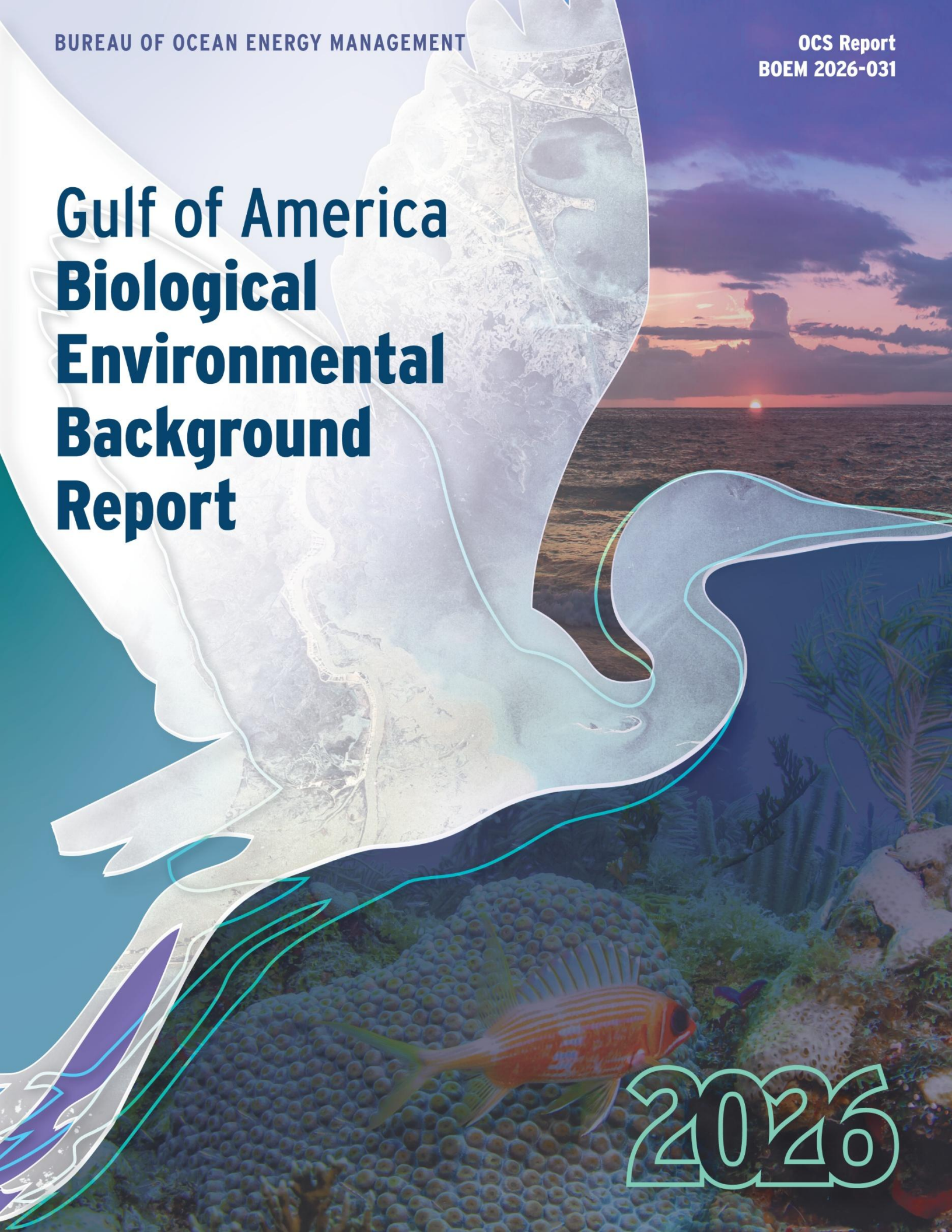
BUREAU OF OCEAN ENERGY MANAGEMENT

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Gulf of America Biological Environmental Background Report



2026





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Bureau of Ocean Energy Management
Gulf of America Region

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LIST OF ABBREVIATIONS AND ACRONYMS

Short Form	Long Form
µm	micrometer
µmPa	micropascal
ac	acre
AUD INJ	auditory injury
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CAA	Clean Air Act
CFR	Code of Federal Regulations
cm	centimeter
cm/s	centimeters per second
CPA	Central Planning Area
CPT	cone penetrometer test
CSSS	Cape Sable seaside sparrow
CWA	Clean Water Act
dB	decibel
dB re 1µPa	decibel at 1 micropascal
DO	dissolved oxygen
DP	dynamic positioning
DPS	Distinct Population Segment
DVM	diel vertical migration
EFGB	East Flower Garden Bank
EFH	essential fish habitat
EPA	Eastern Planning Area
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FGBNMS	Flower Garden Banks National Marine Sanctuary
ft	foot or feet
FWS	U.S. Fish and Wildlife Service
Gulf	Gulf of America
ha	hectare
HABs	harmful algal blooms
hr	hour
HRG	high-resolution geophysical
Hz	Hertz
in	inch
in/s	inches per second
IPF	impact-producing factor
kg	kilogram
kHz	kilohertz
km	kilometer
km^2	square kilometer

Short Form	Long Form
kn	knot
lbs	pounds
Lpk	peak pressure level
Lpk-pk	peak-to-peak sound pressure level
LCE	Loop Current eddies
LME	Large Marine Ecosystem
Lrms	root-mean-square pressure level
m	meter
m/s	meters per second
m^3	cubic meters
MARPOL	International Convention for the Prevention of Pollution from Ships
MBTA	Migratory Bird Treaty Act
mi	mile
mm	millimeter
MMS	Minerals Management Service
MMPA	Marine Mammal Protection Act
MODU	mobile offshore drilling unit
mph	miles per hour
MSA	Magnuson-Stevens Fishery Conservation & Management Act
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
PAH	polycyclic aromatic hydrocarbon
pH	potential of hydrogen
PTS	permanent threshold shift
SAV	submerged aquatic vegetation
SEL	sound exposure level
SPL	sound pressure level
ROV	remotely-operated vehicle
SST	sea surface temperature
TRW	topographic Rossby waves
TTS	temporary threshold shift
U.S.C.	United States Code
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Short Form	Long Form
WFGB	West Flower Garden Bank
WPA	Western Planning Area
yr	year

1 INTRODUCTION

1.1 PURPOSE

The mission of the Bureau of Ocean Energy Management (BOEM), a bureau of the U.S. Department of the Interior, is to manage development of United States (U.S.) Outer Continental Shelf (OCS) energy, mineral, and geological resources in an environmentally and economically responsible way. BOEM oversees the development of offshore energy, including conventional energy (i.e., oil and gas) on the OCS and manages access to marine mineral resources on the OCS (e.g., sand and gravel).

This document compiles information that describes the biological resources of the Gulf region and then explores these resources' general vulnerability to BOEM-regulated activities that are associated with the exploration and development of oil and gas and marine minerals. This background report may inform future potential impact assessments of BOEM's activities, such as those prepared under the National Environmental Policy Act (NEPA), as well as those prepared to support environmental consultations (e.g., consultations required under the Endangered Species Act [ESA] and Magnuson-Stevens Fishery Conservation and Management Act [MSA]). It may also inform other future internal and external efforts to describe Gulf habitats and associated biological resources, including outreach processes with other federal agencies and tribal governments. Importantly, this document does not replace the NEPA process or obligations to consult therein. BOEM will use this document only as a more in-depth and technical reference resource for other relevant documents.

Chapter 2 of this document describes the environmental setting of the Gulf, including a discussion of the geology, physical oceanography, and other major drivers that shape the Gulf ecosystem. **Chapter 3** includes a characterization of the biological resources of the Gulf. These biological resources include coastal, pelagic, and benthic habitats and associated communities, followed by the individual organism groups of fishes 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 oil and gas and marine minerals activities in the Gulf for each relevant biological resource. An IPF is an outcome of a proposed BOEM-regulated activity that might directly or indirectly affect resources, particularly those that are vulnerable due to their biological and physical sensitivities. For a list of IPFs included in this analysis, see **Section 4.1.1**. Routine activities generally occur on a regular basis and are the expected result of BOEM-regulated activities or associated actions. Accidental events do not occur on any regular basis during a BOEM-regulated activity, are unauthorized, and/or are unintentional in nature. Though industry practices and government regulations minimize associated risks, the potential for oil spills and other accidental events still exists. Accidental events are therefore also examined, separately from the routine IPFs. Types of accidental events include reasonably foreseeable spills of fuel, crude oil, or other chemicals resulting from accidents, weather events, and collisions, as well as their response procedures.

Vessel strikes, unintentional releases of marine trash and debris, and entanglement and entrapment are also considered accidental events in this document.

