decrease the number of strandings. Since implementing the required use of turtle excluder devices throughout the shrimp fishing industry, gear improvements continue to be introduced nearly annually. Florida and Texas have banned all but very small nets in State waters. Louisiana, Mississippi, and Alabama have also placed restrictions on gillnet fisheries within State waters, such that minimal commercial gillnetting takes place in southeast waters. Mortality rates have decreased since the implementation of regulations, though because turtles mature slowly, populations are still recovering (Valverde and Holzwart 2017).

3.6.6.4 Vessel Strike

Vessel strikes are a poorly studied threat to sea turtles, though they are known to result in injury and mortality (Work et al. 2010). All sea turtles must surface to breathe, and several species are known to bask at the surface for long periods, including loggerheads. Although sea turtles can move somewhat rapidly, they are still vulnerable to strikes from vessels that are moving at more than 4 km per hour (2.5 mph), which is common in open water (Hazel et al. 2007; Work et al. 2010). Hazel et al. (2007) suggested that green turtles may use auditory cues to react to approaching vessels rather than visual cues, making them more susceptible to strike as vessel speed increases. Both live and dead sea turtles are often found with deep cuts and fractures indicative of collision with a boat hull or propeller (Hazel et al. 2007).

3.6.6.5 Climate Change

High-intensity storms, coupled with higher sea levels, could increase coastal flooding and erosion, and degrade coastal habitats (Morton 2003) (**Chapter 3.2**). For example, a loss of shoreline vegetation could occur from such storms. An increase in storms and sea-level rise may inundate and damage coastal and estuarine habitats, affecting nesting sea turtles, especially on barrier islands (Morton 2003). While some effects are anticipated, the precise impacts of global climate change on sea turtles cannot currently be predicted.

3.6.6.6 Disease

Sea turtles are affected by pathogens and disease, which may be secondary infections following other stressors, such as entanglement injury or nutritional deficiencies. Some of these diseases include fibropapillomatosis; viral, bacterial, and mycotic (fungal) infections; parasites (internal or external); and other environmental health problems (e.g., hypothermic stunning). Fibropapillomatosis, caused by a herpes virus, is characterized by the presence of internal and external tumors that can grow large enough to disrupt swimming, vision, feeding, and predator evasion (Herbst 1994; Van Houtan et al. 2014). It has been reported in all sea turtle species, though its precise cause(s) is unknown (NMFS and FWS 2007a, 2013a). Long-term monitoring and research of possible causes and threats of fibropapillomatosis have been conducted and are ongoing (NMFS and FWS 2007a). Other stressors, such as increased ocean noise levels, can increase susceptibility to disease (Kight and Swaddle 2011). Further, climate change may act additively or synergistically with marine diseases. Host-pathogen relationships are sensitive to environmental conditions; thus, climate change can affect disease risk (Burge et al. 2014).

3.7 Marine Mammals

The marine mammal species found in the U.S. GOM are diverse and distributed throughout the northern Gulf of Mexico waters. The GOM's marine mammals are represented by members of the taxonomic order Cetacea, including suborders Mysticeti (i.e., baleen whales) and Odontoceti (i.e., toothed whales), as well as the order Sirenia (i.e., manatee). There are species that have been reported from GOM waters either by sighting or stranding that, due to their rarity, are not considered in this document (Würsig et al. 2000; Mullin and Fulling 2004; Hayes et al. 2018, 2019). These species include the following: the blue whale; North Atlantic right whale; and Sowerby's beaked whale, all of which are considered extralimital in the GOM; and the humpback whale, fin whale, sei whale, and minke whale, all of which are considered rare occasional migrants in the GOM (Würsig et al. 2000; Mullin and Fulling 2004; Hayes et al. 2018, 2019). Because these species are uncommon in the GOM and because they are not included in the most recent NMFS Gulf of Mexico Stock Assessment Reports, BOEM did not consider them for this analysis.

Twenty-one species of cetaceans and one species of Sirenia regularly occur in the GOM and are identified in the NMFS Stock Assessment Reports (Hayes et al. 2018, 2019). Habitat-based cetacean density models are found in Roberts et al. (2016). More information describing the various GOM marine mammal species can be found in the 2020 NMFS BiOp (NMFS 2020).

3.7.1 Distribution and Trends

Most marine mammal distributions vary widely across the northern GOM with very little known about their respective breeding and calving grounds, as well as any general patterns of movement. Several species (i.e., Bryde's whale, sperm whale, and bottlenose dolphins) have resident populations in the GOM (Van Parijs et al. 2015). The distribution and abundance of cetaceans within the northern GOM is strongly influenced by various mesoscale oceanographic circulation patterns. These patterns are primarily driven by river discharge (primarily the Mississippi River), wind stress, and the Loop Current and its derived circulation phenomena (**Chapter 3**). The Loop Current and its associated eddies can occur throughout the GOM region, including south of the U.S. Exclusive Economic Zone limits, though this area is poorly studied, with little to no information on cetacean distributions. River outflow also may be entrained within the confluence of a cyclone-anticyclone eddy pair and transported beyond the continental slope. Marine mammals may focus their foraging efforts on these abundant prey locations to improve overall efficiency and reduce energy costs (Bailey and Thompson 2010). In addition, marine mammals may forage under *Sargassum* mats due to the abundance of small fishes that typically assemble there (Casazza and Ross 2008; Dooley 1972). Other than factors influencing feeding behaviors, very little is known about other factors that may influence marine mammal distribution in the northern GOM because few studies examine them.

3.7.2 Unusual Mortality Events

Under the Marine Mammal Protection Act, an unusual mortality event (UME) is defined as "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." A list of active and closed UMEs with updated information can be found at the following website, and information is generally updated regularly: https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events.

UME 66

The 2018 to 2019 Southwest Florida Bottlenose Dolphin UME was issued in July 2018 due to an elevation in bottlenose dolphin mortalities. Southwest Florida has been experiencing an ongoing severe bloom of a red tide organism since November 2017. The results from several necropsies showed positive results for the red tide toxin (brevetoxin), indicating this UME is related to the bloom (NOAA Fisheries 2020a). Investigation is ongoing.

3.7.3 ESA-listed Marine Mammal Species

Two cetacean species, the sperm whale and the GOM Bryde's whale, regularly occur in the GOM and are listed as endangered under the ESA. The West Indian manatee is listed as threatened under the ESA and has designated critical habitat in northeastern Florida (*Federal Register* 1976). NMFS is charged with protecting ESA-listed cetaceans, while manatees are under the jurisdiction of the FWS.

3.7.3.1 Cetaceans – Odontocetes

The sperm whale is the largest toothed cetacean. It is found worldwide in deep waters between approximately 60° N. and 60° S. latitude (**Figure 3-15**) (Whitehead 2002), although generally only large males venture to the extreme northern and southern portions of their range (Jefferson et al. 2008b). In the western North Atlantic, they range from Greenland to the GOM and the Caribbean Sea. As deep divers, sperm whales generally inhabit oceanic waters at depths greater than 3,280 ft (1,000 m). Nonetheless, they do come close to shore, where submarine canyons or other geophysical features bring deep water near the coast (Jefferson et al. 2008b). The age distribution of the GOM sperm whale population is unknown, but they are believed to live at least 60 years. Little is known of recruitment and mortality rates; although recent abundance estimates based on surveys indicate that the population appears to be stable, NMFS believes that there is insufficient data to determine population trends in the GOM for this species at this time (Hayes et al. 2019).

The NMFS considers sperm whales in the GOM as a distinct stock in the Marine Mammal Stock Assessment Report (Hayes et al. 2019), and research supports this distinction from the Atlantic and Caribbean stocks (Gero et al. 2007; Jaquet 2006; Jochens et al. 2008). Consistent sightings, satellite tracking, strandings, and historical whale catches indicate that sperm whales occupy the northern GOM throughout all seasons and that aggregations are commonly found in waters over the shelf edge in the vicinity of the Mississippi River Delta, which are 1,641-6,562 ft (500-2,000 m) deep, and represent a resident population (Davis and Fargion 1996; Jefferson and Schiro 1997; Davis et al. 2000; Jochens et al. 2008). Seasonal aerial surveys confirmed that sperm whale sightings are more common during summer (Mullin et al. 1991; Mullin and Hoggard 2000; Mullin and Fulling 2004), though this may be an artifact of movement patterns of sperm whales associated with reproductive behavior, hydrographic features, or other environmental or seasonal factors. Because of the lack of adult males observed in the GOM, it is not known whether females leave the GOM to mate or whether males sporadically enter the area to mate with females, which would make this an important area for sperm whale reproduction.

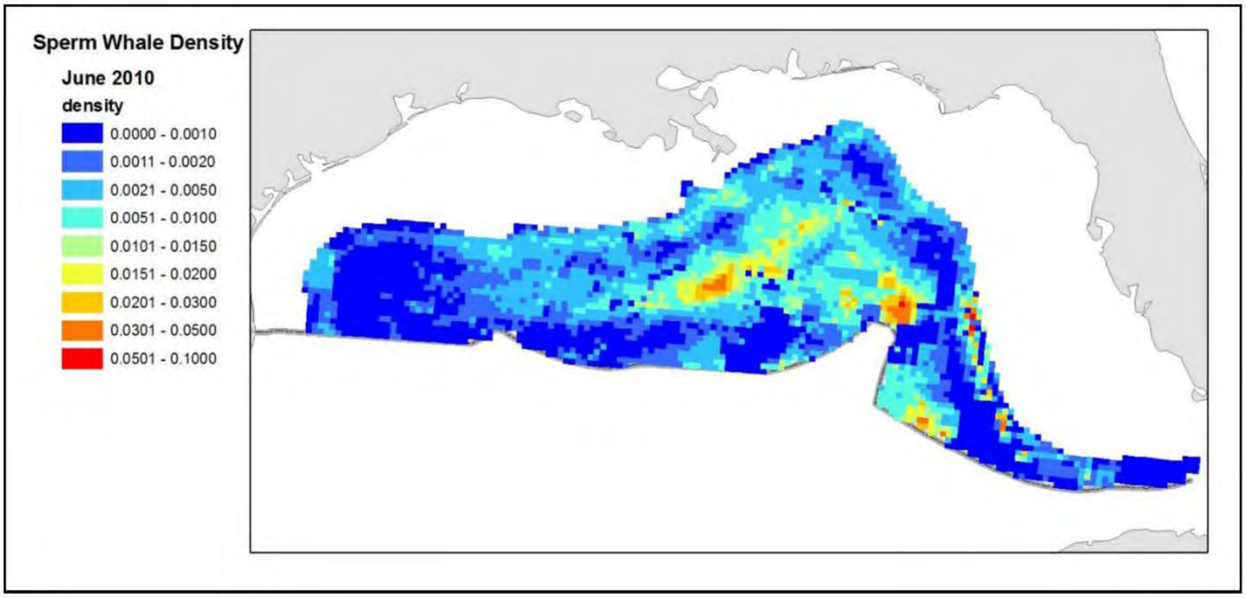

Figure 3-15. Sperm Whale Distribution in the Gulf of Mexico. Predicted sperm whale density from a habitat model based on vessel data collected during 2003-2009 (Garrison et al. 2018).

The low-salinity, nutrient-rich water from the Mississippi River contributes to an enhanced primary and secondary productivity in the north-central GOM, which may explain the presence of sperm whales in the area (Würsig et al. 2000; Davis et al. 2000, 2002; Jochens et al. 2008). The continental margin in the north-central GOM is only 12 mi (20 km) wide at its narrowest point, and the ocean floor descends quickly along the continental slope, reaching a depth of 3,281 ft (1,000 m) within 25 mi (40 km) of the coast. This unique area of the GOM brings deepwater organisms within the influence of coastal fisheries, contaminants, and other human impacts on the entire northern GOM (Davis et al. 2000). Sperm whales are noted for their ability to make prolonged deep dives and are likely the deepest and longest diving mammal. Typical foraging dives last approximately 40 minutes and descend to about 1,312 ft (400 m), followed by approximately 8 minutes of resting at the surface (Papastavrou et al. 1989). However, dives of over 2 hours and deeper than 2.1 mi (3.3 km) have been recorded (Watkins et al. 1993), and individuals may spend extended periods at the surface to recover.

Sperm whales dive to depths exceeding 2,000 ft (610 m) to feed, primarily in canyons (Waring et al. 2016). They prey on cephalopods (i.e., squid, octopi, cuttlefishes, and nautilus) (Garrison et al. 2018), demersal fishes, and benthic invertebrates (Jefferson et al. 2008b). Cephalopods are the main dietary component of sperm whales (Davis et al. 2002; Garrison et al. 2018). Other sperm whale populations are also known to take significant quantities of large demersal and mesopelagic fishes, especially the mature males in higher latitudes (Clarke 1979). Postulated feeding and hunting methods include lying suspended and relatively motionless near the ocean floor and ambushing prey, attracting squid and other prey to the white lining of their mouths by disturbing bioluminescent organisms around them to make their mouths more visible or by stunning prey with ultrasonic sounds (Norris and Mohl 1983; Würsig et al. 2000). Evidence of ingested stones, sand, sponges, and other non-food items suggests they forage on or near the bottom (Jefferson et al. 2008b). A study by Garrison et al. (2018) demonstrated strong associations between mesoscale physical features, sperm whales, and their prey in the GOM. Further, squid biomass was found to be highest at intermediate depths, particularly between 600 and 700 m (1,969 and 2,297 ft), that correspond to primary sperm whale feeding depths (Garrison et al. 2018).

3.7.3.2 Cetaceans – Mysticetes

The only commonly occurring baleen whale in the northern GOM is the Bryde's whale. The Bryde's whale is found in tropical and subtropical waters throughout the world. The present range of the GOM Bryde's whale is limited to portions of the EPA; this subpopulation numbers approximately 33-44 individuals (Hayes et al. 2018; Roberts et al. 2016). Bryde's whales in the northern GOM have been sighted along a narrow corridor near the 328-ft (100-m) isobath (**Figure 3-16**) (Davis and Fargion 1996; Davis et al. 2000) in the De Soto Canyon region and off western Florida, although there have been some in the west-central portion of the northeastern GOM (Rosel et al. 2016) along the continental shelf break between 328- and 1,312-ft (100- and 400-m) water depth. They feed on small pelagic fishes and invertebrates (Rosel et al. 2016).

A study from NMFS' Southeast Fisheries Science Center (Rosel and Wilcox 2014) evaluated genetic diversity and phylogenetic distinctiveness of this population to determine how unique it is in comparison to other Bryde's whales worldwide. The study found that the GOM Bryde's whale population has little genetic diversity, suggesting a small population size and a history of isolation, and that the population is evolutionarily distinct from all other Bryde's whales examined to date. Scientists conclude that the level of divergence suggests a unique evolutionary lineage for this population that is equivalent to currently recognized subspecies and species within the Bryde's complex, and among species and subspecies of certain other baleen whales. The small population in the GOM, which is also morphologically and behaviorally distinct from others in the complex, constitutes the only known members of this unique lineage. The current status of Bryde's whales in the northern GOM, relative to its optimum sustainable population, is unknown, and there are insufficient data to determine the population trends for this stock. Population estimates can vary widely depending on models because data are limited.

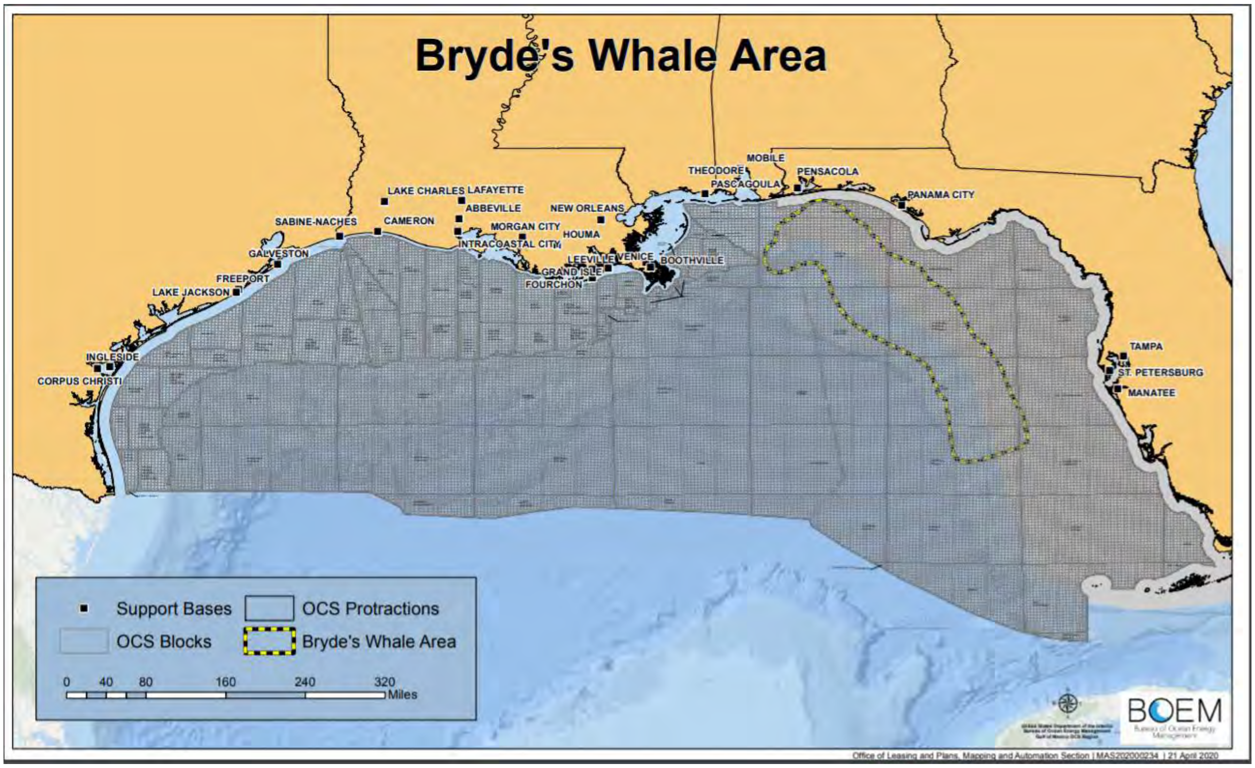

Figure 3-16. Gulf of Mexico Bryde's Whale Distribution. The Gulf of Mexico Bryde's whale area as defined by NMFS in the 2020 GOM BiOp (NMFS 2020).

3.7.3.3 Sirenians

The West Indian manatee has designated critical habitat in inland waterways in four northeastern Florida coastal counties – Brevard, Duval, St. Johns, and Nassau (*Federal Register* 1976). The most recent abundance estimates for manatees can be found on the Florida Fish and Wildlife Conservation Commission's website at http://myfwc.com/research/manatee/research/population-monitoring/synoptic-surveys/ (Florida Fish and Wildlife Conservation Commission 2020b). The Florida manatee, which ranges from the northern GOM to Virginia, is one of two subspecies of the West Indian manatee. It is ESA-listed as threatened throughout its range and has critical habitat in Florida (**Figure 3-17**) (*Federal Register* 2017).

Figure 3-17. Florida Manatee Critical Habitat. Map depicting the Florida manatee critical habitat by Jane Cooke (FWS 2019c).

Florida manatees have been divided into four distinct regional management units:

- the Atlantic Coast Unit that occupies the east coast of Florida, including the Florida Keys and the lower St. Johns River north of Palatka, Florida;
- the Southwest Unit that occurs from Pasco County, Florida, south to Whitewater Bay in Monroe County, Florida;
- the Upper St. Johns River Unit that occurs in the river south of Palatka, Florida; and
- the Northwest Unit that occupies the Florida Panhandle south to Hernando County, Florida (FWS 2014a). Manatees from the Northwest Unit are more likely to be seen in the northern GOM, and they can be found as far west as Texas; however, most sightings are in the eastern GOM (Fertl et al. 2005).

Manatees are commonly found along the Florida coast in the winter and may migrate as far as Texas in the warmer seasons, typically inhabiting only shallow coastal marine, brackish, and freshwater areas (O'Shea et al. 1995; Fertl et al. 2005) (**Chapter 3.2**). Preferred coastal and riverine habitats (e.g., near the mouths of coastal rivers) are used for resting, mating, and calving (FWS 2001, 2007a). Because they have little cold tolerance, manatees are generally restricted to the inland and coastal waters of peninsular Florida during the winter, where they shelter in or near sources of warm water (i.e., springs, industrial effluents, and other warm-water sites) (FWS 2001, 2007a). Manatees are generalist feeders and are known to consume more than 60 species of aquatic vegetation in marine, estuarine, and freshwater habitats (FWS 2001). Seagrass beds provide foraging habitat for manatees (Ward and Tunnell Jr. 2017).

Manatees are vulnerable to various natural and anthropogenic threats. The most common major threats to the Florida manatee are cold stress and watercraft collisions. When manatees experience prolonged exposure to water temperatures below 68 °F (20 °C), they can develop a condition called cold-stress syndrome, which can be fatal (Hardy et al. 2019). Manatees are threatened by habitat loss and fragmentation, and entanglements in fishing gear. Manatees are also susceptible to pathogens or toxins (e.g., red-tide events), which may cause UMEs.

3.7.4 Other Protected Marine Mammal Species

Nineteen out of 20 toothed cetaceans (including beaked whales and dolphins) that regularly occur in the GOM are not ESA-listed. However, the Marine Mammal Protection Act of 1972 protects all marine mammals.

3.7.4.1 Cetaceans – Odontocetes

The pygmy sperm whale and dwarf sperm whale, in the Family Kogiidae, have a worldwide distribution in temperate to tropical waters (Mullin et al. 1991). They mainly feed on squid, though they also eat crabs, shrimp, and smaller fish (Würsig et al. 2000). In the GOM, they occur primarily along the continental shelf edge and in deeper waters off the continental shelf (Mullin et al. 1991). At sea, it is difficult to differentiate dwarf sperm whales from pygmy sperm whales; therefore, sightings are often grouped together as "*Kogia* spp." Very little is known about the species except from studies on stranded individuals.

In the GOM, beaked whales, in the Family Ziphiidae, are identified either as Cuvier's beaked whales or are grouped into an undifferentiated complex because of their similarity in appearance and potential identification errors. In the northern GOM, they are broadly distributed in waters deeper than 3,281 ft (1,000 m) over the lower slope and abyssal landscapes (Davis et al. 1998, 2000). Beaked whales were seen in the GOM in all seasons during GulfCet aerial surveys (Mullin and Hoggard 2000). Beaked whale species that may occur within the GOM are usually observed singly or in small groups of individuals (Jefferson et al. 2008a). As a group, they are poorly studied though are thought to be deep-diving animals since they feed on deepwater cephalopods and fish (Jefferson et al. 2008a).

Three species of *Mesoplodon* are known to occur in the GOM based on sighting and stranding data and are considered provisional stocks (Würsig et al. 2000; Waring et al. 2014). The Gervais' beaked whale appears to be widely, but sparsely, distributed worldwide in temperate to tropical waters (Jefferson and Schiro 1997). Stranding records suggest that this is probably the most common mesoplodont in the northern GOM. The Blainville's beaked whale is distributed throughout temperate and tropical waters worldwide, but it is not considered common (Würsig et al. 2000). Cuvier's beaked whale is widely, though sparsely, distributed throughout temperate and tropical waters worldwide (Würsig et al. 2000). They are sighted in the GOM in all seasons in water depths typically greater than 1,640 ft (500 m) (Maze-Foley and Mullin 2006). Sightings data indicate that the Cuvier's beaked whale is probably the most common beaked whale in the GOM (Jefferson and Schiro 1997; Davis et al. 1998, 2000).

Fourteen members of the Family Delphinidae (dolphins) are known to occur in the GOM. Dolphins are often gregarious and commonly form aggregations that can range from a few to several thousand individuals depending on the species (Würsig et al. 2000; Waring et al. 2016). Of the 14 members, the bottlenose dolphin is the most common inhabitant of the continental shelf and upper slope waters of the northern GOM. Bottlenose dolphins are opportunistic feeders, foraging on a wide variety of fishes, cephalopods, and shrimp (Davis and Fargion 1996; Jefferson and Schiro 1997). There appears to be two ecotypes of bottlenose dolphins, a coastal form (52-210 ft; 16-67 m) and an offshore form (about 820 ft; 250 m) (Duffield et al. 1983; Hoelzel et al. 1998; Rosel et al. 2009). The coastal or inshore stocks are genetically isolated from the offshore stock. Inshore stocks are further provisionally delineated into 31 bay, sound, and estuarine stocks (Waring et al. 2016).

The Atlantic spotted dolphin, Risso's dolphin, rough-toothed dolphin, spinner dolphin, striped dolphin, and the false killer whale are found in tropical to temperate waters (Jefferson and Schiro 1997; Miyazaki and Perrin 1994; Perrin et al. 1994a; Perrin and Gilpatrick Jr. 1994; Perrin et al. 1994b). Another species, the Fraser's dolphin, has a worldwide distribution in tropical waters. These dolphin species are known to feed on a wide variety of fishes, cephalopods, crustaceans, and benthic invertebrates (Jefferson and Schiro 1997; Perrin et al. 1994a). In the GOM, they occur primarily along the continental shelf and continental slope (Mullin and Fulling 2004). The rough-toothed dolphin, striped dolphin, spinner dolphin, and false killer whale can occur in deeper waters off the continental shelf (Davis and Fargion 1996; Mullin and Fulling 2004).

The killer whale has a worldwide distribution from tropical to polar waters (Jefferson and Schiro 1997). They feed on marine mammals, marine birds, sea turtles, cartilaginous and bony fishes, and cephalopods (Würsig et al. 2000). In the GOM, they occur primarily in the deeper waters off the continental shelf (Davis and Fargion 1996). The melon-headed whale and pygmy killer whale have worldwide distributions in subtropical to tropical waters (Jefferson et al. 1992), feeding on cephalopods and fishes (Jefferson and Schiro 1997). In the GOM, they occur in the deeper waters off the continental shelf. The short-finned pilot whale is distributed worldwide in tropical to temperate waters (Jefferson and Schiro 1997). They feed predominantly on squid, with fishes being consumed occasionally (Würsig et al. 2000). Aggregations of short-finned pilot whales are commonly associated with other cetacean species (Maze-Foley and Mullin 2006). In the GOM, they are most frequently sighted along the continental shelf and continental slope.

3.7.5 Threats Unrelated to BOEM's Activities

3.7.5.1 Noise and Bioacoustics

Marine mammals are capable of detecting acoustic pressure. Individual marine mammal species are able to hear sounds over a wider range than fishes, for example, though different mammalian families have distinct hearing capabilities. Bryde's whales are classified within the low-frequency cetacean functional marine mammal hearing group (7 Hz to 22 kHz), while the sperm whale is classified within the mid-frequency cetacean functional hearing group (150 Hz to 160 kHz) (Southall et al. 2007). There are no direct hearing data available for the Bryde's whale.

Marine mammals produce sounds for a variety of natural behaviors over a range of acoustic frequencies (Richardson et al. 1995). Some cetaceans have sophisticated mechanisms for beam-forming and sound localization, which they utilize for hunting prey. Fully aquatic mammals (e.g., cetaceans and sirenians) have additional adaptations. Toothed whales use higher frequency echolocation clicks to navigate and track prey, as well as a variety of whistle types during social interactions (Richardson et al. 1995). Baleen whales produce low-frequency reproductive and social calls that can travel great distances, even across ocean basins (Clark and Gagnon 2002).

Because Bryde's whales are known to produce a variety of low-frequency sounds in the 20- to 900-Hz band (Edds et al. 1993; Oleson et al. 2003), they are classified within the low-frequency cetacean hearing group (7 Hz to 30 kHz) (Southall et al. 2007; Ketten and Mountain 2009). Oleson et al. (2003) reported call types with a fundamental frequency below 60 Hz from Bryde's whales in the Caribbean, eastern tropical Pacific, and off the New Zealand coast. Other observed sounds include pulsed moans recorded at frequencies ranging from 100 to 900 Hz and discrete pulses at 700 to 900 Hz, which were produced by calves (Edds et al. 1993). The functions of these low-frequency sounds are unknown at this time, but it is assumed they are used for communication. Currently, there is no direct measurement of auditory threshold for Bryde's whales.

Evidence suggests that the disproportionately large head of the sperm whale is an adaptation to produce vocalizations (Norris and Harvey 1972). This suggests that vocalizations are extremely important to sperm whales. The function of sperm whale vocalizations is relatively well-studied (Weilgart and Whitehead 1997). Long series of monotonous, regularly spaced clicks are associated with feeding and are thought to be produced for echolocation. Sperm whales also use unique stereotyped click sequence "codas" to possibly convey information about the age, sex, and reproductive status of the sender (Weilgart and Whitehead 1988). Groups of closely related females and their offspring have group-specific dialects (Weilgart and Whitehead 1997). Sperm whale vocalization and audition (i.e., sense of hearing) are important for echolocation and feeding, social behavior and intragroup interactions, and maintaining social cohesion within the group. Sperm whales produce powerful biological sounds to echolocate prey at long ranges, though they reduce acoustic outputs by several orders of magnitude when they are about their body length from their prey (Fais et al. 2016a).

Little is known about the hearing sensitivity of dwarf sperm whales and pygmy sperm whales. Pulsed sounds with peak frequencies below 13 kHz have been recorded from pygmy sperm whales (Caldwell and Caldwell 1987), and the anatomical and physiological features of the dwarf sperm whale head have been shown to be consistent with production of echolocation clicks (Cranford et al. 1996; Goold and Clarke 2000). Audiograms have been obtained for dwarf sperm whales and pygmy sperm whales (Cook et al. 2006; Finneran 2009; Ridgway and Carder 2001), though data remain insufficient to ascribe avoidance thresholds. It is possible that these species may be sensitive to a wide range of sound frequencies.

The Delphinids are considered mid-frequency cetaceans with functional hearing of approximately 150 Hz to 160 kHz. There have been few studies of the impact of seismic surveys on species of Delphinidae (e.g., Richardson et al. 1995; Goold and Fish 1998; Stone and Tasker 2006; Weir 2008; Weilgart 2013). Since the delphinid auditory system has a relatively poor response at the low-frequency end (about 110 dB re 1 µPa at 200 Hz, though refer to Table 2 in Southall et al. 2007) and increases in sensitivity toward the ultrasonic range, there is a clear gradient of increasing sensitivity that exists over a broad frequency range up to the frequency of peak sensitivity.

Marine mammals in the GOM planning areas are exposed to several sources of anthropogenic noise, including maritime activities, dredging, construction, mineral exploration in offshore areas, geophysical (seismic) surveys, sonars, and ocean research activities. Further, these anthropogenic noises are generated by commercial and recreational vessels, aircraft, commercial sonar, military activities, seismic surveys, in-water construction activities, and other human activities.

Vessel traffic is recognized as a major contributor to anthropogenic ocean noise, primarily in the low-frequency bands between 10 and 100 Hz (Erbe et al. 2019). Marine vessel traffic adds noise to the marine environment, mostly from propeller cavitation (Erbe et al. 2019). Over the last few decades, low-frequency ambient ocean noise has increased substantially due to a steady increase in shipping as vessels become more numerous and of larger tonnage (Hildebrand 2009; McKenna et al. 2013; NRC 2003a). Shipping constitutes a major source of low-frequency sound in the ocean, particularly in the Northern Hemisphere where the majority of vessel traffic occurs. Faster, larger ships generally create more noise and lower-frequency sounds (less than 1 kHz), while smaller craft produce sounds in the middle frequencies (1 to 5 kHz). These ranges overlap with different animals' vocalizations and hearing ranges (McKenna et al. 2013).

Although there are significant differences in the acoustic properties (i.e., waveforms, pulse duration, operational frequency, and sound energy direction) of high-energy airguns and military sonar, the impacts caused by the sound sources are similar. Noise impacts might be realized in association with seismic airgun surveys and specific military activities (i.e., sonars and explosives). These impacts are expected to be spatially localized and short-term in duration.

The biological significance of behavioral responses to underwater noise and the population consequences of those responses are not fully understood (NRC 2005a; Southall et al. 2007, 2019). Mounting evidence indicates that noise in the marine environment could interfere with communication in marine mammals, a phenomenon called acoustic masking (Clark et al. 2009; Erbe et al. 2016). Acoustic masking occurs when a sound signal that is of importance to a marine mammal (e.g., communication calls, echolocation, and environmental sound cues) is rendered undetectable due to the high noise-to-signal ratio in a frequency band relevant to a marine mammal's hearing range. In addition to acoustic masking, elevated ocean noise levels can increase stress in marine mammals (Wright et al. 2007), which in turn can lower reproductive output and increased susceptibility to disease (Kight and Swaddle 2011). The increased noise level may steadily erode marine mammals' abilities to communicate and find food and mates (Clark et al. 2009).

3.7.5.2 Pollution

Marine debris affects marine habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking) (Gall and Thompson 2015). Entanglement in marine debris can lead to injury, infection, reduced mobility, increased susceptibility to predation, decreased feeding ability, fitness consequences, and mortality of marine mammals. Refer to **Chapter 4.7.9.2** for more information on the risks of marine debris on marine mammals.

Bottlenose dolphins and manatees are most at risk from nearshore discharges and wastes. Since other marine mammals are not commonly found in coastal waters, they are less likely to be impacted by nearshore pollution. Prey species also affect the influence of pollution on marine mammals. Biomagnification in fish results in the generally higher contaminant levels in fish-eating marine mammals (Gray 2002). Manatees are exposed to herbicides by ingesting aquatic vegetation containing concentrations of pollutants (O'Shea et al. 1984). The propensity of manatees to aggregate at industrial and municipal outfalls also may expose them to high concentrations of contaminants (Stavros et al. 2008).

3.7.5.3 Fisheries Interactions

Commercial fishery interactions are a threat to marine mammals because they may be injured or killed by commercial fishing gear. Fishing line and gear (outside BOEM/BSEE purview) that is not disposed of properly can create hazards to marine mammals, such as via entanglement and ingestion (Wells et al. 1998). Marine mammals can either get caught on longline hooks or can be entrained in a net by a shrimp boat or groundfish vessel. There is also the chance of entanglement in buoy lines from crab traps. Entanglement in fishing gear can cause decreased swimming ability, disruption in feeding, life-threatening injuries, and death. The debris items most often found entangling animals are net fragments and monofilament line from commercial and recreational fishing boats, as well as discarded strapping bands and ropes from a variety of vessels. Fisheries bycatch of marine mammals has also occurred in the GOM, such as from pelagic longline fisheries and shrimp trawl fisheries (NMFS 2016b).

3.7.5.4 Vessel Strike

Vessel strike from non-OCS activities has been implicated in injuries and fatalities for several large whale species (Constantine et al. 2015; Laist et al. 2001). Laist et al. (2001) provides records of the following vessel types associated with collisions with whales (listed in descending order): tanker/cargo vessels; whale watch vessels; passenger liners; ferries; naval vessels; recreational vessels; U.S. Coast Guard vessels; fishing vessels; research vessels; dredges; and pilot boats. Deep-diving whales may be more vulnerable to vessel strikes given the longer surface period required to recover from extended deep dives (Laist et al. 2001). The GOM Bryde's whales spend 90 percent of their time within 39 ft (12 m) of the ocean's surface (Constantine et al. 2015), which could make them vulnerable to collisions with large ships. Manatees are slow moving and are often struck by smaller boats (FWS 2001). Vessel activity along the coast could put both of these species at risk, especially in the EPA, where Bryde's whales typically reside and where manatees undertake seasonal movements along the northern Gulf Coast.

Vessel strikes are the most common cause of human-induced mortality for manatees, and most manatees bear prop scars from contact with vessels (Lightsey et al. 2006). Inadequate hearing sensitivity at low frequencies (Gerstein et al. 1999), slow movement, and use of shallow and surface waters are contributing factors to their vulnerability to vessel strike. The vast majority of strikes result from recreational and fishing vessels.

3.7.5.5 Climate Change and Ocean Acidification

There is concern that ocean acidification from rising carbon dioxide levels will decrease sound absorption in oceans, thereby causing amplified levels of ambient noise (Gazioglu et al. 2015). Further, increased sea-surface temperatures likely enhance the magnitude and frequency of harmful algal blooms and their associated toxins (O'Neil et al. 2012). Several uncertainties exist on how climate change impacts marine mammals (Evans and Bjørge 2013; Silber et al. 2017), though it is assumed that range shifts (e.g., in response to shifting prey distribution or expansion of breeding grounds), timing of important biological activities (e.g., breeding), and regional abundance changes could occur (Learmonth et al. 2006). While some effects are anticipated, the precise impacts of global climate change on the GOM cannot currently be predicted or parsed out from every global act

3.8 Birds

Birds from six distinct taxonomic and ecological groups rely heavily on the marine (i.e., pelagic waters) and coastal habitats (i.e., beaches, mudflats, salt marshes, coastal wetlands, and embayments) found in the GOM region. These wetland and coastal habitats provide for several hundred species of songbirds, seabirds, shorebirds, waterfowl, sea ducks, and wading birds (FWS 2013c). Many passerines, or songbirds, breed and winter within the Gulf Coast States and can be found in the coastal area and offshore during the trans-Gulf migration in the fall and spring. However, these species cannot stop to rest or feed on offshore waters. Alternatively, some seabird species do live primarily offshore, except during their breeding season. These pelagic birds, including shearwaters, storm petrels, boobies, gannets, jaegers, gulls, and terns (Duncan and Harvard 1980), rely on offshore waters for food and rest at stopover sites. The remaining species found in the GOM region are located within coastal and inshore habitats. Species reliant on inshore habitats are not likely to be impacted by the same IPFs that coastal and marine birds in the area face.

Species abundance in the GOM varies by season due to migration and breeding timings. Abundance can also be driven by mesoscale features, such as the Mississippi River freshwater plume and oceanic fronts and eddies (Ribic et al. 1997; Bost et al. 2009; Scales et al. 2014) (**Chapter 2**). Seabirds have a K-selected life history strategy, which means they are species that produce few offspring but invest high amounts of parental care. As such, seabirds' population levels can be impacted by natural climate cycles (Paleczny 2012) and anthropogenic activities. For example, fisheries interactions can result in the overexploitation of prey resources, which can negatively impact seabird abundances (Furness and Tasker 2000; Paleczny 2012). Nutritional conditions of prey are important to seabird reproductive success and population dynamics as well (Lamb 2016).