This analysis does not assess 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 further in this document. For an assessment of potential impacts resulting from and characterized as a low-probability catastrophic spill in the Gulf similar in nature to the *Deepwater Horizon* explosion, oil spill, and subsequent response, see the Gulf of Mexico[1] Catastrophic Spill Event Analysis: High-Volume, Extended-Duration Oil Spill Resulting from Loss of Well Control on the Gulf of Mexico Outer Continental Shelf; 2nd Revision (*Gulf Catastrophic Spill Event Analysis* [BOEM 2021]).

Where appropriate, this document discusses most relevant animal and/or plant types at a general level and is not intended to be all-inclusive. Specific species are mentioned using their common names, when relevant, particularly protected species and important fisheries species. **Appendix A** lists the common and scientific (or Latin) names of species mentioned in this document.

1.2 Geographic and Administrative Setting

The Gulf region comprises 2,623 kilometers (km) (1,630 miles [mi]) 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 Gulf (**Figure 1-1**): the Western Planning Area (WPA); Central Planning Area (CPA); and the Eastern Planning Area (EPA).

[1] Secretary of the Interior Doug Burgum issued Secretary's Order 3423, which directed the renaming of the Gulf of Mexico to the Gulf of America in accordance with Executive Order 14172, "Restoring Names that Honor American Greatness". Throughout this document, BOEM uses the new name where appropriate. Legacy documents, such as previously published reports and environmental documents, remain unchanged.

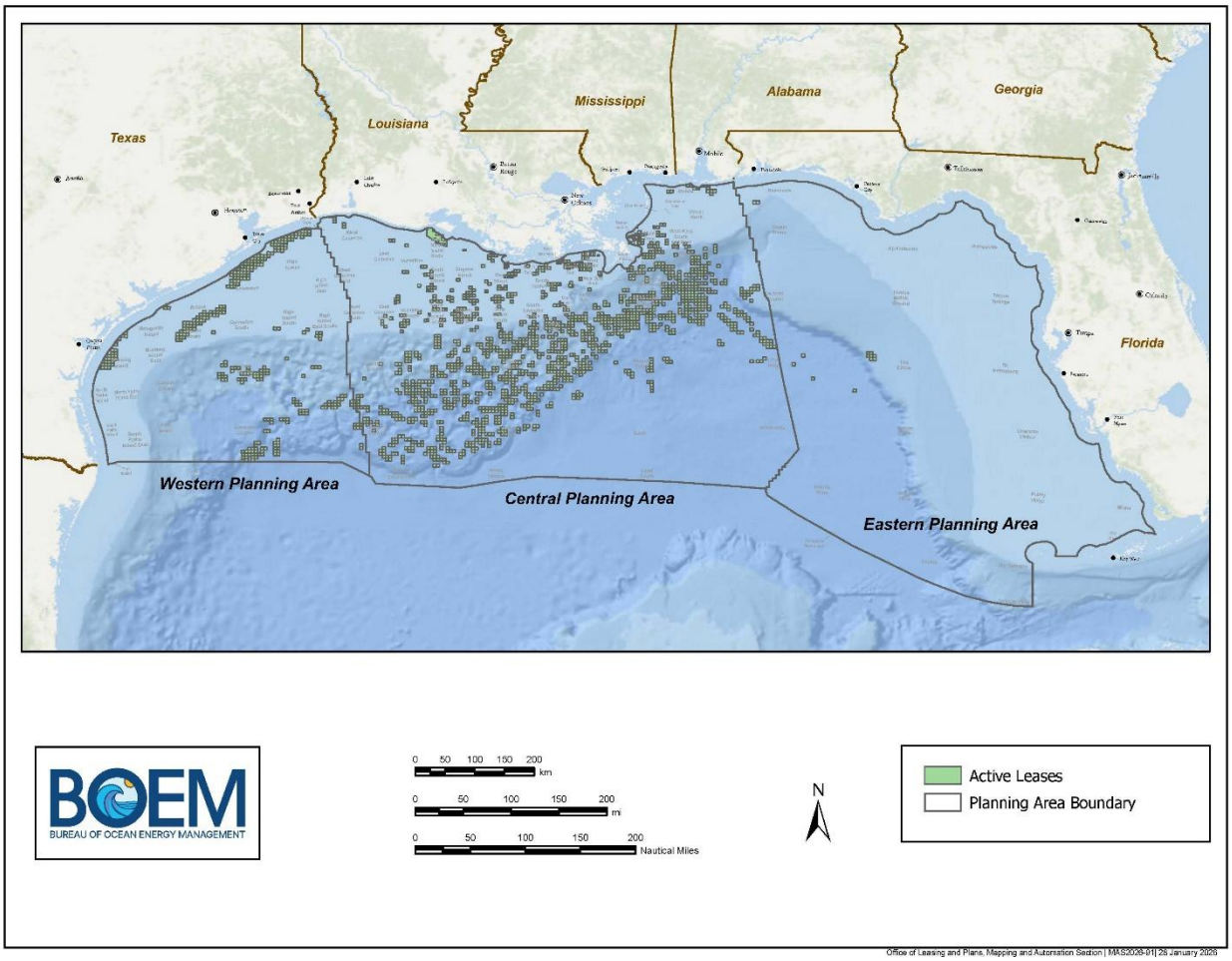


Figure 1-1. Map of BOEM leasing and planning areas in the northern Gulf of America, January 2026.
Note: Green boxes indicate blocks with active oil and gas leases.
Source: BOEM - 2026. Map was created by BOEM geographers using a publicly available Esri Topographic Basemap and publicly available Bureau of Ocean Energy Management Leasing Geospatial data.

As of January 2026, there are 1,913 active oil and gas leases in the Gulf region: 1,551 in the CPA, 349 in the WPA, and 13 in the EPA. 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 was under restriction until 2022 as part of the Gulf of Mexico Energy Security Act of 2006 (GOMESA). The area restricted was that portion of the EPA within 201 km (125 mi) of Florida, all areas in the Gulf east of the Military Mission Line (86°41'W longitude), and the CPA portion that is within 161 km (100 mi) of Florida. Although the GOMESA moratorium expired in 2022, this area was further withdrawn from leasing by the Trump Administration in September 2020 until June 30, 2032. 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 for the United States.

BOEM leases sand and gravel resources from the Gulf OCS for shore protection, beach nourishment, and barrier island restoration. Primarily through negotiated, noncompetitive lease agreements, since 1995, BOEM has conveyed rights to over ~97 million cubic yards (yd^3) (74 million cubic meters [m^3]) of OCS sand and gravel in the Gulf. Borrow areas are typically

located in water depths of 9–18 m (30–60 feet [ft]) and close to the coast (within 6–22 km; 3–12 nautical miles [nmi]; 3–14 mi). Overall, BOEM executes a lease agreement with the lessee that authorizes the use of OCS sand, gravel, and/or shell resources, and the U.S. Army Corps of Engineers (USACE) permits coastal (state waters) actions.

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 Gulf in its entirety, including coastal zones, is identified as an LME under the jurisdiction of three countries: the U.S.; Mexico; and Cuba. In the U.S., federal agencies and/or departments with management responsibilities in the Gulf include the National Oceanic and Atmospheric Administration (NOAA), the National Marine Fisheries Service (NMFS), BOEM, the Bureau of Safety and Environmental Enforcement (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 including the USACE, the U.S. Environmental Protection Agency (USEPA), the Gulf States Marine Fisheries Commission[2], the Gulf Council, 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 LME include recreational and commercial fisheries, oil and gas production, and tourism. Primary anthropogenic stressors in the Gulf LME include overfishing, pollution, eutrophication (over-enrichment with nutrients and minerals), 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-related factors (Sherman and Duda 1999; Schirripa et al. 2013; Álvarez Torres et al. 2017).

Ecosystems within the context of an LME are made up 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 (e.g., habitat). Resident organisms interact with each other through fluxes of energy and organic and inorganic material. Finally, LMEs have dynamic structures that change over time (Wang 2004).

An ecosystem-based approach towards 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

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

built environment are integrated within the LME (Yáñez-Arancibia et al. 2013). There are seven distinct geographic ecosystems in the northern Gulf within the littoral zone of the LME: the Lower Rio Grande, Texas Gulf Coast, Lower Mississippi River, Central Gulf, Florida Panhandle, North Florida, and South Florida (FWS 2010). Subregions within these ecosystems can be defined by discrete interactions among geologic, geomorphologic, oceanographic, and climatic regimes, and their coastal drainage systems, vegetation, fauna, estuary-shelf interactions, and human populations. In the Gulf, subregions include marine-dominated semiarid lagoon-estuarine systems[3], non-river-dominated intermediate systems[4], river-dominated systems[5], marine-dominated karstic systems[6], and coral reefs (Yáñez-Arancibia et al. 2013).