The northern GOM supports a diverse group of avifauna with its variety of coastal habitats and their importance to the ecology and life history of both coastal and marine birds. The northern GOM is also important to migratory species that travel from the south and north, respectively, and pass through the area in large numbers in the spring and fall, respectively (Russell 2005). Other species rely on the area as they move into the coastal habitats of the northern GOM for their wintering period. Several hundred bird species have been reported in the GOM; many occur in the terrestrial habitats of the region and are not likely to be impacted by the same vulnerabilities that coastal and marine birds encounter. Bird count data collected from 1965 to 2011 show that wintering coastal birds in the northern GOM are declining. Twenty species have experienced a decline of about 2 percent, 65 percent of whose ranges are centered in the GOM (Niven and Butcher 2011). Evidence suggests this could be due to a northward shift as a result of warmer weather (Niven et al. 2010). As such, 20 species have experienced an increase of about 3.5 percent, 13 of which are experiencing a northward shift of habitat into the northern GOM (Niven and Butcher 2011).

3.8.1 Important Bird Areas

Important Bird Areas (IBAs) are identified through the National Audubon Society's IBA Program as a global effort to identify and conserve areas that are vital to birds. The IBAs provide important habitat to one or more bird species, and include sites for breeding, wintering, or migrating birds. The IBAs are defined as sites that support the following:

- species of conservation concern (e.g., threatened or endangered species);
- species vulnerable because they are not widely distributed;
- species vulnerable because their populations are concentrated in one general habitat type or biome; or
- species or groups of similar species (e.g., waterfowl or shorebirds) that are vulnerable because they occur at high densities when they congregate (BirdLife International 2020).

The IBAs can be federally or State-regulated (e.g., national wildlife refuges and National Parks) if they occur on Federal or State-protected lands or include ESA-designated critical habitat. There are currently 72 IBAs along the Gulf Coast, including 18 sites in Texas (Audubon Society 2020e), 7 in Louisiana (Audubon Society 2020c), 7 in Mississippi (Audubon Society 2020d), 4 in Alabama (Audubon Society 2020a), and 36 in Florida (Audubon Society 2020b) (**Figure 3-18**). These sites include overwintering habitats, migration stopover sites, and breeding grounds for a diverse group of birds in the area. Furthermore, the GOM contains several National Wildlife Refuges, including coastal habitats: 7 in Texas; 4 in Louisiana; 1 in Mississippi; 1 in Alabama; and 13 in Florida. These are primarily managed for the protection and conservation of migratory birds (FWS 2005).

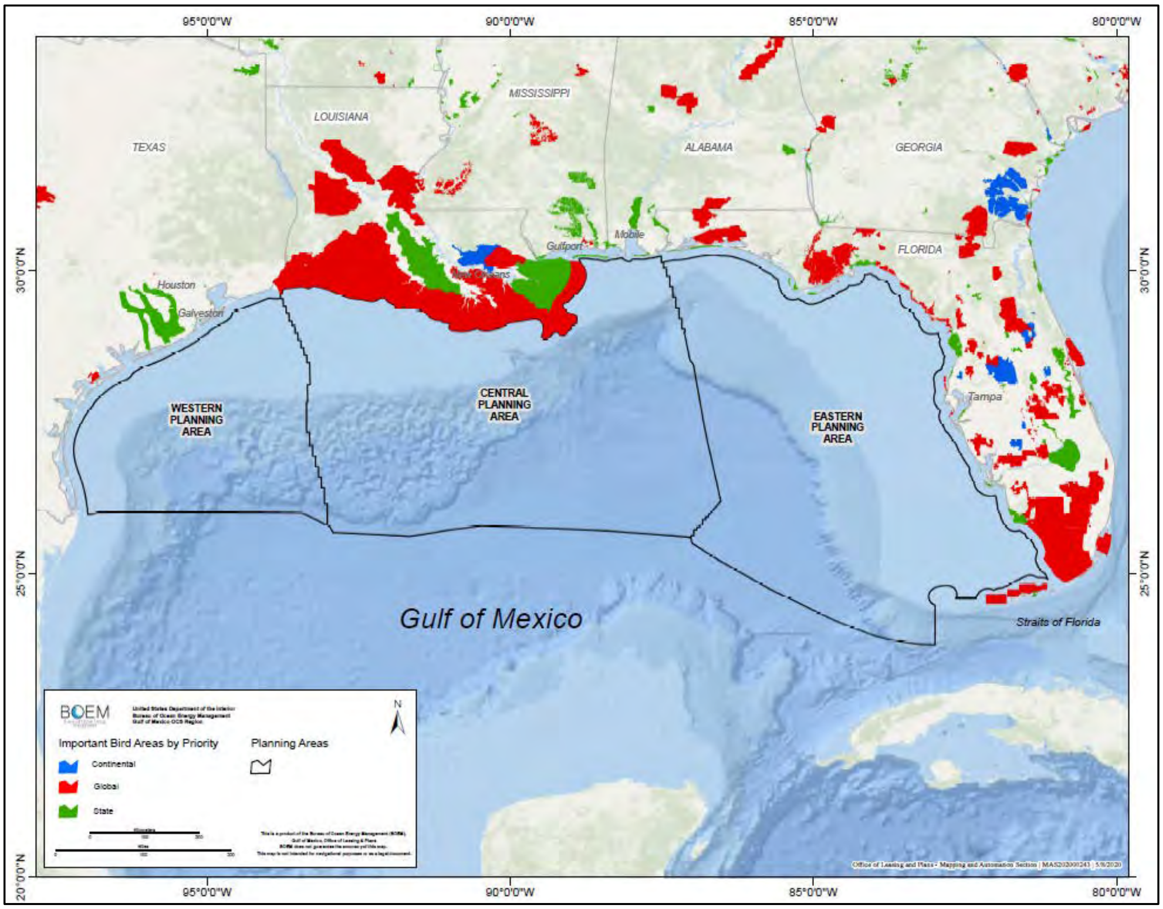

Figure 3-18. National Audubon Society's Important Bird Areas in the Gulf of Mexico Region.

3.8.2 Migration

Migratory birds are any species that migrate and live or reproduce in multiple, separate places at least once during their annual life cycle. Migrations can expand beyond local, State, Federal, and international borders. As such, migratory birds and their nests are protected under the Migratory Bird Treaty Act (MBTA). This Federal law is enforced by the FWS and prohibits the take, possession, importation, exportation, sale, purchase, barter, or offer of such of any migratory bird or their parts, nests, or eggs unless federally permitted (*Federal Register* 2013). The MBTA can protect bird species that are also protected by the ESA or the Bald and Golden Eagle Protection Act. On December 22, 2017, the U.S. Department of the Interior released M-Opinion 37050 regarding the incidental, or unintentional, take of migratory birds and whether this action is prohibited under the MBTA. The Opinion concluded that "the MBTA's prohibition on pursuing, hunting, taking, capturing, killing, or attempting to do the same applies only to direct and affirmative purposeful actions that reduce migratory birds, their eggs, or their nests, by killing or capturing, to human control." This clarification finds that the MBTA does not prohibit the incidental take of migratory birds and/or their active nest contents (Office of the Solicitor 2017); however, this reinterpretation was recently overturned by a Federal district court (Caproni 2020). More information on the MBTA can be found in BOEM's *Gulf of Mexico OCS Regulatory Framework* technical report (BOEM 2020c).

Figure 3-19. Bird Migration Routes. North American migratory birds follow migratory routes, or "flyways." There are four major flyways in North America – the Pacific, Central, Mississippi, and Atlantic Flyways (FWS 2013a).

Migratory movements of most birds across North America are known only in general terms (Harrington and Morrison 1979). Generally, North American birds seasonally migrate from their northern breeding habitats (e.g., the Arctic region, New England, and Canada) to their southern wintering habitats (e.g., Florida, Mexico, and Central and South America). Migratory birds will travel up to 7,457 mi (12,000 km) in one migration trip (Helmers 1992). The GOM is an important area for migratory birds, as three of the four major flyways occur within the GOM (i.e., the Central, Mississippi, and Atlantic Flyways). Areas of these Flyways are used by hundreds of millions of migratory birds, many of whom converge within the diverse coastal and terrestrial habitats in the northern GOM (**Figure 3-19**). Roughly 40 percent of all North American migrating waterfowl and shorebirds use the Mississippi Flyway (FWS 2013c), which runs through the peninsula of southern Ontario to the mouth of the Mississippi River, followed by a short distance across the GOM. During this highly energetic period, stopover sites are critical to migratory birds. These areas provide resting and feeding opportunities (Brown et al. 2001; McWilliams and Karasov 2005). Stopover sites can also serve as temporary shelters from inclement weather. Adequate stopover sites allow migratory birds to arrive in good health (Helmers 1992).

3.8.3 Non-Listed Species of Birds

Both resident and migratory bird species are found in the GOM. Resident species are present throughout the year and do not migrate. Migratory species either migrate through the area or utilize the Gulf Coast States for breeding or wintering grounds. Important stopover sites are found in the GOM for those migrating through. Trans-Gulf migrant birds include species of shorebirds, wading birds, and terrestrial birds. Every spring an estimated 2 billion individuals migrate northward through the GOM to their breeding habitats, dispersed across the U.S. and Canada, from their wintering sites in the neotropics (Russell 2005). Once their respective breeding seasons end, most of these birds return south through the GOM again.

Several hundred species of birds are present within and adjacent to the GOM and include species from several different bird groups. Passerines and near-passerines are found in the GOM, as well as raptors, seabirds, waterfowl, shorebirds, and wading/marsh birds. Bird species within a family share common physical and behavioral characteristics. Rather than discussing each species found in the GOM, the following sections will discuss the characteristics of bird families found in the GOM. Species within these families share common life histories, breeding and wintering habitat requirements, and behavioral characteristics; therefore, they share similar vulnerabilities to BOEM-regulated activities other impact-producing factors.

3.8.3.1 Passerines

Passerines include more than half of all bird species within the Passeriformes order, including sparrows, warblers, thrushes, blackbirds, and wrens. Near-passerines are grouped with these species in this discussion and include kingfishers, woodpeckers, hummingbirds, parrots, pigeons, cuckoos, owls and nightjars. Passerines are perching birds and songbirds, and near-passerines are land birds. Both groups utilize the GOM for resident habitat, wintering grounds, and stopover sites during migration. Passerines are found offshore when migrating but are not able to rest or feed on the water. A wide diversity of passerines and near-passerines can be found in the GOM, representing many of the breeding and wintering birds within the Gulf Coast States.

3.8.3.2 Raptors

Raptors are birds of prey that are represented by the Falconiformes and Accipitriformes orders. Falcons and caracaras comprise the Falconiformes order, and hawks, eagles, and vultures comprise the Accipitriformes order. Raptors' diet mostly consists of terrestrial birds and small mammals. Some raptors, like the bald eagle and osprey, are fish eaters that rely on coastal freshwater and saltwater habitats.

3.8.3.3 Seabirds

Seabirds spend most of their lives either on or over water, and they primarily rely on the sea for foraging (Schreiber and Burger 2002). Five taxonomic orders of seabirds are represented in the coastal and offshore GOM waters: Charadriiformes (gulls and terns); Gaviiformes (loons); Pelecaniformes (pelicans, frigatebirds, gannets, boobies, tropicbirds, and cormorants); Podicipediforms (grebes); and Procellariiformes (petrels, storm petrels, and shearwaters). Many species have distributions spanning the GOM, while others are only present in portions of the GOM. Some species never come ashore the Gulf Coast. The population ecology of seabirds leaves them susceptible to impact as they have delayed maturity, low reproductive potential, periodic non-breeding, low first-year survival, and small clutch size.

Seabirds feed on localized concentrations of prey in single or mixed species aggregations via several foraging techniques, including picking from the sea surface, shallow diving, and deep diving (Shealer 2002). Prey availability to seabirds depends on the depths at which prey occur relative to predator foraging techniques. Also, prey may be driven to the surface and concentrated there as a foraging strategy of pelagic sharks, billfish, tunas, and dolphins. This strategy causes much of the success of pelagic seabird predation. Some seabirds aggregate and forage or rest on floating *Sargassum* mats (Haney 1986; Moser and Lee 2012). Diving seabirds in the GOM include petrels, shearwaters, gannets, boobies, cormorants, and gulls. Diving seabirds can reach depths of several meters for long durations.

The GulfCet II program collected biological oceanography data to determine the environmental patterns and oceanographic processes affecting seabirds in the northern GOM. Terns, storm-petrels, shearwaters, and jaegers were the most frequently sighted seabirds in deep water (>964 ft; 300 m). Summer migrants (i.e., shearwaters, storm-petrels, and boobies), summer breeders (i.e., sooty tern, least tern, sandwich tern, and magnificent frigatebird), winter residents (i.e., northern gannet, gulls, and jaegers), and year-round species (i.e, laughing gull, royal tern, and bridled tern) were all observed in GOM deepwater areas. Bird densities were not estimated, but previous work indicated that densities over the open ocean are typically less than 10 birds per square kilometer. As evidenced by the data collected in the GulfCet II program, hydrographic conditions (i.e., the presence and location of mesoscale features, nutrient levels, and sea-surface level productivity) play an important role in seabird distribution and density in addition to seasonal variability. Currently, a BOEM-funded project, the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS), is conducting extensive at-sea surveys (15 surveys have been conducted since 2017) of GOM seabirds to better understand their abundance and distribution. The preliminary results suggest high numbers of non-breeding black terns in the Mississippi River Delta and western GOM, a widespread presence of brown boobies in pelagic waters, an extended presence of European-breeding, band-rumped storm petrels from March to September, and the regular occurrence of black-capped petrels.

Generally, seabirds occur in low densities over most of the ocean and are patchily distributed. Higher densities correlate with *Sargassum* lines, upwellings, convergence zones, thermal fronts, salinity gradients, and high plankton productivity areas (Ribic et al. 1997; Hess and Ribic 2000). Seabirds can use beaches and dunes for feeding, roosting, and/or nesting habitat (Portnoy 1977, 1981; Hunter et al. 2006). Areas of higher density are areas that should get higher conservation priority.

3.8.3.4 Waterfowl

Waterfowl species that occur in the coastal and inshore waters of the northern GOM include some in the subfamilies Aythyinae (diving ducks) and Merginae (sea ducks) of the Anseriformes order (Sibley 2000). The canvasback, ring-necked duck, lesser and great scaup, bufflehead, and common goldeneye are common diving duck species in freshwater and estuaries in the GOM. The greater scaup and similar species move to marine environments during the winter. Their diet can consist of aquatic vegetation, mollusks, and crustaceans. Sea ducks feed and rest within nearshore and inshore waters during their non-breeding season, typically gathering in large flocks on the sea surface. Hooded mergansers are likely the most common sea duck species in the northern GOM based on their habitat preferences. The order Gaviiformes (i.e., loons) can also be found in coastal GOM waters. Sea duck diet can consist of fish, mollusks, and small invertebrates (Sibley 2000).

3.8.3.5 Shorebirds

Shorebirds are a large group of birds, including sandpipers (Scolopacidae), plovers (Charadriidae), oystercatchers (Haematopodidae), and avocets and stilts (Recurvirostridae), that utilize coastal GOM habitats for nesting, feeding, and resting. Forty-three shorebird species occur in the GOM during their migration or wintering periods; 28 of these species rely on northern GOM coastlines to fuel their migrations to their near-arctic breeding grounds (Henkel and Taylor 2015). Six shorebird species, the American oystercatcher, snowy plover, Wilson’s plover, willet, killdeer, and black-necked stilts breed in the GOM (Helmers 1992). The Lower Mississippi and western coastal GOM serve as rich habitats for a variety of shorebirds. The Gulf Coast provides some of the most important shorebird habitat, particularly the Laguna Madre ecosystem along the southern Texas coast (Brown et al. 2001; Withers 2002).

Shorebirds can use beaches and dunes for feeding, roosting, and/or nesting habitat (Portnoy 1977, 1981; Hunter et al. 2006). Shorebird abundance trend analyses indicate that many species in various parts of the U.S. are declining, including many species that occur along the northern GOM coastline (Morrison et al. 2001; Morrison et al. 2006). Environmental degradation of shoreline habitats, industrial and recreational development of breeding and wintering habitats, environmental change impacts on Arctic breeding sites, and sea-level rise alteration on coastal areas are believed to be responsible for these declines. Further, global environmental change can alter prevailing wind patterns that affect ocean upwelling and productivity, both of which are drivers of shorebird abundance and distribution (Morrison et al. 2001).

3.8.3.6 Wading/Marsh Birds

Wading/marsh birds are a diverse group of birds in the four orders Ciconiiformes, Gruiformes, Pelecaniformes, and Podicipediformes. They utilize most of the coastal aquatic habitats found in the northern GOM, including freshwater swamps and waterways, brackish and saltwater wetlands, and embayments. Herons, egrets, cranes, rails, and storks, as well as diving birds (e.g., grebes), are common wading/marsh birds in the GOM. Most are year-round residents with diets that primarily consist of fish and invertebrates (Sibley 2000). Wading/marsh birds are susceptible to habitat disturbance, degradation, or loss because of their reliance on coastal aquatic habitats.

3.8.4 ESA-Listed (Threatened or Endangered) Species

Currently, there are seven ESA-listed bird species in the GOM: the Cape Sable seaside sparrow (*Federal Register* 1967); Mississippi sandhill crane (*Federal Register* 1973); piping plover (*Federal Register* 1985); red knot (*Federal Register* 2014b); roseate tern (*Federal Register* 1987); whooping crane (*Federal Register* 2011c); and wood stork (*Federal Register* 2012). Species are listed as either threatened or endangered. Listed species are considered and analyzed per consultation with FWS. These seven species are present in the northern GOM; five (Mississippi sandhill crane, piping plover, rufa red knot, whooping crane, and wood stork) are found in or adjacent to the WPA and CPA where they are more vulnerable to potential impacts to the IPFs from BOEM-regulated activities as there are higher activity levels in the WPA and CPA. Two of the listed species are found exclusively in Florida (i.e., Cape Sable seaside sparrow and roseate tern), where they are less vulnerable to BOEM-regulated activities. However, a bird's vulnerability could increase in the EPA if the moratorium established by the Gulf of Mexico Energy Security Act of 2006 (currently schedules for June 2022) was to expire and subsequent oil and gas leasing were to occur in these previously unavailable areas.

Other listed species also occur in the coastal GOM. Still, they are not explored further in this document as they rely more on terrestrial habitats or are not commonly documented in the northern GOM. The latest BiOp issued by the FWS determined that BOEM's proposed Oil and Gas Program (10-year period starting April 2018) is not likely to jeopardize the continued existence of the listed bird species and their designated critical habitat (FWS 2018a).

3.8.4.1 Cape Sable Seaside Sparrow

The Cape Sable seaside sparrow, a small passerine species, was federally listed as endangered on March 11, 1967. Habitat loss and fragmentation through hydrologic alteration from wetland drainage, tilling, diking, controlled burns, agriculture activities, and commercial and private development in its preferred habitat are likely the primary causes for its original listing. A South Florida Multi-Species Recovery Plan was created by the FWS for the Cape Sable seaside sparrow on May 18, 1999. The latest Five-Year Status Review, a process mandated by the ESA, was completed on August 18, 2010. In the review, it was concluded that the Cape Sable seaside sparrow population continues to decline, and its listed status remained. The review estimated that the population size for all six subpopulations from 2005 to 2009 was 3,021 individuals, representing less than half identified in the recovery criterion (FWS 2010a). As of April 11, 2019, the FWS is conducting a new Five-Year Status Review of the Cape Sable seaside sparrow (FWS 2019b). In 2014, a range-wide survey indicated that the population had declined to 2,720 individuals (Beerens and Romañach 2016).

The Cape Sable seaside sparrow is a non-migratory habitat specialist reliant on saltwater to brackish marsh and are found in six "isolated" small populations. They are dietary generalists and commonly feed on soft-bodied insects, marine worms, shrimp, and grass and sedge seeds. They forage by gathering items from low vegetation or substrate. The Cape Sable seaside sparrow's distribution is restricted to the Florida peninsula (i.e., the EPA), specifically the Everglades region of Miami-Dade, Collier, and Monroe Counties and the Big Cypress National Preserve (FWS 1999). Critical habitat in Miami-Dade County was designated in 1977 (*Federal Register* 1977b) and revised in 2007 (*Federal Register* 2007) (**Figure 2-1**).

During their nesting period, the Cape Sable seaside sparrow prefers the mixed marl prairie community, including muhly grass (FWS 1999). Its nest success and survival has been highly variable (Boulton et al. 2009), which is problematic for a species with such low population numbers. The Cape

Sable seaside sparrow population is limited by the nesting habitat availability, which occurs in areas naturally inundated by freshwater for 3-7 months annually. Due to local hydrology alterations, the Cape Sable seaside sparrow's preferred nesting habitat are flooding at higher water levels and for longer periods, leading to lower nesting success (Van Houtan et al. 2010; Nott et al. 1998).

3.8.4.2 Mississippi Sandhill Crane

There are six subspecies of sandhill cranes, including the Mississippi sandhill crane. This subspecies was listed as endangered on June 4, 1973 (*Federal Register* 1973) due to small population size, restricted distribution, habitat loss, and habitat fragmentation (consisting of wet pine savanna). Three separate critical habitats were designated in the 1970s (*Federal Register* 1975) (**Figure 2-1**). The I-10 corridor jeopardized the existence of this population; however, a settlement agreement resulted in the Mississippi Department of Transportation purchasing 1,960 ac (793 ha) for habitat, and an interchange was built (FWS 1991). The Mississippi Sandhill Crane National Wildlife Refuge in Jackson County, Mississippi, represents 74 percent of the total critical habitat (FWS 1991). In February 2016, there were 129 cranes in the wild population; annual reports are provided for updates on the FWS website (FWS 2016). At present, much of its habitat is protected in the Mississippi Sandhill Crane National Wildlife Refuge.

The Mississippi sandhill crane is a non-migratory, wading bird. It is a resident population with an extremely limited distribution within Jackson County, Mississippi. Habitats for this species include wetland areas such as wet pine savannas, cypress stands, and Gulf Coast prairies (FWS 2014b). The sandhill crane feeds primarily on land or in shallow emergent wetlands. They are omnivorous and generalist feeders with a diet consisting of a variety of plant tubers, grains, small vertebrates including mice and snakes, aquatic invertebrates, insects, and worms.

In fall and winter, Mississippi sandhill cranes roost mainly in the Pascagoula Marsh (Tacha et al. 1992). This species is presently reproductively isolated and persists primarily due to augmentation from a captive-breeding program.

3.8.4.3 Piping Plover

Three populations of the piping plover, a small shorebird, were federally listed on December 11, 1985, and are protected under the MBTA (FWS 2013b). Two of these populations winter along the Gulf Coast: the Great Lakes (endangered) and the Great Plains (threatened) populations (*Federal Register* 1985). The latest Five-Year Review was completed on September 29, 2009, with recommendations that their statuses remain unchanged. The piping plover is also a State species of conservation concern in all Gulf Coast States (i.e., Texas, Louisiana, Mississippi, Alabama, and Florida). Population estimates indicate declines for the Great Lakes and Atlantic populations at their breeding grounds (Haig et al. 2005; Roche et al. 2010). Twelve different critical habitat rules have been published for piping plovers, including designations for coastal wintering areas of the Gulf Coast States, i.e., Florida, Alabama, Mississippi, Louisiana, and Texas (July 10, 2001; *Federal Register* 2001) (**Figure 2-1**). Specifically, there are 20 units (parcels of land designated as critical habitat) in western Florida south to Tampa Bay, 3 areas in Alabama, 15 in Mississippi, 7 in Louisiana, and 18 in Texas.

Piping plovers feed on marine worms, fly larvae, beetles, insects, crustaceans, mollusks, and other small invertebrates. They primarily forage along the wrack zone, where dead or dying seaweed, marsh grass, and other debris are left on the upper beach by high tide (FWS 2011a). This reliance on upper beach areas for food creates opportunities to co-exist in areas with higher human activity levels, to which piping plovers are very sensitive. Disturbances from anthropogenic activities can cause parents to abandon their nests (FWS 2009a), which is problematic for a species with low population numbers. Habitat loss and degradation due to commercial, residential, and recreational developments on both breeding and wintering areas are the likely cause for declines.

The piping plover is a migratory species with two populations wintering in the GOM (i.e., the Great Lakes and Great Plains). All piping plovers are considered threatened when on their wintering grounds (*Federal Register* 2001a). As high as 75 percent of all breeding piping plovers may winter in the GOM (up to 8 months). Piping plovers arrive at the area in July through September and begin migrating back to their breeding grounds the following February through May. Habitats used by wintering piping plovers along the GOM include beaches, mudflats, sand flats, algal flats, and washover passes (i.e., areas where breaks in the sand dunes result in an inlet). Wintering plovers depend on a mosaic of habitat patches; the local weather and tide determine their distribution among these patches. Concentrations of piping plovers may be attracted to specific wintering habitat due to a preferred prey base and/or the substrate color provides aerial predator protection via camouflage color (Nicholls and Baldassarre 1990). Habitat attributes (i.e., foraging and roosting opportunities) also drive this selection.

The Great Plains population breeds primarily along the Missouri River system and its tributaries, as well as alkali wetlands and lakes in the Dakotas, Montana, and in prairie Canada (Haig et al. 2005; Roche et al. 2010). The Great Lakes population breeds primarily along the shores and along cobble beaches and associated islands with similar substrate in the Great Lake States and Canadian provinces (Stucker et al. 2010). This population winters primarily along the south Atlantic Coast, but it can be found as far west as the Laguna Madre, Texas (Stucker and Cuthbert 2006; Gratto-Trevor et al. 2009).

3.8.4.4 Roseate Tern

The roseate tern is a worldwide species that is divided into five subspecies. Only two subspecies occur in the GOM: the Northeastern and the Caribbean populations. Both populations were listed on November 11, 1987. Recovery plans for the Northeast and Caribbean populations were completed on September 24, 1993, and November 5, 1998, respectively. Habitat loss and subsequent breeding colony loss, increased competition and predation, a small number of breeding sites, and declines in abundance are cited as causes for their Federal listings. The breeding colony loss is mostly attributed to chick predation by the herring gull and great black-backed gull. The roseate tern is considered a State Species of Conservation Concern in Florida and is protected by the MBTA. No critical habitat has been designated for the roseate tern.

Roseate terns are migratory seabirds that forage on small fish over shallow sandbars, reefs, or fish schools via plunge-diving, contact-dipping (the bird's bill briefly contacts the water), or surface-dipping (the bird dips briefly into the water and picks prey from the surface). They are adapted for fast flight and relatively deep diving, and often fully submerge when diving for fish (FWS 2011b). The Northeastern population occurs along the Atlantic Coast from Nova Scotia to North Carolina and Bermuda, fluctuating around 3,500 breeding pairs and is listed as federally endangered (*Federal Register* 1987). The Southeast U.S./Caribbean population occurs in Florida, Puerto Rico, and the Virgin Islands with 4,000-5,000 breeding pairs and is listed as federally threatened (*Federal Register* 1987; Gochfeld et al. 1998).

The Northeastern roseate tern population breeds in the northeastern U.S. and eastern Canada (Kirkham and Nettleship 1987), following their migration over the open ocean from the West Indies and South America. The Caribbean population's migration is less understood. Still, information for the Florida breeders indicates peak arrival in mid-April to mid-May and peak departure in mid-August to mid-September. By the 1990s, there were two remaining nesting sites in Florida: Pelican Shoal and the rooftop of the Marathon Government Building in Monroe County, Florida (Zambrano et al. 2000). These sites are in the Florida Keys and far from potential interactions from proposed OCS oil- and gas-related activities. In Florida, approximately 350 breeding pairs are estimated, with 15-225 pairs in the Dry Tortugas (FWS 2010b).

3.8.4.5 Rufa Red Knot

The rufa red knot subspecies was listed as threatened on January 12, 2015 (*Federal Register* 2014b) and is protected under the MBTA as of December 2, 2013 (FWS 2013b). Three of the six subspecies of red knot occur in North America, all of which breed in the Arctic; the rufa subspecies occurs along Gulf Coast during fall migration and the winter. There is currently no established critical habitat or recovery plan for the rufa red knot. Based on the best available information, there is currently no precise population estimate for this subspecies; however, since 2000, declines of 70-75 percent have been recorded in Tierra del Fuego for the wintering birds and in Delaware Bay during the spring migration. Declines have also been observed in the population that departs the central Canadian Arctic in August (Niles et al. 2007).

Rufa red knots are small, migratory shorebirds. They travel long distances, roughly up to 9,300 mi (15,000 km), across both North and South America via the Atlantic Coast or continental flyways (i.e., Central and Mississippi Flyways) during the spring and fall migrations. Coastal beaches, bays, tidal flats, salt marshes, and lagoons primarily along the Atlantic and Gulf Coasts serve as essential migration habitats and may become the final wintering destination for some.

For wintering, they generally use coastal marine and estuarine habitats with large areas of exposed intertidal sediments. Rufa red knots' wintering and migration habitats are characteristically similar. In North America, rufa red knots are commonly found along sandy, gravel, or cobble beaches; tidal mudflats; salt marshes; shallow coastal impoundments and lagoons; and peat banks. The supra-tidal (above the high tide) sandy habitats of inlets provide areas for roosting, especially at higher tides when intertidal habitats are inundated. In wintering and migration habitats, red knots commonly forage on bivalves, gastropods, and crustaceans. During both their fall and spring migration, the population stops in Delaware Bay and consumes a large amount of horseshoe crab eggs for energy reserves. This area is crucial to rufa red knots, which are negatively impacted by the commercial harvesting of adult horseshoe crabs. This is likely the reason for the aforementioned population decline in the area (Karpanty et al. 2006).

Specifically, within the GOM region, wintering birds are found primarily in Florida and Texas but have been observed in Louisiana, Alabama, and Florida. On Florida's Gulf Coast (i.e., Lee County), the rufa red knot uses intertidal substrates on ocean beaches at inlets during the fall migration. Along the Texas coast, they forage on beaches, oyster reefs, and exposed bay bottoms, and they roost on high sandflats, reefs, and other sites protected from high tides.

3.8.4.6 Whooping Crane

Whooping cranes are found only in North America in only three locations (CWS and FWS 2007; FWS 2009b). The whooping crane was federally listed as endangered on March 11, 1967 (*Federal Register* 1967) primarily due to overhunting and habitat loss. In 1941, only 15 whooping cranes remained. As of February 2015, there were 603 whooping cranes in the total North America wild and captive populations. Whooping cranes in Louisiana (*Federal Register* 2011c) and Florida (*Federal Register* 2001b) represent nonessential, experimental populations, meaning "the population is considered experimental because it is being (re)introduced into suitable habitat that is outside of the whooping crane's current range, but within its historic range. It is designated not essential because the likelihood of survival of the whooping crane, as a species, would not be reduced if this entire population was not successful and was lost." Critical habitat (established in 1978) along the Gulf Coast is within the Aransas National Wildlife Refuge in Texas (*Federal Register* 1978) (**Figure 2-1**).

The whooping crane currently exists in the wild as one self-sustaining wild population, the Aransas-Wood Buffalo National Park Population, and the released, experimental, nonessential populations in several states, including Florida and Louisiana. Twelve captive sites contribute to the captive breeding and release program (FWS 2012). The self-sustaining Aransas-Wood Buffalo population spans across Kansas, Montana, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas during migration. The population is estimated at 308 birds from the FWS 2014-2015 annual survey of their wintering grounds in the coastal marshes of Texas (FWS 2015d) and is estimated at 504 birds from the FWS 2018-2019 annual survey (FWS 2018b). Most of the Aransas-Wood Buffalo National Park population migrates down through the Central and Mississippi Flyways to Texas, arriving in late October to mid-November and departing in late March to mid-April.

Whooping cranes have a strong tendency to show site fidelity to previously used locations for breeding, migrating, and roosting sites. Preferred roosting habitat includes open areas with sand and gravel bars or shallow water in rivers and lakes (Federal Register 1978).

3.8.4.7 Wood Stork

The U.S. breeding population of the wood stork was listed as endangered on February 28, 1984 (*Federal Register* 1984). The species was formally down-listed to threatened on July 30, 2014, upon the recommendation of the Five-Year Status Review in 2007. This was due to a population increase and expansion of the breeding range (*Federal Register* 2010). The wood stork was originally listed as a result of three potentially interacting factors: loss of preferred wetland habitats and associated available nesting sites; lack of protection at nest sites; and loss of preferred foraging habitats and/or prey (Brooks and Dean 2008). The wood stork population in the southeastern U.S. appears to be stable or increasing (Borkhataria et al. 2008; Brooks and Dean 2008). The wood stork is considered a State species of Conservation Concern in all Gulf Coast States except Louisiana. No critical habitat rules have been published for this species.

The wood stork is the only stork and largest breeding wading bird in the U.S. Within the U.S., Its distribution is restricted to the southeastern states, including in the Gulf Coast States (Coulter et al. 1999). Wood storks are also year-round residents of Florida and Georgia. They feed in freshwater marshes, narrow tidal creeks, or flooded tidal pools (FWS 2015e). Their diet primarily consists of small fish (e.g., sunfish, topminnows), which they forage for using a unique feeding technique known as grope-feeding or tacto-location. The stork probes the water with the bill partly open, and when a fish touches the bill, the stork quickly snaps it shut (FWS 2015e).

Within the southeastern U.S., the center of the wood stork's traditional breeding range has shifted northward primarily into north and central Florida, Georgia, and South Carolina (Kushlan and Frohring 1986; Ogden et al. 1987; Rodgers Jr. et al. 2008), with breeding no longer occurring in Alabama, Mississippi, and Louisiana (Coulter et al. 1999). The wood stork also breeds in Mexico, Central America, Cuba, Dominican Republic, and South America. Breeding locations often change annually due to variation in wetland conditions and because of the ability of breeding pairs to track resource availability (i.e., wetland conditions and food); not all colonies are occupied every year (Bryan Jr. and Robinette 2008; Kushlan and Frohring 1986). Wood storks are highly colonial and will nest in large rookeries with several nests in the upper branches of large cypress trees or in island mangroves. Those that breed at the northern edge of the breeding range tend to migrate south to winter in Florida and southern Georgia (FWS 2007b). Relatively major post-breeding dispersal with large numbers of birds has been frequently observed in the Mississippi River Valley, and some mixing of U.S. and Mexican populations may occur (Bryan and Robinette 2008).

3.8.5 Candidate Species

The FWS also lists species as candidate species of concern (*Federal Register* 2006) when it has enough information on their biological status and threats to propose them as ESA-listed, but for which other higher priority listing activities preclude the development of a proposed listing regulation.

These species do not receive statutory protection under the ESA, but the FWS encourages cooperative conservation efforts as these species may warrant future ESA protection. Currently, there are several candidate bird species identified in the northern GOM (FWS 2020b). Three species (i.e., the Florida sandhill crane, smooth-billed ani, and southeastern snowy plover) were proposed for listing but were found to not warrant an ESA listing.

3.8.5.1 Golden-Winged Warbler

The golden-winged warbler is a small songbird that migrates through the GOM and is under consideration for ESA listing. Their migration route primarily lies between the Mississippi River and the Appalachian Mountains, with some occurring in Texas as well. Their breeding range spans the northeast to northwest of North America, and they spend their winters in southern Central America and South America (Confer et al. 2020). Golden-winged warblers are insectivores that feed primarily on moths (Will 1986).

The golden-winged warbler faces several threats, including habitat loss and modification, deforestation, and resource competition. The golden-winged warbler is currently undergoing a status review by the FWS to determine if the species will become listed (*Federal Register* 2011b).

3.8.5.2 Black-Capped Petrel

The black-capped petrel is a seabird that forages in the offshore waters of North America and the Caribbean. It has been proposed for ESA listing. The entire breeding population is distributed across 13 breeding colonies on the Island of Hispaniola in the Caribbean. They are known to occur in the offshore waters from Maine to Florida, the eastern and central GOM, and in the Caribbean Sea as far south as South America. Their diet primarily consists of squid and fish, as they are surface foragers (FWS 2019a).

The black-capped petrel faces several threats, including human encroachment, deforestation, habitat modification due to agriculture, offshore energy, invasive species, pollution, mercury bioaccumulation, and climate change-related events (FWS 2019a). The black-capped petrel is currently proposed to be listed as threatened (*Federal Register* 2018b). They are currently protected under the MBTA (FWS 2013b).

3.8.5.3 Eastern Black Rail

The eastern black rail is a small, secretive marsh subspecies of the black rail that has been proposed for ESA listing. They are found year-round along the coast of Texas and Florida in the GOM, with a small number of recordings in Louisiana. Records indicate that the eastern black rail primarily occupies coastal marshes in this region. Outside of the GOM, the eastern black rail is found along the U.S. Atlantic Coast spanning from New Jersey to the Florida Keys in both inland freshwater and coastal saltwater marshes (FWS 2020a). Little is known about the eastern black rail's diet, but it is suggested that they are opportunistic foragers feeding on a variety of items, such as small aquatic and terrestrial invertebrates and small seeds.

The eastern black rail faces several threats, including fire suppression, invasive species, climate change, sea-level rise, and anthropogenic activities (e.g., habitat fragmentation and conversion, oil spills). The eastern black rail is currently proposed to be listed as threatened (*Federal Register* 2018a). The eastern black rail is currently protected under the MBTA (FWS 2013b), and is State listed as either endangered or threatened in seven states, none of which are Gulf Coast States. There is no designated critical habitat proposed or listed for the eastern black rail (FWS 2020a).

3.8.5.4 Saltmarsh Sparrow

The saltmarsh sparrow is a medium-sized bird that mainly inhabits tidal marshes in the eastern U.S., with breeding grounds concentrated in the northeastern coastal U.S. However, their wintering range is fragmented with some occurring in the herbaceous wetlands mostly along the U.S. Atlantic Coast, with some uncommon wintering grounds ranging along the coast from Panama to Tampa, Florida (Audubon Society 2020f; Cornell University 2019). Their diet consists primarily of insects and invertebrates found in the marsh plants (Audubon Society 2020f).

The saltmarsh sparrow faces several threats, including tidal flooding, predation, habitat degradation, toxic mercury bioaccumulation, sea-level rise, and coastal development (All About Birds 2019; FWS 2019c). The saltmarsh sparrow is currently under review for possible ESA status by the FWS (FWS 2020b).

3.8.6 Threats to Birds Unrelated to BOEM's Activities

3.8.6.1 Disease

Emerging infectious diseases (e.g., West Nile virus) currently present a challenge to native species conservation. Emerging diseases are considered those that experience a recent incident or impact increase or have recently spread to a new host population or region (Lederberg et al. 1992; Smolinski et al. 2003). Emerging wildlife diseases have been commonly linked to anthropogenic environmental changes (Schrag and Wiener 1995; Daszak et al. 2001). Bird species have so far experienced complex population response to West Nile virus (LaDeau et al. 2007), which was introduced to North America in 1999 (McLean 2006). Seven out of 20 (35%) selected avian species from across North America that were potential hosts to the virus exhibited changes attributed to West Nile virus at the population level. Only two of these species recovered to pre-virus levels by 2005, based on 26 years of data (LaDeau et al. 2007). However, this likely underestimates the impacts to birds as recruitment and immigration can hide population declines (Ward et al. 2010). These continental estimates can be qualitatively extrapolated to other species as well as the northern GOM, where West Nile virus and potentially other infectious diseases would be expected to have severe impacts on avian populations. George et al.'s (2015) study demonstrated how widespread and long-term effects from West Nile Virus and other emerging diseases can be on naïve landbird populations. There have been few large-scale studies to evaluate infectious and non-infectious emerging diseases in birds (Friend et al. 2001, Newman et al. 2007). However, one 30-year study of necropsy data of aquatic North American birds found that infectious diseases are a significant cause of bird mortality in the U.S., particularly for nearshore and coastal birds (Newman et al. 2007).

3.8.6.2 Climate Change and Ocean Acidification

Climate change and ocean acidification are also expected to impact marine and coastal birds. For more information on climate change impacts on birds, refer to BOEM's *Outer Continental Shelf Oil and Gas Leasing Program: 2022-2027; Final Programmatic Environmental Impact Statement*, Volume I (BOEM 2020a). Though climate change impacts on birds are difficult to predict, they are expected to influence bird's ecology through changes in habitat ranges (Mustin et al. 2007), increased risk of predation and competition, exposure to different prey and parasites, shifts in seasonal events (e.g., breeding and migration), and changes to local food webs, and habitat alterations (Butler and Taylor 2005; Liebezeit et al. 2012; Tillmann and Siemann 2011; Wauchope et al. 2017; Wormworth and Mallon 2006).

The influence of climate change on birds is difficult to predict due to the complexity of predicting climate-induced ecological impacts (Mustin et al. 2007). Climate change is likely to impact a wide range of aspects of a bird's ecology, and the question remains as to whether species can shift to new habitat ranges (Mustin et al. 2007) as range contractions are expected to occur more frequently than range expansions. Shifts in bird species' ranges can disrupt ecological communities of birds and interdependent plants and animals. Range shifts could lead to increased exposure of some birds to different prey species, parasites, predators, or competitors. Species could be forced into areas less suitable for habitation. Impacts on birds could also include shifts in the timing of important seasonal events (e.g., breeding and migration), which could, in turn, force birds' lifecycles out of synchrony with prey sources (i.e., plants and insects). Alterations of the timing and magnitude of biological productivity could force bird populations to seek new levels and distribution of prey items in response to all seasonal timing and range shifts, possibly triggering effects to local food webs. Additionally, habitat alterations (e.g., loss of sea ice or freshwater habitats drying up) could impact various stages of development (Butler and Taylor 2005; Liebezeit et al. 2012; Tillmann and Siemann 2011; Wauchope et al. 2017; Wormworth and Mallon 2006).

Ocean acidification (refer to **Chapter 2.1.2**) is the reduction of the oceans' pH levels, making the waters more acidic (IPCC 2014). The changes in pH levels alter food web dynamics. Ocean acidification alters pH levels, which can affect sensitive planktonic species at the organismal level up to a population-level response due to food web dynamic changes, which can lead to impacts on marine and coastal birds. If climate change is not curtailed, biodiversity vital to the ecosystems that support all bird life could decline (McDaniel and Borton 2002). Global climate change may also increase the frequency and intensity of hurricanes, which can increase the risk of accidental oil spills at Gulf of Mexico OCS oil and gas facilities (refer to **Chapter 4.1.8** for more information on accidental spills effects on birds) and possibly exacerbate damage to important breeding and wintering habitats in the northern GOM.

3.8.6.3 Other

There are numerous anthropogenic avian mortality sources, including collisions and predation by domestic cats. Collisions with human-made structures are one of the highest-ranked threats to birds worldwide when observing the numbers of individuals killed (Loss et al. 2014a). There are currently no GOM regional estimates for annual mortality rates for vehicle or building bird strikes, as well as predation by cats. National estimated annual mortality from vehicle bird strikes is at 62-275 million birds per year (Loss et al. 2014b), building bird strikes is 599 million birds per year (Loss et al. 2014a), and predation by free-ranging domestic cats is 1.4-3.7 billion birds per year (Loss et al. 2013). Cat predation mainly impacts small birds (e.g., passerines). As these are national rates, the mortality rates are expected to be less in the northern GOM.

4 RESOURCE VULNERABILITY ANALYSIS

4.1 INTRODUCTION

This chapter explores the vulnerabilities of GOM biological resources to routine activities and accidental events associated with BOEM-regulated activities. This vulnerability analysis is not based on the likelihood that a resource will be exposed to any given IPF. For this document, the BOEM-regulated activities described are assumed to occur throughout the GOM region. Unlike some NEPA analyses, there are no assumptions made about the extent, timing, and potential locations of OCS conventional and renewable energy or marine mineral activities. This vulnerability assessment does not estimate the impact levels (i.e., the context and intensity) of any effects from potential future conventional energy, renewable energy, or marine mineral activities. There are general IPFs typical of offshore oil and gas, renewable energy, and marine mineral activity that manifest regardless of activity levels and location. This report aims to determine the vulnerability of the GOM region's biological resources to these activities and better inform future analyses, assessments, and consultations, as well as identify areas of future study.

For the vulnerability analysis in this chapter, vulnerability is defined as the reasonable, scientifically supportable potential for an IPF to affect a resource. Vulnerability does not necessarily indicate past, present, or future impacts. For organismal resource groups, a vulnerability has the reasonable potential to have consequences at the population level. Vulnerabilities to an IPF may exist even though lease stipulations, Notices to Lessees and Operators (NTLs), and other guidance from BOEM may prevent the IPF from affecting the resource. Existing laws and regulations do prevent vulnerabilities between IPFs and resources. The determination of a resource's vulnerability to an IPF does not necessarily indicate the impact determination of any subsequent NEPA analyses (e.g., negligible, minor, moderate, or major).

Important Definitions

Impact-Producing Factor (IPF): The outcome of a proposed activity that may pose a vulnerability risk or potentially impact a resource.

Vulnerability: The reasonable, scientifically supportable potential for an IPF to affect a resource. For organismal resource groups, a vulnerability has the reasonable potential to have consequences at the population level. Vulnerabilities to an IPF may exist even though lease stipulations, NTLs, and other guidance from BOEM may prevent the IPF from affecting the resource. Existing laws and regulations *do* prevent vulnerabilities between IPFs and resources. Vulnerability does not necessarily indicate past, present, or future impacts.

BOEM-Regulated Activity: A direct or indirect activity or process(es) resulting from BOEM-regulated actions that has the potential to create IPFs (e.g., vessel traffic or geophysical surveying).

Impact/Effect: In the context of a NEPA analysis, a direct, indirect, or cumulative result of an action on a resource(s).

Routine Activity: Activities that generally occur on a regular basis; events expected as a result of BOEM-regulated activities or associated actions that would occur during BOEM-regulated activities.

Accidental Event: Events that do not occur on a regular basis during a BOEM-regulated activity and are unintentional by nature (e.g., spills of fuel, crude oil, or other chemicals resulting from accidents [<10,000 barrels], weather events, and collisions). Vessel strikes and trash and marine debris are included as accidental events. Catastrophic oil spills such as the *Deepwater Horizon* explosion, oil spill, and response are not considered reasonably foreseeable accidental events and are not considered in this document.

4.1.1 Impact-Producing Factors (IPFs) and the Vulnerability Table

An IPF is the outcome of a proposed activity that may pose a vulnerability risk or potentially impact a resource. For this analysis, the broad expanse of possible IPFs from all BOEM-regulated activities have been grouped into categories based on previous and ongoing assessments and outreach efforts. The list of IPF categories and their definitions are provided below. **Table 4-1** provides examples of BOEM-regulated activities that are associated with each IPF category.

- **Noise:** A subjective term reflective of societal values regarding what constitutes unwanted or undesirable intrusions of sounds. Noise can have negative effects on biological resources and environmental quality through several pathways, including direct physical injury or indirectly through masking and other behavioral disruptions. The severity of impact partly depends on the frequency range and sound intensity, as well as the hearing abilities of the species of interest.
- **Discharges and Wastes:** Releases into the environment resulting from multiple sources. This generally refers to routine, permitted operational effluent discharges to receiving waters. These discharges are generally restricted to uncontaminated or properly treated effluents that may have best management practice or numeric pollutant concentration limitations imposed through the USEPA's National Pollutant Discharge Elimination System (NPDES) permits or U.S. Coast Guard (USCG) regulations.
- **Coastal Land Disturbance:** Physical disturbance to coastal habitats and waters that can be caused by activities (e.g., infrastructure emplacement and vessel traffic). This disturbance is limited to roughly the 20-m (66-ft) isobath and shoreward. Seabed disturbance is covered under the bottom disturbance IPF.
- **Offshore Habitat Modification:** Long-term alteration to offshore habitat on the seabed, in the water column, or at the water's surface (e.g., infrastructure

emplacement and subsea facilities). This modification may include decommissioning activities.

- **Air Emissions:** Refers to the release of gaseous or particulate pollutants into the atmosphere from stationary sources, vessels, vehicles, or aircraft, which can affect air quality and associated resources. Can occur both on and offshore. Includes emissions from helicopters, vessels, stationary engines (e.g., generators), and equipment leaks (*i.e.,* fugitive emissions). The USEPA defined criteria pollutants released by OCS sources include CO, NO_2, PM_{10}, $PM_{2.5}$, and SO_2.
- **Lighting and Visual Impacts:** The structural presence and associated lighting in both the onshore and offshore environment.
- **Accidental Releases to the Environment:** During BOEM-regulated activities, the accidental release of substances may occur. These may include oil spills, chemical spills, pipeline failures, losses of well control, accidental air emissions, hydrogen sulfide and sulfurous petroleum releases, and trash and debris. Response activities associated with these unintended releases are also included.
- **Accidental Collisions:** Describes the unintended collision between OCS-associated vessels with structures or other vessels. This includes collisions between two vessels, collisions between a vessel and an artificial structure, and vessels running aground.
- **Accidental Vessel Strike:** Refers to the collision of a moving vessel/vehicle with biota or natural habitat.

Table 4-1. Examples of BOEM-Regulated Activities Associated with Each Impact-Producing Factor Category. (Examples include activities from oil and gas exploration and development, wind energy development, and marine minerals extraction and use.)

Impact-Producing Factor	BOEM-Regulated Activity
Routine Activities	
Noise	Geological and geophysical acoustic sources Vessels Aircraft Drilling and production Trenching Construction (including both onshore and offshore) Structure removal (including explosives) Dredging Vibration Pile driving Sonar Turbines
Discharges and Wastes	Operational wastes and discharges Drilling muds and cuttings Produced water Well treatment, workover, and completion fluids Production solids and equipment Bilge ballast and fire water Cooling water Deck drainage Domestic and sanitary wastes Onshore disposal of waste generated offshore Discharges from onshore facilities and storage Dredge outwash
Bottom Disturbance	Drilling Infrastructure emplacement Anchoring Geological and geophysical coring Geological and geophysical ocean bottom nodes Decommissioning/ structure removal Dredging Deep-sea mining Pile driving Pipeline and cable emplacement and maintenance

Impact-Producing Factor	BOEM-Regulated Activity
Coastal Land Disturbance	Coastal infrastructure Construction facilities Support and transportation facilities Processing facilities Pipeline landfalls Vessel traffic Transmission line landfalls Sand and gravel placement Navigation dredging/ maintenance Port expansion
Offshore Habitat Modification	Drilling Offshore infrastructure emplacement (e.g., pipelines, platforms, and turbines) Decommissioning/structure removal Placement or removal of coastal infrastructure (including onshore facilities) Sand and gravel borrowing
Air Emissions	Drilling Pile driving Dredging Pipeline installations Vessel support Transportation vehicles and vessels (including aircraft, cars, trucks, and tankers) Flaring and venting on oil and gas platforms Decommissioning Fugitive emissions
Lighting and Visual Impacts	Structure emplacement (including both on and offshore) Vessel presence Moored floating facilities Floating, production, storage and offloading
Accidental Events	
Accidental Releases into the Environment	Oil/chemical spills and associated response (<10,000 barrels) from pipelines, wells, or vessel operations Non-routine air emissions Marine trash and debris release
Accidental Collisions	Vessel/vehicle operations (e.g., ships, aircraft, ROVs, ground transportation) Vessels running aground
Accidental Vessel Strike	Vessel/vehicle operations (including ships, aircraft, barging, and tankering) and collisions with wildlife above or below the water's surface

BOEM's interdisciplinary team of subject-matter experts applied existing scientific knowledge and experience to assess the vulnerabilities of each biological resource to the IPFs. **Table 4-2** provides an overview of the IPF categories that pose vulnerabilities to the biological resources of the GOM region. The following sections of this chapter describe each resource/IPF interaction and discuss any potential risks from these interactions. The rationale for the determination of vulnerabilities of the resources to each IPF category is also provided. The magnitude and severity of the vulnerabilities discussed for each resource vary depending on numerous factors, including location, frequency, and duration of the activities and resource; time of year; and the current condition of the resource.

Table 4-2. Impact-Producing Factor Categories of BOEM-Regulated Activities That Pose Vulnerabilities to the Biological Resources of the Gulf of Mexico Region. (An X indicates a vulnerability between that IPF\resource combination. The subsequent sections of this chapter provide a rationale for these vulnerability determinations.)

Resource	Noise	Operational Discharges and Wastes[1]	Bottom Disturbance	Coastal Land Disturbance	Offshore Habitat Modification	Air Emissions[2]	Lighting and Visual Impacts	Accidental Events[3]
Coastal Habitats and Communities		X	X	X	X			X
Pelagic Habitats and Communities	X				X			X
Benthic Habitats and Communities	X	X	X		X		X	X
Fish and Invertebrate Resources					X			X
Sea Turtles	X				X		X	X
Marine Mammals	X							X
Birds	X			X	X		X	X

[1] USEPA Water Quality Standards; Section 301(a) of the Clean Water Act, 33 U.S.C. § 1311(a), makes it unlawful for any person to discharge any pollutant, except in compliance with other Clean Water Act provisions that may apply, including compliance with an NPDES permit.

[2] The USEPA has set National Ambient Air Quality Standards for six principal pollutants called “criteria” pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution (listed as $PM_{2.5}$ and PM_{10}), and sulfur dioxide.

[3] Includes oil spills <10,000 barrels; marine trash and debris under MARPOL Annex V and the Marine Debris Act, 33 U.S.C. §§ 1951 *et seq.*, and regulations imposed by various agencies including the U.S. Coast Guard and USEPA.

4.2 COASTAL AND ESTUARINE HABITATS

4.2.1 Noise

Noise is not expected to have deleterious effects on coastal and estuarine habitats, largely because of the physics of sound propagation in shallow waters. In coastal areas, noise from onshore construction, pipeline trenching, or vessel traffic could occur. But given the fact that low-frequency sounds do not propagate well through shallow water (the “low-frequency cutoff” [Urick 1983]), and the fact that invertebrates and most fish are primarily sensitive to particle motion, these impacts are expected to be highly localized. It has been shown that some of the species that commonly occur in these areas, such as crabs, oysters, mussels, and shrimp, are capable of perceiving low-frequency sounds (e.g., Charifi et al. 2017; de Soto et al. 2013; Roberts et al. 2015). In addition, larval stages of some estuarine species may use acoustic cues to navigate towards appropriate settlement habitat or to initiate metamorphosis (Lillis et al. 2015; Lillis et al. 2013; Stanley et al. 2015). Although these animals may use natural acoustic cues for basic life functions, the particle motion signal from anthropogenic noise sources would propagate only a few wavelengths from the sound source (Kalmijn 1988; Popper and Hawkins 2018; Urick 1983).

4.2.2 Operational Discharges and Wastes

Most operational discharges, such as produced sands and oil-based or synthetic-based drilling muds and cuttings, along with fluids from well treatment, workover, and completion activities, are produced offshore. These materials are either transported to shore or diluted and discharged during operations offshore. In most cases, produced-water discharges from OCS wells is too distant to pose a threat to coastal and estuarine habitats. Because of wetland-protection regulations, no new waste disposal sites are expected to be developed in wetlands. Some seepage or discharges from existing waste sites into adjacent wetland areas may occur, and toxic wastes could kill vegetation and pollute soils. This would lead to habitat degradation and destruction.

All vessels in U.S. and international waters are required to adhere to International Maritime Organization regulations under the International Convention for the Prevention of Pollution from Ships (MARPOL) limiting discharges, avoiding release of oily water, and prohibiting disposal of solid wastes. Therefore, discharges from vessels is not expected to have measurable effects on coastal and estuarine habitats.

Ballast water often carries biological materials, including plants, animals, and microorganisms. The discharge of ballast water in coastal and estuarine habitats is the single largest source of introduced species. Many Federal regulations exist to minimize the risk of introducing species through ballast water, including the National Invasive Species Act.

4.2.3 Bottom Disturbance

4.2.3.1 Pipelines

Many existing OCS pipelines make landfall on barrier island and wetland shorelines. Approximately 4,971 mi (8,000 km) of OCS oil- and gas-related pipelines cross marsh and upland habitat in Louisiana (Johnston 2009). At least two studies have shown a connection between land loss and existing pipelines. One study indicated that existing pipelines have caused direct land loss, averaging 6 ac (2.43 ha) per linear kilometer of pipeline for the 1955-1978 time period (Bauman and Turner 1990). Bauman and Turner (1990) also indicated that the widening of OCS pipeline canals does not appear to be an important factor for total net wetland loss in the coastal zone because few pipeline canals are open to navigation. In contrast, Johnston et al. (2009) found that land loss was consistently higher in the vicinity of pipelines compared with more general, regional trends of land loss, suggesting that they contributed to the loss.

Five pipeline installation techniques are used throughout the coastal zone of the GOM: upland trenching; jetting; building flotation canals; push-pull ditching; and directional drilling. Of these, flotation canals have the most harmful effects. Push-pull ditching can also be used to effectively minimize wetland impacts when post-construction mitigation methods such as backfilling are used (Johnston et al. 2009). Trenchless, or directional drilling, is the newest and favored technique in sensitive habitats. This technique is considered to be protective of sensitive habitats, such as estuarine systems, beaches, and wetlands. At present, directional drilling is required almost without exception for crossing barrier island and shore faces. Impacts are limited to the access and staging sites for the equipment. By using directional drilling, pipeline installation can occur without having to cut through shore facings, minimizing any erosion and surface habitat disturbance. Currently, no new construction of flotation canals (the most harmful construction technique) is being allowed in vegetated areas (Johnston et al. 2009).

Typically, the installation of new pipelines that make landfall is rare. When pipelines do make landfall, there are mitigating measures from the present regulatory programs of Federal or State agencies that may be applied, including compensatory mitigation. Modern pipeline installation techniques are less destructive for wetlands than previous methods. Because of the regulations and new construction methods, and the limited projection for new pipeline landfall, the damages of pipeline landfalls to coastal and estuarine habitats are minimized. The addition of pipelines to distribution points could further stress coastal and estuarine habitats along the GOM, leading to erosion and loss. Installation of pipelines in or near wetland habitats could lead to the hydrologic alteration, disturbance, fragmentation, and loss of wetlands (Ko and Day 2004a). Most impacts would be long term and could affect the biological communities, such as coastal bird species, that rely on these habitats for nesting and feeding. These vulnerabilities may be higher in the EPA where existing infrastructure and pipelines are limited. As discussed in **Chapter 3.2**, coastal land loss is already an issue of immense concern in the GOM and pipeline installation would exacerbate this loss.

4.2.3.2 Dredging

Maintenance dredging of navigation channels and canals is routinely conducted, in part, to support OCS activities. Occasionally a channel would be dredged ahead of its normal maintenance schedule in order to accommodate the transport of large OCS platforms. Dredging for beach nourishment is a BOEM-regulated activity on the OCS. Dredging for sand and other marine minerals generally occurs at depths of 10-30 m (33-98 ft).

Beneficial use of dredged material can be used to enhance and create coastal wetlands after material has been tested for the presence of contaminants. The U.S. Army Corps of Engineers' New Orleans District dredges an average of 78 million cubic yards of material annually during maintenance dredging of Federal navigation channels, with approximately 38 percent of that average used for the beneficial use of the dredge materials program (USACE 2014). The Corps of Engineers reported that, over the last 20 years, approximately 12,545 ha (31,000 ac) of wetlands were created with dredged materials, most of which are located on the Louisiana Coastal Area delta plain (USACE 2013). As a result of the tremendous wetlands land loss in the Louisiana coastal region, the beneficial use of dredged material is expected to increase. Executive Order 11990 (*Federal Register* 1977a) requires that, where appropriate, material from maintenance dredging be considered for use as a sediment supplement in deteriorating wetland areas to enhance and increase wetland acreage. Given the Corps of Engineers' policy of beneficial use of dredged material, increased emphasis has been placed on the use of dredged material for marsh creation.

Despite the beneficial uses described above, dredging and dredged-material disposal can also be detrimental to coastal and estuarine habitats and associated fish and wildlife that use them for nursery grounds and protection. These vulnerabilities may include increased erosion rates, removal of sediments, increased turbidity, land loss, and changes in salinity (Boesch et al. 1996; Wilber et al. 2001; Onuf 1996). The combined impacts of increased turbidity, physical removal, and burial from dredging activities would disturb and destroy seagrass beds (Kenworthy and Fonseca 1996; Erftemeijer and Lewis 2006), such as those in the EPA. Many of these impacts are reduced through the use of modern disposal practices.

4.2.3.3 Cable Burial

If wind energy were developed in the GOM, power cables would need to be installed to carry generated electricity to shore. Installation of cables may include dredging, jetting, and trenching. Therefore, the vulnerabilities of coastal and estuarine habitats to cable burial are similar as those for pipeline installation and dredging (**Chapters 4.2.3.1 and 4.2.3.2**).

Cable installation may be completed with rock or concrete protection atop sections of the buried cable. Given that most of the coastal seabed in the GOM is flat sand, silt, and mud, the addition of rock or concrete would change the nature of the seabed habitat. By adding hard surfaces, vertical relief, and habitat complexity, such changes could lead to increases in faunal diversity (Langhamer 2012; Taormina et al. 2018). This conversion to rare hard bottom habitat would change the habitat structure of the coastal benthos. There would be an initial period of reduced ecological function during installation and for some time afterward as the processes of colonization and succession occurred on the new substrate.

4.2.4 Coastal Land Disturbance

Coastal land disturbance can impact coastal and estuarine habitats through construction and operation of coastal infrastructure (i.e., construction facilities, support facilities, oil and gas transportation, and processing facilities), vessel traffic, navigation canals, and interactions. Coastal land disturbance could permanently alter coastal and estuarine habitats.

4.2.4.1 Onshore Construction

Various kinds of onshore facilities service OCS development. The GOM coastal and estuarine habitats would be further stressed with the addition of infrastructure (e.g., roads and onshore support bases) to support offshore activities (e.g., oil and gas) and could result in loss of ecosystem function, physical ecosystem structure, and functional and structural value loss, as well as loss of recreational opportunities and value. Construction and operations associated with onshore facilities would result in some removal of coastal habitat. It is possible that shore-based organisms, such as birds and alligators, could experience stress related to onshore construction. Sedimentation of nearby wetlands and streams would be another risk. Long-term habitat loss or alteration may result from onshore construction.

Onshore support activity may result in increased vehicular traffic, especially in the vicinity of the facilities. This would occur as a result of new roads and vehicles associated with construction and operation of the facility (i.e., the commuting facility staff). Installation of roads in or near coastal and estuarine habitats could lead to the hydrologic alteration, disturbance, fragmentation, and loss of wetlands (Ko and Day 2004a). Collisions between animals and vehicles or construction equipment might cause direct mortality. Limited disturbance may occur as a result of vehicles traveling over the onshore habitat.

Coastal habitats along the GOM are already impacted by and responding to the impacts from sea-level rise and land loss. Wetlands may be particularly vulnerable because development and infilling may remove or change the ecosystem function. Most impacts would be long term and could affect the biological communities, such as coastal bird species, that rely on these habitats for nesting and feeding. Coastal land disturbance can lead to turbidity, which can negatively impact important habitats such as oyster reefs. Major construction projects that destroy oyster reefs and/or reduce water quality could have substantial impacts on the eastern oyster and the communities they support. Coastal land disturbance could modify and/or destroy these coastal habitats (i.e., oyster reefs and seagrasses beds) and the species that depend on them. Many nesting and foraging coastal animals, including some ESA-listed bird and sea turtle species, may experience negative habitat impacts. These habitat losses would likely be localized but could lead to long-term impacts and shoreline loss.

State and Federal permitting agencies discourage the placement of new facilities and the expansion of existing facilities in wetlands. However, any large construction project in the coastal zone is likely to impact some wetland acreage. Any impacts upon wetlands are mitigated in accordance with the Clean Water Act requirements and the Corps of Engineers' 404 permit and State permitting programs. The high cost of wetland mitigation discourages industry from causing damage to wetlands when building onshore facilities.

Depending on the location of newly established infrastructure, special places (i.e., national and State parks and wildlife refuges, national marine sanctuaries, and national estuaries) could be at risk as well. The EPA, which has less onshore infrastructure to support offshore energy, may be more susceptible to these consequences. As discussed in **Chapter 3.2**, coastal habitats along the GOM are already impacted by and responding to the impacts from sea-level rise and land loss. Mitigation measures could reduce impacts.

4.2.4.2 Navigation Channels and Vessel Traffic

Vessel activity (e.g., tankers, barges, support vessels, and seismic survey vessels) associated with oil and gas activities and pipeline installation could increase wave erosion and habitat loss or degradation in coastal and estuarine habitats (Robb 2014). Coastal organisms and vegetation may be impacted by increased turbidity from the wake from vessels such as tankers, barges, survey vessels, and support vessels. In addition, increased OCS vessel traffic could increase shoreline erosion of coastal and estuarine habitats from wave activity, which could lead to loss or degradation of habitat in these areas. Vessel traffic is especially harmful to unprotected shorelines and may accelerate erosion in areas already affected by natural erosion processes. Because of these impacts, the many nesting and foraging coastal animals, including some ESA-listed bird and sea turtle species, may experience negative habitat impacts. Saltwater intrusion into coastal, freshwater habitats may also result from vessel traffic.

Much of the service-vessel traffic associated with OCS oil- and gas-related activities uses the channels and canals along the Louisiana coast. BOEM conservatively estimates that there are approximately 3,013 mi (4,850 km) of Federal navigation channels, bayous, and rivers potentially exposed to OCS oil- and gas-related traffic in the GOM. Of that total, approximately 1,988 mi (3,200 km) of existing OCS oil and gas-related navigation canals, bayous, and rivers pass through wetlands, as opposed to passing through large bays, sounds, and lagoons. The vulnerability of coastal and estuarine habitats to vessel traffic depends, in part, upon the type of canal used. Recent studies have found that armored canals have reduced loss rates compared with unarmored canals (Johnston et al. 2009; Thatcher et al. 2011) and that widening rates due to erosion have slowed based on maintenance techniques. Port Fourchon, Louisiana, which currently services approximately 90 percent of all deepwater rigs and platforms in the GOM (Loren C. Scott and Associates, Inc. 2014), is heavily armored and is less erodible. However, some of this traffic may also use Bayou Lafourche from Leeville to Port Fourchon, which is not armored. Ports that have navigation channels deep enough to accommodate deeper-draft vessels may expand their infrastructure for better accommodation of BOEM-regulated activities. For example, Port Fourchon has been significantly expanded over the years by deepening the existing channel and dredging additional new channels. Refer to **Chapter 4.2.3.1** for a discussion on dredging consequences.

4.2.4.3 Habitat Modification

One of the many consequences of coastal land disturbance is permanent habitat modification. Coastal landfall of pipelines converts wetlands to open water and introduces hard substrates. The creation and maintenance of navigation canals also permanently modifies coastal habitats. The construction of onshore facilities and roads may convert natural habitat to a built environment or may infringe upon neighboring coastal and estuarine habitats. Many of these vulnerabilities are discussed above in **Chapters 4.2.4.1 and 4.2.4.2**.

The construction of roads and navigation canals and the installation of pipelines through coastal and estuarine habitats may serve as obstacles to the movement and migration of coastal species. The construction of onshore facilities would permanently convert natural habitat; port expansion and construction would degrade and destroy coastal and estuarine habitats. Coastal and land-based habitat modification would lead to a fragmentation of usable habitat for coastal organisms. These habitat modifications would displace coastal organisms. Vegetation and less mobile species would be killed. These habitat modifications from onshore and coastal activity may inhibit feeding and reproduction and lead to reduced fitness of individuals. Mortality is a reasonable consequence of habitat modification. For particularly sensitive groups, such as ESA-listed species, population-level impacts may occur.

4.2.5 Offshore Habitat Modification/Space Use

Effects to coastal and estuarine habitats are not expected from offshore habitat modification simply because these communities' habitats do not occur offshore. For a description of the potential impacts from onshore habitat modification, refer to coastal land disturbance (**Chapter 4.2.4**).

4.2.6 Air Emissions

The air emissions from routine offshore BOEM-regulated activities are not likely to pose vulnerability to coastal habitats and communities. The degree of vulnerability of coastal habitats to air emissions would depend upon the amount of emissions as well as the duration. It is unlikely that routine operations from conventional and renewable energy or marine mineral activity would produce sufficient air emissions to pose a threat to coastal habitats and communities. Air emissions are likely to dissipate quickly, and teasing apart the contribution from BOEM's routine activities from the background air emissions would be technically quite difficult if not impossible.

The combustion of fossil fuels during operations, as well as the consumption of the oil and gas derived from the OCS, release nitrogen, sulfur, and carbon compounds into the atmosphere. In the form of nitrogen, sulfur, and carbon oxides and ammonia, these chemicals can disrupt the chemistry of coastal soils and surface waters, leading to acidification and reduced total alkalinity. Coastal ocean acidification can affect coastal communities (e.g., oysters, corals, and zooplankton). In addition to altering local pH, atmospheric deposition of sulfur and nitrogen oxides enhance nutrient loads in coastal ecosystems, causing eutrophication and potentially leading to algae blooms (Paerl 1997). Atmospheric nitrogen deposition may account for up to 40 percent of new nitrogen inputs in coastal systems (Paerl et al. 2002). These impacts may be compounded by nutrient pollution (refer to the "Discharges and Wastes" section in **Chapter 4.2.2**).

Elevated concentrations of carbon dioxide in the atmosphere, including anthropogenic sources, may act as a fertilizer and stimulate plant production, although the response is variable and influenced by local environmental factors. In coastal vegetation, increased carbon dioxide may enhance growth in C3 type coastal vegetation (e.g., mangroves and brackish and freshwater wetlands) by stimulating higher rates of photosynthesis (as reviewed in Kirwan and Megonigal 2013). In C4 type dominated wetlands (e.g., *Spartina*, a dominant saltmarsh grass in the Gulf of Mexico), higher concentrations of carbon dioxide do not affect photosynthesis. These findings are largely based on laboratory and microcosm experiments, and it is difficult to predict long-term consequences of elevated carbon dioxide concentrations on coastal vegetation, especially given the complex interactions with accompanying consequences of elevated carbon dioxide, namely rising temperatures and sea levels.

4.2.7 Lighting and Visual Impacts

Artificial light sources on the Gulf Coast are prevalent. It is unlikely that consequences of OCS-related light pollution can be teased apart from the background levels of light pollution along this industrialized coastline. Therefore, the threat posed by lighting and visual impacts to coastal and estuarine habitats is low. Beachfront lighting deters sea turtles from coming onto beaches to nest and disorients hatchlings (**Chapter 4.6**). Lights attract birds and insects that forage and migrate at night, resulting in substantial mortality from collisions with structures in the vicinity of lights (**Chapter 4.8**). Shore-based lighting may also affect predator-prey interactions of coastal fish species (Bolton et al. 2017; **Chapter 4.5**).

4.2.8 Accidental Events

4.2.8.1 Accidental Spills

Both coastal and offshore oil spills can be caused by large tropical storm events, faulty equipment, or human error. The distance from shore of OCS oil- and gas-related activity reduces the probability of unweathered oil reaching coastal wetlands. The OCS production facilities are located at least 3 nmi (3.5 mi; 5.6 km) from coastal wetlands, and much of the OCS oil- and gas-related activity is much farther out to sea. This allows for the toxicity of spilled oil from offshore to be greatly reduced or eliminated by weathering and biodegradation before it reaches the coast (OSAT-2 2011). Nonetheless, accidental spills are reasonably foreseeable, and coastal and estuarine habitats may be vulnerable to these incidents. The degree of coastal impact is a function of many factors, including the source oil type, volume, and condition of the oil as it reaches shore, along with the season of the spill and the composition of the wetland plant community affected. The greatest threat to estuarine habitat with regards to an oil spill is from a coastal spill resulting from a vessel accident or pipeline rupture. These spills are a concern since they would be much closer to the estuarine resources, and pipeline accidents could result in high concentrations of oil directly contacting localized areas of wetland habitats (Fischel et al. 1989). Refer to BOEM's *Gulf of Mexico Catastrophic Spill Event Analysis* technical report for an analysis of impacts from a low-probability, catastrophic spill event (BOEM 2021).

Coastal and estuarine habitats can be indirectly and directly impacted by releases into the environment (e.g., oil spills). These impacts are complex and can vary in intensity based on several interrelated factors, including oil type, time of year, and specific habitat characteristics such as porosity. The NOAA created the Environmental Sensitivity Index (ESI) to assess the risk posed to coastal habitats in the event of a nearby oil spill. The ESI ranks shorelines according to their sensitivity to oil, the natural persistence of oil, and the expected ease of clean up after an oil spill. These factors affect the impacts of oil spills in coastal and estuarine areas. Based on the ESI, marshes, mangroves, and swamps are the most sensitive shoreline habitats to oiling as oil tends to persist in these areas and are difficult to clean (MMS 2010; NOAA 2020d). The GOM shoreline is dominated by marshes and wetlands, making it highly sensitive to oil spills. Intertidal habitat vulnerability is generally highest for vegetated wetlands (Hayes et al. 1992; NOAA 2010), as well as semipermeable substrates that have low wave energy and high tidal currents. Barrier island loss due to hurricanes and anthropogenic factors has reduced protection of wetlands from offshore oil spills; this loss has increased the potential for the oiling of coastal wetlands during an accidental event.

Oil that impacts wetlands or submerged aquatic vegetation would result in substantive injury to vegetation, plant mortality, and some permanent wetland loss. Oil that impacts beaches would thicken as its volatile components are degraded and forms tar balls or aggregations that incorporate sand, shell, and other materials. Completely submerged seagrasses are less susceptible to oil spills as they largely avoid direct contact with the oil pollutant (U.S. Department of the Navy 2018). Releases into the environment (e.g., spilled oil) could result in loss of ecosystem function, physical ecosystem structure, and functional and structural value loss, as well as loss of recreational opportunities and value. Depending on the location of the spill, protected areas (i.e., national parks, national wildlife refuges, national marine sanctuaries, and national estuaries) could be at risk as well.

The short-term effects of oil on wetland plants range from reduction in transpiration and carbon fixation to plant mortality. Due to the difference in oil tolerances of various wetland plants, changes in species composition may be evident as a secondary impact of the spill (Pezeshki et al. 2000). Oil can indirectly affect animals that rely on submerged aquatic vegetation and wetlands during their lifecycles, especially benthic organisms that reside in the sediments and comprise an important component of the food web. Habitat degradation could persist and have long-term residual impacts on species' populations, community structure, and habitat function, resulting in loss of ecosystem function, value, and physical ecosystem structure. Depletion of marsh vegetation following a spill may increase and accelerate erosion, resulting in land loss (Alexander and Webb Jr. 1987; Fischel et al. 1989; McClenachan et al. 2013; Silliman et al. 2012; Turner et al. 2016). This could increase coastal vulnerability to storms and sea-level rise, potentially impacting tourism, recreation, and environmental value.

Mangroves, which occur on the coasts of Florida, Louisiana, and parts of Texas, are also highly vulnerable to oil spills (Duke and Burns 2003; Duke et al. 1999; Hensel et al. 2014; Hinwood et al. 1994). Oil can coat breathing surfaces of the mangroves, which kills shorter plants and animals within days. Symptoms of chronic impacts from oil spills include the death of trees with seedling regeneration, defoliation and canopy thinning, leaf yellowing, reduced height growth for surviving trees, and poor seedling establishment (Duke et al. 1997; Hensel et al. 2014; Lewis et al. 2011). Toxic response deformities and morphological changes may also occur after oil exposure, including pneumatophore branching (Duke et al. 2005), reduced lenticel numbers (Böer 1993), and genetic mutations like variegated leaves and chlorophyll-deficient propagules (Duke and Watkinson 2002). These effects could result in loss of ecosystem function and structure, as well as loss of recreational opportunities and value.

While oil can completely foul wetland plants, it is the amount and type of oil, as well as the particular plant type that determines recovery. Data indicate that vegetation that is lightly oiled would experience plant die-back, followed by recovery without replanting; therefore, most impacts from light oiling to vegetation are considered to be short term and reversible (Lytle 1975; DeLaune et al. 1979; Webb et al. 1985). In a study of a coastal pipeline break by Mendelssohn et al. (1993), a 300-bbl spill of Louisiana crude oil impacted 49 ac (20 ha) of wetlands, resulting in considerable short-term effects on the brackish marsh community. While considerable die out of the marsh was noted, recovery of the marsh was complete within 5 years despite the residual hydrocarbons that were found in the marsh sediment. Different species of plants respond differently to oiling (Delaune and Wright 2011). Pezeshki et al. (2000) found that Louisiana crude oil was less damaging and fatal to *Spartina alterniflora* marsh grass than the heavier crudes. Heavy oiling can stop photosynthetic activity, but the *S. alterniflora* produced additional leaves and was able to recover without shoreline cleanup. Lin and Mendelssohn (1996) found that Louisiana crude oil applied to three species of marsh plants resulted in no regrowth after 1 year in applications for *Spartina alterniflora* and *S. patens* but resulted in increased regrowth with increased oil application for *Sagittaria lancifolia*. Kokaly et al. (2011) found that, where the predominant marsh grass is tall (*Phragmites australis*) and less susceptible to being completely oiled, damage is minimized. Judy et al. (2014) also found high tolerance of *P. australis* to weathered and emulsified oil.