The biological components of the Gulf LME are discussed in detail in this chapter. They are described within the context of three habitat regimes: coastal, pelagic, and benthic. These biological components are categorized by organism or community type, including fishes and invertebrates (**Section 3.5**), sea turtles (**Section 3.6**), marine mammals (**Section 3.7**), and birds (**Section 3.8**). The Gulf LME provides critical habitats for several ESA-listed species, 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 (**Sections 3.1 and 3.2**), pelagic communities (**Section 3.3**), and benthic communities (**Section 3.4**). The following subsections describe the physical and hydrographical regime of the Gulf LME and the primary production that supports the resident biological community.

2.1 PHYSICAL SETTING

2.1.1 Surficial Geology

The Gulf 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 1,573 km (977 mi), and maximum north-south dimension of 900 km (559 mi). The shallow OCS is generally less than 200 m (656 ft) in depth. It 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 Gulf 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 2-1**).

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

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

[5] 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).

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

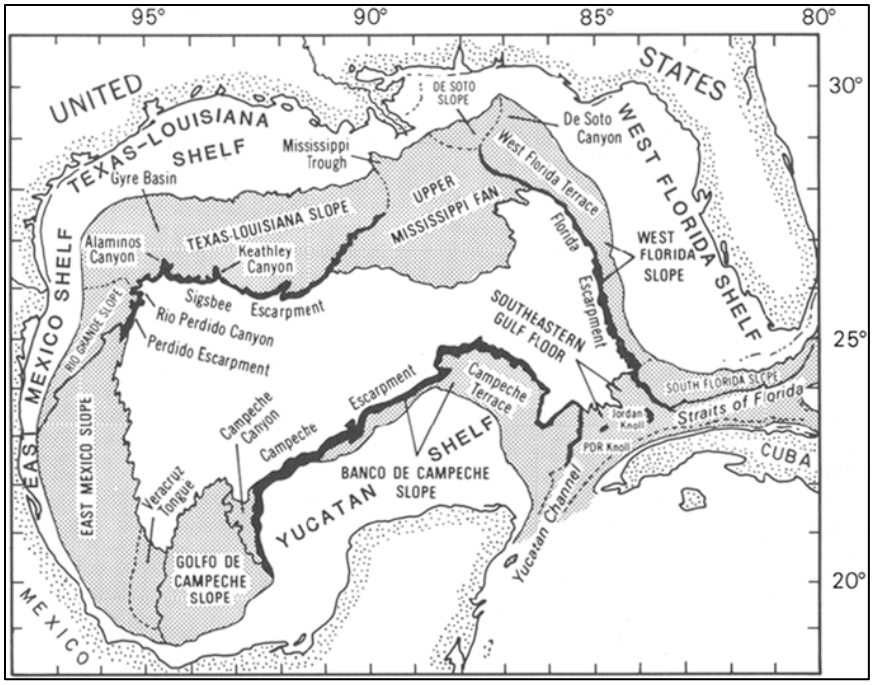


Figure 2-1. Physiographic setting of the Gulf.
Credit: Physiographic map showing the major provinces of the Gulf of Mexico (from Martin and Bouma 1978). Creative Commons Attribution-NonCommercial 2.5 Generic.

For biological communities and habitat, the definition of shallow water compared to deep water depends on local hydrography, sediment load, light penetration, organisms commonly present, and community structure. In general, shallow water for benthic habitats is defined as less than 300-m (984-ft) water depth and deep water as greater than 300-m (984-ft) water depth.

Sediments in the Gulf 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 basin is primarily due to waves, tides, and currents in shallow waters and gravity flow[7] 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 Gulf. The continental shelf in the western Gulf 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 Gulf region 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

[7] 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 continental slope.

(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 Gulf between the Yucatán Channel and Cuba, circulate through the basin clockwise in the Loop Current (from more information, see **Section 2.1.2**), and exit via the Florida Straits where they form the Gulf Stream. The Mississippi River dominates the terrestrial drainage system in the northern Gulf, into which two-thirds of the U.S. watershed drain.

2.1.2 Physical Oceanography

Currents

Loop Current

The Loop Current, the dominant circulation feature in the Gulf, enters through the Yucatán Channel and exits through the Florida Straits (see **Figure 3-1**). The sill depth at the Florida Straits is about 700 m (2,300 ft); the effective sill depth at the Yucatán Channel is nearly 2,000 m (6,560 ft) (Badan Jr. et al. 2005). Water masses in the Atlantic Ocean and Caribbean Sea that occur at greater depths cannot enter the Gulf. 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 Gulf. The Loop Current has a mean area of 142,000 km^2 (35 million acres [ac]) but it is not constant (Hamilton et al. 2000). It may be confined to the southeastern Gulf, but it can extend well into the northeastern or north-central Gulf, with intrusions of Loop Current water northward and on to the West Florida Shelf (Vukovich 2005; Hamilton et al. 2019). Closed rings of clockwise-rotating (i.e., anticyclonic) water, called Loop Current eddies (LCEs), separate from the Loop Current at intervals of 6–11 months (Vukovich 2005; Hamilton et al. 2019). These LCEs are also called warm-core eddies because they surround a central core of warm Loop Current water. The Loop Current usually penetrates about as far north as 27°N latitude just before shedding an LCE (Vukovich 2005; Lugo-Fernández et al. 2016).

Currents associated with the Loop Current and its eddies extend to at least depths of 800 m (2,624 ft), the sill depth of the Florida Straits; and geostrophic shear is observed to extend to the sill depth of the Yucatán Channel. These features may have surface speeds of 1.5 m/second (s) (Cooper et al. 1990; Hamilton et al. 2016). 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 that can persist for up to about a year (Elliott 1982; Vukovich 2012); therefore, their effects can persist at one location for long periods—weeks or even months (e.g., Vukovich 2012). After separating from the Loop Current, these eddies often

translate westward across the Gulf 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 (Science Applications International Corporation 1989) by interactions with boundaries, ring shedding, and ring-ring interactions. Consequently, the Gulf is typically populated with numerous eddies, which are interacting with one another and with the margins (Science Applications International Corporation 1989; Hamilton and Lee 2005).

Cold-core cyclonic (counterclockwise rotating masses of cold water) eddies have been observed in the Gulf. These eddies are cold-core because they surround a central mass of seawater that is cooler and fresher than adjacent waters. Their cyclonic circulation is associated with upwelling, which brings cooler, deeper water towards the surface. A cyclone will form north of an LCE encountering northern Gulf bathymetry because of off-shelf advection (Frolov et al. 2004). Cyclones are also associated with the Loop Current (Schmitz Jr. 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 six 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 Gulf (Science Applications International Corporation 1989; Hamilton 1990; Sturges et al. 2004). Exchange of surface and deep water occurs with descent of surface water beneath the Loop Current in the eastern Gulf and with the ascent of deep water in the northwestern Gulf where LCEs spin down (Welsh and Inoue 2000). The Sturges et al. (2004) model suggests a surprisingly complex circulation pattern beneath LCEs, 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 Gulf. 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; Johnson Exley et al. 2022). These TRWs transition from short to longer period in going from east to west over the Gulf 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 Gulf have revealed decreases in current speed with depth. During late 1999, a limited number of high-speed current events, at

times approaching 100 centimeter [cm]/s (39 in/s), were observed at depths exceeding 1,500 m (4,921 ft) in the northern Gulf (Hamilton and Lugo-Fernandez 2001; Hamilton et al. 2003). Furrows oriented nearly parallel to depth contours have been observed 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 Gulf 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 Gulf (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 Gulf is an anticyclonic (clockwise-rotating) feature oriented about ENE-WSW with its western extent near 24°N latitude off Mexico. Though early studies debated whether LCEs or wind stress curl was the primary source of energy for the feature, a recent study suggests both mechanisms contribute (Elliott 1982; Sturges et al. 1993; Olvera-Prado et al. 2024). Sturges et al. (1993) argued that wind stress curl over the western Gulf 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 Gulf boundary to ring-slope-ring interactions (Vidal et al. 1999).

Episodic wind events from storms could intensify currents in the deepwater regions of the Gulf. The initial currents give rise to inertial oscillations, which decrease in amplitudes, last for up to 10 days and are superimposed on longer period signals (Cox et al. 2010).

On-Shelf Processes

Atmospheric interactions from cold fronts, as well as diurnal and seasonal cycles of heat flux at the air and sea interface, affect surface water temperatures. However, 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 that are the transition zone between the shallow continental shelf and deep ocean of the Gulf. 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 "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 (water traveling onto the shallow shelf) and downwelling (water traveling into deeper areas) processes (Nowlin Jr. et al. 2000).

A class of energetic surface currents previously unreported in the Gulf was found over the Texas and Louisiana shelves during the Texas-Louisiana Shelf Circulation and Transport Process program of the early 1990s (Nowlin Jr. 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 Jr. et al. 1998). 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. 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 Jr. 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 Jr. 2000).