Oil has been found or estimated to persist for at least 17-20 years in low-energy environments like salt marshes (Teal et al. 1992; Baker et al. 1993; Burns et al. 1993; Irvine 2000). If thick oil is deposited on marsh in low-energy environments, effects on marsh vegetation can be severe and recovery can take decades (Baca et al. 1987; Baker et al. 1993). The sediment type, anoxic condition of the soils, and whether the area is in a low- or high-energy environment all play a part in the persistence of oil in marsh sediment (Teal and Howarth 1984); thus, different shorelines exhibit varying levels of oil persistence (Hayes et al. 1980; Irvine 2000). Oil is more persistent in anoxic sediments and, as a result of this longer residence time, has the potential to do damage to both marsh vegetation and associated benthic species. Batubara et al. (2014) found that PAH degradation is higher in intertidal than in subtidal wetland soils. The same is true for submerged vegetation; oil can cause decreased water clarity from coating, and shading could cause reduced chlorophyll production and could lead to a decrease in vegetation (Erftemeijer and Lewis 2006).

4.2.8.2 Spill Response

Response activities in coastal habitats include boom placement adjacent to shorelines to prevent oil from reaching shorelines; barrier berms, flushing salt marshes with water; cutting and raking vegetation; raking heavy oil deposits from soil surfaces; and placing loose sorbent materials. The use of nearshore booming protection for beaches and wetlands could also help to reduce oiling of these resources, if done correctly. However, booms deployed adjacent to marsh shorelines can be lifted by wave action onto marsh vegetation, resulting in plant mortality under the displaced booms. After the *Deepwater Horizon* explosion and oil spill, the use of barriers such as booms and sand berms did not work as well as planned (Martinez et al. 2012; Jones and Davis 2011; Zengel and Michel 2013). Physical prevention methods such as booms, barrier berms, and diversions can alter hydrology, specifically changing salinity and water clarity. These changes could cause mortality or reduced productivity in certain species of submerged vegetation because the species are only tolerant to certain salinities and light levels (Zieman et al. 1984; Kenworthy and Fonesca 1996; Frazer et al. 2006). Close monitoring and restrictions on the use of bottom-disturbing equipment would be needed to avoid or minimize those impacts.

Oil-spill cleanup in coastal marshes remains an issue because wetlands and submerged vegetation can be extremely sensitive to the disturbances associated with cleanup activities. While a resulting slick may cause impacts to estuarine habitat, the cleanup effort (i.e., equipment, chemicals, and personnel) can generate additional impacts to the area. Oiled marshes may incur secondary impacts associated with the cleanup process, such as trampling vegetation, accelerating erosion, and burying or mixing oil into marsh soils (Zengel et al. 2015; Long and Vandermeulen 1983; Mendelssohn et al. 1993). Associated foot and vehicular traffic may work oil farther into the sediment than would otherwise occur. Cleanup activities in marshes may last years to decades following a spill and may accelerate erosion rates and retard recovery rates. Some dominant freshwater marsh species (*Sagittaria lancifolia*) are tolerant to oil fouling and may recover without being cleaned (Lin and Mendelssohn 1996). For smaller oil spills, it may be prudent to allow wetland areas to recover naturally (Zengel et al. 2014). This is especially effective in marshes with adequate tides where natural tidal flushing can naturally reduce oil concentrations (Kiesling et al. 1988). In areas of thick oil deposits, however, a cleanup effort would result in greater recovery (Baker et al. 1993). Heavily oiled, untreated marsh areas showed negative effects on the vegetation, intertidal communities, and erosion tendency compared to the control (Beyer et al. 2016).

Oil-spill response may damage sand beaches. Sand beaches provide several key services as a habitat, including sediment storage and transport, wave dissipation and buffering during storms, scenic vistas and recreation, groundwater filtration, nutrient mineralization and recycling, maintenance of biodiversity and genetic resources, carbon transfer, and functional links between terrestrial and marine environments (Defeo and McLachlan 2005). Shoreline cleanup actions to address oiling of beaches can alter and/or diminish these services. Cleanup activities can require extensive and prolonged uses of mechanical and manual treatments. Most mechanical beach cleanup activities occur in the supratidal zone, where wrack commonly accumulates, which supports a community of up to 40 percent of intertidal species and supports important prey resources for higher trophic levels (Dugan et al. 2003). The intertidal zone comprises a much higher invertebrate biomass than the supratidal zone (Raffaelli et al. 1991; Colombini and Chelazzi 2003; Janssen and Mulder 2005). These intertidal species are considered tolerant to disturbances due to their adaptation to a dynamic environment. Despite their high tolerance, these fauna can be directly and indirectly impacted by spill response cleanup activities. Intertidal fauna are directly impacted by crushing, which can result in mortality, and desiccation during sediment shifting and removal. Intertidal fauna are indirectly impacted by response activities through alteration of the habitat and its suitability, reproduction disruption, and food supply removal (Michel et al. 2017).

4.2.8.3 Marine Trash and Debris

Trash and debris from offshore and onshore facilities and vessels may pollute coastal and estuarine habitats. Fauna, such as birds, marine mammals, and fish, may become entangled in objects or may ingest them. As items degrade they may further release contaminants in the environment, including organic pollutants and microplastics.

4.2.8.4 Collisions and Strikes

Ship strikes to coastal and estuarine environments are not reasonably foreseeable. Should they occur, the damages would be similar to those discussed in **Chapter 4.2.4**, Coastal Land Disturbance. If a ship were to run aground in a coastal environment, an accidental spill may occur (**Chapter 4.2.8.1**).

4.3 Pelagic Habitats

4.3.1 Noise

Several noise sources could potentially interact with pelagic habitats and associated communities in the GOM and are produced by either active acoustics (e.g., seismic surveying) or vessels and equipment. Noise has the potential to alter the soundscape in the pelagic zone (refer to **Chapter 3.3** for more information about pelagic soundscapes). A soundscape is the combination of biological, physical, and anthropogenic sounds in a landscape, which can temporally and spatially vary within a habitat. The physical structure of the habitat naturally impacts underwater soundscapes (e.g., bays, basins, canyons), seafloor type (e.g., hard bottom and soft bottom), and intermittent geologic activity (e.g., underwater earthquakes, volcanoes, and mudslides). The daily movements of animals in and out of habitats in response to tidal and light cycles can alter the natural soundscape. Finally, seasonal changes can occur in response to weather patterns, tidal magnitudes, and local human activity (e.g., recreation, fishing, and shipping), which can alter the distribution and abundance of different organisms in an area. Anthropogenic sound sources could change the signature (i.e., original) soundscapes of habitat, and the impacts of this depend on the type of sound produced (e.g., high frequency and low frequency), proximity to the source, and a variety of anatomical and behavioral factors that pertain to individual animals groups found in pelagic habitats. Soundscapes are essential to several biological functions, including communication, reproduction, predator avoidance, prey identification, and larval settlement in many marine organisms. As such, anthropogenic noise introduced into pelagic habitats may mask sounds needed for these critical behaviors. Refer to **Chapter 4.7.1** for information on the effects of noise (including masking) on marine mammals, **Chapter 4.6.1** for information on the impacts of noise on sea turtles, and **Chapter 4.5.1** for fish and invertebrates.

4.3.1.1 Active Acoustics

The low-frequency underwater noise created by active acoustic noise sources (e.g., airguns and subbottom profilers) can affect the hearing and sound reception of organisms associated with pelagic habitats (McQueen et al. 2020). Airguns are the only noise source capable of carrying impacts throughout the water column to deep water, including the abyssopelagic zone. Seismic surveying could cause body malformations in planktonic organisms post-exposure (de Soto et al. 2013). Most of the work on noise impacts to plankton has been done on relatively small spatial scales (i.e., 10s of meters) and has shown minimal effects at these short distances (Booman et al. 1996; Dalen et al. 2007; Holliday et al. 1987; Kostyuchenko 1973; Pearson et al. 1994). McCauley et al. (2017) observed an elevated mortality rate in zooplankton after exposure to seismic airguns at larger distances (>3,280 ft; 1,000 m); however, Richardson et al. (2017) modeled that, despite a spike in the mortality rate, zooplankton would recover quickly due to rapid turnover and natural mixing. The impact zone from airgun surveying can overlap with pelagic habitats also occupied by marine mammals, sea turtles, fish and invertebrates, and diving seabirds. For more information on the impacts of active acoustics on these resources, refer to **Chapter 4.5.1** (fish and invertebrates), **Chapter 4.6.1** (sea turtles), **Chapter 4.7.1** (marine mammals), and **Chapter 4.8.1** (birds). Given the vastness of suitable pelagic areas for sea turtles, marine mammals, fish and invertebrates, and seabirds as well as the mobility of these species, it is likely these organisms could displace to other suitable areas not impacted by geological and geophysical surveying (i.e., active acoustics).

4.3.1.2 Vessel and Equipment Noise

Vessels (i.e., semisubmersibles, drillships, heavy lift vessels, and crew and supply vessels) contribute to anthropogenic noise in pelagic habitats. Other equipment noises could be added from construction activities (e.g., pile-driving), drilling, dredging, and decommissioning activities (e.g., explosives). These noise sources can impact the soundscape of pelagic habitats with the potential to impact the abundance and distribution of pelagic organisms throughout the GOM. These noise sources can also lead to direct and indirect impacts on pelagic organisms. For example, some fish larvae use acoustic signals to maintain group cohesion (Staaterman et al. 2014) or to navigate towards appropriate settlement habitat (Montgomery and Coombs 2011; Montgomery et al. 2006; Radford et al. 2011; Simpson et al. 2005). High-intensity noises (e.g., explosives) possibly cause irreversible damage to the internal anatomy and physiology of planktonic organisms if they are close to the sound source (Govoni et al. 2003; Govoni et al. 2008), but most work on noise impacts to plankton has been done on a small scale (Bolle et al. 2012; Govoni et al. 2008).

4.3.2 Discharges and Wastes

Elevated turbidity from routine discharges and wastes can reduce the amount of light available for photosynthesis by phytoplankton and could impair feeding opportunities for visual-foraging zooplankton (e.g., larval fish). Additionally, suspended material in the water can clog and damage appendages and feeding structures on some zooplankton species (Wilber and Clarke 2001; Kjelland et al. 2015). However, the impacts from this increased turbidity would be localized and short term due to dilution, thus not likely to cause a population-level impact on pelagic communities or habitat degradation to the GOM pelagic zone. For more information on the effects of discharges and wastes, refer to **Chapter 4.5.2** (fish and invertebrates), **Chapter 4.6.2** (sea turtles), **Chapter 4.7.2** (marine mammals), and **Chapter 4.8.2** (birds).

Impacts on pelagic communities and habitat are not expected to negatively affect GOM pelagic habitat function or use by marine biota as all operational discharges and wastes are regulated. The USEPA and USCG regulate produced water, drilling muds, and cuttings releases to keep contaminants below harmful levels. These, along with sanitary wastes, gray water, and miscellaneous discharges, are not expected to persist in the water column. Drilling muds released into the water column do not increase to high concentrations and only affect a small area of water (Neff 2005). Most mud cuttings settle rapidly to the seafloor and only around the drill site (area dependent on drilling depth and mud line cellar size). Impacts on water quality are localized and transient, thus unlikely to have lasting effects on pelagic habitats and associated communities. It is also assumed that operators on the OCS will adhere to additional BSEE regulations and BOEM guidance, as well as the USEPA (via the NPDES permits) and USCG regulations.

4.3.3 Bottom Disturbance

Bottom-disturbing activities can lead to resuspension of particulate matter and increased turbidity in the surrounding water column. The effects of turbidity on pelagic habitats and associated communities are discussed in **Chapter 4.3.5**. Otherwise, bottom disturbance from BOEM-regulated activity occurs on the seafloor, which is not considered pelagic habitat. For more information on the effects of bottom disturbance on benthic habitat and associated communities, refer to **Chapter 4.4.5**.

4.3.4 Coastal Land Disturbance

Coastal land disturbance from BOEM-regulated activity occurs in coastal waters and, therefore, not in pelagic habitat. For more information on the effects of coastal land disturbance on coastal habitat and associated communities, refer to **Chapter 4.2.4**.

4.3.5 Offshore Habitat Modification

The emplacement of platforms for BOEM-regulated activities in GOM pelagic habitats has long-term impacts as they remain in the water column for up to several decades. During this time, platforms can become ecologically important artificial reefs and support higher biodiversity than surrounding open waters. This habitat alteration exists in a habitat that would otherwise have no vertical structures. In areas where the water bottom is mostly soft sediment, installed platforms create the opportunity for hard bottom habitats to exist. These structures can attract sea turtles, marine mammals, and seabirds likely by providing foraging opportunities (Lohoefener et al. 1990; Gitschlag et al. 1997; Ronconi et al. 2014; Todd et al. 2020). Refer to **Chapters 4.6.5**, **4.7.5, and 4.8.5**, respectively, for more information on offshore habitat modification impacts on these resources.

Fish and invertebrates are also attracted to structural habitats. The large-scale introduction of platforms in the pelagic GOM waters has created a network of artificial reefs that attract and enhance the production of pelagic species of fish (Franks 2000; Franks et al. 2015; Gallaway et al. 2019). One study found indirect evidence of the potential spawning, nursery, and recruitment habitat provided by platforms (Shaw et al. 2002). Moreover, the predominant taxa of post-larval and juvenile fishes collected down current of platforms are primarily represented by pelagic species and pre-settlement stages of soft-bottom taxa, which may be taking advantage of the high zooplankton and ichthyofauna concentrations near the platforms (Shaw et al. 2002). These organisms are likely attracted to the light field or the structure provided by the platforms in an otherwise barren underwater landscape (refer to **Chapter 4.5.7** for more information on visual and lighting impacts on fish and invertebrates).

Drill spudding, offshore infrastructure emplacement, structure or pipeline removal, the OCS Marine Minerals Program, and OCS sand borrowing activities individually create short-term turbidity plumes. Still, cumulatively these effects can be present long term in pelagic habitats. Sand from the OCS borrowing activities would create lesser turbidity in the water column because sand is heavier than silt or clay, and thus could sink to the seafloor. Turbidity is a reduction in water clarity due to the resuspension of seafloor particles. Turbidity in the water column can impact the planktonic communities of pelagic habitats. Suspended particles can reduce light penetration, making it more difficult for photosynthesis to occur (Grobbelaar 2009). This effect would likely happen in shallow, coastal waters where resuspension from bottom-disturbing activities could reach the photic zone (0-656 ft; 0-200 m). A reduction in phytoplankton would cascade into a decline of the zooplankton that feed on them. This decline can have downstream effects on fish and invertebrate species (Fiksen 2002). Turbidity effects would occur in the bottom waters surrounding the activity area (BOEM 2011).

Vessel traffic in pelagic waters could also affect pelagic communities. Vessels transiting through the area may increase local circulation and turbulence (e.g., ship wake), which could cause mortality or injury to some planktonic organisms nearby. These local disturbances are not likely to cause major impacts as planktonic abundance is naturally high, as well as the localized and small-scale nature of ship wake. Vessel traffic can also impact larger pelagic organisms; for more information on the effects on and fish and invertebrates, sea turtles, marine mammals, and birds, refer to **Chapters 4.5, 4.6, 4.7, and 4.8**, respectively.

4.3.6 Air Emissions

All air emissions as a result of BOEM-regulated activities are permitted and regulated to a point that both onshore and offshore releases are unlikely to pose risk to pelagic communities and habitats. The Clean Air Act established the NAAQS for specified pollutants (42 U.S.C. §§ 7401 *et seq*.). As required by the OCSLA, BOEM assesses these in relation to oil and gas development projects, as well as volatile organic compounds to the extent that activities significantly affect the air quality of any State. BOEM-regulated activities release air emissions from sources related to drilling and production via vessels, flaring and venting, decommissioning, fugitive emissions, and oil spills.

Transport and dispersion processes via prevailing wind circulations immediately begin to circulate pollutants when released. Dispersion depends on several factors, including emission height, atmospheric stability, mixing height (i.e., the height above the surface through which vigorous vertical mixing occurs), exhaust gas temperature and velocity, and wind speed. The mixing height is important because it dictates the vertical space available for spreading the pollutants. Mixing height information in the GOM is scarce, but measurements near Panama City, Florida (Hsu et al. 1980) found that the mixing height can vary between 1,312 and 4,265 ft (400 and 1,300 m), with a mean of 2,953 ft (900 m).

Heat flux calculations in the WPA (Barber et al. 1988; Han and Park 1988) indicate an upward flux year-round – highest during winter and lowest in summer.

Air emissions from BOEM-regulated activity occur above the sea surface but could indirectly impact pelagic waters through the absorption of CO_2. Emissions resulting from routine OCS oil- and gas-related activities are not anticipated to reach a level that would affect GOM pelagic habitat function or use by marine biota as these emissions are regulated and localized, and air pollution would dissipate quickly.

4.3.7 Lighting and Visual Impacts

Lighting as a result of BOEM-regulated activities has effects on phototactic organisms (e.g., dinoflagellates) and can attract such organisms to sources of lights (e.g., platform lighting). This alteration of the natural light field could lead to a higher abundance of such organisms around offshore platforms and increased ability to see and hunt prey. One study found that the type of lighting used can affect the amount of light that can reach deeper in the water column. LED lighting with a stronger blue component was found to reach the deepest (Tamir et al. 2017). The irradiance of lighting is also an important factor as some artificial lighting is equal to or exceeds the irradiance of a full moon. Nighttime light pollution caused by such artificial lighting could interfere with the biological functions of marine organisms that are synchronized with moon phases, including diurnal-based feeding patterns exhibited by pelagic organisms and demersal plankton (Tamir et al. 2017). Zooplankton diurnally vertically migrate through the water column to reduce predation risk based on light intensity (Gliwicz 1986; Cohen and Forward 2009), and artificial lighting can disturb this activity (Moore et al. 2000; Depledge et al. 2010; Davies et al. 2014). Negative impacts on the planktonic community in pelagic habitats can have cascading effects on the food web. Further, the consumption of phytoplankton by the migrating zooplankton higher in the water column and the subsequent defecation of fecal pellets lower in the water column (Cohen and Forward Jr. 2009; Hays 2003) is a major carbon cycle pathway in marine environments (Davies et al. 2014).

4.3.8 Accidental Events

Several accidental events can occur on the Gulf of Mexico OCS from BOEM-regulated activities. These include oil and chemical spills, oil-spill response, accidental collisions, vessel strikes, and marine trash and debris. Pelagic habitat and associated communities are vulnerable to oil and chemical spills and oil-spill response. The pelagic habitat itself is not vulnerable to accidental collisions or vessel strikes; instead, marine organisms in the pelagic communities are vulnerable. For more information about these vulnerabilities and the potential effects on fish and invertebrates, sea turtles, marine mammals, and birds, refer to **Chapters 4.5.8**, **4.6.8**, **4.7.8, and 4.8.8**, respectively.

4.3.8.1 Spills

Accidental surface releases of oil from platforms or vessels, or seafloor releases from pipelines or wellheads could affect pelagic habitats. Habitat quality, as well as local ecosystem functions, would be temporally reduced. Impacts from accidental small spills are expected to be short term due to dilution and hydrocarbon breakdown. Long-term degradation of pelagic habitats from an accidental spill is not expected. Upper water column and sea surface spilled oil could enter the epipelagic food web and reduce zooplankton that graze on phytoplankton, causing phytoplankton blooms (Fisher et al. 2016). These blooms could have indirect impacts on fish and invertebrates, marine mammals, sea turtles, and birds.

4.3.8.2 Oil-Spill Response

Burning, skimming, and chemical dispersants or coagulants can affect pelagic habitats and associated communities, including *Sargassum*, sea turtles, marine mammals, and sea surface fishes (e.g., flying fishes). Burning could kill pelagic biota in the activity area. Skimming could remove pelagic biota from the activity area or trap them in oiled water (BOEM 2011). These cleanup processes could also trap and destroy patches of *Sargassum*; however, these patches would likely already by destroyed by oil contamination even if the response activities were absent.

Though unlikely to be used on smaller spills, dispersants could also affect pelagic habitats and associated communities in the water column. Chemicals used during an oil-spill response are toxic, though less toxic than spilled oil (Hemmer et al. 2011; NRC 2005b), and their toxicity varies by dispersant type as well as varying levels of toxicity among species (CDC 2010; Fingas and DeCola 2017). There is controversy about whether the combination of oil and dispersants is more toxic than oil alone (Fingas and DeCola 2017; Kolak 2011; NRC 2005b). Post-*Deepwater Horizon*, many lab-based studies sought to determine the toxicity of oil, dispersed oil, and dispersants. However, due to a lack of consistency in the media preparation, exposure procedures, and chemical analyses (NRC 2005), researchers have been unable to determine a comprehensive conclusion on the toxicity of oil and dispersants. The National Academy of Sciences published guidance on how to address these inconsistencies in future research to address the controversy over the toxicity of chemically dispersed oils (National Academies of Sciences Engineering and Medicine 2020). Dispersants blend with oil, thus mimicking impacts of an oiled area, and can likely increase the areal extent of oil dispersion and subsequent exposure to pelagic communities (BOEM 2011). For more information about dispersant impacts on fish, sea turtles, marine mammals, and birds, refer to **Chapters 4.5.8.2, 4.6.8.2, 4.7.8.2, and 4.8.8.2**, respectively.

4.3.8.3 Marine Trash and Debris

MARPOL and other regulations regulate marine trash and debris. However, the accidental release of marine debris could occur. Losses of large quantities of debris are rare, but losses of smaller pieces might happen. Floating debris is subject to the same oceanographic processes that influence and move *Sargassum* mats, which can lead to marine trash and debris rafting together with *Sargassum*. This overlap may have little impact on the plants themselves but can impact the associated organisms. Given the lack of stationary GOM gyres, marine trash and debris are not expected to remain long enough in contact with the mats to undergo degradation. Some could be advected within the Gulf Stream and carried to the mid-Atlantic, where it could undergo degradation.

4.3.8.4 Collisions and Strikes

Vessel strikes could occur with *Sargassum* mats and associated communities. *Sargassum* would either encounter the vessel hull or the propulsion systems, possibly resulting in breaking up the mat into smaller pieces, death of the *Sargassum* plants, or dislodging or death of epiphytic organisms or organisms living near the mats. Impacts would only occur if the strike happened while the vessel was traveling at high speeds. If individual plants are broken into moderately sized pieces, it is expected that the plants would continue to grow as multiple separate entities. Organisms that survived dislodgement from the mat are expected to return to the mat once the vessel passes.

4.4 Benthic Habitats and Communities

4.4.1 Noise

There are many sources of both natural and anthropogenic noise in the marine environment. Noise in the marine benthic environment may be propagated directly, within seafloor sediments, or indirectly, through the water column. It is likely that acoustic vibration is important for mobile benthic species to navigate, communicate, and find food (Roberts and Elliott 2017). Sources of acoustic vibration within marine sediments related to the oil and gas industry include drilling, infrastructure construction and installation, pile driving, and seismic and high-resolution geophysical surveys.

A review of current literature on the potential vulnerability from noise (mechanical vibrations) indicates that most of the research on the subject to date is associated with installation and operation of offshore wind turbines – an activity not expected to occur in the Gulf of Mexico in the immediate future. The impact of noise on benthic habitats has not been studied in the Gulf of Mexico OCS or in deep water.

Laboratory analyses of the vulnerability of benthic marine invertebrates to both continuous and impulsive broadband noise has been conducted for several invertebrate species. Evidence indicates that marine intertidal hermit crabs (*Pagurus bernhardus L.*) (Roberts et al. 2016b), the venus clam (*Ruditapes philippinarum*), the Norway lobster (*Nephrops norvegicus*), and a species of brittlestar (*Amphiura filiformis*) (Solan et al. 2016), in response to sound propagation within sediments, can alter behaviors important to ecosystem functioning. This is likely due to mechanical particle motion as opposed to the pressure component of acoustic waves (Roberts et al. 2016). Evidence also suggests that some organisms are capable of physiological and/or behavioral acclimation to variable acoustic impacts. Their capability to do so may be moderated by attributes at the level of the individual, including exposure history, environmental context, and physiological condition. Though species may persist within a soundscape, they may be subject to functional, fitness, and ecological stress (Solan et al. 2016) though it is still unclear whether these impacts are short- or long-term or have translatable community or population impacts (Roberts and Elliott 2017).

There is currently no evidence that shallow-water benthic communities are vulnerable to 3D seismic geophysical survey. A pre- and post-survey monitoring study of scleractinian corals at eight sites detected no effect to coral mortality, skeletal damage, or other visible signs of stress (Heyward et al. 2018). Differences in local environment, water depth, community structure, and potential survey parameters make it difficult to extrapolate these findings to the breadth of benthic habitats throughout the Gulf of Mexico.

4.4.2 Operational Discharges and Wastes

Toxic discharges from oil and gas industry activities are managed through the NPDES permitting process or MARPOL Annex V Treaty. Enforcement of the relevant laws and regulations is conducted by several Federal agencies, including the USEPA, NOAA, BSEE, and USGS. For the purpose of this analysis, compliance with these laws and regulations is assumed.

4.4.2.1 Drilling Discharges

Drilling operations have the capacity to deposit up to 2,000 metric tons of combined muds and cuttings and drilling fluid onto the seafloor (Neff 2005). The spatial footprint of discharge varies with discharge volume, water depth, local hydrography, sediment particle size distribution, settlement rate, floc formation, and time (Neff 2005; Niu et al. 2009). Cuttings discharged at the sea surface tend to disperse in the water column and be distributed at low concentrations (CSA 2004b). In deep water, most cuttings discharged at the sea surface are likely to be deposited within 250 m (820 ft) of the well (CSA 2006), although ecological changes have been observed within 300 m (984 ft) and up to 1-2 km (0.6-1.2 mi) for especially sensitive species (summarized in Cordes et al. 2016). Cuttings shunted to the seafloor form sediment piles with a generally smaller surface area than those formed from sea-surface discharge (Neff 2005).

Operational discharges from drilling can bury and/or smother benthic habitat and associated organisms. Habitat and organisms most vulnerable to impacts from muds and cuttings are those in low-energy environments within a few hundred meters of the wellsite. Cuttings may form resistant mounds on which distinctive fauna characterized by mobile predators may develop (Lissner et al. 1991). At a wellsite in the Faroe-Shetland Channel, smothering of the seabed from a radius of 50-120 m (164-394 ft) resulted in a reduction of megafaunal abundance of up to 92.3 percent and reduction in diversity between disturbed and undisturbed areas was apparent. Motility was inversely proportional to mortality (Jones et al. 2006). The vulnerability of sessile organisms to impacts from drilling discharges is directly related to levels of suspended solids and the organisms' ability to clear particles from feeding and respiratory surfaces (Rogers 1990). Coverage with discharged sediments as low as 3 mm (0.12 in) can cause detectable impacts to infauna (Schaanning et al. 2008).

The chemical content of drilling muds and cuttings, and to a lesser extent produced waters, may contain hydrocarbons, trace metals including heavy metals, elemental sulphur, and radionuclides (Kendall and Rainey 1991; Trefry et al. 1995). Undiluted heavy metals and toxic compounds have the potential to be moderately toxic to benthic organisms (CSA 2004a). Sediment infauna have shown effects from toxins at less than 100 m (330 ft) from discharge locations, including reduced reproductive fitness, altered populations, and acute toxicity (Carr et al. 1996; Chapman et al. 1991; CSA 2004a; Hart et al. 1989; Kennicutt II et al. 1996; Montagna and Harper Jr. 1996).

Produced waters dilute rapidly with distance from the source; impacts are generally only observed within very close proximity to the source (Gittings et al. 1992; Neff 2005). The exposure of warm-water coral species to drilling fluid may result in reduced viability, morphological changes, altered feeding behavior, altered physiology, or disruption to the pattern of polyp expansion (summarized in Freiwold et al. 2004).

4.4.2.2 Dredge Spoil

Typically dredge spoil materials are disposed at established dredge material disposal areas permitted by the Corps of Engineers, USEPA, and relevant State agencies. Dredged sediments could smother benthic communities in or near a disposal site (Bishop et al. 2006). Benthic communities within permitted dredge spoil areas may suffer reduced survival, fecundity, and growth; reduced community abundance; and reduced species richness.

4.4.3 Bottom Disturbance

4.4.3.1 Physical Disturbance

The physical disturbance of the seafloor may result in the destruction of sessile benthic organisms and hard bottom and/or chemosynthetic habitat and soft sediment turbation. Impacts that cause bottom disturbance may be temporary (e.g., anchoring) or more persistent within the environment (e.g., platform or pipeline installation). Potential effects from bottom disturbance may include crushing of hard substrates and structure-forming organisms including corals and sponges, burial of organisms, and scarring of the seafloor. The spatial extent of the seafloor disturbance would depend on the specific activity, local environmental conditions, and physical regime (e.g., water depth, bottom currents, light penetration, etc.) and local habitat and community composition, extent, and health. It is generally assumed that benthic communities associated with unconsolidated soft sediments will recover more quickly than those associated with hard bottom habitat (Dernie et al. 2003).

On average, 8-12 anchors are used for offshore oil and gas operations. The extent of the influence of direct impacts from infrastructure use and installation, including anchors and pipelines, is up to ~100 m (328 ft) (Cordes et al. 2016; Ulfsnes et al. 2013). The spatial extent of anchor impacts to the seafloor is typically between 1.5 and 2.5 times the local water depth (Vryhoff Anchors BV 2010).

The type of hard bottom habitat (e.g., topographic features, pinnacles, low-relief features, cold seeps, brine pools, etc.), individual features' sizes and surface areas, distance between features, community structure, species richness, and organism density, among other attributes coupled with the spatial scale and temporal duration of the bottom disturbance, influence the degree of impact and the ability of the local community to recover from the impact. For example, for patches of disturbed hard bottom habitat and organisms surrounded by unimpacted mature colonies of the same species, recolonization of the impacted area may occur relatively rapidly. If the disturbed patch is surrounded by solitary organisms, recovery may be slower and occur as a function of short-distance larval dispersal. Disturbed habitat that is isolated from undisturbed communities may take much longer to recover, with recolonization a function of long-range larval dispersal (Lissner et al. 1991). Anthropogenic bottom disturbance is often sufficient to cause loss of species diversity within benthic communities, particularly in the deep sea (summarized in Jones et al. 2006).

4.4.3.2 Sediment Suspension

Regardless of duration, bottom disturbance causes at a minimum localized, temporary resuspension of sediment (Morgan et al. 2006) and increased turbidity. Some mobile invertebrates may be able to move to avoid the heaviest sediment displacement and highest suspended sediment loads, while sessile invertebrates (e.g., corals and sponges) cannot. In shallow water, sediment particles can reduce light available for photosynthesis. In corals, heavy, chronic sedimentation is associated with fewer species, less live coral, lower growth rates, greater abundance of branching forms, reduced recruitment, decreased calcification, decreased net productivity, and slower rates of reef accretion (Rogers 1990). Sedimentation damage to reefs can have cascade effects on reef-associated species (Rogers 1990).

Increased turbidity can reduce feeding efficiency and clogging of filter-feeder structures and decrease the success of larval settlement (summarized in Lissner et al. 1991). The impact to filter feeders as a result of bottom disturbance and sediment suspension may result in preferential recolonization by epibenthic deposit feeders, resulting in an overall change of species composition (Jones et al. 2006). Sessile and mobile invertebrate species adapted to living in turbid environments, such as several tall and flexible gorgonian species, may be less affected by increased turbidity. Reduction in available geological or biogenic substrate may also have secondary ecological effects on organisms that use complex structural microhabitats to, for example, lay eggs (Etnoyer and Warrenchuk 2007; Shea et al. 2018).

4.4.4 Coastal Land Disturbance

Benthic habitats and communities are not vulnerable to coastal land disturbance because of the physical distance between the IPF and the resource. The vulnerabilities of coastal habitats to coastal land disturbance, including potential effects on coastal benthic habitats, is discussed in **Chapter 4.2.4**.

4.4.5 Offshore Habitat Modification

4.4.5.1 Mineral Dredging

Sand shoals represent significant sources of sand on the OCS for potential coastal beach nourishment and coastal stabilization projects. There is little research on the potential impacts to soft bottom benthic communities from sand dredging activities. Dubois et al. (2009) predict that sand extraction from significant sand shoals (e.g., Ship Shoal) in the northern Gulf of Mexico will cause a shift in species dominance to small, fast growing and reproducing species such as spionid polychaetes, which could, in turn, impact higher trophic levels. Mineral dredging also results in direct bottom disturbance and sediment suspension (refer to **Chapter 4.4.3**).

4.4.5.2 Artificial Reef Effect

Sessile benthic organisms commonly associated with OCS oil and gas structures are influenced by the presence of these structures. As of April 2019, there were ~1,862 oil and gas platforms in the Gulf of Mexico. The presence, removal, and/or conversion of artificial hard substrate colonized by sessile invertebrates is likely to result in localized community changes, such as changes in species diversity in the local area (Schroeder and Love 2004). Larvae originating from productive coastal waters, carried by regional water movement, may colonize throughout the lifespan of the rig (Sink et al. 2010). Scleractinian, octocoral, and antipatharian corals have colonized many offshore platforms in shallow water (up to 30 m [~100 ft] water depth) (Kolian et al. 2017). Colonization and growth of these organisms likely represent biomass production (Macreadie et al. 2011). Oil and gas platforms off California are among the most productive fish habitat (secondary production) per unit area of seafloor of all marine ecosystems (Claisse et al. 2014). Spatial distribution of these organisms may shift over time because of the presence or removal of infrastructure in otherwise soft bottom-dominated areas. A change in a species' spatial distributions may have potential long-term effects related to dispersal and genetic connectivity to other populations of said species. Evidence of these types of changes has been documented for some shallow-water hermatypic species (Sammarco et al. 2012); however, parallel research in deep water is lacking.

At the end of their use-life, operators are legally required to remove platforms; however, as of April 2018, 532 decommissioned oil and gas platforms have been reefed on the Gulf of Mexico OCS through BSEE's Rigs to Reef Program. A typical four-leg platform jacket provides 0.81-1.2 ha (2-3 ac) of surficial hard substrate that may be colonized by benthic organisms (BSEE 2016). Reefed platforms may enhance biological productivity and facilitate the conservation and/or restoration of benthic organisms by restricting access to other bottom-disturbing activities such as bottom trawling (Macreadie et al. 2011). Microalgae and nearly all invertebrate taxa (i.e., corals, anemones, hydroids, sponges, bivalves, mollusks, and polychaetes) have been observed on artificial reefs (summarized in Macreadie et al. 2011). Communities that develop on artificial substrate are often different than those on natural reefs (Burt et al. 2009). Over long distances, both operating platforms and reefs may act as "stepping stones" across areas with little to no natural hard substrate that act to increase connectivity with biogeographical consequences (summarized in Cordes et al. 2016). This may include increased genetic homogeneity and reduced opportunity for allopatric speciation (Macreadie et al. 2011).

Offshore oil and gas platforms are also a known vector for the movement of non-native and invasive species (Bax et al. 2003; Simons et al. 2016). In the Gulf of Mexico, the most common introduced benthic species are the cup coral *Tubastraea* sp., mussels, and a diademnid ascidian. Mussels have the greatest impact through fouling, clogging, competition with indigenous species, and disease transfer. The ascidian smothered and overgrew other established species (Sheehy and Vik 2010; Sink et al. 2010). *Tubastraea coccinea* has been reported on platforms along with indigenous coral species within 15 km (9.3 mi) of the Flower Garden Banks (Sammarco et al. 2004). *T. coccinea*, originally from the Pacific Ocean, is considered an invasive species in the Gulf of Mexico and prefers artificial to natural substrates, but at this time, it does not appear to threaten natural coral communities (Kolian et al. 2017).

4.4.6 Air Emissions

Benthic habitats on the OCS are not expected to be vulnerable to air emissions from BOEM-regulated activity because the emissions would be localized and would dissipate quickly. There is no evidence that benthic organisms are directly vulnerable to atmospheric deposition.

4.4.7 Lighting and Visual Impacts

Components of artificial light spectrum have been documented reaching the seafloor (Tamir et al. 2017); however, direct effects to benthic organisms in the Gulf of Mexico have not been evaluated. Biological processes of benthic organisms that may be negatively impacted by seafloor irradiance include circadian regulation, synchronization of coral spawning, recruitment and competition, vertical (diurnal) migration of demersal plankton, feeding patterns, and visual interactions (Tamir et al. 2017).

4.4.8 Accidental Events

4.4.8.1 Spills

The vulnerability of benthic habitats to an accidental release of oil or other contaminants would depend on the combination of several components: surface oil; subsurface oil; chemical dispersants and dispersed oil; sedimented oil (oil adsorbed to sediment particles); sedimentation caused by a loss of well control; and certain spill-response activities.

Sublethal impacts that may occur to exposed benthic organisms may include reduced feeding, reduced reproduction and growth, physical tissue damage, and altered behavior. For example, short-term, sublethal responses of a shallow-water coral species included mesenterial filament extrusion, extreme tissue contraction, tentacle retraction, and localized tissue rupture reported after 24 hours of exposure to dispersed oil at a concentration of 20 ppm (Knap et al. 1983; Wyers et al. 1986). Laboratory tests by DeLeo et al. (2016) on the relative effects of oil, chemical dispersants, and chemically dispersed oil mixtures on three species of northern GOM deepwater corals found much greater health declines in response to chemical dispersants and to oil-dispersant mixtures than to oil-only treatments that did not result in mortality. It is important to note that, generally, laboratory experimental concentrations are designed to discover toxicity thresholds (as in DeLeo et al. 2016) that exceed probable exposure concentrations in the field.

If an oil spill occurs at depth in deep water and the oil is ejected under pressure, some oil would rise to the surface, but some oil droplets may become entrained deep in the water column (Boehm and Fiest 1982), creating a subsurface plume (Adcroft et al. 2010). If this plume were to come into contact with the benthic organisms on a topographic feature, the impacts could be severe. Consequences may include mortality, loss of habitat, reduced biodiversity, reduced live bottom coverage, changes in community structure, and reduced reproductive success (Reimer 1975; Guzmán and Holst 1993; Negri and Heyward 2000; Silva et al. 2016). The extent and severity of impacts would depend on the location and weathering of the oil and the hydrographic characteristics of the area (Bright and Rezak 1978; Rezak et al. 1983; McGrail 1982; Le Henáff et al. 2012). If dispersants are applied to a subsurface plume, any dispersed oil in the water column that comes into contact with corals may evoke short-term negative responses, including reduced feeding and photosynthesis or altered behavior (Wyers et al. 1986; Cook and Knap 1983; Dodge et al. 1984; Ross and Hallock 2014).