Circulation on the continental shelf in the northeastern Gulf 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 and Darnell 1991). 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. Also, the nearshore regions are influenced by freshwater outflow from rivers and estuaries. During the spring and summer, Mississippi River water is advected onto the West Florida shelf at times because of strong currents along the shelf break. Sometimes freshwater from the Mississippi River is entrained by the Loop Current as well (Weisberg et al. 2005).

Extremes in water mass properties are closely associated with specific density surfaces. Summer heating and stratification affect continental shelf waters in the Gulf (Dzwonkowski et al. 2018). Salinity is generally lower nearshore, although freshwater from the Mississippi River and other rivers occasionally moves into outer shelf waters. Subsurface waters derive from outside the Gulf and enter from the Caribbean Sea through the Yucatán Channel. At depths below about 1,800 m (5,906 ft), horizontal distributions of temperature and salinity within the Gulf are essentially uniform (Nowlin Jr. 1972).

Tropical Storms and Cyclones

Severe weather can influence physical oceanographic processes, such as sea surface temperature (SST), circulation, and wave dynamics. Tropical cyclones, known as hurricanes, that impact the Gulf originate over the equatorial portions of the Atlantic Ocean, the Caribbean Sea, and the Gulf. The peak season for tropical cyclones is between June and November. On average from 1991 to 2020, the Atlantic has had about 14.4 named storms and 7.2 hurricanes annually. Data from 1950 to 2020 show that 97 percent of hurricane seasons had more than two hurricanes per year that affected the Gulf (Klotzbach et al. 2025). The Yucatán Channel is the main entrance of Atlantic storms into the Gulf, and a reduced translation speed over Gulf waters leads to longer residence times in this basin.

Tropical cyclones can result in extreme waves and cause currents with speeds of 100–150 cm/s (40–59 inch [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 Gulf. Tropical cyclones can trigger a series of internal waves with near inertial period. Waves as high as 28 m (91 ft) were measured under Hurricane Ivan in 2004 as it passed through the northeastern Gulf as a category 4 storm (Wang et al. 2005). Tropical cyclones may develop or migrate into the Gulf during the warmer months and can rapidly intensify (Liu et al.

2025). These storms may affect any area of the Gulf and substantially alter the local wind circulation around them. Tropical cyclone activity may also lower offshore salinity through freshwater input from terrestrial sources.

Primary Production

Phytoplankton, photosynthetic and typically unicellular organisms, are the primary fixers of organic matter that support the Gulf 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, in the Gulf, followed by phosphate (Rowe 2017). Ninety percent of the water and most of the terrestrial-sourced nitrate and phosphate into the Gulf come from the Mississippi and Atchafalaya Rivers. Seasonal variability in river flow causes significant fluctuations in nutrient flux (Zhao and Quigg 2014), and peak nutrient input generally occurs in the spring (Lohrenz et al. 1997). The nutrient-rich Mississippi River plume in the north-central Gulf 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 Gulf (Wawrik et al. 2003).

Though growth-limiting nutrients are sourced primarily from rivers, most of the nutrient flow into the Gulf 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 Gulf, 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/year (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 Gulf basin. Therefore, primary production in the Gulf is dominated by processes along the margins of the Gulf (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 Gulf 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 (Liu et al. 2021). Synoptic-scale processes include seasonal variations in solar and atmospheric conditions and Loop Current excursions. The interaction of these many 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-Related Factors

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 gases that have the most impact 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 (Intergovernmental Panel on Climate Change 2014). These changes may affect marine Gulf 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).

Temperature increases in the atmosphere and ocean have the potential to influence hurricanes (tropical cyclones) and extreme weather events in the Gulf, and the potential oil spill risk associated with them. Scientists have predicted an increase in the frequency and intensity of storms (Intergovernmental Panel on Climate Change 2014) with increasing temperatures. In the Gulf, high-intensity storms coupled with the highest rates of sea-level rise in the U.S. (Lindsey 2020) contribute to coastal flooding and erosion, damage coastal infrastructure, and degrade coastal habitats. The Gulf is prone to extreme storm events. As reported by NOAA in the 2023 Atlantic Hurricane and Climate Change State of the Science Fact Sheet, observations since the 1980s show that here has been an increasing trend in the intensity and rate of intensification of tropical cyclones observed for the North Atlantic basin, which includes the Atlantic Ocean, Caribbean Sea, and the Gulf (Deehan et al. 2024). However, evidence for the future continuation of any increasing trend is much weaker, partly due to observed data limitations (Deehan et al. 2024). According to NOAA, though greenhouse gas-induced warming may have affected Atlantic basin hurricane activity, a detectable greenhouse gas influence on hurricane activity in the North Atlantic basin has not been identified with high confidence (NOAA 2012b; Bruyère et al. 2017; Knutson et al. 2021; Deehan et al. 2024). This makes estimations of future climate impacts on hurricane intensity uncertain at the current time. Also, more observational

data is needed for a robust analysis, and before drawing any conclusions about how climate-induced changes to the frequency and intensity of hurricanes may impact oil spill risks over the long term in the Gulf. 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 would be exacerbated if shoreline vegetation is lost. It is possible that the trend of increasing storm intensity could continue as increases in temperature may make the Gulf more favorable for stronger storms. However, there is also evidence to suggest that temperature increases have already increased storm intensity in the Gulf as much as it would for the foreseeable future. Currently there is no evidence to suggest that storm intensity would drop across the Gulf in the near future.

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 (Intergovernmental Panel on Climate Change 2014). Zooplankton may serve as sentinel species for ocean temperature 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).

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 (Fabry et al. 2008; Doney et al. 2009). Increased seawater acidity is also a challenge for both shallow and deepwater coral species because of 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, ocean acidification would affect not only the success of some species; it would also impact oceanic carbon sequestration, as some calcifying plankton have a crucial role in the global carbon cycle (Hofmann 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 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 Gulf, SST, 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 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 SSTs on plankton and larval fishes would be species-specific, making it difficult to predict overall trends. Some predict that changes in ocean temperature and chemistry would 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 and habitats of the Gulf region. Each section 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. For a table of common and scientific names of organisms that appear in the text, and their relevant protective status, see **Appendix A**.

3.2 COASTAL HABITATS AND COMMUNITIES

The Gulf coastline spans 2.623 km (1,630 mi) from the southern tip of Texas to the Florida Keys and contains more than 750 bays, estuaries, and sub-estuary systems (USEPA 2012; **Figure 3-1**). Coastal habitats, which include shallow nearshore (e.g., sand banks and shoals), shoreline (e.g., beach, dune, barrier island), and estuarine (e.g., salt marsh, submerged aquatic vegetation [SAV], mangroves, oyster reefs, tidal flats) habitat, provide critical nursery grounds, foraging areas, spawning areas, and/or protective cover for numerous marine species. Saltwater marshes, saltwater mangrove swamps, and non-vegetated areas (e.g., sand bars, mudflats, and shoals) are the most common Gulf coastal habitats (Dahl and Stedman 2013). In the Gulf region, most coastal waters are designated as essential fish habitat (EFH); see **Section 3.5**).

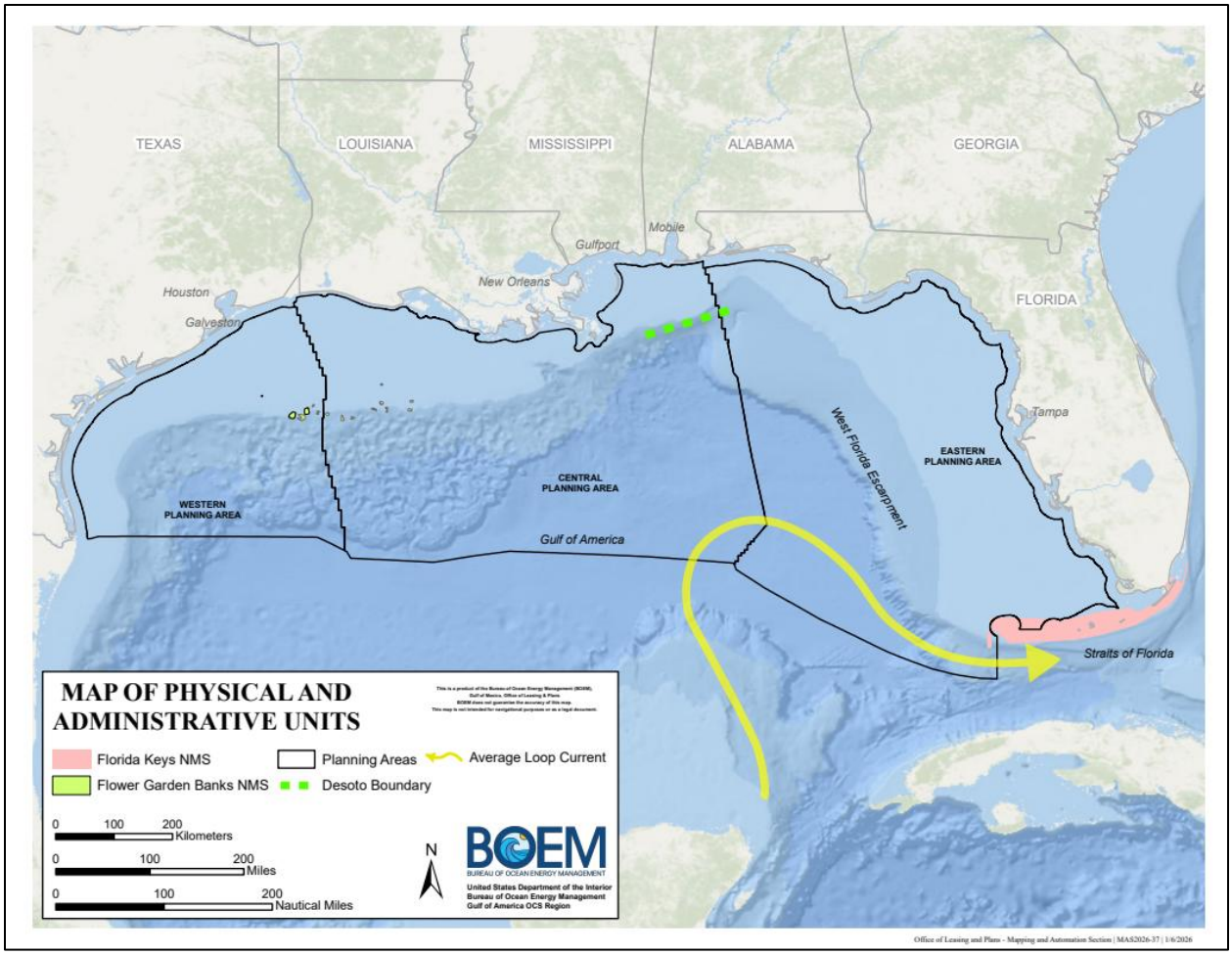


Figure 3-1. Map of physical features and administrative units of the Gulf region.
Source: BOEM - 2026. The map was created by BOEM geographers using a publicly available Esri Topographic Basemap. The Florida Keys National Marine Sanctuary geospatial data is from the Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute. The Desoto Boundary was created by BOEM geographers and the Office of Environment.

The primary physical oceanographic factors which influence coastal environments and habitat include hydrodynamics (i.e., wave energy, currents), water depth, temperature, salinity, dissolved oxygen (DO), chlorophyll content, nutrients, potential of hydrogen (pH), oxidation reduction potential, 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 primary defining feature. The Mississippi River is located along the coastline of BOEM's CPA. Before the construction of extensive levees and other controls, the lower Mississippi River used to shift its course to the Gulf 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 or Balize Delta. Older, historic lobes have shaped the Louisiana coast and contributed to the associated, extensive coastal wetland system (Coleman et al. 1998). The Louisiana coastal area 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, as well as its nutrient- and sediment-rich freshwater outflow, are driving features that influence the habitats (e.g.,

wetlands and estuaries) within its proximity, which include the Deltaic and Chenier Plains (USACE 2004). The adjacent coastal waters are also enriched by the organic material exported from estuaries and rivers that empty into the Gulf region.

3.2.1 Estuaries

Estuaries are typically semi-enclosed areas where marine saltwater is diluted by freshwater input. Salinity can vary widely in estuaries. Freshwater input (e.g., bayou, stream, or river) into the estuary delivers sediment and nutrients that result in turbid, productive environments. Estuaries can be made up of many important habitat types (e.g., marsh, seagrasses, mangroves, and tidal flats) and support significant marine life biomass. In the Gulf, 35 major estuarine systems account for 28 percent of the coastal wetland area and 41 percent of the open water area in the U.S. Compared to other estuaries, the average Gulf estuary is characterized by its shallower depths, faster freshwater flushing rates, higher wetland-to-open water area ratio, lower tidal range, and higher sediment accumulation (Turner 2001). Living within estuarine habitats can have high energetic costs to resident organisms due to fluctuating conditions (e.g., salinity). Estuaries may be subject to extreme tidal exchange, strong currents, water-column stratification, and/or rapid fluctuations in DO.

Estuarine habitats are home to a diverse array of fish, invertebrates, marine mammals, sea turtles, and birds, and provide important foraging and nursery grounds for these biota. Many fish and invertebrate species found in mid- or near-shelf waters are dependent on, 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 grouper. Bull sharks opportunistically make use of estuarine habitat and are common in both estuarine and nearshore waters. Manatees, bottlenose dolphins, and sea turtles frequent estuarine areas, particularly for foraging opportunities and nursery habitat. Critical habitat has been designated in estuarine areas for ESA-listed species including smalltooth sawfish (estuarine nearshore waters of southwest Florida), Gulf sturgeon (select rivers and associated estuarine and nearshore habitat off Louisiana, Mississippi, Alabama, and Florida), loggerhead sea turtle (nearshore reproductive habitat off Florida, Alabama, and Mississippi), green sea turtle (proposed estuarine waters of Florida and Texas), and the Florida manatee (estuarine waters of Florida, though critical habitat revisions are proposed [89 FR 78134]). More information on these biota can be found in subsequent sections of this document.

3.2.2 Wetlands

Wetlands (or marsh) habitat occurs along the northern Gulf coast with the highest density found in Louisiana and southern Florida (Dahl and Stedman 2013). As “living filters,” wetlands improve water quality by removing pollutants and nutrients, and trapping sediments. High organic productivity and efficient nutrient recycling are characteristic of coastal wetlands. Coastal wetlands provide essential functions to avoid or mitigate many pressing environmental stressors, including increasing temperatures, sea-level rise, hurricanes and severe storms, droughts, floods, wildfires, and the growing need for readily available clean water (Lang et al.

2024). Wetlands can function as buffers against storms due to their frictional resistance that absorbs wave energy, reduces wave amplitude, and slows the forward motion of surges, thereby reducing impacts on inland ecosystems (Engle 2011). 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.

Northern Gulf wetlands provide habitat for a large and diverse group of resident plants, invertebrates, fishes, reptiles, birds, and mammals. This includes key foraging and resting areas for more than 400 species of birds (FWS 2013c), including ESA-listed species like the Eastern black rail and whooping crane. Some ESA-listed species, such as the Cape Sable seaside sparrow, may spend all their life stages in coastal marshes. Wetland environments are also particularly vital nursery grounds for many economically important fish and shellfish juveniles.

Although wetlands help mitigate the impacts of many environmental stressors, they are vulnerable to severe natural and anthropogenic stressors, and a long-term trend of wetland loss has been observed along the northern Gulf region. 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. Half of the total wetlands loss in the U.S. is concentrated in Florida, Texas, California, and Louisiana. Artificial flood controls (e.g., levees) have reduced the natural riverine input to most of the Gulf, resulting in a decrease in the sediment loads and nutrients needed for wetland survival (Kesel 1989; Ko and Day 2004b). Additionally, the creation of channels and canals, often resulting from oil and gas industry activities, can cause saltwater intrusion, which can lead to freshwater marsh degradation (Ko and Day 2004b).

Marsh erosion, in conjunction with natural subsidence of the uncompacted deltaic sediments in the region, contributes to some of the highest rates of relative sea-level rise in the U.S. (NOAA 2025). Sea-level rise results in marshland converting to open water at staggering rates (see **Figure 3-2**). In some areas of the Gulf, 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. Invasive nutria also graze on wetland vegetation, exacerbating ongoing erosion, land loss, and saltwater intrusion. These rodents are native to South America and were introduced to the Gulf Coast in the 1940s for the fur trade; they are now found in all five Gulf Coast states.

In coastal Louisiana and Texas, oil, gas, and groundwater extractions have contributed to land 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 1988a; 1988b; 1988c; Ko and Day 2004b; 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).

Net wetland loss in the U.S. has significantly increased from the previous Wetlands Status and Trends study (2004–2009), resulting in the loss of 89,000 hectares (ha) (221,000 ac) of wetlands between 2009 and 2019 (Lang et al. 2024). Relative patterns of wetland loss throughout the U.S. are depicted in **Figure 3-2**. Coastal watersheds make up 13 percent of the conterminous U.S. by area, yet they have accounted for 86 percent of the total net wetland losses nationally. The Gulf region was among the coastal watersheds with the highest net losses (Lang et al. 2024). The wetland loss trends for each Gulf Coast state are discussed below.