Chemosynthetic organisms are adapted to handle the limited amounts of hydrocarbons that are typical at slow-flowing seeps. It is possible that some deepwater coral species also have limited capabilities to endure oil exposure. Results from DeLeo et al. (2016) suggested that *Callogorgia delta*, a soft coral often associated with hydrocarbon seeps, may have some natural adaptation to short-term oil exposure. Al-Dahash and Mahmoud (2013) suggest that a possible mechanism for this is coral harboring of symbiotic oil-degrading bacteria.

For any accidental spill, it is expected that a certain quantity of oil may eventually settle on the seafloor through a binding process with suspended sediment particles (adsorption) or after being consumed and excreted by phytoplankton (Passow et al. 2012; Valentine et al. 2014). The product of these processes is sometimes referred to as “marine snow.” It is expected that the greatest amount of adsorbed oil particles would occur close to the spill, with the concentrations reducing over distance. If a spill does occur close to a benthic habitat, some of the organisms may become smothered by marine snow particles and/or other sediments, and experience long-term exposure to hydrocarbons and/or oil-dispersant mixtures that could persist within the sediments (Hsing et al. 2013; Fisher et al. 2014; Valentine et al. 2014). Localized impacts may include reduced recruitment success, reduced growth, and reduced biological cover as a result of impaired recruitment (Rogers 1990; Kushmaro et al. 1997).

4.4.8.2 Spill Response

Benthic organisms are also vulnerable to spill cleanup/response activities. During a response operation, the risk of accidental impacts of bottom-disturbing equipment is increased. There could be unplanned emergency anchoring or accidental losses of equipment from responding vessels. Response-related equipment such as seafloor-anchored booms may be used and could inadvertently contact deepwater habitats and organisms. In addition, drilling muds may be pumped into a well to stop a loss of well control. It is possible that during this process some of this mud may be forced out of the well and deposited on the seafloor near the well site. If this occurs, the impacts would be severe for any organisms buried; however, the impact beyond the immediate area would be limited.

4.4.8.3 Marine Trash and Debris

Trash and/or debris from BOEM-regulated activities could be inadvertently deposited or placed on benthic habitat. Accidental loss of equipment could occur during transfer operations between vessels and platforms, during vessel transit, during an “on deck” accident, because of a severe storm, or if a structure, drill, or anchor is unintentionally placed in the wrong location during operations. The vulnerability of benthic organisms from accidental deposition of trash, debris, or lost equipment on hard bottom habitat is largely the same as the effects discussed for bottom disturbance (**Chapter 4.4.3**) and could include crushing, breaking, compaction, and smothering of benthic communities.

4.4.8.4 Collisions

It is expected that shallow-water hard bottom benthic habitats that are potentially vulnerable to accidental strikes from vessel traffic would occur only within the coastal zone and not on the OCS. A strike could cause breaking or fracturing of a hard bottom habitat, which could result in injury or death to those benthic species. Accidental effects from collisions are expected to be infrequent and highly localized. Refer to **Chapter 4.2.8** for an analysis of vulnerabilities to coastal and estuarine benthic habitats and organisms from accidental vessel collisions and strikes.

4.5 Fish and Invertebrate Resources

4.5.1 Noise

Natural background noise is efficiently propagated in marine environments and is the result of physical processes (i.e., wind, wave action, tidal movement, and geological activity) and bioacoustic signals (i.e., sounds produced by animals) (Wysocki and Ladich 2005; Hildebrand 2009; Radford et al. 2010; Ladich 2013). As such, many marine species have evolved mechanisms for producing and receiving sound, which are used in sound-mediated behaviors such as spawning aggregations, larval settlement, territorial disputes, and predator-prey detection (Radford et al. 2010, 2014; Slabbekoorn et al. 2010). Anthropogenic noise produced in marine environments may mask these biologically important sounds, as well as cause physiological injury or behavioral responses. This has resulted in a growing concern of the potential impacts of underwater noise to fishes and invertebrates. Despite the growing body of information on fishes, there is comparatively little information available on sound detection and sound-mediated behaviors for marine invertebrates (Aguilar de Soto et al. 2013; Mooney et al. 2012; Normeandeau Associates 2012; Popper et al. 2014; Samson et al. 2014). The large diversity of marine fishes and invertebrates compared to the small number of studied species suggests that study findings may not be representative of the full range of auditory sensory mechanisms and hearing capabilities. Therefore, caution was used in extrapolating potential impacts to fishes and invertebrate resources from documented behavioral responses and physiological impacts resulting from exposure to anthropogenic sound sources. For purposes of this assessment, it was deemed reasonable to use observed results as an indication of the types of effects and responses that may occur as a result of exposures to anthropogenic sound produced by BOEM's proposed routine OCS activities.

Common sounds produced by BOEM's proposed routine OCS activities include propeller cavitation, rotating machinery, and reciprocating machinery, which are associated with marine vessel supported activities (e.g., oil and gas, renewable energy, and mineral extractions). Anthropogenic sound in the marine environment has the potential to affect marine organisms by stimulating behavioral response, masking biologically important signals, causing temporary or permanent hearing loss (Popper et al. 2005, 2014, 2019), or causing physiological injury (e.g., barotrauma) resulting in mortality (Popper and Hastings 2009). The potential for anthropogenic sound to affect an organism is dependent on the proximity to the source, signal characteristics, received peak pressures relative to the static pressure, cumulative sound exposure, species, motivation, and the receiver's prior experience. In addition, environmental conditions (e.g., temperature, water depth, and substrate) affect sound speed, propagation paths, and attenuation, resulting in temporal and spatial variations in the received signal for organisms throughout the ensonified area (Hildebrand 2009). These factors are of particular importance when considering the use of data and results produced by various studies. For example, a study by McCauley et al. (2017) was conducted in shallow waters near Tasmania, Australia, and the methods used differ significantly from and are not representative of OCS seismic survey activities. While the study is informative, care should be taken in interpreting the study's results.

Sound detection capabilities among fishes vary. All fishes are able to detect low-frequency particle motion at short ranges by means of the otolith and lateral line organs (Popper et al. 2003). Detection of the particle velocity and the ability to determine the position of the source is only possible over distances of 1-2 body lengths, but it is important for orientation in flowing water and maneuvering in close proximity to other organisms (Popper et al. 2014). Species with a swim bladder and accessory structure close to or in contact with the inner ear have increased hearing sensitivity and a wider range of detectable frequencies than do fishes with a swim bladder only or fishes with no gas-filled structure (Popper et al. 2003). For most fish species, it is reasonable to assume hearing sensitivity to frequencies below 500 Hz (Popper et al. 2003, 2014, 2019; Popper and Hastings 2009; Radford et al. 2014; Slabbekoorn et al. 2010). Ambient noise may be divided into three general frequency bands (i.e., low, medium, and high), each dominated by different sound sources (Hildebrand 2009). The band of greatest interest to this analysis, low-frequency sound (30-500 Hz), has come to be dominated by anthropogenic sources and includes the frequencies most likely to be detected by most fish species. For example, the noise generated by large vessel traffic typically results from propeller cavitation and falls within 40-150 Hz (Hildebrand 2009; McKenna et al. 2012). This range is similar to that of fish vocalizations and hearing, which could result in a masking effect.

Masking occurs when background noise increases the threshold for a sound to be detected; masking can be partial or complete. If detection thresholds are raised for biologically relevant signals, there is a potential for increased predation, reduced foraging success, reduced reproductive success, or other effects like the masking of sounds larval fish and invertebrates use to find suitable settlement locations. However, fish hearing and sound production may be adapted to a noisy environment (Wysocki and Ladich 2005). There is evidence that fishes are able to efficiently discriminate between signals, extracting important sounds from background noise (Popper et al. 2003; Wysocki and Ladich 2005). Sophisticated sound processing capabilities and filtering by the sound-sensing organs essentially narrows the band of masking frequencies, potentially decreasing masking effects. In addition, the low-frequency sounds of interest propagate over very long distances in deep water, but these frequencies are quickly lost in water depths between ½ and ¼ the wavelength (Ladich 2013). This would suggest that the potential for a masking effect from low-frequency noise on behaviors occurring in shallow coastal waters may be reduced by the receiver's distance from sound sources, such as busy ports or construction activities.

Pulsed sounds generated by OCS activities (e.g., impact-driven piles and airguns) can potentially cause behavioral response, reduce hearing sensitivity, or result in physiological injury to fishes and invertebrate. The effects of these sound-producing activities would extend only to communities of fishes and invertebrates within a relatively small area. Benthic fishes and invertebrates could receive sound waves propagated through the water and sound waves propagated through the substrate. However, Wardle et al. (2001) found that, although fishes and invertebrates associated with a reef exhibited a brief startle response when exposed to pulsed low-frequency signals, disruption of diurnal patterns was not observed. Fishes disturbed by the noise were observed to resume their previous activity within 1-2 seconds and only exhibited flight response if the airguns were visible when discharged (Wardle et al. 2001). Other studies of fishes exposed to pulsed anthropogenic sound signals in natural environments have produced a wide range of results, suggesting that species, life-stage, experience, and motivation are very important factors and indicating that habituation may occur (Engås et al. 1996; Løkkeborg et al. 2012; Popper et al. 2014). Organisms in close proximity to a pulsed sound source are at increased risk of barotrauma. A signal with a very rapid rise and peak pressures that vary substantially from the static pressure at the receiver's location can cause physiological injury or mortality (Popper et al. 2014). However, the range at which physiological injury may occur is short (<10 m; <33 ft) and, given fish avoidance behavior, the potential for widespread impacts to populations is not likely. Although physiological stress/injury or behavioral responses in invertebrates with no or limited movement capabilities may occur, impacts would be localized and restricted to surface waters as the majority of Gulf of Mexico OCS-related seismic activity using airguns occurs in deep water.

When oil and gas platforms become obsolete, they go through a decommissioning process, which may include partial removal or complete removal of the platform structure using an explosive severance technique. These explosive detonations are some of the largest sounds generated by anthropogenic activities. When using explosives for platform severance, the underwater pressure signature of a detonation is composed of an initial shock wave followed by a succession of oscillating bubble pulses. The rapid oscillation in the pressure waveform associated with detonation is likely responsible for fish mortality observed at explosive removal sites because it causes rapid contraction and overextension of the swim bladder in fish. Invertebrates and fish without or with less developed swim bladders are more resistant to underwater blasts. For those susceptible to physiological injury from the rapid changes in pressure associated with shock wave propagation, mortality is likely, and can impact the number and age structure of fishes in localized communities. However, documented mortalities of several commercially and recreationally valuable fishes (e.g., red snapper, vermilion snapper, greater amberjack, gray triggerfish, and cobia) resulting from the explosive removal of 24 platforms in 2017 and 23 platforms in 2018 constituted a small fraction of the total stocks in the GOM (Gallaway et al. 2020). Although the results from this study investigated only five recreationally and commercially important species, it can be reasonably assumed that other represented fish populations would respond similarly.

Despite the importance of many sound-mediated behaviors and the potential biological costs associated with behavioral response to anthropogenic sounds, many environmental and biological factors limit potential exposure and the effects that sounds produced from BOEM-regulated activities will have on fish and invertebrate resources. For several species (e.g., red snapper, cobia, and gray triggerfish) that experience direct mortality as a result of explosive removals, the total loss represents a small fraction of total stocks currently present in the GOM (Gallaway et al. 2020). Overall, impacts to populations of fishes and invertebrates due to anthropogenic sound introduced into the marine environment by BOEM's routine activities is currently expected to be minor, and they are not considered to be vulnerable in this analysis.

4.5.2 Operational Discharges and Wastes

Routine discharges and wastes associated with BOEM -regulated activities in the GOM include sanitary wastes, gray water, cooling water, drilling muds and cuttings, and other miscellaneous discharges (e.g., bilge, ballast, and fire water; deck drainage). Sources of these discharges are vessels (i.e., support, service/construction, seismic, and drilling) and platforms. The USEPA and USCG administers regulations and permits, which are designed to keep contaminants in operational discharges and wastes below harmful levels. Once they are discharged into the water column, they are not expected to persist for long, particularly when considering the depths at which OCS-related activities occur along the continental shelf and beyond, where they are exposed to strong currents, wind, and wave action.

Current evidence has shown that any observed effects of drilling wastes, as well as produced water, are local and generally confined to the water column and seabed between 1,000 and 2,000 m (3,281 and 6,562 ft) from the source and that widespread impacts to fish and invertebrate communities and populations are generally low (Bakke et al. 2013). The discharge of drilling fluids and cuttings offshore may contribute to localized, temporary marine environmental degradation (Neff 2005), particularly when shunted to the seafloor. For example, drilling muds and cuttings shunted to the seafloor can cause turbidity in the water column and sedimentation on the seabed, which can be problematic for species with limited to no mobility (e.g., corals and sponges; refer to **Chapter 4.4**). For mobile fish and invertebrates, time restrictions in place for drilling operations would allow for avoidance of large discharge plumes. As such, there is currently no available information to suggest population-level vulnerabilities of fish and invertebrate resources as a result of BOEM's routine operational discharges and wastes.

4.5.3 Bottom Disturbance

For the purpose of this analysis, bottom-disturbing activities are distinguished from habitat modification by the relatively short period of time over which disturbances occur. Anchoring, drilling, trenching, jetting, pipe laying, dredging, and structure emplacement are examples of BOEM regulated activities that disturb the seafloor. The specific activity, ocean currents, and water depth can affect the extent of the water column and seafloor disturbance, and the magnitude of the effect. For example, dredging sand for coastal restoration projects can cause turbidity in the water column and direct mortality of epifaunal and infaunal benthic organisms; however, organisms living in shallow sand shoals are adapted to high-energy, turbid environments and can recolonize relatively quickly (Dernie et al. 2003). Drilling an exploratory well produces approximately 2,000 metric tons (2,205 tons) of combined drilling fluid and cuttings, though the total mass may vary widely for different wells (Neff

2005). Cuttings discharged at the surface tend to disperse in the water column and are distributed at low concentrations (CSA 2004a). In deep water, cuttings discharged at the sea surface may spread 1,000 m (3,280 ft) from the source, with the majority of the sediment deposited within 250 m (820 ft) of the well (CSA 2006). Drilling mud plumes may be visible 1 km (0.6 mi) from the discharge point, but the plumes rapidly become diluted (Shinn et al. 1980; Hudson et al. 1982; Neff 2005). Cuttings shunted to the seafloor form piles concentrated within a smaller area than that affected by sediments discharged at the sea surface (Neff 2005). Emplacement of infrastructure (i.e., pipelines, platforms, and subsea systems) can also displace large volumes of sediment, resulting in increased turbidity and sedimentation.

Turbidity and sedimentation can be caused by routine BOEM-regulated, bottom-disturbing activities, but these effects are short term and have localized effects. The potential impacts to fishes and invertebrates (e.g., reduced feeding efficiency, decreased predator avoidance, and behavioral responses) may be related to species-specific behaviors and habitat preference (Minello et al. 1987; Benfield and Minello 1996; Chesney et al. 2000; de Robertis et al. 2003; Jönsson et al. 2013; Lunt and Smee 2014). Mobile fishes and invertebrates are expected to avoid the heaviest seimentation and highest suspended sediment loads within 10 m (33 ft) of a disturbance. Icthyoplankton cannot avoid sediment plumes at or near the surface and may be exposed for longer durations than adults. However, evidence suggesting increased turbidity, which may reduce hatching success or delay larval development, is limited, and other studies have shown larval foraging success and growth may benefit from nutrient-rich plumes (Wenger et al. 2014; Gray et al. 2012). Coastal fishes and invertebrate species adapted to turbid environments, such as shallow bays, estuaries, and coastal habitat influenced by the Mississippi River plume, may be less vulnerable to increased turbidity in the water column than species inhabiting less turbid environments.

Due to a combination of the spatiotemporally limited nature of suspended sediments, avoidance behaviors, and a range of tolerances for various environmental conditions, fish and invertebrate populations are not considered to be vulnerable to bottom disturbances associated with routine BOEM-regulated activities in the GOM.

4.5.4 Coastal Land Disturbance

The coastal habitats of the GOM are highly modified, primarily due to the amount of freshwater influx received from the over 750 bays, estuaries, and sub-estuary systems that discharge into the region (USEPA 2012). This discharge brings sediments, nutrients, and pollutants from over 60 percent of the U.S. into the GOM, particularly in the northern GOM where the majority of BOEM-regulated activities occur. The modification of tributaries using dams and levee systems has contributed to shifts in ecosystem functionality, causing saltwater intrusion farther inland and changes in species distributions. The Gulf Coast is also highly populated and, as a result, there is a large amount of coastal development, as well as commercial and recreational boating traffic. Some of the major consequences of the aforementioned large-scale modifications to the GOM have resulted in habitat loss, fair water quality, larger hypoxic zones, fish kills, toxic algal blooms, and an increase of underwater sound in highly populated areas. These can have important environmental implications as shallow, coastal waters house important habitats (refer to **Chapter 3.2**) that can serve as important feeding grounds for adult fish and invertebrates, as well as nursery grounds for juveniles.

Coastal land disturbance activities routinely conducted by BOEM that could potentially impact fish and invertebrate resources include the dredging of navigation canals, vessel traffic, and the construction of new onshore facilities and pipeline landfalls. However, the creation of new pipeline landfalls has decreased significantly since the 1970s and coastal infrastructure is confined to a few locations in the northern GOM. Vessel traffic and maintenance dredging of canals leading to onshore processing facilities could cause increased turbidity in the water column and sedimentation in benthic habitats (**Chapter 4.5.3**). Although this may cause the displacement of benthic fish and invertebrates, this effect is expected to be short term and localized. Further, the majority of fish and invertebrate assemblages occupying coastal habitats in the northern GOM are adapted to living in turbid environments and would be less vulnerable than organisms in other regions. Any new construction and routine vessel traffic to and from onshore processing facilities can also introduce sound into the underwater soundscape (**Chapter 4.5.1**). Nonpoint sources of pollution from onshore facilities could occur, particularly as run-off from paved surfaces during heavy rain events; however, the contribution would be localized and miniscule compared to the cumulative runoff received from other sources (e.g., river outflows and coastal developments).

4.5.5 Offshore Habitat Modification

Fish and invertebrate resources may be vulnerable to routine activities that cause modifications to offshore habitat, including the installation and removal of structures (e.g., platforms, pipelines, and subsea systems) and dredging for marine minerals (e.g., sand). Although structure emplacements are temporary, the operational life is long-term and may impact the distribution of species in an area (Carr and Hixon 1997; Gallaway et al. 2009; Shipp and Bortone 2009). It is generally assumed that artificial structures serve as both fish-attracting and production-enhancing devices (i.e., producing an increase in the total population), depending upon the species (Carr and Hixon 1997; Gallaway et al. 2009; Shipp and Bortone 2009; Gallaway et al. 2020). The resulting assemblages frequently include commercially and recreationally valuable coastal and oceanic fishes. The well-known association with OCS oil- and gas-related structures attracts fishermen targeting these species and may subject some fishes to locally increased fishing pressure (Dance et al. 2011; Addis et al. 2013). However, infrastructure or pipeline removal also impacts fishes and invertebrates associated with the substrate. Removal of the structure is necessary to restore the seafloor to the original soft bottom habitat, but it would likely result in an altered community as the restored site is recolonized. The removal of hard substrate may result in community-level changes, such as an overall reduction in species diversity of epifaunal organisms, fishes, and invertebrates (Schroeder and Love 2004).

Fish mortality occurs as a result of decommissioning operations using explosive severance methods; however, studies of the associated mortality for several recreationally and commercially important fishes have indicated that the level of explosive severance activity in the GOM does not significantly alter stocks (Gitschlag et al. 2001; Gallaway et al. 2020). Although these studies were limited and cannot be directly applied to all species or habitats, it is reasonable to assume that other represented fish stocks would respond similarly. Impacts to sessile benthic organisms (e.g., barnacles and bivalves) and many mobile invertebrates (e.g., shrimp and crabs) that do not possess swim bladders are expected to be minimal (Keevin and Hempen 1997; Schroeder and Love 2004) because it is typically the rapid expansion and contraction of gas-filled spaces in response to pressure changes that results in the greatest physiological injury. Larvae and small juvenile fishes have been found to be more susceptible to injury from shock waves than large juveniles or adults (Govoni et al. 2008). At the projected rate of removal, these activities are not expected to have a substantial negative impact on stocks of managed fish or other fish and invertebrates associated with OCS infrastructure.

Some structures may be converted to artificial reefs. If portions of a platform were permitted to be reefed in place, the hard substrate and encrusting communities would remain part of the benthic habitat. The diversity of the community would change due to the reduced presence in the water column, but some associated fish species would be expected to continue use of the structure. Structures removed and redeployed as artificial reef substrate at another location may support substantially different communities, depending on the environmental characteristics of the reef site and other factors. The plugging of wells and other decommissioning activities that disturb the seafloor would impact benthic communities as discussed above.

Some ichthyoplankton studies have been conducted, focusing specifically on the influence of offshore platforms. The first of these projects investigated the potential role of platforms as nursery habitat for larvae or refugia for postlarval and juvenile fish (Hernandez Jr. et al. 2001). A follow-up study by Shaw et al. (2002) used data collected at several platforms both east and west of the Mississippi River Delta to examine the significance of platforms to larval and juvenile fishes. Both Hernandez et al. (2001) and Shaw et al. (2002) found highest taxonomic richness and diversity at mid-shelf platforms. Results indicated that the distribution of larval and juvenile life stages is influenced by across-shelf gradients of increasing depth, similar to the distribution of adult fishes. Differences observed in the abundance of certain taxa in larval and juvenile fish assemblages across longitudinal gradients may reflect differences in the hydrographic conditions and/or habitat availability (Shaw et al. 2002). These results indicate that the predominant factors influencing the distribution of larvae and juvenile life stages are environmental conditions and the distribution of adult conspecifics.

4.5.6 Air Emissions

Due to steady vertical and horizontal air motion throughout the GOM region (Wang and Angell 1999), which rapidly disperses any pollutants from routine BOEM-regulated activities, fish and invertebrate populations are not considered vulnerable in this analysis.

4.5.7 Visual and Lighting Impacts

BOEM's onshore facilities, docked vessels, and offshore structures (e.g., standing platforms, wind turbines, drillships, tension-leg platforms, etc.) emit artificial light at night. Research on the effects of artificial light to fishes and invertebrates is limited. Artificial light that is emitted at night from anthropogenic infrastructures has been shown to alter predator-prey interactions, potentially creating unnatural top-down regulation of fish populations in coastal urbanized areas (Becker et al. 2013). In offshore waters, similar relationships have been observed, indicating that larval, juvenile, and adult piscivores (e.g., jacks and mackerels) take advantage of the attraction of prey (both planktonic organisms and small planktivorous fishes) to artificial light (Keenan et al. 2007). Conversely, fishes observed using SONAR under shore-based infrastructure have been shown to be more abundant and relatively sedentary under no-light conditions, indicating their natural use of these structures for shelter during the night (Bolton et al. 2017). Unnaturally introduced light at night has also been shown to indirectly affect assemblages of sessile invertebrates by increasing the amount of predation during a time when these organisms likely perform essential activities such as spawning, settlement, and feeding under reduced predation pressure (Davies et al. 2015; Bolton et al. 2017). Further, artificial light illuminating shallow benthic communities at night likely gives rise to unanticipated effects such as sub-optimal settlement site selection and consequent increases in post-settlement mortality in sessile marine invertebrates (Davies et al. 2015). The widespread impacts of artificial light at night to marine and estuarine populations of fish and invertebrates are still unknown. Considering the lack of population-level impact information and the localized areas in which this IPF occurs, fish and invertebrate populations are not currently considered to be vulnerable to artificial light produced by BOEM’s routine activities and emplaced structures.

4.5.8 Accidental Events

4.5.8.1 Spills

Fish and invertebrates may be vulnerable to the accidental release of oil in the environment. An oil spill in open waters of the OCS proximal to mobile adult fish would likely be sublethal; potential effects could be reduced because adult fish can avoid adverse conditions, metabolize hydrocarbons, and excrete metabolites and parent compounds (Lee et al. 1972; Snyder et al. 2019). However, long-term exposure to concentrated volumes of contaminants could result in a higher incidence of chronic sublethal effects (Murawski et al. 2014; Baguley et al. 2015; Millemann et al. 2015; Snyder et al. 2015). This can occur through the interaction of fish and invertebrates with PAH-contaminated water and sediments, which can occur by a variety of routes including respiration, ingestion of food, sediment, detritus, and absorption through the skin (Logan 2007). Oil floating on the surface could directly contact and coat the eggs and larvae of fish and invertebrates found at or near the surface. Eggs and larvae would be unable to avoid spills, and affected individuals may be at risk of death, delayed development, abnormalities, endocrine disruption, or other effects resulting in decreased fitness and reduced survival rates (Fucik et al. 1995; Incardona et al. 2014; Mager et al. 2014); however, these effects would largely depend on the concentrations and duration of exposure. In general, early life stages of fish are more sensitive to acute oil exposure than adults, but some research indicates that embryos, depending on their developmental stage, would be less sensitive to acute exposure than larval stages (Fucik et al. 1995).

Spills reaching nursery habitat or overlapping spatiotemporally with a spawning event have the greatest potential for affecting the early life stages of fish and invertebrates, particularly in shallow waters. Fish and invertebrates inhabiting shallow-water habitats (e.g., estuaries, coral reefs, and shorelines) are at increased risk because they can receive higher oil loading per unit volume of seawater than deeper offshore water (Pfetzing and Cuddeback 1993). However, much of the OCS oil- and gas-related activity occurs far offshore. As such, interactions of released oil with currents, waves, and other physiological processes would allow for the toxicity of spilled oil to be greatly reduced or eliminated by weathering and biodegradation before it reaches coastal habitats (OSAT-2 2011). Nonetheless, accidental spills are reasonably foreseeable and fish and invertebrates occupying coastal and estuarine habitats may be vulnerable to these incidents.

Although an unlikely occurrence, a subsea loss of well control could suspend large amounts of sediment. For the reasons stated above (**Chapter 4.5.3**), the potential effects of suspended sediments would be minimal, and populations are not considered to be vulnerable to BOEM-induced bottom disturbances.

4.5.8.2 Spill Response

The use of chemical dispersants may be used during oil spills. Oil-spill dispersants may be applied to break down surface oil into smaller oil droplets, making them easier to ingest by oil-eating microbes. Unfortunately, this process may also increase the water solubility of petroleum hydrocarbons, which makes them more bioavailable for uptake by fish and invertebrates (Wolfe et al. 2001). For example, Laramore et al. (2016) found that larval pink shrimp exposed to oil alone and oil treated with dispersants experienced greater negative impacts to the dispersant, and the impacts differed between larval stages, with zoea being the most sensitive. Similarly, eastern oysters exposed to dispersants experienced some negative effects to immunological and physiological functions, which could result in serious health implications (e.g., increased parasitism and decreased growth) (Jasperse et al. 2018). In contrast, the effects of chemical dispersants on the larvae of blue crabs was laboratory tested, and only the larvae exposed to the highest treatment levels experienced significant increases in mortality (Anderson and McKenzie 2014). Fish exposed to dispersants were found to have higher concentrations of PAHs versus fish exposed to crude oil without dispersants (Ramachandran et al. 2004). Overall, research has suggested that dispersed oil may be more toxic to fish and invertebrates than exposure to crude oil alone; however, life-stage, exposure levels, duration, and geographic extent dictate the impacts to individuals, and the long-term effects are not well understood.

4.5.8.3 Marine Trash and Debris

Routine BOEM-regulated activities, such as vessel operations, are required to be proactive against the loss of solid waste items by developing waste management plans, posting informational placards, manifesting trash sent to shore, and using special precautions such as covering outside trash bins to prevent accidental loss of solid waste. All discharge of trash and debris from offshore platforms and all ships within 500 m (1,640 ft) of such platforms is prohibited (33 CFR § 151.51-77), except for food wastes discharged more than 12 mi (19 km) from shore, which it is passed through a comminutor (a machine that breaks up solids) and can pass through a 25-mm (1-in) mesh screen. All other trash and debris must be returned to shore for proper disposal with municipal and solid waste. However, it is still possible to have accidental release of trash and debris into the marine environment, specifically plastic waste, which has documented impacts to fish and invertebrates.

The negative effects of microplastics to copepod feeding, fecundity, and survival have been documented in previous laboratory-based toxicological studies (Cole et al. 2016). Many larval fish species in the ocean are also being found with microplastics in their systems (Gove et al. 2019), which has been found to decrease growth rates and alter feeding behavior in laboratory-based studies (Lonnstedt and Eklov 2016). Foley et al. (2018) conducted a meta-analysis of the scientific literature investigating the effects of microplastic exposure on consumption (and feeding), growth, reproduction, and survival of fish and aquatic invertebrates. The analysis revealed that many of the studies showed neutral effects and inter-species variation. Generally, the most consistent effect was a reduction in consumption of natural prey when microplastics were present. There were also examples of within taxa negative effects to growth, reproduction, and survival (Foley et al. 2018).

4.5.8.4 Collisions and Strikes

Accidental strikes by oil and gas vessels operating in the OCS would likely not affect most fish and invertebrates because many can actively avoid oncoming ships. Larval fish and invertebrates with limited mobility may experience highly localized and minimal mortalities, but most would only be temporarily displaced. However, there is the potential for OCS-associated vessels to strike large, surface-feeding fish such as whale sharks (Ramirez-Macias et al. 2012; Schoeman et al. 2020). During the spring and summer, some whale sharks travel to the north-central GOM where they have been observed feeding at the surface in aggregations of 16-100 individuals (Hoffmayer et al. 2007; McKinney et al. 2017; Chen 2017). These aggregations occur near existing oil and gas infrastructure on the OCS, which potentially makes them vulnerable to ship strikes (**Figure 4-1**). No data currently exist indicating that vessel strikes to whale sharks have occurred in the north-central GOM; however, whale sharks are negatively buoyant and may sink quickly if a mortality occurred due to a vessel strike (Speed et al. 2008), possibly allowing a vessel strike to go unnoticed. Whale shark feeding aggregations near the Mexican State of Quintana Roo in the southern GOM have had documented vessel strikes by ecotourism vessels during surface feeding. This suggests that, depending on motivation, some behaviors may increase potential interactions with surface vessels due to a reduced avoidance/flight response. As such, whale sharks may experience increased seasonal vulnerability to accidental strikes in the north-central GOM by OCS-related vessel activity.

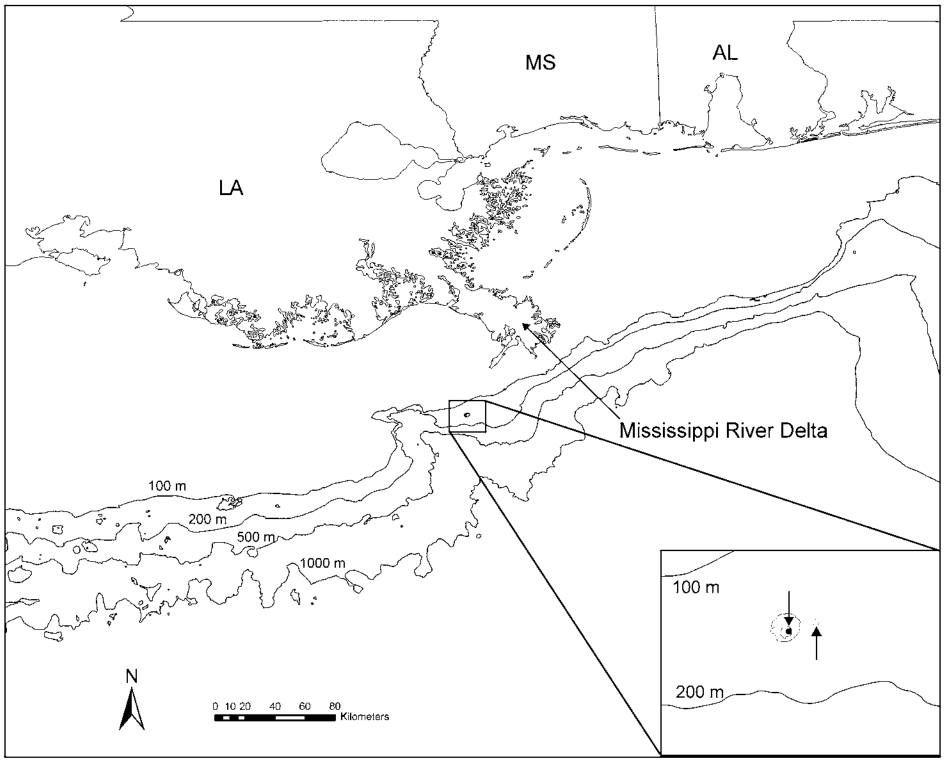

Figure 4-1. Map Depicting the Location of a Whale Shark Feeding Aggregation as Reported in Hoffmayer et al. (2007) during June 2006 in the North-central Gulf of Mexico. The inset map depicts the location where the aggregation was sighted (closed circle) and control sites (open circle) show where zooplankton samples were taken. The study site was located in surface waters 78 meters (256 feet) above the eastern edge of the crest of a topographic high, the base of which is located at 100-meter (328-foot) water depth. (Reprinted by permission of Dr. Mark Peterson on May 5, 2020, whose permission is required for further use.)

4.6 Sea Turtles

4.6.1 Noise

Noise sources that sea turtles could be vulnerable to include active acoustic sources, vessels, drilling, production, trenching, construction, and platform removal (including use of explosive decommissioning). Sea turtles could be vulnerable to noise from marine seismic surveys and the use of decommissioning explosives in all GOM planning areas, though minimally so in the EPA (Nelms et al. 2016). It is generally accepted that sea turtles can detect sounds between 100 Hz and 2 kHz, although there is relatively little data on sea turtles' hearing sensitivity (Bartol and Musick 2003; Popper et al. 2014). Results from the limited behavioral studies that have been conducted on sea turtles have yielded mixed results (Nelms et al. 2016). Behavioral disturbance or masking of salient acoustic cues could be more widespread, though little is known about noise levels that induce such changes in sea turtles (McCauley et al. 2000; Moein et al. 1994).

Since sea turtles appear to be sensitive to low-frequency sounds, they are likely to hear much of the low-frequency and high-intensity anthropogenic noise in the ocean, such as vessel traffic and offshore exploration and development activities such as pile driving and drilling (**Figure 4-2**). Noise impacts could include behavioral changes, acoustic masking, temporary threshold shift (TTS), permanent threshold shift (PTS), or mortality. Limited data exist on the noise levels that induce behavioral changes in sea turtles (McCauley et al. 2000; Moein et al. 1994). Once detected, some sounds may elicit a behavioral response, including temporary changes in habitat selection to avoid areas of higher sound levels or changes in diving behavior.

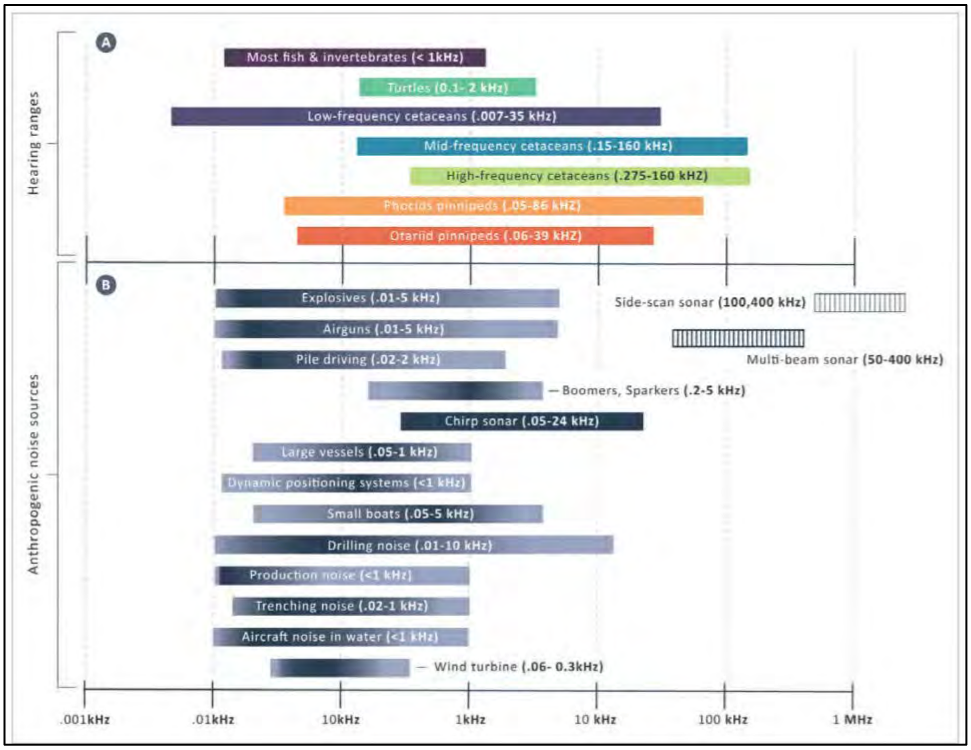

Figure 4-2. (A) Approximate Hearing Ranges of Marine Species; (B) Frequency Ranges of Various Anthropogenic Sources. These ranges represent approximately 90% of the acoustic energy, and color shading roughly corresponds to the dominant energy band of each source. Dashed lines represent broadband sonars to depict the multi-frequency nature of these sounds. The frequency axis of both plots shows kHz in a logarithmic scale. Sources: Popper et al. (2014), Richardson et al. (1995), and NMFS (2016a).

4.6.1.1 Active Acoustics

Seismic operations have the potential to harm sea turtles in close proximity to active airgun arrays. Seismic airgun surveys could affect individuals from all sea turtle species. Subadult and adult turtles may be more likely to be affected by seismic airgun noise than post-hatchling turtles because of the time that they remain submerged and at depth. Post-hatchling turtles generally reside at or near the sea surface and may be less likely to be injured by the sound field produced by an airgun array below the surface projecting downward. It is anticipated that seismic airgun surveys conducted in shallower areas may affect a greater number of individual turtles, particularly species other than leatherbacks. Deepwater surveys are likely to affect fewer individual turtles though are more likely to affect leatherback turtles, particularly within areas of upwelling where individuals may be found in feeding aggregations. Also, surveys conducted during summer sea turtle nesting periods may affect greater numbers of adult turtles, particularly loggerhead, green, and leatherback turtles, than surveys conducted during non-nesting periods (Popper et al. 2014).