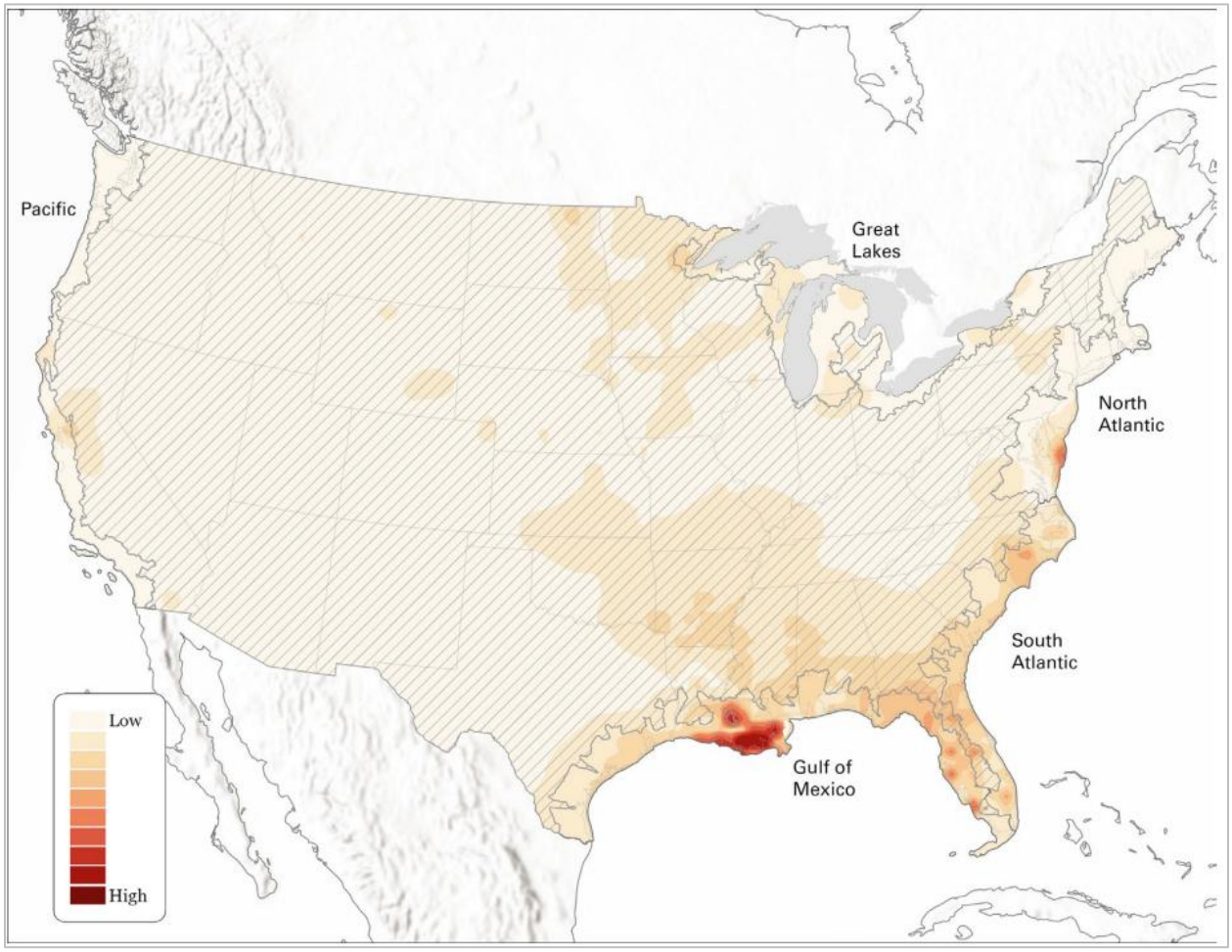


Figure 3-2. Relative density of net vegetated wetland decrease (loss to upland and deepwater and change to non-vegetated wetlands) in the conterminous United States, 2009 to 2019.
Source: Lang et al. (2024).

An estimated 1.7 million ha (4.1 million ac) of wetlands existed on the Texas coast in the mid-1950s with an estimated 1.6 million ha (3.9 million ac) left by 1992. Approximately 687,966 ha (1.7 million ac) or 52 percent of the freshwater wetlands in coastal Texas were classified as farmed wetlands used to cultivate rice and for other agricultural purposes (Moulton et al. 1997). The greatest losses have been to freshwater emergent and forested wetlands. The primary cause is considered to be faulting and land subsidence due to the withdrawal of underground water and onshore oil and gas activity, leading to marsh submergence (Moulton et al. 1997).

Louisiana contains about 37 percent of the estuarine herbaceous marshes in the conterminous U.S. (Couvillion et al. 2011) and supports the largest commercial fishery by weight in in the lower 48 States (NMFS 2024b). From 1932 to 2016, Louisiana lost approximately 4,833 km^2 (1,866.63 mi^2) of land (Couvillion et al. 2017). This accounts for about 90 percent of the total coastal wetland loss in the continental U.S., with a current loss rate of 1.52 km^2/yr (0.59 mi^2/yr) (Zou et al. 2024). However, this rate is a significant improvement from the 108.8 km^2/yr (42 mi^2/yr) rate experienced during the late 1960s. Ninety-five percent of continual land loss is 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 8 to 17 percent of Louisiana's total wetland loss (Turner and Cahoon 1988a; 1988c; 1988b).

Estuarine wetlands are common in Mississippi, with marshes around Mississippi Sound and its associated bays occurring 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 (Wallace 1996; Mississippi Department of Marine Resources 1999; Couvillion et al. 2011). In 1999, Mississippi had approximately 64,000 ac (25,900 ha) of vegetated coastal wetlands (Mississippi Department of Marine Resources 1999); the Mississippi Department of Environmental Quality estimates a loss of 4,047 ha (10,000 ac) of wetlands in the 60 years from 1947 to 2007 (Mississippi Department of Environmental Quality 2016).

Most coastal wetlands in Alabama occur on the Mobile River Delta or along the northern Mississippi Sound. Though Alabama's historic coastal wetland loss was considerable, the areal extent is considered to have changed very little between 1974 and 2010 (Ellis et al. 2011).

At one time Florida wetlands were estimated to encompass over 8.1 million ha (20 million ac). However, having been converted through draining, dredging, filling, and flooding until 1996, approximately 4.6 million ha (11.4 million ac) remain (Dahl 2005). Wetland loss rates as high as 29,137 ha/yr (72,000 ac/yr) occurred from the mid-1950s to the mid-1970s, declining to 2,023 ha/yr (5,000 ac/yr) from 1985 to 1996 (nearly 80 percent rate decline) due to increased regulations and the elimination of incentives for wetland drainage. More recently, Florida has experienced the highest rate of wetland loss among states: 2,319 ha/yr (5,730 ac/yr) (Zou et al. 2024). Despite accounting for only 2 percent of the nation's total land area, Florida's wetland loss represents more than 20 percent of the total U.S. wetland loss (Zou et al. 2024). Zou et al. (2024) suggest this loss may be linked to the state's significant population growth, which is three times the U.S. average per year, coupled with a demand for new housing, which is more than two times the U.S. average.

In recognition of the ongoing and projected patterns of coastal land loss, several programs have been established for the conservation, protection, and preservation of coastal areas. USACE has a national policy for "no net loss of wetlands". The goal of the policy is to balance wetland development with wetland mitigation and restorations efforts, so that the total acreage of wetlands within a watershed and/or drainage basin does not decrease but rather remains

constant or increases. 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. Since 2007, Louisiana's Coastal Protection and Restoration Authority has secured roughly $2.5 billion in state and federal funding for over 140 restoration projects and benefitted over 22,584 ha (55,807 ac) of coastal habitat (Louisiana Coastal Protection and Restoration Authority 2023). 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. Presently, however, these efforts are not sufficient to reverse the current and projected trends for land loss along the Gulf Coast. Coastal and estuarine habitat acreage would likely continue to decline, particularly in Louisiana, due to global sea-level rise and subsidence. The shoreline surrounding the Mississippi River Delta is expected to continue to erode, as agricultural, residential, and commercial development persists (Boesch et al. 1994; Day Jr. et al. 2000; Day Jr. et al. 2001). Stressors that lead to the degradation or loss of wetlands will put additional stress on the associated biota, including estuarine fish, shellfish, and birds.

3.2.2.1 Salt Marshes

Coastal salt marshes are one of the most productive ecosystems, in terms of primary production, rate of organic matter production per unit surface area per unit time. The Gulf contains the largest extent of salt marsh in North America, with the majority in the northern Gulf region. The current areal estimate of salt marsh in the Gulf region is 538,637 ha (1,331,001 ac) (Thorhaug et al. 2019). Salt marshes are dominant along northern Gulf shorelines from Nueces Bay, Texas to north Tampa Bay, Florida. Their high primary productivity supports invertebrate detritivores/omnivores that provide an important link to higher-level consumers. These highly productive ecosystems function as nursery habitats, offering essential resources for many estuarine species that transition to marine habitats as adults (Ziegler et al. 2021). Salt marsh vegetation in the eastern Gulf is dominated by *Juncus roemerianus,* while salt marsh west of the Pearl River at the Mississippi-Louisiana border is dominated by *Spartina alterniflora*, *S. patens*, and *Distichlis spicata.* Marshes further west in Texas are primarily dominated by *S. alterniflora*.

Hydrology is one of the most important factors influencing coastal wetland function and sustainability. The hydroperiod, defined by Rozas (1995), refers to the duration, frequency, and depth of flooding of the intertidal salt marsh surface. It directly affects the ability of nekton to access intertidal areas within the salt marsh and also indirectly influences habitat use by altering vegetation structure through zonation (Ziegler et al. 2021). Salt marshes show strong zonation based on elevation and tidal inundation, resulting in what is termed the "high" and "low" marsh. The low marsh is regularly flooded (tidally inundated) once or twice a day. Species

richness is relatively low in the low marsh, and sometimes monospecific. In contrast, the high marsh is irregularly flooded, sometimes only during spring tides or extreme wind tides. Vegetation within the high marsh, although more diverse than the low marsh, is less diverse than freshwater marsh habitat. The highest elevations of a salt marsh can develop into a hypersaline salt pan, either devoid of vegetation or consisting of stunted halophytes. Salt marshes can have a relatively high infaunal and epifaunal species diversity compared to freshwater marshes which also demonstrate strong zonation based on elevation and tidal influence (Mendelssohn et al. 1993). Salt marshes also support high nekton densities, including recreationally and commercially important crustacean and fish species (Hollweg et al. 2020). When salt marsh is present, nekton tend to be found concentrated near the marsh edge (i.e., interface of the marsh shoreline and open water) with abundance decreasing farther into the marsh interior or out into adjacent open water. However, trends for edge versus interior marsh or nearby open water habitat use appear to be variable and species-specific for fish (Hollweg et al. 2020).

In the northern Gulf, the plant species *Phragmites australis* (common reed) inhabits marsh areas from Texas to Florida. In the last few decades, *Phragmites* has expanded into areas affected by tidal restrictions, habitat modification, and disturbance. Because the species can form large, dense, monotypic stands, outcompeting other salt marsh species, it has been identified as a potential species of concern that could alter ecosystem services (e.g., habitat for birds, fish). This species can cause a decrease in plant diversity, changes in soil properties, salinity levels and topographic relief of shorelines, marshes, and wetlands through its aggressive colonization of shoreline and shallow areas (Velez-Gavilan 2024). Though it is not typically regarded as a serious threat to other plant species, it is listed as an invasive or noxious weed in various U.S. states. This is due to its ability to displace native marsh plants, particularly in the eastern U.S., where it is considered a serious weed. However, *Phragmites* has also been recognized as having an important role in stabilizing soils and contributing to secondary production, providing habitat and food for a variety of fish, crustaceans, and aquatic invertebrates (Gucker 2008; Mendelssohn et al. 2017). Since 2012, *Phragmites* has exhibited an extensive dieback in the Lower Mississippi River Delta, resulting in concerns of potential land loss (Elsey-Quirk et al. 2024; Lee et al. 2024).

3.2.3 Mangroves

Mangrove habitat can be found from Texas to Florida along the northern Gulf, and Florida's southwest coast supports one of the world's most extensive mangrove swamps. 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. 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. They are also vital nursery grounds for many fish species. Mangroves stabilize shorelines, function as storm buffers, and regulate turbidity by filtering upland runoff and trapping water-borne sediments and debris. Like marsh habitat, mangroves provide direct

human value by minimizing upland erosion, protecting property and infrastructure, and supporting the tourism and fishing sectors of the economy.

Within the northern Gulf, mangroves make up approximately 253,400 ha (626,165 ac) of habitat, of which, almost 98 percent is along the Florida coast, representing approximately 3 percent of mangrove cover globally. Outside of Florida, mangroves in Texas and Louisiana represent approximately 1.4 and 0.6 percent of total mangrove cover in the northern Gulf, respectively. Mangroves are not present along the Alabama or Mississippi coasts (Osland et al. 2018). Increased temperatures are expected to result in an expansion in the northern range of mangroves in the Gulf region. However, their future distribution can be hard to predict. Freezing temperatures are the primary driver of mangrove distribution and community structure, but they are also heavily influenced by other factors, including elevation above sea-level, nutrient availability, salinity, and propagule (seedling) dispersal pathways (Snyder et al. 2022).

3.2.4 Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) is a vital component of coastal aquatic ecosystems; at least 26 species of SAV grow in the northern Gulf (Carter et al. 2011; Heck et al. 2011; Hillmann et al. 2016). SAV consists of benthic plants and plant-like organisms (e.g., seagrasses, macroalgae) that settle and grow without emerging above the water's surface, although they can be exposed during low tides. The distribution and composition of 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), as well as macroclimatic drivers such as precipitation and air temperature (DeMarco et al. 2022). SAV is particularly vulnerable to changes in salinity and water depth because these factors are two key drivers of SAV biomass, production, community assemblage, and distribution (Orth et al. 2006; Merino et al. 2009; Hillmann et al. 2016). In the northern Gulf, SAV typically occurs in relatively shallow and clear protected waters (i.e., protected from high wave and current energy) within soft substrates firm enough to enable colonization of the seafloor (Short et al. 2001). At lower salinities, species such as water celery and water nymph may dominate (Handley et al. 2007; Carter et al. 2009). Typical mesohaline species found in the Gulf region include wigeon grass, shoal grass, pond weed, and turtle grass (Handley et al. 2007; Cho and May 2008; Carter et al. 2009; Merino 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). Over a two-year period, Hillmann et al. (2016) identified 14 SAV species from the Nueces River, Texas to Mobile Bay, Alabama. Eight of the 14 species constituted 97 percent of the total SAV biomass; three species (i.e., widgeon grass, Eurasian watermilfoil, and coontail) account for 54 percent of above-ground biomass. Salinity and water depth were determined to be the primary drivers of species assemblages, although they had little effect on biomass (Hillmann et al. 2016).

SAV provides shelter, foraging habitat, predator protection, and essential nursery grounds for commercially and recreationally important fish and invertebrate species. SAV habitats are also

important for carbon sequestration, nutrient cycling, improving water quality, and sediment stabilization (Heck Jr. et al. 2003; Duarte et al. 2005; Orth et al. 2006; Frankovich et al. 2011; Hillmann et al. 2016). SAV is considered to have a large role in carbon sequestration by capturing carbon dioxide from the atmosphere and storing it in plant material and sediment (Lang et al. 2024). Further, SAV provides food resources for associated grazers, including infaunal species, nekton, megaherbivores (e.g., manatees), and overwintering waterfowl (Rozas and Odum 1988; Rooker et al. 1998; Castellanos and Rozas 2001; Heck Jr. et al. 2003; Orth et al. 2006; Maiaro 2007). One of the more critical functions of SAV systems is consequently the transfer of primary production through the food chain. If there is a lack of grazers present, excessive epiphyte growth can negatively affect SAV growth and community (Howard and Short 1986; Bologna and Heck Jr. 1999; Heck Jr. et al. 2006).

DeMarco et al. (2022) estimates there are 225,000 ha (555,000 ac) of SAV habitat in the Gulf region. Elevated nutrient concentrations, declining water quality, and sedimentation from natural and anthropogenic events are a common cause of seagrass declines worldwide (Orth et al. 2006; Carlson Jr. and Madley 2007; Waycott et al. 2009). Changes in the Gulf region could alter SAV production and composition, potentially shifting toward more saline-and depth-tolerant assemblages (Hillmann et al. 2016). For example, in the northern Gulf, extensive marsh loss is altering the distribution of shallow-water habitats, reducing SAV coverage from the bays of Texas to the Gulf shores of Florida (Handley et al. 2007; Hillmann et al. 2016). Though 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. Alternatively, SAV may mitigate some of the effects of sea-level rise. As coastlines are reduced from rising sea levels, the area of shallow water in estuaries will increase, potentially allowing SAV habitats to expand, providing important benefits for wildlife and supporting the remaining wetlands (DeMarco et al. 2022).

3.2.5 Oyster Reefs

The Eastern oyster is a species that benefits from the environmental conditions of estuarine habitat while also serving as an important substrate for other invertebrates and fishes. The Eastern oyster is the dominant reef-building species in the northern Gulf and is primarily found within shallow estuarine areas. Research suggests the existence of at least three distinct genetic populations of Eastern oysters in the Gulf: (1) an eastern population, spanning from the southern Atlantic coast of Florida to Cedar Key and Apalachicola in the Florida Panhandle; (2) a northern population, extending from Apalachicola to Aransas Bay, Texas; and (3) a western population, ranging from Aransas Bay to estuaries further west in the Gulf (Hajovsky et al. 2021). 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 nursery, shelter, and foraging habitat for recreationally and commercially important fish, crustaceans, and other invertebrates;

- Enhancing water quality through the filtering of phytoplankton, detritus, bacteria, and contaminants;
- Preventing coastal erosion (e.g., mitigating the impacts of boat wakes); and
- Functioning as sentinels for environmental disturbance (e.g., contamination) (Volety et al. 2014).