Although little is known about the effects of anthropogenic noise on sea turtles, potential impacts of seismic surveys may include auditory effects (TTS or PTS) and/or behavioral disturbance. There is limited evidence of TTS in sea turtles. Studies have noted possible reactions to low-frequency noise, including startle responses and rapid swimming (McCauley et al. 2000) and swimming toward the surface at the onset of the sound (Lenhardt 1994). Investigations have reported that green and loggerhead sea turtles increased their swimming activities when exposed to low-frequency noise; these activities become more erratic as the exposure level increases (McCauley et al. 2000). Weir (2007) did not document obvious behavioral avoidance to airguns though suggested responsive actions by sea turtles to the vessel and towed equipment. Sea turtles may alter their behaviors when a vessel approaches, and thereby suspend feeding, resting, or interacting with conspecifics. Such disruptions are expected to be temporary, however, and should not affect the overall survival and reproduction of individual turtles.

Sea turtles could be exposed to multiple airgun pulses within a given survey from different surveys within a year and in different months. For seismic sources, sea turtles have the potential for mortality or injury at or above 210 decibel (dB) re 1 $\mu Pa^2 s$ cumulative sound exposure level and above 207 dB re 1 µPa peak pressure level (Popper et al. 2014). Sea turtles have been observed noticeably increasing their swimming in response to an operating seismic source at 166 dB re 1 µPa in water (McCauley et al. 2000). Moein et al. (1995) showed that sea turtles initially avoided airgun sounds and later became habituated, but avoidance responses to other low-frequency sounds have also been observed (Lenhardt 1994). Avoidance responses to seismic signals have been observed in sea turtles at received sound pressure levels between 166 and 179 dB re 1 µPa (Lenhardt 1994; Moein et al. 1995; McCauley et al. 2000; Weir 2007; DeRuiter and Doukara 2012). Therefore, it is reasonable to assume that sea turtles would avoid approaching seismic vessels, which means the potential risk of TTS or PTS would be highly localized, i.e., limited to individuals that are too close to the source to swim away (assuming no “ramp up” is utilized).

A sea turtle would need to be close to the seismic sound source at 210 dB cumulative (cum) or >207 dB peak to cause mortal injury (Popper et al. 2014). Low-frequency sounds can cause moderate TTS in turtles at relatively near or intermediate vicinity to the source. Continuous sounds can cause masking and behavioral effects, though the consequences for survival of sea turtles are unknown (Popper et al. 2014). Noise associated with geological and geophysical activities may result in behavioral effects (e.g., changes in direction or swimming speed) or auditory masking in sea turtles. Based on current information on sea turtle hearing capabilities, it is not clear whether or not sea turtles rely on sound or would be affected by auditory masking (Popper et al. 2014). The most likely impacts on sea turtles are expected to be short-term behavioral responses.

4.6.1.2 Vessel and Equipment Noise

The dominant source of noise from vessels is propeller operation (i.e., cavitation), and the intensity of this noise is largely related to ship size and speed. Vessel and equipment noise is transitory and generally does not propagate at great distances from the vessel; the source levels are too low to cause injuries such as auditory threshold shifts. Behavioral responses to vessels have been observed though are difficult to attribute exclusively to noise rather than to visual or other cues.

Reactions to aircraft or vessel noise, such as avoidance behavior, may temporarily disrupt normal activities, including feeding. Important habitat areas (e.g., feeding, mating, and nesting) may be avoided because of noise generated in the vicinity. There is no information regarding the long-term consequences that these disturbances may have on sea turtles. Based on existing studies on the role of hearing in sea turtle ecology, it is unclear whether masking would have any effect on sea turtles (Mrosovsky 1972; Nunny et al. 2008; Samuel et al. 2005).

Noise from service-vessel traffic and helicopter overflights may elicit a startle response from sea turtles, and there is the possibility of short-term disruption of activity patterns and temporary sublethal stress (NRC 1990). It is conservative to assume that noise associated with survey vessels may elicit behavioral changes, such as evasive maneuvers, in individual sea turtles. The most likely effects of vessel and equipment noise on sea turtles could include short-term behavioral changes and possibly auditory masking.

Drilling and production facilities produce an acoustically wide range of sounds at frequencies and intensities that could possibly be detected by sea turtles. Drilling noise from conventional metal-legged structures, and semisubmersibles is not particularly intense and is strongest at low frequencies. Oil and gas exploration and extraction generates high-intensity, low-frequency, impulsive sounds (Dow Piniak et al. 2012).

Noise associated with the explosive removal of oil and gas structures has been linked to mortality of a small number of sea turtles (Klima et al. 1988; Gitschlag and Herczeg 1994), but other studies suggest that sea turtle ears may be relatively resistant to damage from explosives (Ketten et al. 2005). Impacts from any sound source are relative to the source type; frequency, intensity, and duration of the source; and distance to the animal.

4.6.2 Operational Discharges and Wastes

The USEPA and USCG administered regulations that would prevent impacts from produced water, drilling muds, and cuttings; these regulations are designed to keep contaminants below harmful levels for public health and welfare. These discharges are not expected to persist in the water column. Due to the localized and transient nature of the water quality impacts, these discharges are unlikely to affect foraging or other activities by sea turtles. Operational discharges are diluted and dispersed when released in offshore areas, and they are not expected to directly or indirectly affect any sea turtle species. Therefore, drilling discharges are not likely to have any detectable effect on sea turtles.

4.6.3 Bottom Disturbance

Although many sea turtles forage in benthic areas, this tends to occur in nearshore areas (e.g., seagrass beds). Green, Kemp's ridley, and loggerhead turtles use soft bottom benthic habitats for foraging. Hawksbill turtles feed in coral and hard bottom areas, which would be avoided. Farther offshore where drilling is more likely, sea turtles generally spend time closer to the surface and feed on other prey (e.g., jellies). Drilling would be localized and impacts are not expected to occur outside of the immediate area, nor is habitat loss expected (Neff 2005). In addition, infrastructure emplacement, pipeline trenching, and structure removal would be localized and temporary, and habitat loss is not expected. It is assumed that careful timing of activities and siting of onshore and OCS infrastructure, particularly with regard to ESA-listed species, would be applied.

4.6.4 Coastal Land Disturbance

Adverse modification of critical habitat, such as that for loggerheads, would not be legally authorized under the ESA. Therefore, since onshore construction would not occur on nesting beaches, nesting sea turtles and hatchlings are not expected to be vulnerable to coastal land disturbance. Onshore construction is not within the OCS and would be outside of BOEM or BSEE's regulatory authority. In addition, any activity would be under other regulatory authorizations (e.g., the Corps of Engineers and the and Federal Energy Regulatory Commission).

4.6.5 Offshore Habitat Modification

Several activities, including drilling, coastal and offshore infrastructure emplacement, decommissioning, and OCS sand and gravel borrowing, could alter coastal and/or estuarine habitats (**Chapter 4.2.4**). Adverse modification of critical habitat, such as that for loggerheads, would not be legally authorized under the ESA. Coastal construction can degrade or destroy coastal habitats and put sea turtles at risk. Coastal habitat disturbance, including to estuaries and rivers, from construction of new pipelines or shore facilities could affect sea turtles. The addition of roads, onshore support bases, and pipelines to distribution points could further stress coastal and estuarine habitats, leading to erosion and subsequent landloss. Since sea turtles are slow to reach sexual maturity, they may be vulnerable to any coastal construction that disrupts egg laying. Sea turtles could be vulnerable to coastal development that leads to permanent alteration of nesting habitats (i.e., beach), or even short-term disturbance during nesting periods.

Offshore habitat modification could destroy submerged aquatic vegetation habitat that sea turtles depend on for feeding and breeding. Further, it could disrupt or destroy submerged coastal habitats, such as seagrass beds, which are a key food source for sea turtles. These losses would likely be localized but could lead to long-term impacts and shoreline loss.

Vessel traffic (e.g., tankers, barges, support vessels, and seismic survey vessels) within estuaries can result in habitat loss or degradation and environmental contamination (Robb 2014). Coastal organisms and vegetation may be impacted by increased turbidity from the wake (though speed restrictions are required) from vessels. The OCS vessel traffic could increase shoreline erosion of coastal and estuarine habitats from wave activity, which could lead to loss or degradation of habitat in these areas. Onshore traffic aiding the construction of supporting infrastructure such as roads, facilities, and pipelines could also disturb or destroy coastal and estuarine habitats. Thus, nesting or foraging sea turtles may be vulnerable to these impacts.

4.6.6 Air Emissions

To protect public health and welfare, the Clean Air Act established the National Ambient Air Quality Standards (NAAQS) for certain common and widespread pollutants. In addition to the criteria pollutants, BOEM assesses volatile organic compounds since these are precursors to O_3 formation. Air emissions from BOEM-regulated activities in the GOM would arise from emission sources related to associated vessel traffic, flaring and venting, decommissioning, fugitive emissions, and oil spills. The Outer Continental Shelf Lands Act requires BOEM to comply with the NAAQS pursuant to the Clean Air Act (42 U.S.C. §§ 7401 *et seq*.) to the extent that activities significantly affect the air quality of any State. Therefore, BOEM focuses its analyses on the impact of these activities on the States. Human activity within the OCS is transitory at best as would be any sea turtle or air-breathing aquatic species.

Once pollutants are released into the atmosphere, transport and dispersion processes begin circulating the emissions. Transport processes are carried out by the prevailing wind circulations, which can vary depending on the time of year. Dispersion depends on emission height, atmospheric stability, mixing height, exhaust gas temperature and velocity, and wind speed. The mixing height is the height above the surface through which vigorous vertical mixing occurs. The mixing height is important because it dictates the vertical space available for spreading the pollutants. Although mixing height information throughout the GOM is scarce, measurements near Panama City, Florida (Hsu et al. 1980) show that the mixing height can vary between 1,312 and 4,265 ft (400 and 1,300 m), with a mean of 2,953 ft (900 m). Heat flux calculations in the WPA (Barber et al. 1988; Han and Park 1988) indicate an upward flux year-round – highest during winter and lowest in summer.

Due to the atmospheric processes on air pollutant transport, stack height, exit gas velocity from the stack, distance of the marine species from the sources, and temporary nature of vessel activity, sea turtles are not vulnerable to air emissions (Hsu et al. 1980; Barber et al. 1988; Han and Park 1988). Because of the combination of 2,953-ft (900-m) mixing height and upward flux of discharged regulated pollutants year-round from stacks, the contribution of routine activities and accidental events (flaring or venting) to the air-water interface are either insignificant or unlikely to occur (and are therefore discountable). Overall, sea turtles are not expected to be vulnerable to onshore or offshore air emissions because emissions would be localized and air pollution would dissipate quickly upward in the air at considerable distances.

4.6.7 Lighting and Visual Impacts

Ports, support facilities, construction facilities, transportation infrastructure, and processing facilities emit light onshore, which can impact sea turtles. Sea turtles in the GOM may be impacted by onshore lighting during the nesting season.

Depending on the location of onshore facilities in relation to nesting beaches, lighting can disorient nesting sea turtles and hatchlings. Upon hatching, sea turtles use natural light cues to orient themselves and advance toward the ocean (Witherington and Martin 2003). Artificial light sources (or light pollution) on land might draw hatchlings away from the ocean, resulting in high mortality due to dehydration and predation (Silva et al. 2017; Witherington and Martin 2003). This is particularly important for the loggerhead sea turtle, which has critical reproductive habitat along the Gulf Coast (*Federal Register* 2014a; NMFS and FWS 2008), and the Kemp's ridley turtle, which also might use this coastal habitat for nesting (Valverde and Holzwart 2017).

Offshore (or OCS) lighting is not expected to affect free-swimming juveniles or adults and would be located too far away to disorient hatchlings.

4.6.8 Accidental Events

4.6.8.1 Spills

The potential impacts of an oil spill could vary depending on the spill magnitude, frequency, timing, location, and the meteorological and oceanographic conditions at the time (NRC 2003b). Several aspects of sea turtle biology and behavior place them at risk, including lack of avoidance behavior, indiscriminate feeding in convergence zones, inhalation of large volumes of air before dives (Milton et al. 2003; Shigenaka 2010), and affinity to the *Sargassum* community for food and cover (Witherington et al. 2012). In general, a small spill (10-49 bbl) would be expected to disperse quickly in the open ocean and would not be likely to contact more than a few individual sea turtles. Prolonged exposure would not be likely for any individuals in the open ocean. A small spill would be unlikely to result in mortality or the life-threatening injury of individual sea turtles, or the long-term displacement of sea turtles from preferred feeding, breeding, or nesting habitats or migratory routes, while a large spill could be more likely to result in these effects.

Eggs, hatchlings, and small juveniles are particularly vulnerable if they come into contact with spilled oil (Fritts and McGehee 1982; Lutz and Lutcavage 1989). Sea turtle hatchling exposure to, fouling by, or consumption of tarballs would likely be fatal. Sea turtle eggs are likely to be lethally impacted by contact with spilled oil (NPS 2010). During nesting, a female turtle might crawl through tar prior to laying her eggs or might push oil mixed with sand into the nest and contaminate the eggs (Chan and Liew 1988). Assuming a sea turtle's sense of smell is critical, oil fouling of a nesting area might disturb imprinting of hatchling turtles or confuse the turtles on their return migration (Chan and Liew 1988). Potential toxic impacts to embryos would depend on the type of oil and degree of weathering, type of beach substrate, and especially upon the developmental stage of the embryo. Embryonic development in an egg may be altered or hindered by contact with oil (Fritts and McGehee 1982). Fresh oil was found to be highly toxic, especially during the last quarter of the incubation period, whereas aged oil produced no detectable impacts. Fritts and McGehee (1982) concluded that oil contamination of nesting beaches would have its greatest impact on nests that were already constructed; nests made on fouled beaches are less likely to be affected, if at all. Residue oil may adhere to sand grains where eggs are deposited, later impeding hatchlings from successfully evacuating nests and ultimately leading to their death. Reproductive success could ultimately be impacted. Though sea turtles could physically nest on oiled beaches, it is likely that nesting females would abandon nesting attempts. If nesting occurs, the nesting female, hatchlings, and eggs could get oiled.

Hatchling and small juvenile turtles are particularly vulnerable to contacting or ingesting hydrocarbons because the currents that concentrate oil spills also form the debris mats in which young turtles are sometimes found (Carr 1980; Collard and Ogren 1990; Witherington 1994). This would also be true for juvenile sea turtles that are sometimes found in floating mats of *Sargassum*. Oil slicks, slickets, or tarballs moving through offshore waters may foul *Sargassum* mats that hatchling and juvenile sea turtles inhabit. High rates of oil contact in young turtles suggest that bioaccumulation may occur over their potentially long lifespan. Some captive sea turtles exposed to oil either reduced the amount of time spent at the surface, possibly avoiding the oil, or became agitated and had short submergence levels (Lutcavage et al. 1995). Sea turtles pursue and swallow tarballs, and there is no firm evidence that free-ranging turtles can detect and avoid oil (Odell and MacMurray 1986). Therefore, oil might have a more indirect impact on the behavior of sea turtles.

Sea turtles accidentally exposed to oil or tarballs may suffer inflammatory dermatitis, ventilatory disturbance, salt gland dysfunction or failure, red blood cell disturbances, immune responses, and digestive disorders or blockages (Vargo et al. 1986; Lutz and Lutcavage 1989; Lutcavage et al. 1995). Significant changes in blood chemistry following contact with hydrocarbons have been reported ranging from changes to blood's oxygen transport system to elevation in white blood cells, indicating stress (Lutcavage et al. 1995). Although disturbances may be temporary, long-term impacts remain unknown, and chronically ingested oil may accumulate in organs. Periocular tissues and other mucous membranes would presumably be most sensitive to contact with hydrocarbons. All structural and biochemical changes in the epidermis of sea turtles have been shown to be minor and reversible. A break in the skin barrier could act as a portal of entry for pathogenic organisms, leading to infection, neoplastic conditions, and debilitation (Vargo et al. 1986).

Contact with hydrocarbons may not cause direct or immediate death, though it may result in cumulative sublethal impacts, such as salt gland disruption or liver impairment (Vargo et al. 1986; Lutz and Lutcavage 1989; Camacho et al. 2012). The impact of tissue oil intake on the long-term health and survival of sea turtles remains unknown (Lutcavage et al. 1995). Camacho et al. (2013) conducted blood plasma testing on stranded sea turtles to determine PAH concentrations and found that oil spills were considered as being a potential environmental source of PAHs detected in turtle blood plasma. The PAH biomagnification does not occur in sea turtles, suggesting that sea turtles may be able to efficiently metabolize PAHs (Camacho et al. 2014).

Overall, impacts would occur as a result of contact with the spilled oil, regardless of the source. Oil would affect sea turtles through various pathways, including direct contact, inhalation of the fuel and its volatile components, and ingestion directly or indirectly through the consumption of fouled prey species (Geraci and St. Aubin 1987). Studies have shown that direct exposure of sensitive tissues (e.g., eyes, nares, and other mucous membranes) and soft tissues to diesel fuel may produce irritation and inflammation, and can adhere to turtle skin or shells (Overton et al. 1983; Van Vleet and Pauly

1987; Lutcavage et al. 1995). Sea turtles surfacing within or near an oil spill would be expected to inhale petroleum vapors, potentially causing respiratory stress. Ingested oil, particularly the lighter fractions, can be acutely toxic to sea turtles. The effects of contact with spilled oil could include mortality and decreased health, reproductive fitness, and longevity, as well as increased vulnerability to disease and contamination of prey species. Required preventative measures could reduce the frequency of spills contacting sea turtles.

4.6.8.2 Spill Response

Spill-response features that may impact sea turtles include artificial lighting from night operations, booms, machine activity, human activity, increased vessel traffic, equipment on beaches and in intertidal areas, sand removal and cleaning, and changed beach landscape and composition. The strategy for cleanup operations varies, depending on the season, recognizing that disturbance to the nest may be more detrimental than the oil (Fritts and McGehee 1982). After passage of the Oil Pollution Act of 1990, seagrass beds and live bottom communities are expected to receive individual consideration during spill cleanup. Required spill contingency plans include special notices to minimize adverse effects from vehicular traffic during cleanup activities and to maximize protection efforts to prevent contact of these areas with spilled oil. Spill-response activities could adversely affect sea turtle habitat and cause temporary displacement from suitable habitat.

Oil-spill response vessels may operate near offshore structures or the shore in response to a spill or to conduct exercises. Spill-response activities could also cause an increase in vessel traffic, and thus, an increased possibility for vessel strikes. Little is known about the effects of dispersants on sea turtles and, in the absence of direct testing, impacts are difficult to predict. Dispersant components absorbed through the lungs or gut may affect multiple organ systems and interfere with digestion, excretion, respiration, and/or salt-gland function. Inhalation of dispersant can interfere with function through the surfactant (detergent) effect. These impacts are likely similar to the empirically demonstrated effects of oil alone (Hoff and Shigenaka 2003). The impacts to sea turtles from chemical dispersants could include nonlethal injury (e.g., tissue irritation, chemical burns, and inhalation), long-term exposure through bioaccumulation, infection, and potential shifts in distribution from some habitat (NOAA 2015; Shigenaka 2010).

As a result of spill response and cleanup efforts, much of an oil spill may be recovered before it reaches the coast. However, cleanup efforts in offshore waters may result in additional injury or mortality of sea turtles, particularly to neonates and juveniles. Depending on the nature of the response activities, impacts could occur by a short-term behavioral change of sea turtles in the immediate affected area. Spill-response impacts include interrupted or deterred nesting behavior, crushed nests, entanglement in booms, and increased hatchling mortality due to predation from the increased time required to reach the water, assuming no outside intervention (Lutcavage et al. 1997). Increased human presence could influence turtle behavior and/or distribution, thereby stressing animals and making them more vulnerable to predators, the toxicological effects of oil, or other anthropogenic sources of mortality.

4.6.8.3 Marine Trash and Debris

Forty-nine percent of marine debris originates from land-based sources, 18 percent originates from ocean-based sources, and 33 percent originates from general sources (sources that are a combination of land-based and ocean-based activities) (USEPA 2009). Pollutants released into streams, rivers, bays and estuaries can enter the open ocean where they can stress marine life, including sea turtles. Pollution, including point and non-point discharges of metals and organic compounds, can degrade water quality, as can contaminants in sediment if resuspended into the water by anthropogenic activities, storms, or other events. In addition, plastics have been found inside deceased sea turtles (Gregory 2009; Schuyler et al. 2016). Toxins directly harm the organisms that ingest them, but they can also have impacts further up the food chain through biomagnification, the process in which chemicals are passed to higher trophic levels through predation (Gray 2002). Therefore, although filter-feeding benthic organisms may be the first to encounter toxic chemicals, these compounds can also contaminate sea turtles.

Marine debris affects marine habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking) (Gall and Thompson 2015). Entanglement in marine debris can lead to injury, infection, reduced mobility, increased susceptibility to predation, decreased feeding ability, fitness consequences, and mortality (e.g., drowning) of sea turtles. Marine debris ingestion can lead to intestinal blockage, which can impact feeding ability and lead to injury or death. There are little data on marine debris in the GOM; therefore, it is difficult to draw conclusions as to the precise extent of the problem and its impacts on sea turtle populations.

4.6.8.4 Vessel Strike

Sea turtles spend at least 3-6 percent of their time at the surface for respiration and perhaps as much as 26 percent of their time at the surface for basking, feeding, orientation, and mating, which makes them vulnerable to vessel strikes (Lutcavage et al. 1997). Several species, such as loggerheads, are known to bask at the surface for long periods, resulting in a total of 20-30 percent of time spent at the surface (Lutcavage et al. 1997). Further, post-hatchlings, which generally reside at or near the sea surface (sometimes associated with *Sargassum*), could be more vulnerable to vessel strike compared to subadult and adult turtles, which spend more time submerged and at depth. Sea turtles located in shallower waters have shorter surface intervals, whereas turtles occurring in deeper waters have longer surface intervals.

Although sea turtles can move somewhat rapidly, they are still vulnerable to strikes from vessels that are moving at more than 4 km per hour (2.5 miles per hour [mph]), which is common in open water (Hazel et al. 2007; Work et al. 2010). For instance, while adult turtles would likely swim away from approaching seismic vessels and only experience behavioral disturbance (Lenhardt 1994), younger, slower turtles may struggle with avoidance. Based on behavioral observations of turtle avoidance of small vessels, green turtles may be susceptible to vessel strikes at speeds as low as 2 knots (kn) (2.3 mph) (Hazel et al. 2007). Hazel et al. (2007) suggested that green turtles may use auditory cues to react to approaching vessels rather than visual cues, making them more susceptible to strike as vessel speed increases. Sea turtles are also known to startle at the presence of boats and ships, causing immediate additional metabolic expenditure.

There is little data available concerning potential sea turtle impacts from vessel strikes due to a lack of studies and/or challenges with detecting such impacts (Nelms et al. 2016). Nonetheless, vessel strike from all types of vessels is known to result in sea turtle injury and mortality in the GOM (Lutcavage et al. 1997; Work et al. 2010; Nelms et al. 2016), particularly off the coast of Florida (NMFS and FWS 2008). Sea turtles occur in all GOM planning areas and could experience increased risk of strike from vessels that support OCS activities. If a sea turtle is struck by a vessel, effects can include serious injury, and/or minor, non-lethal injury, with the associated response depending on the size and speed of the vessel. Both live and dead sea turtles are often found with deep cuts and fractures, indicative of collision with a boat hull or propeller (Hazel et al. 2007). There have been no documented sea turtle collisions with OCS oil- and gas-related vessels in the GOM; however, collisions with small or submerged sea turtles may go undetected.

4.7 Marine Mammals

4.7.1 Noise

Noise sources that marine mammals could be vulnerable to include active acoustic sources, vessels, drilling, production, trenching, construction, and platform decommissioning (including use of explosives) (**Figure 4-2**). Acoustic sources are described by their sound characteristics and are generally divided into impulsive noise and non-impulsive noise for the regulatory process. Impulsive noises (e.g., seismic surveys and pile driving) are generally considered powerful sounds with relatively short durations, broadband frequency content, and rapid rise times to peak levels. Non-impulsive noise generally includes all other noise (e.g., drilling) and includes continuous anthropogenic noise (e.g., vessel noise).

The potential for noise impacts from anthropogenic sound sources on marine mammals is highly variable and depends on the specific circumstances of a given situation (Richardson et al. 1995; Nowacek et al. 2007; Southall et al. 2007, 2019). Furthermore, the same sound source can propagate differently depending on the physical environment. How a sound from a specific source propagates through a particular environment depends on a variety of factors, including physical environmental factors (e.g., salinity, temperature, bathymetry, seafloor type, and tow depth), sound characteristics associated with different sources (e.g., source level, directionality, source type, and duration for both impulsive or continuous signals), frequency (i.e., higher frequencies dissipate faster and lower frequencies may travel farther depending on water depth), and intensity (i.e., decibel level) (Richardson et al. 1995; Southall et al. 2007, 2019).

Populations of sperm whales and beaked whales are expected to be most susceptible to auditory injury or behavioral disturbance from deep-penetration seismic surveys (Farmer et al. 2018). The GOM Bryde’s whale subpopulation is unique to the EPA and could be impacted by increased noise from vessels or seismic airguns conducted in this area (Estabrook et al. 2016). Manatees spend most of their time near coastlines and have greatest hearing sensitivity in higher frequencies (Gaspard et al. 2012), so they may be less affected by airgun noise. Likewise, several distinct populations of resident bottlenose dolphins live along the western and northern coasts of Florida (Van Parijs et al. 2015) and may experience behavioral disturbance from anthropogenic noise when they venture farther from the coast.

Marine mammals could experience behavioral changes, acoustic masking, temporary threshold shift (TTS), permanent threshold shift (PTS), or mortality as a result of OCS-related noise. The TTS is defined as temporary and reversible hearing loss, which may continue for minutes to hours or even days. The duration of TTS depends on a variety of factors, including intensity and duration of the auditory stimulus; and recovery can take minutes, hours, or days as well. Permanent hearing loss (i.e., PTS) is defined as the deterioration of hearing due to prolonged or repeated exposure to sounds that accelerate the normal process of gradual hearing loss or the permanent hearing damage due to brief exposure to extremely high sound levels (Richardson et al. 1995). The PTS results in a permanent elevation in hearing threshold, i.e., an unrecoverable reduction in hearing sensitivity (Southall et al. 2007).

Most observations of marine mammal reactions to oil- and gas-related noise have been limited to short-term behavioral responses, which included temporary cessation of feeding, resting, or social interactions; however, habitat abandonment can lead to more long-term effects (Nowacek et al. 2007). Masking may also occur, in which an animal may not be able to detect, interpret, and/or respond to biologically relevant sounds (Parks 2012). Masking can reduce the range of communication, particularly long-range communication. This could have a variety of implications for marine mammals including, though not limited to, inability to avoid predators and to reproduce successfully (Marine Mammal Commission 2007). Marine mammals may compensate for masking by changing the frequency, source level, redundancy, or timing of their signals, though the long-term implications of these adjustments are currently unknown (Parks 2012).

In general, mysticete (baleen) whales, which communicate in lower frequencies, are more susceptible to noise-related impacts than odontocetes (toothed whales) because their hearing ranges overlap in frequency with several sound sources from OCS-related activities (Di Iorio and Clark 2010; Nowacek et al. 2015; Richardson et al. 1995; Southall et al. 2007b). Behavioral reactions to anthropogenic sounds have included changing diving behavior (e.g., North Atlantic right whales [Nowacek et al. 2004]), rapidly swimming away (e.g., beaked whales [DeRuiter et al. 2013]), changing migration speed or direction (e.g., humpback whales [Dunlop et al. 2016]) and gray whales [Malme et al. 1985]), or reducing foraging activity (e.g., sperm whales [Miller et al. 2009]). There is evidence that some marine mammals avoid acoustic masking by changing their vocalization rates (e.g., bowhead whale [Blackwell et al. 2013], blue whale [Di Iorio and Clark 2010]), and humpback whale [Cerchio et al. 2014]), increasing call amplitude (e.g., beluga whale [Scheifele et al. 2004] and killer whales [Holt et al. 2009]) or shifting dominant frequencies of their calls (Lesage et al. 1999; Parks et al. 2007). Other species may lose the ability to locate and communicate with other individuals. Many marine mammals maintain social bonds acoustically; thus, increased noise could reduce a population's capacity for social learning (Whitehead et al. 2004). However, only a few studies have examined changes in stress levels in response to noise (Rolland et al. 2012; Romano et al. 2004).

4.7.1.1 Active Acoustics

Underwater noise sources from geological and geophysical activities include impulsive active acoustic sound sources such as airguns; boomers; and non-airgun, high-resolution geophysical sources such as CHIRP subbottom profilers; multibeam echosounders; and side-scan sonars. Scientific uncertainty remains regarding the nature and magnitude of the actual impacts of seismic noise on the behavior of marine mammals, particularly when it comes to distinguishing between a general behavioral response and a biologically significant one. As noted in Southall et al. (2007, 2019), some of this uncertainty is related to data suffering from low sample sizes, limited information on received sound levels and background noise, insufficient measurements of all potentially important contextual variables, and/or insufficient controls with most behavioral studies suffering from at least some of these problems.

In Southall et al. (2007), an expert panel reviewing available literature on behavioral response to anthropogenic noise were unable to reach a consensus on what level of sound may serve as a threshold for behavioral reactions in marine mammals. A number of studies document behavioral effects in response to seismic surveys, primarily for mysticetes (Richardson et al. 1995). Mysticetes are considered low-frequency cetaceans with an estimated auditory bandwidth of 7 Hz to 30 kHz. The mysticetes (i.e., baleen whales) have been one of the most studied groups of marine mammals in terms of observations of behavioral changes in response to seismic operations. There is a possible overlap between the expected frequencies of best-hearing sensitivity (low threshold) in mysticetes and maximal airgun output at source. It is generally considered that the auditory abilities of all mysticete species are broadly similar, based upon vocalization frequencies and ear anatomy (Ketten 1998).

Mate et al. (1994) reported temporarily decreased sperm whale abundance in an area of seismic operations in the northeastern GOM. However, acoustic arrays recorded sperm whales producing click sequences during dives within 4 nautical miles (5 mi; 7 km) of an active, 3D seismic vessel during surveys conducted in 2001. Codas, or sperm whale communication clicks, are not expected to be affected by seismic survey sound at far distances. There are insufficient data to assign thresholds for acoustic disturbance to sperm whales. An additional factor to consider is the deep-diving habit of sperm whales. Unlike mysticetes, which may remain close to the surface for long periods, sperm whales spend a small percentage of time at the surface during the course of feeding activity. They surface for longer periods (average 9 minutes) between deeper dives to replenish myoglobin oxygen reserves (Watwood et al. 2006). This means they may be less likely to receive any mitigative effects afforded by sea state and near surface conditions that could buffer or dissipate sound that can occur in some instances. Also, the sperm whale may dive to a depth where an operating seismic vessel could potentially pass directly over it without visually detecting the sperm whale.

From 2002 to 2005, BOEM funded the “Sperm Whale Seismic Study,” which was a multiyear, interdisciplinary study on sperm whales in the GOM. A summary report was published in 2006 (Jochens et al. 2006) and a synthesis report was published in 2008 (Jochens et al. 2008). These reports provide the conclusions below regarding sperm whales in the GOM and their response to seismic surveys.

- During controlled exposure experiments, researchers could detect “no horizontal avoidance of the seismic source for exposure levels (RL) of <150 dB re 1 μPa (rms).” Similarly, opportunistic studies detected no apparent horizontal avoidance or displacement of sperm whales associated with operational seismic surveys.
- Although a small sample, the controlled exposure experiments’ data results did not confirm the assumption that whales swim away from an airgun as it ramps up or approaches the whale at full power.
- In contrast to the lack of avoidance response, the controlled exposure experiments’ results showed there may be statistically significant changes in the swimming and foraging behavior of sperm whales exposed to the sound of airguns in the exposure range (RL) of 111-147 dB re 1 μPa (rms) (131-164 dB re 1 μPa [peak to peak]; refer to Table I in Madsen et al. 2006) at distances of approximately 1.4-12.6 km (0.9-7.8 mi) from the sound source.
- There was the “discovery of a statistically significant 60 percent reduction in foraging for one whale coupled with evidence that other whales are less sensitive…”

The impacts of noise from geological and geophysical activities could include one or more of the following: masking of natural sounds, which could reduce an individual’s ability to effectively communicate, detect predators or prey, and detect important environmental features (Clark et al. 2009); behavioral disturbance (e.g., changes in feeding or mating behaviors); tolerance; and temporary or permanent hearing impairment, or nonauditory physical or physiological impacts (Richardson et al. 1995; Nowacek et al. 2007; Southall et al. 2007). Given that mysticetes (e.g., GOM Bryde’s whale) produce calls that span a low-frequency range (20 Hz to 30 kHz) with their best hearing abilities presumably falling into this range as well, they would be most likely to experience impacts from the low-frequency sounds produced by seismic surveys (Richardson et al. 1995). In contrast, odontocetes (e.g., sperm whale) produce calls and hear best at mid to high frequencies (Richardson et al. 1995) and appear less vulnerable to low-frequency sound sources than mysticetes. These frequency ranges have changed over time (Southall et al. 2019).

Direct physical effects, such as PTS, require relatively intense, received energy that would be expected to occur only at short distances from the seismic survey source (Nowacek et al. 2007). According to Southall et al. (2007), PTS for cetaceans from multiple pulse sources (e.g., seismic) is established at 230 dB re 1 μPa (peak). Permanent hearing impairment would constitute injury; however, TTS is not considered an injury (Southall et al. 2007).

In the case of seismic surveys in the GOM, where potential masking noise takes a pulsed form with a low duty cycle (~6-10%, or a 1-second disturbance in the sound field in every 10-15 seconds of ambient noise), the effect of masking is likely to be low relative to continuous sounds (e.g., ship noise). Some whales are known to continue calling in the presence of seismic pulses. Since most of the energy from airguns is radiated at frequencies below 200 Hz, low-frequency cetaceans would most likely hear the acoustic source that falls within their hearing range. Although low-frequency cetaceans would be expected to hear airguns, mid-frequency cetaceans have auditory bandwidths that overlap slightly with the frequencies of maximum airgun output. The potential effects of underwater sound from an active acoustic source could result in mortality, TTS or PTS, behavioral disturbance stress, masking, and nonauditory physical or physiological effects (Richardson et al. 1995; Southall et al. 2007; Nowacek et al. 2007). The degree of the potential impact depends on the species' hearing frequency, sound characteristics, received level, distance of the animal from the sound source, and duration of the sound exposure.

4.7.1.2 Vessel and Equipment Noise

The dominant source of human noise in the sea is ship noise (Tyack 2008). The primary sources of vessel noise are propeller cavitation, propeller singing, and propulsion; other sources include auxiliaries, flow noise from water dragging along the hull, and bubbles breaking in the wake (Richardson et al. 1995). Vessel and equipment noise produce non-pulsed or continuous types of sounds that have the potential to disturb marine mammals (Erbe et al. 2019). Vessel and equipment noise are transitory and generally do not propagate at great distances from the vessel. The intensity of noise from service vessels is roughly related to ship size and speed (Erbe et al. 2019). Large ships tend to be noisier than small vessels, and ships underway with a full load (or towing or pushing a load) produce more noise than unladen vessels. For a given vessel, relative noise also tends to increase with increased speed.

Many of the industry-related noises are generally temporary, short-lived, and believed to be out of, or on the limits of, marine mammal hearing. For most of the time that seismic survey vessels are underway, they would be operating their airguns or other active acoustic sound sources. During those periods when non-seismic vessels are operating or when seismic vessels have shut down their airguns, the potential for behavioral impacts from vessel and equipment noise remains. Impacts from vessel noise could disturb animals in the immediate vicinity of the vessel (Erbe et al. 2019).

The effects of noise produced by moving geological and geophysical survey vessels on marine mammals are difficult to assess because of the wide array of reports of their observed behavioral responses, both between and within species. Actual responses of individuals could vary widely and are heavily dependent on context (Richardson et al. 1995; Southall et al. 2007; Ellison et al. 2011). Several species of small-toothed cetaceans have been observed to avoid boats when they are approached to within 0.5-1.5 km (0.3-0.9 mi), with occasional reports of avoidance at greater distances (Richardson et al. 1995). Reports of responses of cetacean species to moving power vessels are variable, both between species and temporally (Richardson et al. 1995). It is conservative to assume that vessel noise may, in some cases, elicit behavioral changes in individual marine mammals that are in close proximity to these vessels. These behavioral changes may include evasive maneuvers such as diving or changes in swimming direction and/or speed.

The continued presence of various cetacean species in areas with heavy vessel traffic suggests a considerable degree of tolerance to vessel noise and disturbance. Evidence suggests, however, that some whale species have reduced their use of certain areas heavily utilized by ships (Richardson et al. 1995), possibly avoiding or abandoning important feeding areas, breeding areas, resting areas, or migratory routes. Vessel noise could interfere with marine mammal communication either by masking important sounds from conspecifics (a member of the same species), masking sounds from predators, or by forcing animals to alter their vocalizations (Tyack 2008). There is the possibility of short-term disruption of movement patterns and/or behavior caused by vessel noise and disturbance.

Drilling and production activities, which include operating platforms and drillships, produce underwater noise that may be detected by marine mammals. Noises produced by these types of activities, including pile driving, are generally low frequency and have the potential to mask cetaceans' reception of sounds produced for echolocation and communication. Most species of marine mammals in the GOM (except the Bryde's whale) use sounds at frequencies that are generally higher than the dominant noise generated by offshore drilling and production activities. Baleen whales use low-frequency sounds that overlap broadly with the dominant frequencies of many industrial sounds, and there are indications that baleen whales are sensitive to low- and moderate-frequency sounds (Richardson et al. 1995). It is expected that noise from drilling activities would be relatively constant during the temporary duration of drilling. Drilling noise from conventional metal-legged structures and semisubmersibles is not particularly intense and is strongest at low frequencies, averaging 5 Hz and 10-500 Hz, respectively (Richardson et al. 1995). Drillships produce higher levels of underwater noise than other types of platforms. There are few published data on underwater noise levels near production platforms and on the marine mammals near those facilities (Richardson et al. 1995). However, underwater noise levels may often be low, steady, and not very disturbing (Richardson et al. 1995). Stronger reactions would be expected when sound levels are elevated by support vessels or other noisy activities (Richardson et al. 1995).

Noise can mask important sounds from conspecifics, mask sounds from predators, or force animals to alter their vocalizations. Noises may frighten, aggravate, or distract marine mammals and lead to physiological and behavioral disturbances (Southall et al. 2007). The response threshold may depend on whether habituation (gradual waning of behavioral responsiveness) or sensitization (increased behavioral responsiveness) occurs (Richardson et al. 1995). Noises can cause reactions that might include the disruption of marine mammals' normal activities (behavioral and/or social disruption) and, in some cases, short- or long-term displacement from areas important for feeding and reproduction (Richardson et al. 1995). The energetic consequences of one or more disturbance-induced periods of interrupted feeding or rapid swimming, or both, have not been evaluated quantitatively. Some demographic groups may be more vulnerable to noise impacts, including females in late pregnancy or lactating.

Human-made noise may cause temporary or permanent hearing impairment in marine mammals if the noise is strong enough (Southall et al. 2007). Such impairment would have the potential to diminish the individual's chance for survival. Tolerance of noise is often demonstrated, though marine mammals may be affected by noise in ways that are difficult to observe. For example, they may become stressed, making the animal(s) more vulnerable to parasites, disease, environmental contaminants, and/or predation (Erbe et al. 2019). Noise-induced stress is possible, though it is little studied in marine mammals. Tyack (2008) suggests that a more significant risk to marine mammals from sound are these less visible impacts of chronic exposure. Drilling and production noise would contribute to increases in the ambient noise environment of the GOM, but these noises are not expected in amplitudes sufficient to cause either hearing or behavioral impacts.

Aircraft noise is generally short in duration and transient in nature, although it may ensonify large areas. Much of the noise from a passing aircraft is reflected and does not penetrate the air-water interface (Urick 1972). Helicopter noises contain dominant tones (resulting from rotors) generally below 500 Hz (Richardson et al. 1995). The Federal Aviation Administration's Advisory Circular 91-36D (2004) encourages pilots to maintain an altitude of higher than 610 m (2,000 ft) over noise-sensitive areas. Corporate helicopter policy states that helicopters should maintain a minimum altitude of 231 m (700 ft) while in transit offshore and 152 m (500 ft) while working between platforms. It is unlikely that marine mammals would be affected by routine OCS helicopter traffic operating at these altitudes. Routine overflights (either helicopter or fixed-wing) may elicit a startle response from and interrupt marine mammals nearby (depending on the activity of the animals), possibly causing temporary displacement from feeding, mating, or traveling activities. These responses are due to either the increasing noise as the aircraft approaches or due to the physical presence of the aircraft in the air. This temporary disturbance to marine mammals may occur as helicopters approach or depart OCS-related facilities if animals are near the offshore facility.

4.7.2 Operational Discharges and Wastes

Discharges are regulated by the USEPA through the issuance of NPDES permits. Pollutants discharged into navigable waters of the U.S. are regulated by the USEPA under the Clean Water Act of 1972 and subsequent provisions (33 U.S.C. §§ 1251 *et seq*.). Specifically, an NPDES permit must be obtained from the USEPA under Sections 301(h) and 403 of the Clean Water Act of 1972 (*Federal Register* 1980). It is assumed that compliance with the USEPA and USCG regulations, which are designed to keep contaminants below harmful levels for public health and welfare, would prevent impacts from produced water, drilling muds, and cuttings. These discharges are not expected to persist in the water column.

Due to the localized and transient nature of the water quality impacts, these discharges are unlikely to affect foraging or other activities by marine mammals. Operational discharges are diluted and dispersed when released in offshore areas, and they are not expected to directly or indirectly affect any marine mammal species (Kennicutt 1995). Therefore, drilling discharges are not likely to have any detectable effect on marine mammals.

4.7.3 Bottom Disturbance

Drilling would be localized and impacts are not expected to occur outside of the immediate area. In addition, infrastructure emplacement, pipeline trenching, and structure removal would be localized and temporary, and habitat loss is not expected. The listed whale species do not use benthic or seafloor habitats to any discernable extent. The benthic habitats used by the Florida manatee are in coastal, inland waters, which would not be within typical locations for BOEM-regulated activities. Adverse modification of critical habitat would not be legally authorized under the ESA. Further, it is assumed that care in the timing of activities and siting of onshore and OCS infrastructure, particularly with regard to ESA-listed species, would be applied. Therefore, bottom disturbance is not expected to have any detectable effect on marine mammals in the GOM planning areas.

4.7.4 Coastal Land Disturbance

It is assumed that careful planning will be applied to avoid coastal land disturbance in areas utilized by the Florida manatee, which are mainly located in the EPA where BOEM has no expected activity. Adverse modification of critical habitat of any marine species would not likely be legally authorized under the ESA or the Marine Mammal Protection Act. Coastal land disturbance would not affect cetaceans since they are strictly marine inhabitors. Also, marine mammals are not expected to be affected by a pipeline landfall due to the unlikely potential for it to occur in the WPA and CPA and due to the fact that most cetaceans strictly utilize pelagic waters. Onshore construction is not within the OCS and would be outside of BOEM or BSEE's regulatory authority. Any activity would be under other regulatory authorizations (e.g., the USACE and Federal Energy Regulatory Commission).

4.7.5 Offshore Habitat Modification

It is assumed that careful planning and siting of infrastructure, particularly with regard to ESA-listed species, would be applied to avoid long-term marine mammal habitat modification. Adverse modification of critical habitat would not be legally authorized under the ESA. ESA-listed whale species in the GOM do not use benthic or seafloor habitats to any discernable extent. The benthic habitats used by the Florida manatee are in coastal, inland waters, which would not be within typical locations for BOEM-regulated activities. BOEM-regulated drilling would be localized, and effects are not expected to occur outside of the immediate area. Infrastructure emplacement, pipeline trenching, and structure removal would be localized and temporary, and habitat loss is not expected. Coastal land disturbance would not affect cetaceans since they strictly utilize pelagic waters. Onshore construction is not within the OCS and would be outside of BOEM or BSEE's regulatory authority. Any onshore activity would be under other regulatory authorizations (e.g., the USACE and Federal Energy Regulatory Commission).

The USEPA regulates discharges through the issuance of NPDES permits. Pollutants discharged into navigable waters of the U.S. are regulated by the USEPA under the Clean Water Act of 1972 and subsequent provisions (33 U.S.C. §§ 1251 *et seq*.). Specifically, an NPDES permit must be obtained from the USEPA under Sections 301(h) and 403 of the Clean Water Act of 1972 (*Federal Register* 1980). It is assumed that compliance with the USEPA and USCG regulations, which are designed to keep contaminants below harmful levels for public health and welfare, would prevent impacts from produced water, drilling muds, and cuttings. These discharges are not expected to persist in the water column. Due to the localized and transient nature of the water quality impacts, these discharges are unlikely to affect foraging or other activities by marine mammals. Operational discharges are diluted and dispersed when released in offshore areas, and therefore are not expected to directly or indirectly affect (Kennicutt 1995) or have any detectable effect on marine mammals. It is assumed that BSEE, USCG, and USEPA regulations, and BOEM guidance will be applied and strictly followed by oil and gas operators. For instance, the USCG and USEPA regulations require operators to be proactive in avoiding accidental loss of solid waste items by developing waste management plans, posting informational placards, manifesting trash sent to shore, and using special precautions (e.g., covering outside trash bins) to prevent accidental loss of solid waste. It is prohibited to discharge trash and debris (33 CFR §§ 151.51-77) unless it is passed through a comminutor (a machine that breaks up solids) and ultimately pass through a 25-mm (1-in) mesh screen. All other trash and debris must be returned to shore for proper disposal with municipal and solid waste. Therefore, it is unlikely that significant amounts of trash and debris will be released into the marine environment, and debris impacts are expected to be avoided.

4.7.6 Air Emissions

To protect public health and welfare, the Clean Air Act established NAAQS for certain common and widespread pollutants. In addition to the criteria pollutants, BOEM assesses volatile organic compounds since these are precursors to oxygen formation. Air emissions from BOEM-regulated activities in the GOM would arise from emission sources related to drilling and production with associated vessel support, flaring and venting, decommissioning, fugitive emissions, and oil spills. The Outer Continental Shelf Lands Act requires BOEM to comply with the NAAQS pursuant to the Clean Air Act (42 U.S.C. §§ 7401 *et seq*.), to the extent that activities significantly affect the air quality of any State. Therefore, BOEM focuses its analyses on the impact of these activities on the States. Human activity within the OCS is transitory at best as would be any marine mammal, though activities may be recurring and certain facilities may remain for several years. Additionally, emissions are occurring above the air-water interface, which is well out of the natural habitat of any marine mammal.

Once pollutants are released into the atmosphere, transport and dispersion processes begin circulating the emissions. Transport processes are carried out by the prevailing wind circulations, which can vary depending on the time of year. Dispersion depends on emission height, atmospheric stability, mixing height, exhaust gas temperature and velocity, and wind speed. The mixing height is the height above the surface through which vigorous vertical mixing occurs. The mixing height is important because it dictates the vertical space available for spreading the pollutants. Although mixing height information throughout the Gulf of Mexico is scarce, measurements near Panama City, Florida (Hsu et al. 1980), show that the mixing height can vary between 1,312 and 4,265 ft (400 and 1,300 m), with a mean of 2,953 ft (900 m). Heat flux calculations in the WPA (Barber et al. 1988; Han and Park 1988) indicate an upward flux year-round – highest during winter and lowest in summer.

Due to the atmospheric processes on air pollutant transport, stack height above any infrastructure, exit gas velocity from the stack, distance of the marine species from the sources, and temporary vessel activity, marine mammals are not vulnerable to air emissions (Hsu et al. 1980; Barber et al. 1988; Han and Park 1988). Because of the combination of 2,953-ft (900-m) mixing height and upward flux of discharged-regulated pollutants year-round from stacks, the contribution of routine activities and accidental events (flaring or venting) to the air-water interface are either insignificant (negligible) or unlikely to occur (and are therefore discountable). Overall, marine mammals are not expected to be vulnerable to onshore or offshore air emissions because emissions would be localized and air pollution would dissipate quickly upward in the air at considerable distances.

4.7.7 Lighting and Visual Impacts

Migratory, feeding, and breeding behaviors of cetaceans are not significantly impacted by artificial light since they depend on acoustic rather than visual cues. Lighting and visual impacts are not expected to occur on marine mammals since infrastructure is above the water and is not expected to be in the visible range and/or an attractant source for marine mammals.

4.7.8 Accidental Events

4.7.8.1 Oil Spills

In the event of an accidental oil spill, the eruption of gases and fluids may generate significant pressure waves and noise that may harass, injure, or kill marine mammals, depending on their proximity to the accident. The probability that a marine mammal would be in the vicinity of a loss of well control (not considered in this example as catastrophic) at the exact moment it occurs is relatively small due to the wide-ranging movement of marine mammal species, along with the low probability of a loss of well control. There are relatively few studies assessing the physiological impacts of oil spills on marine mammals because laboratory experiments present ethical concerns. The impacts of an oil spill on marine mammals depend on many variables, such as location and size of the spill, oil characteristics, meteorological and oceanographic conditions, time of year, and types of habitats, as well as the behavior and physiology of the marine mammals themselves (Johnson and Ziccardi 2006). Further, these factors would determine which species would be affected and the extent of the effect.

Several factors increase the probability of marine mammal/oil-spill contact, including the following: (1) marine mammals often travel long distances in the GOM, increasing the geographic areas of potential impact; (2) marine mammals are relatively long-lived and have many years during which they may be exposed (natural seeps or otherwise); and (3) some spills would be larger, increasing the area of potential impact. It is impossible to know precisely which cetacean species, population, or individuals would be most impacted, to what magnitude, or in what numbers since each species has unique distribution patterns in the GOM and because of difficulties attributed to predicting when and where oil spills would occur. The potential impacts associated with an accidental spill may be more severe depending on the size of the accidental spill. The impact from a reasonably foreseeable, higher volume accidental spill could potentially contribute to more significant and longer-lasting impacts that could include mortality and longer-lasting chronic or sublethal health impacts.

Effects of spilled oil on marine mammals are discussed by Geraci (1990); Geraci and St. Aubin (1980, 1982, 1985) and Lee and Anderson (2005). Marine mammals could be affected by oil spills through various pathways: direct surface contact; inhalation of fuel or its volatile components; or ingestion (via direct ingestion or by the ingestion of contaminated prey). These pathways could affect marine mammals by leading to mortality, decreased health, reproductive fitness, and longevity, as well as increased vulnerability to disease. The oil from a spill can adversely affect marine mammals by causing soft-tissue irritation, respiratory stress from the inhalation of toxic fumes, food reduction or contamination, direct ingestion of oil and/or tar, and temporary displacement from preferred habitats. The long-term impacts to marine mammal populations are poorly understood. An oil spill may physiologically stress an animal (Geraci and St. Aubin 1980), making it more vulnerable to disease, parasitism, environmental contaminants, and/or predation. In any case, the impact could negatively impact a marine mammal population or stock.

An oil spill also can lead to the localized contamination, reduction, or elimination of prey species. Generally, the potential for ingesting oil-contaminated prey is highest for benthic-feeding marine mammals (e.g., those that feed on clams and polychaetes, which tend to concentrate petroleum hydrocarbons), reduced for plankton-feeding whales, and lowest for fish-eating marine mammals as food web biomagnification of petroleum hydrocarbons does not occur (Würsig 1988). Increased risk of impacts to marine mammals has been seen in protected bays and estuaries where oil may concentrate and lead to long-term exposure (Schwacke et al. 2014).

Fresh crude oil or volatile distillates release toxic vapors that, when inhaled, can lead to irritation of respiratory membranes, lung congestion, and pneumonia. Subsequent absorption of volatile hydrocarbons into the bloodstream may accumulate into such tissues as the brain and liver, causing neurological disorders and liver damage (Geraci 1990; Geraci and St. Aubin 1982). Toxic vapor concentrations just above the water's surface (where cetaceans draw breath) may reach critical levels for the first few hours after a spill, prior to evaporation and dispersion of volatile aromatic hydrocarbons and other light components (Geraci and St. Aubin 1982).

Studies by Geraci and St. Aubin (1982 and 1985) have shown that the cetacean epidermis functions as an effective barrier to many of the toxic substances found in petroleum. The cetacean epidermis is nearly impenetrable, even to the highly volatile compounds in oil, and when skin is breached, exposure to these compounds does not impede the progress of healing (Geraci and St. Aubin 1985). Marine mammals are more likely to have dermal contact with weathered oil, which is more persistent but contains fewer of the toxic compounds found in fresh oil (Geraci and St. Aubin 1990).

In general, a small spill (10-49 bbl) would be expected to disperse quickly in the open ocean and would not be likely to contact more than a few if any individual marine mammals. Prolonged exposure would not be likely for any individuals in the open ocean. A small spill would be unlikely to result in mortality or life threatening injury of individual marine mammals or the long-term displacement of marine mammals from preferred feeding, breeding, or calving areas.

Reactions of free-ranging dolphins to spilled oil appear varied, ranging from avoidance to apparent indifference (Geraci 1990). It is unknown whether animals in some cases are simply not affected by the presence of oil or perhaps are even drawn to the area in search of prey organisms attracted to the oil's protective surface shadow (Geraci 1990). The probable impacts on cetaceans swimming through an area of oil would depend on a number of factors, including ease of escape from the vicinity, the health of the individual animal, and its immediate response to stress (Geraci and St. Aubin 1985).

Manatees often rest at or just below the surface in coastal waters, which may bring them in contact with spilled oil (St. Aubin and Lounsbury 1990). Direct contact with discharged oil likely does not impact adult manatees' thermoregulatory abilities since they use blubber for insulation. Manatees are nonselective, generalized feeders that might consume tarballs along with their normal food, although such occurrences have rarely been reported (St. Aubin and Lounsbury 1990). A manatee might also ingest fresh petroleum, which some researchers have suggested might interfere with the manatee's secretory activity of their unique gastric glands or harm intestinal flora vital to digestion (Geraci and St. Aubin 1980). Spilled oil may also affect the quality or availability of aquatic vegetation, including seagrasses, upon which manatees feed. There have been no experimental studies and only a few observations suggesting that oil has harmed any manatees (St. Aubin and Lounsbury 1990). The physiological costs of animals moving to colder waters to escape oiled areas may result in thermal stress that could exacerbate the impacts of even brief exposure to oil (St. Aubin and Lounsbury 1990).

Marine mammals may have direct contact with oil by swimming through oil on the surface and/or subsurface. Surfacing behavior exposes skin, eyes, nares, and other mucus membranes to volatile hydrocarbons. This contact with oil could cause soft-tissue damage to eye tissues, potentially leading to ulcers, conjunctivitis, or blindness. Whale baleen has not been shown to be altered structurally or functionally by oil adsorption (Werth et al. 2019).

Given the distribution of potential leases and pipelines, and the distribution of marine mammals in the northern GOM, the fate of an oil spill must be considered relative to the region and period of exposure. Spills of any size can degrade water quality at least locally, and residuals become available for bioaccumulation within the food chain. Slicks may spread at the sea surface or may migrate underwater from the seafloor through the water column and never broach the sea surface. Regardless, a slick is an expanding but aggregated mass of oil that, with time, would disperse into smaller units as it evaporates (if at the sea surface) and weathers. As the slick breaks up into smaller units (e.g., slickets) and soluble components dissolve into the seawater, tarballs may remain within the water column. Tarballs may subsequently settle to the seafloor or attach to other particles or bodies in the sea. As residues of an oil spill disperse, marine mammals may be exposed via the waters that they inhabit, as well as via the prey they consume. For example, tarballs may be consumed by marine mammals and by other marine organisms that are eaten by marine mammals. Although marine mammals may avoid oil spills or slicks, it is highly unlikely that they are capable of avoiding spill residuals in their environment at some point in their lifetime. Consequently, the probability that a marine mammal is exposed to hydrocarbons resulting from a spill extends well after the oil spill has dispersed from its initial aggregated mass. Populations of marine mammals in the northern GOM would likely be exposed to residuals of spilled oil throughout their lifetime, whether human caused or natural seeps.

4.7.8.2 Spill Response

Spill-response activities that may impact marine mammals include increased vessel traffic, the use of dispersants, and remediation activities (e.g., controlled burns, skimmers, boom, etc.). The increased human presence in the water after an oil spill (e.g., vessels) would likely add to changes in behavior and/or distribution, thereby potentially stressing marine mammals further and perhaps making them more vulnerable to various physiologic and toxic effects of spilled oil. In addition, the large number of response vessels could place marine mammals at a greater risk of vessel collisions, which could cause fatal injuries. Manatees are particularly vulnerable to vessel collisions that may result from increased vessel traffic. Vessel noise would also increase as a result of increased vessel activity and could result in immediate behavioral changes in some individuals.

Spill-response activities could also include the application of dispersants to the affected area depending on the size and location. Dispersants are designed to break oil on the water's surface into minute droplets, which then break down in seawater. Little is known about the impacts of oil dispersants on cetaceans, except that removing oil from the surface would reduce the risk of contact and render it less likely to adhere to skin or other body surfaces (Neff 1990). However, it is difficult to determine how these exposures relate to the actual exposures in the GOM since there is no known accurate method to measure the amount of whale exposure to dispersants (Wise et al. 2014). The acute toxicity of most oil dispersant chemicals is considered to be low relative to the constituents and fractions of crude oil and refined products. Varieties of aquatic organisms readily accumulate and metabolize surfactants from oil dispersants; however, metabolism of surfactants is thought to be rapid enough that there is little likelihood of food chain transfer from marine invertebrates and fish to predators, including marine mammals (Neff 1990). Impacts from dispersants are unknown but may be irritants to tissues and sensitive membranes (NRC 2005a). One assumption concerning the use of dispersants is that the chemical dispersion of oil would considerably reduce the impacts to marine mammals, primarily by reducing their exposure to petroleum hydrocarbons (French-McCay 2004; NRC 2005a). However, the impacts to marine mammals from chemical dispersants could include nonlethal injury such as tissue irritation and inhalation, long-term exposure through bioaccumulation, and potential shifts in distribution from some habitats.

Some remediation activities likely to be used for spills <10,000 bbl that could impact marine mammals include the use of skimmers, booms, and in-situ burns. Impacts through skimmers could be through capture and/or entrainment. Booming operations could potentially impact marine mammals, particularly manatees, as they are close to shore and known to explore and interact with objects in their environment (Hartman 1979). Lines used to anchor booms are more likely than the boom itself to impact manatees by entanglement. In-situ burns could impact marine mammals if they were in the burning oil; however, it is expected that animals would avoid the area once it is ignited. In both skimming and controlled burning activities, the use of trained observers is common. Due to the low probability of marine mammals being in the vicinity of an OCS oil- and gas-related, oil-spill response activity due to their wide-ranging behavior reduces the likelihood of impacts to marine mammals.

4.7.8.3 Marine Trash and Debris

Forty-nine percent of marine debris originates from land-based sources, 18 percent originates from ocean-based sources, and 33 percent originates from general sources (sources that are a combination of land-based and ocean-based activities) (USEPA 2009). Pollutants released into streams, rivers, bays and estuaries can enter the open ocean where they can stress marine life, including marine mammals. Pollution, including point and non-point discharges of metals and organic compounds, can degrade water quality, as can contaminants in sediment if resuspended into the water by anthropogenic activities, storms, or other events. In addition, plastics have been found inside deceased marine mammals (Gregory 2009). Toxins directly harm the organisms that ingest them but can also have impacts further up the food chain through biomagnification, the process in which chemicals are passed to higher trophic levels through predation (Gray 2002). Therefore, although filter-feeding benthic organisms may be the first to encounter toxic chemicals, these compounds can also contaminate marine mammals.

Marine debris affects marine habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking) (Gall and Thompson 2015). Entanglement in marine debris can lead to injury, infection, reduced mobility, increased susceptibility to predation, decreased feeding ability, fitness consequences, and mortality (e.g., drowning) of marine mammals. Marine debris ingestion can lead to intestinal blockage, which can impact feeding ability and lead to injury or death. Data on marine debris in some locations of the GOM is largely lacking; therefore, it is difficult to draw conclusions as to the extent of the problem and its impacts on marine mammal populations.

4.7.8.4 Vessel Strike

Many marine mammal species are vulnerable to vessel strike, which can result in injury or death (Laist et al. 2001; Vanderlaan and Taggert 2007; van Waerebeek et al. 2007; Pace 2011). Most reports of vessel collisions with marine mammals involve large whales, though collisions with smaller species also occur (van Waerebeek et al. 2007). Laist et al. (2001) compiled data and found that most severe and lethal whale injuries involve large ships (>262 ft; 80 m) at higher speeds; 89 percent of ship strike records show that vessels were moving at >14 kn (16 mph). They also concluded that the majority of collisions appear to occur over or near the continental shelf and that the whales usually are not seen beforehand or are seen too late to be avoided (Laist et al. 2001). Seismic operations with towed gear generally are conducted at relatively slow speeds of 4-6 kn (4.6-7 mph), with a maximum speed <8 kn (9 mph), though small crew change or support vessels move faster.

Marine mammal species of concern for possible vessel strike with all vessels operating at speed include primarily slow-moving species or those that spend extended periods of time at the surface and deep-diving species while on the surface (e.g., sperm whales) (Vanderlaan and Taggert 2007). For instance, Bryde's whales spend 90 percent of their time within 39 ft (12 m) of the ocean's surface (Constantine et al. 2015), which makes them vulnerable to collisions with large ships. Deep-diving whales may be more vulnerable to vessel strikes because of the extended surface period required to recover from extended deep dives (Fais et al. 2016b). Sperm whales have been shown to be unable to outmaneuver a fast vessel approaching under stratified water conditions (Gannier and Marty 2015).

Manatees are slow moving and are often struck by smaller boats (FWS 2001). Vessel strikes are the most common cause of human-induced mortality for manatees, and most manatees bear prop scars from contact with vessels. Service and support vessels traveling through coastal areas to and from the OCS have the potential to impact manatees by vessel collisions. Inadequate hearing sensitivity at low frequencies (Gerstein et al. 1999), slow movement, and the use of shallow and surface waters are contributing factors to their vulnerability to vessel strike. While manatees are less common in the western GOM, they are being seen more frequently, and increased sightings indicate that there is a slight potential for risks to this species from OCS vessel traffic.

4.8 BIRDS

4.8.1 Noise

Several noise sources could potentially interact with coastal and marine birds in the GOM and are either considered active acoustics (e.g., seismic surveys) or produced from vessels and equipment. Noise has the potential to mask communication, displace birds from important breeding or foraging areas, disturb predator-prey interactions, and cause noise-induced threshold shifts (Crowell 2016). Vocalizations are essential to seabirds in-air; it is currently unknown if seabirds utilize vocalizations for communication or navigation underwater. Birds are known to have a relatively restricted hearing range for airborne noise, with acute sensitivity occurring in the range of 1-5 kHz (Dooling and Popper 2007). Less is known about the auditory hearing range of birds underwater; however, one study found that a cormorant had similar hearing thresholds to seals and toothed whales at 1-4 kHz (Hansen et al. 2017). Another survey of diving seabirds found their greatest hearing sensitivity to be at 1-3 kHz (McGrew 2019), which matches the range found by other researchers (Crowell et al. 2015). These data, though limited, suggest that seabirds are not particularly sensitive to sounds below 1 kHz. **Table 4-3** includes the frequency range information of the various anthropogenic sound sources from BOEM-regulated activities in comparison to this acute sensitivity range in seabirds.

Table 4-3. Frequency Ranges of Various Anthropogenic Sources of Sound Produced via BOEM-Regulated Activities (BOEM 2016), Representing Approximately 90 Percent of the Acoustic Energy.

Noise Source	Sound Range (kHz)	Bird Greatest Sensitivity Range In-Air (kHz)	Bird Greatest Sensitivity Range Underwater (kHz)
Seismic (active)	0.01-5	1-5	1-3
Ship	0.05-5		
Aircraft (i.e., helicopters)	0.4-2		
Drilling	0.01-10		
Trenching	0.02-1		
Production	0.0045-0.12		
Offshore and onshore construction (i.e., pile driving)	0.02-2		
Platform removal (i.e., explosives)	0.01-5		

Sources: (Dooling and Popper 2007; NMFS 2016a; Popper et al. 2014; Richardson et al. 1995; Tatić et al. 2012).

4.8.1.1 Active Acoustics

The low-frequency underwater noise created by airguns as well as subbottom profilers (a type of survey equipment) would fall within the underwater hearing range of birds. Conversely, the noise created by other survey equipment (e.g., side-scan sonar and echosounders) is outside of birds' underwater hearing range and is expected to be inaudible to birds. Some seabirds and waterfowl rest on the water's surface or make short and shallow dives. Others (e.g., long-tailed duck and common loon) dive deeper (up to 197 ft [60 m]) and spend more time submerged. Airgun array pulses are directional so only diving birds would encounter active acoustics.

Seismic noise, if any exposure, would be for a short period. Diving seabirds (e.g., grebes, loons, cormorants, and sea ducks) would be the most likely group to interact with this noise source (Turnpenny and Nedwell 1994), especially those that forage via plunge-diving. Also, seismic surveys conducted during the spring and fall migration period may increase the chance of affecting diving seabirds. Energetic cost or loss of foraging opportunities (i.e., disturbance and displacement) of diving seabirds are the likeliest impacts of seismic surveying and may last for a day at most. The effects of underwater seismic survey airguns on diving seabirds have been studied very little, but no observed mortality events occurred during Stemp (1985) and Lacroi et al. (2003). Distribution or abundance of the exposed species did not change either.

4.8.1.2 Equipment Noise

Equipment noise makes up most of the sounds produced by BOEM-regulated activities, including vessel drilling, trenching, production, offshore and onshore construction, and explosive platform decommissioning and removal noise. Most of these produced sounds are short-term and have transient effects on birds, as well as predominantly below diving birds' hearing ranges. Diving seabirds would be the most likely group to interact with the underwater sound sources (e.g., drilling, trenching, and production). Seabirds' various feeding methods (e.g., surface feeding, pursuit diving, and plunge diving) can influence their possibility of exposure to equipment noise. Migratory seabirds would also have a higher chance of interacting with the offshore noises. Anticipated impacts on birds exposed to these sound sources include localized disturbance, temporary displacement, and masking of bird vocalization and communication. Other birds at high risk of vulnerability (e.g., displacement and disturbance) to drilling and production noises are those that are attracted to offshore structures for resting or foraging opportunities (Tasker et al. 1986; Baird 1990; Russell 2005; Montevecchi 2006).

4.8.1.3 Vessel and Aircraft Noise

Vessel traffic noise also makes up most of the sounds produced by BOEM-regulated activities. Coastal and marine birds are vulnerable to aircraft noise, though the effects would be short-term and transient. Studies have shown that bird exposure to frequent, low-level military jet aircraft and simulated mid- to high-altitude sonics booms resulted in some short-term behavioral responses with little effect on reproductive success (Ellis et al. 1991). For example, greater crested tern colonies exposed to simulated aircraft noises responded with an increase in head-turning and alert calls, but the animals did not flush (i.e., a strong behavioral response) until the sound exceeds 85 dB (Brown 1990). Further, birds of prey reportedly habituate to the sounds produced by low-level helicopter flight and do not show signs of impacts to their reproductive success (Andersen et al. 1989; Delaney et al. 1999). In Florida, low-level military training flights demonstrated no effect on local wading bird colonies' establishment, size, or reproductive success (Black et al. 1984). If disturbance were to occur, birds have shown the ability to return to pre-disturbance behavior within 5 minutes (Komenda-Zehnder et al. 2003).

Vessel or aircraft traffic noise can disturb and temporally displace locally resting or foraging located birds up to 0.6 mi (1 km) away (Efroymson et al. 2000). Diving birds may be more sensitive to marine traffic noise and can avoid or leave areas with higher vessel activity. Loons, sea ducks, cormorants, and grebes all reportedly experience high displacement levels in correlation to shipping traffic (MMO 2018). Flock size also influences the impact that marine traffic has on birds; the distance from vessel traffic that causes flushing (i.e., flying away from location) increases with flock size. Flushing disturbance can reduce critical feeding and resting opportunities (Guillemette et al. 1992; Schwemmer et al. 2011). Flushing as a response to marine traffic may also occur while parents are incubating or brooding, which exposes eggs and chicks to harm from weather conditions (e.g., sun intensity, wind, and rain); pecking by neighboring parents; predators; and other impacts. Site-specific mitigations (e.g., careful selection of vessel and flight routes) can minimize the impact.

Vessels and helicopters could cause disturbance to breeding birds and possibly decrease nesting success if the traffic occurs too close to a breeding colony. Some BOEM-regulated activities may require daily roundtrips from a shore base to an offshore work site. These would likely occur at an already established port; therefore, birds are not expected to roost near these areas. Those that continue to roost or nest in areas adjacent to shore bases have likely adapted to vessel traffic noise.

4.8.1.4 Construction and Decommissioning Noise

Regarding construction sounds, some seabird species become acclimatized and return to the area despite the noise. Onshore noise can mask local bird vocalization and communication, which can lead to disturbance and displacement. It is suggested that some species would avoid the construction area until it is finished, and others may acclimatize to the construction noise. Generally, birds would be less vulnerable to onshore construction noises if operators placed the facilities, such as by locating pipeline corridors and associated construction projects in a site without nest aggregations or in a non-nesting period.

As birds are attracted to platforms, there is the potential for individuals to be present during platform decommissioning and removal activities. Decommissioning involves dismantling the above-platform structures, sometimes with the use of underwater explosives, to collapse the platform. As for explosives, one study analyzed a western grebe mortality event in California where 70 individuals died as a result of a military underwater detonation (Danil and St. Leger 2011), which are sometimes used in decommissioning practices. Another found that weapons testing noises had no significant effects on bald eagle activity or reproduction (Brown et al. 1999). Explosives have the potential to cause barotrauma and possibly death of one or more individuals if they are present during the activity. However, most of the birds using the platform would have likely left the area during the dismantling process prior to the explosives use. Underwater detonations may occasionally harm deep-diving birds if they were diving in the immediate vicinity during the explosion.

4.8.1.5 Renewable Energy Noise

Renewable energy activity can also create noise pollution via wind turbines. The mechanical noises produced by wind turbines while in operation are generally below 700 Hz, which is outside of birds' hearing sensitivity ranges both in the air and underwater. The effects from noises generated during wind turbine construction would be like those produced during oil and gas infrastructure construction.

4.8.2 Operational Discharges and Wastes

All operational discharges and wastes are regulated. The USEPA and USCG regulate produced water, drilling muds, and cuttings releases to keep contaminants below harmful levels. These, along with sanitary wastes, gray water, and miscellaneous discharges, are not expected to persist in the water column. Oil sheens from produced waters could potentially contribute to seabird mortality if the sheen contacts the birds' feathers at sea (Fraser et al. 2006). Further, oil can compromise the feather structure, possibly leading to hypothermia and starvation, especially in colder waters (Wiese and Ryan 2003). Currently, no studies have evaluated the possible attraction of seabirds to the plumes of discharged produced waters. Drilling muds released into the water column do not increase to high concentrations and only affect a small area of water (Neff 2005). Most mud cuttings settle rapidly to the seafloor and only around the drill site (area dependent on drilling depth and mud line cellar size), which could lead to temporary loss of benthic foraging habitat (Neff et al.

2000). Impacts on water quality are localized and transient; therefore, they are unlikely to affect foraging and roosting activities by seabirds.

4.8.3 Bottom Disturbance

Pipeline trenching could result in the temporary displacement of some marine birds and some potential loss of benthic foraging habitat. Impacts would be greatest along the line of the trenching activity; but after the trenching process is complete, birds are expected to return to the area. Bottom disturbance offshore is not expected to significantly impact diving seabirds given the limited footprint of disturbance and widespread availability of similar feeding grounds (i.e., offshore pelagic waters). Overall, bottom disturbance is not expected to pose risks to marine and coastal birds as they do not inhabit the seafloor beyond quick, infrequent foraging trips mostly in inshore or coastal waters.

4.8.4 Coastal Land Disturbance

Marine and coastal birds are vulnerable to the impacts from coastal land disturbance, particularly if occurring in key bird habitats. Expansive onshore infrastructure (e.g., construction facilities, service bases, waste disposal facilities, and processing facilities) exists to support BOEM-regulated activities. As discussed in **Chapter 4.2.4**, new construction or expansion of onshore facilities, temporary and permanent roads, and pipeline landfalls can permanently alter local coastal and estuarine habitats. These effects would be long-term (i.e., decades) and would affect those bird species that rely on them for nesting and feeding habitats. The presence of pipeline landfalls and roads during production would also result in long-term disturbance.

Habitat loss as a result of coastal land disturbance could lead to permanent displacement of birds. Construction may also increase the suspension of sediments in the coastal water column and decrease the local water quality. Birds' ability to locate prey could be compromised and any degradation of local fish or invertebrate could decrease the quality of their prey. Mitigation in the form of careful placement (e.g., avoiding important bird nesting habitats) of facilities could minimize the effects of coastal land disturbance on local colonial or nesting bird species. Consultation with Federal agencies regarding bird species covered by the ESA or the MBTA would further mitigate these effects.

4.8.5 Offshore Habitat Modification

The placement of oil and gas platforms, wind turbines, and other associated offshore equipment has the potential to affect seabirds found in the GOM. Consultation with Federal agencies regarding bird species covered by the ESA or the MBTA would mitigate these effects. Platform removal (i.e., decommissioning) could also cause short-term disturbance and displacement of seabirds attracted to the areas. For more information regarding the noise effects on birds during platform removals, refer to **Chapter 4.8.1**. Decommissioned platforms that are subsequently used for the Rigs-to-Reefs program could provide foraging habitats for birds in a similar fashion as that of operational platforms. Offshore habitat modification from infrastructure emplacement can cause temporary and long-term disturbance via avoidance or attraction (Tasker et al. 1986; Baird 1990; Russell 2005; Montevecchi 2006). Although attraction is documented more, platforms can displace birds from previously suitable foraging habitats. One study in the Scotian Shelf found dovekies, shearwaters, storm-petrels, and northern fulmars had lower densities within 6.2 mi (10 km) compared to 6.2-31 mi (10-50 km) from platforms (AMEC Black and McDonald 2009). Consequences from displacement are not known but are likely small, unless the affected areas previously supported high concentrations or productivity due to physiographic features (e.g., shelf breaks) (Hedd et al. 2011). Avoidance behaviors could also subject birds to higher energetic demands (Masden et al. 2010), but this is difficult to predict since avoidance of platforms has not been extensively studied.

Bird attraction to platforms can be attributed to increased foraging opportunities (Ortego 1978), oceanographic drivers (Fedoryako 1989; Castro et al. 2002), roosting refuge, and artificial lighting. One study found that seabird density was seven times higher within 1,640 ft (500 m) of an offshore oil platform than the surrounding areas likely due to increased food availability and roosting opportunities (Tasker et al. 1986). A more recent study found evidence of species-specific seasonal risks contributing to seabird concentrations at offshore platforms in Grand Bank (Burke et al. 2012). Another found that bird densities increased six- to seven-fold after "spudding" occurred (Baird 1990). Platforms can serve as artificial reefs supporting biodiverse communities, including seabird prey (i.e., fish), and localized feeding events in masked boobies have been demonstrated (Duffy 1975; Ortego 1978). For more information regarding seabird attraction to offshore platforms via lighting, refer to **Chapter 4.8.7**. Offshore platforms can continue operating for several decades until production is complete. Spatially, they cover a relatively small area compared to the total pelagic habitat available to seabirds. However, the platform or infrastructure's location influences its interaction potential with seabirds. For example, if a platform occurs within a common feeding route of a breeding colony, a higher frequency of interaction(s) with that platform could occur.

Offshore infrastructure can lead to collision events with seabirds migrating, roosting, or foraging in the area, especially for birds attracted to the platforms. **Figure 4-3** displays the overlap of two commonly used trans-Gulf bird migration routes and offshore oil and gas platforms. However, collision risk to birds from oil and gas platforms is poorly studied. Collisions with human-made structures are one of the highest-ranked threats to birds worldwide when observing the numbers of individuals killed (Loss et al. 2012). One study conducted on a research platform in the North Sea (roughly 28 mi [45 km] offshore) found that an average of 150 collision mortalities per year occurred. Using this finding, the researchers conservatively estimate that hundreds of thousands of nocturnally migrating birds could die from colliding with a platform in the North Sea (Hüppop et al. 2016); other studies estimate up to 6 million annual collision mortalities (Bruinzeel et al. 2009; Bruinzeel and van Belle 2010). A multi-year, standardized survey on GOM platforms found that nocturnal collisions of migratory birds is a significant source of mortality during fall migration; they estimated that the nearly 4,000 platforms may cause roughly 200,000 annual collision deaths (Russell 2005). Direct platform mortality rates may be regional, species specific, or seasonal (Burke et al. 2012; Ronconi et al. 2015). Underwater infrastructure also poses a potential vulnerability to diving seabirds, which could collide or become entangled with the infrastructure while foraging.

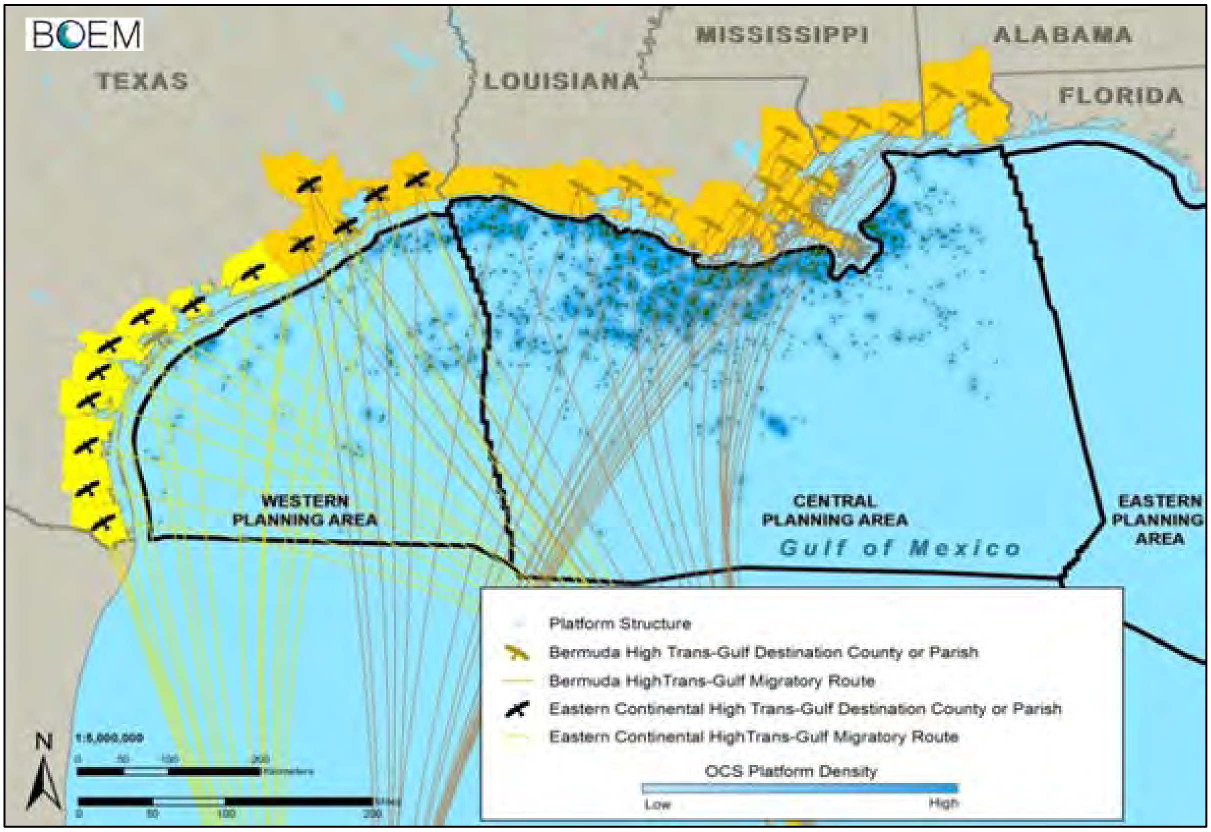

Figure 4-3. Offshore Platforms and Bird Migration. Platform density and spring migration routes for trans-Gulf migratory birds.

Offshore oil and gas platforms create structural presence in the GOM that otherwise would not exist or serve as habitats for birds. Many species opportunistically utilize these spaces for roosting and resting sites. For example, gulls will frequently roost on platforms during both day and night (Burke et al. 2012). Migratory birds have also been documented to stop at platforms to rest and recover from fatigue (Russell 2005); however, stop-over behavior may be detrimental as birds will still expend energy reserves while at the platforms (Hope Jones 1980). Further, migratory birds using platforms for stop-over sites could be increasing their exposure to predators (e.g., falcons) (Russell 2005). Traditional landbirds have also been sighted at GOM platforms. For example, North American peregrine falcon juveniles will use platforms to rest and hunt during migration.

Other factors also influence the interactions between birds and offshore platforms, including light attraction (refer to **Chapter 4.8.7**) and weather. Anecdotally, fog, precipitation, low cloud coverage, and other poor weather conditions can increase the effects of nocturnal light attraction (Hope Jones 1980; Montevecchi 2006). This effect is greater in migratory bird populations than in seabirds (Day et al. 2005), although seabirds that feed nocturnally on bioluminescent prey can be affected greater than other seabird species. Other factors are thought to influence the interaction between birds and platforms, including environmental (e.g., moon phases, tides, and ocean temperature) (Rodriguez and Rodriguez 2009), anthropogenic (e.g., humans on the platforms and fishing vessels) (Votier et al. 2010), spatial dynamics (e.g., proximity to other platforms, nesting colonies, and shelf breaks) (Tasker et al. 1986; Russell 2005; Burke et al. 2005), and temporal variables (e.g., time of day and year and breeding cycles) (Hüppop et al. 2006).

Renewable energy infrastructure can also affect marine and coastal birds. The development of wind turbines, for example, can pose entanglement risk, avoidance behaviors, collision risk, habitat changes to benthic and pelagic zones, food web changes, contaminant release from the seabed, and increased vessel traffic during construction (Boehlert and Gill 2010; Bailey et al. 2014). Collision risk, food web changes, avoidance, energetic costs, and changes to migration routes are of concern, particularly to seabirds (Punt et al. 2009). Despite these potential impacts, two recent BOEM studies on the feasibility to develop renewable energy in the GOM (Musial et al. 2019, 2020) found that the viable areas are in State waters (i.e., not a BOEM-regulated activity).

4.8.6 Air Emissions

All air emissions as a result of BOEM-regulated activities are permitted and regulated to a point that both onshore and offshore releases are unlikely to pose risk to birds. The Clean Air Act established the NAAQS for specified pollutants (42 U.S.C. §§ 7401 *et seq*.). As required by the Outer Continental Shelf Lands Act, BOEM assesses these in relation to oil and gas development projects as well as volatile organic compounds to the extent that activities significantly affect the air quality of any State. BOEM-regulated activities release air emissions from sources related to drilling and production via vessels, flaring (refer to **Chapter 4.8.7** for light attraction via flaring) and venting, decommissioning, fugitive emissions, and oil spills. Many of the BOEM-regulated activities within the OCS are transitory, as are most marine and coastal GOM birds, which may reduce interaction opportunities.

Transport and dispersion processes via prevailing wind circulations immediately begin to circulate pollutants when released. Dispersion depends on several factors, including emission height, atmospheric stability, mixing height (i.e., the height above the surface through which vigorous vertical mixing occurs), exhaust gas temperature and velocity, and wind speed. The mixing height is important to dispersion because it dictates the vertical space available for spreading the pollutants.

Mixing height information in the GOM is scarce, but measurements near Panama City, Florida (Hsu et al. 1980), found that the mixing height can vary between 1,312 and 4,265 ft (400 and 1,300 m), with a mean of 2,953 ft (900 m). Heat flux calculations in the WPA (Barber et al. 1988; Han and Park 1988) indicate an upward flux year-round – highest during winter and lowest in summer.

Due to the atmospheric processes on air pollutant transport, stack height, exit gas velocity from the stack, distance of the marine species from the sources, and temporary vessel activity, coastal and marine birds are not expected to be vulnerable to air emissions. Further, air emissions would be localized and air pollution would dissipate quickly upward in the air at considerable distances.

4.8.7 Lighting and Visual Impacts

Birds are vulnerable to lighting impacts. Many seabird species are attracted to vessels due to light attraction at night, including petrels, storm-petrels, shearwaters, pelicans, gulls, terns, and skimmers (Montevecchi et al. 1999; Wiese and Jones 2001; Black 2005; Montevecchi 2006), which can lead to vessel strikes (refer to **Chapter 4.8.8.4**). Lights attract seabirds and migrating land birds, drawing them to onshore and offshore facilities and other infrastructure (e.g., wind turbines) and equipment (e.g., vessels). The number of times a bird stops at platforms is currently unknown. Research has shown that birds are more likely to stop-over on platforms with spectral red lights (Marquenie et al. 2013). Species and age can influence the susceptibility of birds to lighting impacts (Montevecchi 2006). Nocturnal seabirds are more likely to have more rods in their retinas, more rhodopsin, and larger eyes (McNeil et al. 1993), and thus are likely more impacted by artificial lighting. Smaller planktivorous nocturnal species are also likely attracted to, and subsequently influenced by, artificial lighting at night (Imber 1975; Bretagnolle 1990), especially those that feed on bioluminescent prey (Montevecchi 2006). Fledgling storm-petrels, petrels, and shearwaters may be more attracted to artificial light than their adult counterparts due to their environmental inexperience or their reliance on bioluminescent prey (Imber 1975). Attraction to artificial lighting could impose energetic costs to individual birds, as well as collision risk with structures, which could result in injury or mortality. For more information concerning bird collisions with offshore platforms, refer to **Chapter 4.8.8**. Collision events are highly individualistic, but if a collision occurs with a threatened or endangered species, this can be a concern for that species' population.

Artificial lighting at night can disorient birds, especially those migrating offshore. Poor weather conditions (e.g., fog, precipitation and low cloud cover) can further increase birds' attraction to lighting, especially at dusk or during a full moon (Rodriguez and Rodriguez 2009; Miles et al. 2010). Large aggregations of nocturnal migrants can be attracted to artificial lighting. Disoriented birds can circle the light source for hours, leading to exhaustion, depleted fat reserves, and starvation (Longcore and Rich 2004; Russell 2005; Montevecchi 2006; Ronconi et al. 2015). Light attraction can also increase the risk of collision with each other or other offshore structures, as well as vessel strikes (Longcore and Rich 2004; Montevecchi 2006). While circling in the lighted area, birds are also more vulnerable to predation (Longcore and Rich 2004). Alternatively, artificial lighting can create foraging opportunities for birds. For example, gulls will rest and forage at night on the sea surface under the platform lights, which are thought to attract their prey to the surface (Burke et al. 2012).

Birds are also attracted to flares used on offshore platforms (Russell 2005; Montevecchi 2006; Poot et al. 2008; Ronconi et al. 2015). One study in Alaska found that migrating birds were attracted to a nocturnal gas-flaring event despite an installed anti-collision lighting system that was intended to deter birds from the platform (Day et al. 2005, 2015). Attracted birds also displayed non-directional flight behaviors, suggesting that the birds were circling the gas flare. The response to the gas-flaring event varied among species, with long-tailed ducks being the most represented taxa among those attracted (Day et al. 2015). Several early studies on the effects of gas-flares on birds reported no mortality events or injury to birds (Sage 1979; Hope Jones 1980; Wallis 1981). However, one study suggests that incinerations from colliding with gas flares may be killing more birds than previously thought (Bjorge 1987). Another gas flare event in 2013 was estimated to have killed 7,500 migrating land birds at a platform off the coast of the Bay of Fundy (CBC 2013). These events involved passerine species and not seabirds. Bourne (1979) estimated that annual mortality rates from interactions with gas flares are a few hundred birds per platform.

Mitigation measures could minimize the effects of artificial lighting on birds. Lease stipulations imposed by BOEM require the minimization of light pollution using techniques such as down-shielding lights, using the minimum necessary amount of lighting, and using LED or low-energy lights, which lead to less lighting overall. Consultation with Federal agencies regarding bird species covered by the ESA or the MBTA would further mitigate these effects.

4.9 ACCIDENTAL EVENTS

4.9.1.1 Spills and Other Releases into the Environment

Emergency air emissions, such as a hydrogen sulfide leak from a pipeline, can affect birds. Exposed birds or flocks can experience various toxic effects. This exposure would likely be limited to an individual or an individual flock passing through the area.

The effects of an oil spill on birds depend on many variables, including the spill location, spill size, oil characteristics, weather events, oceanographic conditions, and time of year, as well as the behavior and physiology of the birds. Repeated exposure to oil spills can also be a factor in determining the level of impact on birds. An accidental oil spill could occur in offshore waters or in coastal, nearshore areas, determining which bird species would be affected and the extent of such effect (Wiese and Jones 2001; Castege et al. 2007).

A nearshore accidental oil spill could directly or indirectly impact shorebirds, waterfowl, and coastal seabirds. Impacted birds could include gulls, terns, skimmers, loons, pelicans, cormorants, frigatebirds, herons, rails, and grebes. Important coastal habitats for birds could also be impacted (refer to **Chapter 4.2.8**), which could lead to birds experiencing nesting and foraging habitat loss and displacement. Oiling can take a greater toll in shallower waters, wetlands, bay and gulf intertidal shorelines, beaches, and dunes as bird diversity and abundance may be high. Hydrocarbon accumulation and persistence can also be high in these habitats. This may be especially true for barrier islands, as they support many breeding and wintering waterbirds and are important migratory stopovers (Curtiss and Pierce 2016; Selman et al. 2016).

Direct impacts to birds that encounter accidentally spilled oil include tissue and organ damage from ingested or inhaled oil, as well as interference with food detection, predator avoidance, homing of migratory species, disease resistance, growth rates, reproduction, and respiration. Birds can ingest and inhale spilled oil while feeding on oiled benthic, planktonic, or pelagic prey; grooming (i.e., preening) oiled plumage; or drinking hydrocarbons in water. The ingestion or inhalation to the extent of toxic oiling can kill birds. Oiled plumage can cause loss of insulation, the ability to fly, and buoyancy, which can all result in mortality. If the oiling occurs during incubation, contaminated plumage can transfer oil to the eggshells and can result in embryo mortality (Leighton 1993). Feather fouling can reduce a bird's flight ability, which can lead to longer flight times, decreased migration speeds, and increased energy costs. This can cause late arrivals to wintering grounds, breeding grounds, or stopover sites, which may have downstream effects on the bird (Perez et al. 2017). Exposure to sublethal levels of oil can result in oxidative injury (e.g., muscle fatigue, decreased energy availability for metabolic processes, and adverse reproductive impacts), negative impacts on plasma and liver metabolome (as demonstrated in double-crested cormorants), and liver hypertrophy and energy homeostasis changes (as demonstrated in seaside sparrows) (Fallon et al. 2018; Dorr et al. 2019; Bursian et al. 2017; Dean et al. 2017; Harr et al. 2017a, 2017b; Bonisoli-Alquati et al., 2020; Albers 2006; Miller et al. 1978; Peakall et al. 1989; Xu et al. 2016, 2017).

Some oiled birds can be rehabilitated post-contamination. Others may sustain injuries or die after the oiling event. Birds whose prey are aquatic or who rely on oceanic waters for foraging are more vulnerable to oiling events. Migrants who pass through the GOM and residents of the GOM are also more vulnerable to a spill in the area. Long-lived seabirds may also experience impacts longer, and impacts may also be delayed. For example, first-time breeders would have a delayed reduction in recruitment, which would not occur until years after oil exposure (Dunnet et al. 1982). Researchers have found that focusing rehabilitation practices on moderate to heavily oiled birds may enhance their long-term survival but would depend on the bird group, foraging behavior, and level of oil exposure (Horak et al. 2020). Gulls affected by sublethal external oiling may be good candidates for rescue and rehabilitation (Dannemiller et al. 2019).

Seabirds may need longer periods of time to recover from oil-spill impacts due to their unique population ecology, particularly their small clutch sizes, deferred maturity and low adult mortality rates (Furness and Monaghan 1987). Long-term impacts can also occur when local colonies or flocks experience extirpation, causing species richness losses. Long-term impacts can also occur with oil persisting up to years in seafloor sediments, becoming resuspended in the water column, or contacting prey organisms or diving seabirds. Resuspended oil can also be transferred to other areas, increasing the probability of exposure to birds. The level of impact would depend on the habitat affected (e.g., shallower waters), local abundance of birds affected, and the persistence of oil in the area. Other impacts include raptors and scavenging birds ingesting oil while foraging, which can lead to vomiting, diarrhea, and hemorrhaging. Even a small oil or fuel spill could have a large effect on ESA-listed species. The effectiveness of the containment and cleanup activities also influences the degree of impact that oil or chemical spills have on birds.

4.9.1.2 Spill Response

Dispersants are used in spill responses to move oil from the water surface into the water column, but they are also toxic. The dispersant Corexit 9500 was found to significantly decrease hatching success in mallard eggs when compared to the control results (Wooten et al. 2012). Finch et al. (2011) also found that mallard eggs exposed to weathered crude oil had less toxicity than when treated with a high dispersant-to-oil ratio but not when compared to those treated with a low ratio. These studies demonstrated that the level of toxicity of dispersed, weathered oil could be less than levels with high dispersant usage.

Depending on the volume and spatial extent of a spill, the subsequent cleanup and response efforts in coastal habitats and beaches can be a large-scale activity. Large-scale response can require a large amount of personnel that could potentially disturb nesting birds. Proper training of response personnel is a critical component to reducing the likelihood of these types of effects. Non-nesting shorebirds could experience decreased fitness from lost access to breeding and/or foraging grounds. For example, shorebirds impacted by the *Deepwater Horizon* oil spill cleanup may have experienced reduced fitness later when arriving at their northern breeding grounds (Henkel et al. 2014). More information on very large, catastrophic events like the *Deepwater Horizon* oil spill, and the impacts of an events of this size can be found in BOEM's *Gulf of Mexico Catastrophic Spill Event Analysis* technical report (BOEM 2021).

Oil-spill response and cleanup activities can affect birds' prey and their coastal habitats. They could experience fewer foraging opportunities and lower quality food availability (**Chapter 4.5.8**). Birds could also face habitat loss of foraging, breeding, wintering, and roosting grounds (**Chapter 4.2.8**). Overall, few studies have been done to study the effects of beach cleanup activities on marine and coastal birds. Mechanical equipment and increased human activity could disturb and negatively affect local populations. Nesting and foraging areas could be damaged, breeding activities could be prevented or altered, and displacement could occur.

4.9.1.3 Marine Trash and Debris

The discard of trash and debris from non-OCS oil- and gas-related sources (e.g., State oil- and gas-related activities, recreational fishing boats, and land-based sources) is prohibited. However, unknown quantities of plastics and other materials are discarded despite regulation and are subsequently lost in the marine environment. Plastics and other trash and debris remain a threat to birds. Many species consume plastic debris, both intentionally and incidentally, through prey sources. Birds can also become trapped or entangled in discarded fishing lines or nets and commercial fishermen's gear. Seabird bycatch numbers in the GOM by pelagic and bottom longline fisheries indicate negligible impacts on seabird populations (Hale et al. 2011). Seabirds are known to feed on discarded fishery bycatch, which can be both beneficial (i.e., increased foraging opportunities) and detrimental (i.e., increased collision or entanglement risk).

4.9.1.4 Collisions and Strikes

The likelihood of a vessel collision is low, and the chance of a fuel spill from a vessel collision is even smaller. Still, accidental collision events that could result in the release of diesel or other fuel sources could affect birds. Diesel and other fuels that would likely be used by vessels on the OCS are light and would float on the surface for several days. These released fuels would likely disperse and weather, and volatile components would quickly evaporate. The location of the collision event and resultant spill event help determine the level of potential impact. If an event occurs within or near an Important Bird Area, there could be a greater potential for impact to birds.

Direct impacts from a nearshore fuel spill to birds would be unlikely, but indirect impacts via prey could occur. An offshore surface fuel spill could directly and indirectly affect gannets, boobies, tropicbirds, storm-petrels, shearwaters, and fulmars. For more information about the direct and indirect effects of accidental chemical releases on birds, refer to **Chapter 4.8.8.1**.

Some birds will follow ships as a foraging strategy, though this is more common with commercial and recreational fishing vessels. In the open ocean, vessels are more easily detected from long distances and can attract birds to investigate. Many seabird species are also attracted to the vessel's lights at night (refer to **Chapter 4.8.7**). These instances can increase the chance of a subsequent vessel strike, most particularly light-induced attraction to vessels at night (Black 2005).

Just like with platforms, BOEM has historically directed vessels to have down-shielded lighting to minimize attraction and subsequent strikes from occurring. Vessel speed can also influence the chance of collision. For example, some seabirds that are attracted to vessels or dive near a seismic survey vessel have a low potential for collision or entanglement as the vessels are moving relatively slowly (4-6 kn; 5-7 mph) and the surveying gear (e.g., hydrophone streamers) is towed 3-11.5 ft (1-3.5 m) below the surface. Further, no empirical evidence suggests that marine and coastal birds could become entangled in seismic survey gear. Shorebirds, including the piping plover and red knot (ESA-listed species) are not known to be attracted to vessels. They may fly at lower altitudes during inclement weather conditions during their migrations across the GOM, which may increase the potential for vessel strikes. Loons and other low-flying waterfowl could also be susceptible to vessel collisions if vessel traffic occurs near Important Bird Areas.

Low-flying aircraft (e.g., helicopters) can disturb birds, including those resting or foraging on the water surface or those in flight. Birds can respond to flying aircraft by flushing into flight or rapidly changing their flight speed or direction. These behavioral responses to the aircraft can result in strikes. However, the potential for bird collisions with aircraft decreases at speeds greater than 81 kn (93 mph) (Efroymson et al. 2000). Additionally, the Federal Aviation Administration recommends that aircraft fly at least 2,000 ft (610 m) above the ground when passing over noise sensitive areas (i.e., national parks, national wildlife refuges, waterfowl protection areas, and wilderness areas), which decreases the chances of behavioral responses and subsequent collisions from the higher density of birds in those areas (FAA 2004).

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APPENDICES

A ABBREVIATIONS AND ACRONYMS

°C	degrees Centigrade
°F	degrees Fahrenheit
3D	three dimensional
ac	acre
AHTS	anchor handling, towing, and supply
BiOp	biological opinion
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CFR	Code of Federal Regulations
cm	centimeter
cm/s	centimeters/second
CO_2	carbon dioxide
CPA	Central Planning Area
CWA	Clean Water Act
dB	decibel
dB re 1µPa	decibel at 1 microPascal
DOD	Department of Defense (also USDOD)
DOI	Department of the Interior (also USDOI)
EFH	essential fish habitat
EP	exploration plan
EPA	Eastern Planning Area
ESA	Endangered Species Act
ESI	environmental sensitivity index
ft	foot
FWS	Fish and Wildlife Service (U.S.)
GOM	Gulf of Mexico
ha	hectare
hr	hour
Hz	Hertz
in	inch
in/s	inches/second
IPF	impact-producing factor
IPCC	Intergovernmental Panel on Climate Change
ISR	internal scoping report
kHz	kilohertz
km	kilometer
km^2	square kilometer
kn	knot
LCE	Loop Current eddies
m	meter
MBTA	Migratory Bird Treaty Act

mi	mile
mph	mile per hour
mm	millimeter
MMS	Minerals Management Service
MMPA	Marine Mammal Protection Act
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi	nautical mile
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	National Research Council
O_3	ozone
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
PAH	polycyclic aromatic hydrocarbon
pH	potential for hydrogen
$PM_{2.5}$	particulate matter 2.5 micrometers or less in aerodynamic diameter
PM_{10}	particulate matter 10 micrometers or less in aerodynamic diameter
PM	particulate matter
ppm	parts per million
PSBF	potentially sensitive biological features
RESTORE Act	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act
ROV	remotely operated vehicle
TRW	Topographic Rossby Waves
UME	unusual mortality event
U.S.	United States
U.S.C.	United States Code
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard (also CG)
USDOE	U.S. Department of Energy
USDOI	U.S. Department of the Interior (also DOI)
USEPA	U.S. Environmental Protection Agency
WPA	Western Planning Area
yr	year

B COMMON AND SCIENTIFIC NAMES

Common and scientific names of organisms that appear in the document are listed below. The protective status of relevant species is indicated.

Common Name	*Scientific Name*	*Common Name*	*Scientific Name*
Marine Mammals			
Dolphins		Whales	
Atlantic spotted dolphin*	*Stenella frontalis**	Blainville's beaked whale*	*Mesoplodon densirostris**
bottlenose dolphin*	*Tursiops truncatus**	Bryde's whale[1]	*Balaenoptera edeni**
clymene dolphin*	*Stenella clymene**	Cuvier's beaked whale*	*Ziphius cavirostris**
false killer whale*	*Pseudorca crassidens**	dwarf sperm whale*	*Kogia sima**
Fraser's dolphin*	*Lagenodelphis hosei**	Gervais' beaked whale*	*Mesoplodon europaeus**
killer whale*	*Orcinus orca**	pygmy sperm whale*	*Kogia breviceps**
melon-headed whale*	*Peponocephala electra**	sperm whale[1]	*Physeter macrocephalus*[1]
pantropical spotted dolphin*	*Stenella attenuata**	West Indian manatee[1]	*Trichechus manatus*[1]
pygmy killer whale*	*Feresa attenuata**	**Sea Turtles**	
Risso's dolphin*	*Grampus griseus**	green sea turtle[2]	*Chelonia mydas*[2]
rough-toothed dolphin*	*Steno bredanensis**	hawksbill sea turtle[3]	*Eretmochelys imbricata*[3]
short-finned pilot whale*	*Globicephala macrorhynchus**	Kemp's ridley sea turtle[3]	*Lepidochelys kempii*[3]
spinner dolphin*	*Stenella longirostris**	northwest Atlantic ocean loggerhead sea turtle[2]	*Caretta caretta*[2]
striped dolphin*	*Stenella coeruleoalba**	leatherback sea turtle (Atlantic northwest)[3]	*Dermochelys coriacea*[3]
Birds			
Shorebirds (i.e., Charadriiformes)		Passerines (i.e., Passeriformes)	
American oystercatcher	*Haematopus palliates*	Cape Sable seaside sparrow[3]	*Ammodramus maritimus mirabilis*
black tern	*Chlidonias niger*	MacGillivray's seaside sparrow	*Ammodramus maritimus macgillivraii*
black-necked stilt	*Himantopus mexicanus*	Sprague's pipit	*Anthus spragueii*
bridled tern		Raptors (i.e., Falconiformes, Accipitriformes)	
great black-backed gull	*Larus marinus*	bald eagle	*Haliaeetus palliates*
greater crested tern	*Thalasseus bergii*	everglade's snail kite	*Rostrhamus sociabilis plumbeus*
herring gull	*Larus argentatus*	northern aplomado falcon	*Falco femoralis septentrionalis*
laughing gull	*Larus atricilla*	osprey	*Paridion haliaetus*
least tern	*Sterna antillarum*	peregrine falcon	*Falco peregrinus*
roseate tern[2 3 4]	*Sterna dougallii*	Seabirds (i.e., Charadriiformes, Pelecaniformes, Procellariiformes, Gaviiformes, Podicipediformes)	

Common Name	*Scientific Name*	*Common Name*	*Scientific Name*
royal tern	*Sterna maxima*	band-rumped storm petrel	*Oceanodroma castro*
rufa red knot[2 4]	*Calidris canutus rufa*	black-capped petrel	*Pterodroma hasitata*
sandwich tern	*Sterna sandvicensis*	brown booby	*Sula leucogaster*
sooty tern	*Sterna fuscata*	brown pelican	*Pelecanus occidentalis*
southeastern snowy plover	*Charadrius alexandrinus tenuirostris*	magnificent frigatebird	*Fregata magnificens*
willet	*Catoptrophorus semipalmatus*	masked booby	*Sula dactylatra*
Wading and Marsh Birds (i.e., Ciconiiformes, Gruiformes)		northern gannets	*Morus bassanus*
eastern black rail	*Laterallus jamaicensis jamaicensis*	northern fulmar	*Fulmarus glacialis*
Florida sandhill crane	*Grus canadensis pratensis*	white pelican	*Pelecanus erythrorhynchos*
killdeer	*Charadrius vociferous*	Waterfowl (i.e., Anseriformes, Gaviiformes)	
Mississippi sandhill crane[3 4]	*Grus canadensis pulla*	bufflehead	Bucephala albeola
mountain plover	*Charadrius montanus*	canvasback	Aythya valisineria
piping plover[2 3 4]	*Charadrius melodus*	common goldeneye	*Bucephala clangula*
snowy plover	*Charadrius alexandrines*	common loon	*Gavia immer*
western grebe	*Aechmophorus occidentalis*	greater scaup	*Aythya marila*
whooping crane[3 4]	*Grus americana*	hooded merganser	*Lophodytes cucullatus*
Wilson's plover	*Charadrius wilsonia*	lesser scaup	*Aythya affinis*
wood stork[2 4]	*Mycteria americana*	long-tailed duck	*Clangula hyemalis*
Other		mallard ducks	*Anas platyrhynchos*
Attwater's prairie chicken	*Tympanuchus cupido attwateri*	ring-necked duck	*Aythya collaris*
red cockaded woodpecker	*Leuconotopicus borealis*		
smooth-billed ani	*Crotophaga ani*		
Plants			
black mangrove	*Avicennia germinans*	star grass	*Halophila englemannii*
manatee grass	*Syringodium filiform*	turtle grass	*Thalassia testudinum*
pondweed	*Potamogeton spp*	water celery	*Vallisneria americana*
red mangrove	*Rhizophora mangle*	water nymph	*Najas guadalupensis*
Sargassum	*Sargassum natans* and *Sargassum fluitans*	white mangrove	*Laguncularia racemosa*
shoal grass	*Halodule wrightii*	wigeon grass	*Ruppia maritima*
Invertebrates			
Bivalves		Cephalopods	
eastern oyster	*Crassostrea viginica*	Atlantic brief squid	*Lolliguncula brevis*

Common Name	*Scientific Name*	*Common Name*	*Scientific Name*
thorny oyster	*Spondlus americana*	longfin inshore squid	*Doryteuthis pealeii*
Corals		Gastropods	
boulder star coral[2]	*Orbicella franksi*[2]	heteropod molluscs	*Pterotracheoidea* spp.
elkhorn coral[2]	*Acropora palmata*[2]	pteropods	*Pteropoda* spp.
fire coral	*Millepora alcicornis*	*Sargassum* nudibranch	*Scyllaea pelagica*
lobed star coral[2]	*Orbicella annularis*[2]	Gelatinous Organisms	
mountainus star coral[2]	*Orbicella faveolata*[2]	cnidarians	*Cnidaria* spp.
staghorn coral[2]	*Acropora cervicornis*[2]	ctenophores	*Ctenophora* spp.
Crustaceans		salps	*Salpidae* spp.
Atlantic seabob	*Xiphopenaeus kroyeri*	siphonophores	*Siphonophorae* spp.
blue crab	*Callinectes sapidus*	tunicates	*Tunicata* spp.
brown shrimp	*Farfantepenaeus aztecus*	Marine Worms	
Caribbean spiny lobsters	*Panulirus argus*	chaetognaths	*Chaetognatha* spp.
ghost shrimp	*Palaemonetes paludosus*	fire worm	*Hermodice carunculata*
golden crab	*Chaceon fenneri*	polychaete worms	*Polychaeta* spp.
Gulf stone crab	*Menippe adina*	Other	
horseshoe crab	*Limulus polyphemus*	foraminifera	*Foraminifera* spp.
lesser blue crab	*Callinectes similis*	protozoans	*Protozoa* spp.
mantis shrimp	*Stomatopoda spp.*	Echinoderms	
mole crab	*Emerita spp.*	basket stars	Euryalida spp.
pink shrimp	*Pandalus borealis*	black spiny sea urchin	Diadema antillarum
rock shrimp	*Sicyoniidae spp.*	brittle stars	Ophiuroidea spp.
royal red shrimp	*pleoticus robustus*		
Sargassum crab	*Portunus sayi*		
slender Sargassum shrimp	*Latreutes fucorum*		
squat lobster	*Eumunida picta*		
white shrimp	*Litopenaeus setiferus*		
Fish			
Coastal Pelagics		Coastal Demersals	
amberjacks	*Seriola* spp.	angelfishes	*Pomacanthidae* spp.
anchovies	*Engraulidae* spp.	armored searobins	*Peristedion miniatum*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	Atlantic croaker	*Micropogonias undulatus*
basking shark	*Cetorhinus maximus*	black grouper	*Mycteroperca bonaci*
bigeye sand tiger	*Odontaspis noronhai*	cocoa damselfish	*Stegastes variabilis*
bignose shark	*Carcharhinus altimus*	cubera snapper	*Lutjanus cyanopterus*
blacknose shark	*Carcharhinus acronotus*	dog snapper	*Lutjanus jocu*
blacktip shark	*Carcharhinus limbatus*	drums	*Sciaenidae* spp.
bonnethead shark	*Sphyrna tiburo*	filefishes	*Monacanthidae* spp.
bull shark	*Carcharhinus leucas*	flatfishes	*Pleuronectiformes*

Common Name	*Scientific Name*	*Common Name*	*Scientific Name*
Caribbean reef shark	*Mugil cephalus*	gag	*Mycteroperca microlepis*
Caribbean sharpnose shark	*Rhizoprionodon porosus*	goliath grouper	*Epinephelus itajara*
cobia	*Rachycentron canadum*	grey snapper	*Lutjanus griseus*
dusky shark	*Carcharhinus obscurus*	groupers, hinds, seabasses	*Serrandiae*: *Epinephelus* and *Mycteroperca* spp.
finescale menhaden	*Brevoortia gunteri*	Gulf sturgeon[2]	*Acipenser oxyrhynchus desotoi*
finetooth shark	*Carcharhinus isodon*	hardhead catfish	*Arius felis*
Galapagos shark	*Carcharhinus galapagensis*	lane snapper	*Lutjanus synagris*
great hammerhead shark	*Sphyrna mokarran*	misty grouper	*Hyporthodus mystacinus*
great white shark	*Carcharodon Carcharias*	mutton snapper	*Lutjanus analis*
gulf menhaden	*Brevoortia patronus*	Nassau grouper	*Epinephelus striatus*
herrings	*Clupea* spp.	pinfish	*Lagodon spp.*
jacks	*Carangidae* spp.	purple reef fish	*Chromis scotti*
king mackerel	*Scomberomorus cavalla*	queen snapper	*Etelis oculatus*
lemon shark	*Negaprion brevirostris*	red drum	*Sciaenops ocellatus*
mackerels	*Scombrini* and *Scomberomorini* spp.	red grouper	*Epinephelus morio*
narrow tooth shark	*Carcharhinus brachyurus*	red snapper	*Lutjanus campechanus*
night shark	*Carcharhinus signatus*	rock hinds	*Epinephelus adscensionis*
sand tiger shark	*Carcharias taurus*	scamp	*Mycteroperca phenax*
sandbar shark	*Carcharhinus plumbeus*	slippery dick	*Halichoeres bivittatus*
scalloped hammerhead	*Sphyrna lewini*	smalltooth sawfish[3]	*Pristis pectinate*
silky shark	*Carcharhinus falciformis*	snappers	Lutjanidae spp.
smalltail shark	*Carcharhinus porosus*	snowy grouper	*Epinephelus niveatus*
Spanish mackerel	*Scomberomorus maculatus*	speckled hind	*Epinephelus drummondhayi*
spinner shark	*Carcharhinus brevipinna*	spot	*Leiostomus xanthurus*
striped mullet	*Mugil cephalus*	spotted sea trout	*Cynoscion nebulosus*
tiger shark	*Galeocerdo cuvier*	striped parrot fish	*Scarus iserti*
wahoo	*Acanthocybium solandri*	three-eye flounder	*Ancylopsetta dilecta*
yellowfin menhaden	*Brevoortia smithi*	tilefish	*Malacanthidae* spp.
Ocean Epipelagic Fishes		triggerfish	*Balistidae* spp.

Common Name	*Scientific Name*	*Common Name*	*Scientific Name*
albacore	*Thunnus alalunga*	vermilion snapper	*Rhomboplites aurorubens*
bigeye tuna	*Thunnus obesus*	Warsaw grouper	*Epinephelus nigritus*
billfish	*Istiophoridae* spp.	whale shark	*Rhincodon typus*
blackfin tuna	*Thunnus atlanticus* spp.	yellow reef fish	*Chromis rysura*
bluefin tuna	*Thunnus thynnus*	yellowedge grouper	*Epinephelus flavolimbatus*
dolphinfishes (mahi-mahi)	*Coryphaena* spp.	yellowfin grouper	*Mycteroperca venenosa*
driftfishes	*Nomeidae* spp.	yellowmouth grouper	*Mycteroperca interstitialis*
flying fish	*Exocoetidae* spp.	yellowtail snapper	*Ocyurus chrysurus*
giant manta ray	*Mobula birostris*	Deepwater Fishes (mesopelagic, bathypelagic)	
halfbeaks	*Hemirhamphidae* spp.	anglerfishes	*Ceratioidei* spp.
little tunny	*Euthynnus alletteratus*	barrelfish	*Hyperoglyphe perdiformis*
Sargassum frogfish	*Histrio histrio*	barricudinas	*Paralepididae* spp.
shortfin mako shark	*Isurus oxyrinchus*	blackbelly rosefish	*Helicolenus dactylopterus*
skipjack tuna	*Katsuwonus pelamis*	bristlemouths	*Gonostomatidae* spp.
swordfish	*Xiphias gladius*	cookie cutter shark	*Isistius brasiliensis*
tunas	*Scombridae* spp.	deepbody boarfish	*Antigonia capros*
whale shark	*Rhincodon typus*	deep-sea pelagic eels	*Saccopharyngiformes*
yellowfin tuna	*Thunnus albacares*	deep-sea smelts	*Bathylagidae* spp.
		dragonfishes	*Stomiidae* spp.
		escolar	*Lepidocybium flavobrunneum*
		fangtooths	*Anoplogastridae* spp.
		hatchetfishes	*Sternoptychinae* spp.
		lanternfish	*Myctophidae* spp.
		ridgeheads	*Melamphaidae* spp.
		roughys	*Hoplotsethus* spp.
		sixgill shark	*Hexanchus griseus*
		sleeper shark	*Somniosus pacificus*
		smooth-heads or slickheads	*Alepocephalidae* spp.
		thornyheads	*Sebastolobus* spp.
		whalefishes	*Cetomimidae* spp.
		wreckfish	*Polyprion americanus*

* This species is protected under the Marine Mammal Protection Act (MMPA).
[1] This species/subspecies is listed under the Endangered Species Act (ESA) as “endangered” and is also protected under the MMPA.
[2] This species/subspecies is listed under the ESA as “threatened.”
[3] This species/subspecies is listed under the ESA as “endangered.”
[4] This species/subspecies is protected under the Migratory Bird Treaty Act.

The Department of the Interior Mission

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The Bureau of Ocean Energy Management Mission

The Bureau of Ocean Energy Management (BOEM) is responsible for managing development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.