Eastern oysters typically have an elongated shape, with a rounded and asymmetrical shell. They are broadcast spawners, meaning they release eggs and sperm into the water column, where fertilization occurs. Once the fertilized eggs hatch, the larvae seek out and attach themselves to hard substrate, a process known as "settlement". Both abiotic and biotic factors influence their growth, leading to considerable individual variation depending on environmental conditions (Hajovsky et al. 2021). Younger oysters tend to have a wider, more circular shell, while older oysters become more elongated, with most growth occurring on one side. The unique variation in shape and characteristics of Eastern oysters could serve as useful variables in assessing population structures within reef communities (Hajovsky et al. 2021). Reef characteristics, such as adjacent habitat, connectivity, redundancy, complexity, and water quality, affect associated oyster reef assemblages. In addition, the cycle of oyster recruitment, growth, death, and degradation creates a succession of available benthic habitat. For example, relict oyster reefs can create habitat that provides refuge from predation and substrate for egg laying by mobile organisms (Tolley and Volety 2005). A synthesis of studies found that 115 fish and 41 decapod crustacean species are known to inhabit oyster reefs in northern Gulf estuaries (La Peyre et al. 2019).

Eastern oysters are sensitive to decreases in freshwater input, changes in pH, and, during the larval stage, turbulence and light. In the Big Bend region of Florida, evidence suggests reef loss from reduced survival and recruitment is primarily a result of decreased freshwater input, increasing the reefs' vulnerability to wave action and sea-level rise (Seavey et al. 2011). Eastern oysters are vulnerable to changes in pH, particularly decreases that hinder the formation of calcium carbonate shells (Beniash et al. 2010; Tomanek et al. 2011; Boulais et al. 2017; Osborne et al. 2022). Wheeler et al. (2017) examined the effects of light on Eastern oyster larvae and found that larvae exhibited a distinct increase in dive frequency and speed in exploratory helical swimming behavior when in the presence of light. This suggests that light encourages swimming behavior modes like exploration, settlement, and predator avoidance. Artificial lighting, then, could influence behavioral changes in Eastern oyster larvae, with potential implications for larval survivorship and settlement (Wheeler et al. 2017).

Oyster reefs are sensitive to damage and impairment. To combat the loss of oyster reefs, restoration efforts have become a high priority throughout the Gulf and have prompted research in the following areas: (1) identifying suitable habitat based on water quality, ecological, and physical drivers; (2) determining larval behavior, growth and survival under various environmental conditions; (3) advancing oyster hatchery technology while prioritizing sustainability; and (4) improving water quality and supporting research for oyster management and restoration activities (Spies et al. 2016; La Peyre et al. 2021; Wiesenburg et al. 2021; The

Nature Conservancy 2023). Aggregate analysis and in-situ sampling of restoration sites in the north-central Gulf indicate that 73 percent of restoration efforts produce at least one living oyster (La Peyre et al. 2014).

3.2.6 Intertidal Flats

Unvegetated intertidal sandflats and mudflats are important estuarine habitat in the Gulf region and occur where areas become protected from wave and tidal action. Intertidal flats are typically exposed only at very low tide, which is why they are generally devoid of macrophyte vegetation. These areas are often associated with barrier islands but can also occur along shorelines in bays and lagoons. Mudflats, as opposed to sand flats, are rich in organic matter and occur where sediment particle sizes are finer (i.e., there is no winnowing away of the finer-grained sediments). Dominant infauna on intertidal sand flats are similar to sand beaches (e.g., polychaetes, bivalves, and crustaceans). Fauna on mudflats differ because of the adaptations required for living in fine sediments with anaerobic pore water. Most organisms inhabiting mudflats either burrow or construct tubes in and/or on the substrate.

Intertidal flats can support prey sources for nekton, and their proximity to adjacent habitat types (e.g., seagrass, tidal marsh, mangrove) influences which species use them. Intertidal flats can provide potential migratory corridors for taxa (e.g., penaeid shrimps, blue crab) moving from estuarine nurseries into nearshore spawning grounds. In addition to nekton, tidal flats also provide valuable foraging habitat for many wading bird species, including ESA-listed piping plovers and rufa red knots. Further, intertidal flats can provide an important erosional buffer for coastal wetlands and mangroves (Mendelssohn et al. 2017; Michel 2021a)

3.2.7 Sand Shoals

A shoal is a natural, underwater ridge, bank, or bar consisting of, or covered by, sand or other unconsolidated material, resulting in shallower water depths than surrounding areas (Rutecki et al. 2014). Most OCS sediments west of 88°W longitude (near Mobile Bay, Alabama) are predominantly mud with some interspersed sand shoals (Pickens et al. 2020). These interspersed sand bodies formed as sand and shell material were deposited and accumulated during slowdowns or stillstands of the Holocene sea-level rises (Davis 2017) and from deposits associated with ancient river channels (Xu et al. 2022). They are morphologically dynamic features shaped primarily by waves and currents during episodic weather events, such as tropical storms and hurricanes, in addition to other lower-intensity weather events. These elevated deposits may be surrounded by hypoxia-prone mud deposits, allowing them to be oxygen-rich refuge for organisms and create diversity “hotspots” (Dubois et al. 2009; Grippo et al. 2009; Gelpi Jr. 2012). Notable sand shoal formations occur near Louisiana (Ship Shoal) and Texas (Sabine Bank, Heald Bank, Freeport Rocks) (Rutecki et al. 2014; Byrnes et al. 2017). Bedform shoals have also been identified along the West Florida Shelf, and linear shelf sand shoals can be found along the Mississippi-Alabama Shelf eastward of the entrance to Mobile Bay (Rutecki et al. 2014).

Shoals can be used to provide sediments for nourishment of the coastline (Davis 2017; Xu et al. 2024) and also act as spawning sites for some demersal and schooling planktivorous fishes. In addition, juvenile reef fish (e.g., lane snapper, rock seabass, dwarf sand perch, sand perch, red snapper) have been documented in surveys of sand shoals off Louisiana and Texas, indicating that these areas potentially provide important nursery habitat and a possible link between estuarine and offshore habitats (Pickens and Taylor 2020).

3.2.8 Beaches and Barrier Islands

Sand beaches provide several key services, including habitat; 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). The beaches' supratidal zone, the area above the high tide line, is where wrack commonly accumulates; it supports important prey resources for higher trophic levels (Dugan et al. 2003). The intertidal zone, the area between the high and low tide lines, is a more dynamic environment than the supratidal with a higher invertebrate biomass (Raffaelli et al. 1991; Colombini and Chelazzi 2003; Janssen and Mulder 2005) comprising species considered tolerant to disturbance (Michel et al. 2017).

Beaches in the Gulf region provide important nesting habitat for several species of sea turtles (**Section 3.6**), including Kemp's ridley, loggerhead, green, leatherback, and hawksbills (Valverde and Holzwart 2017). Beaches in the northern Gulf also provide important habitat for overwintering shorebirds, including ESA-listed piping plovers and rufa red knot. For more information about sea turtles and birds in the Gulf, see **Sections 3.6 and 3.8,** respectively.

Barrier islands are present along more than half of the northern Gulf coastline (BOEM 2015) and protect the mainland from shoreline erosion by reducing wave action (Morton 2003; Rosati 2009). Barrier islands are critical stopover areas for numerous migrating birds and are important habitat for nesting and wintering birds (**Section 3.8**). Barrier islands also provide habitat for sand-dwelling crustaceans (e.g., mole crabs, ghost shrimp, and clams) and small burrowing mammals (e.g., beach mice and rabbits) (Britton and Morton 1989).

3.2.8.1 Beach Mice

Beach mice are nocturnal herbivores that forage on sea oats and beachgrass, occasionally consuming invertebrates. They are restricted to the coastal barrier sand dunes along coastal Alabama and the Florida panhandle (Ehrhart 1978; Moyers 1996). Optimal beach mouse habitat is a heterogeneous mix of interconnected habitats that include 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, food storage, and protection from inclement weather conditions.

Five subspecies of beach mouse are found along the coastal Gulf, four of which are ESA-listed species: the Alabama beach mouse; the Perdido Key beach mouse; the Choctawhatchee beach mouse; and the St. Andrew beach mouse. The remaining subspecies of the common oldfield mouse, the Santa Rosa beach mouse, is not currently protected under the ESA. Critical habitat for the ESA-listed species extends from Baldwin County, Alabama, to Gulf County, Florida (see **Figure 3-3**). These four subspecies of beach mice are similar in appearance but can be identified by pelage color and location (Bowen 1968). 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. In general, none of the known factors affecting beach mice populations would be related to BOEM-regulated activities or potential oil spills.

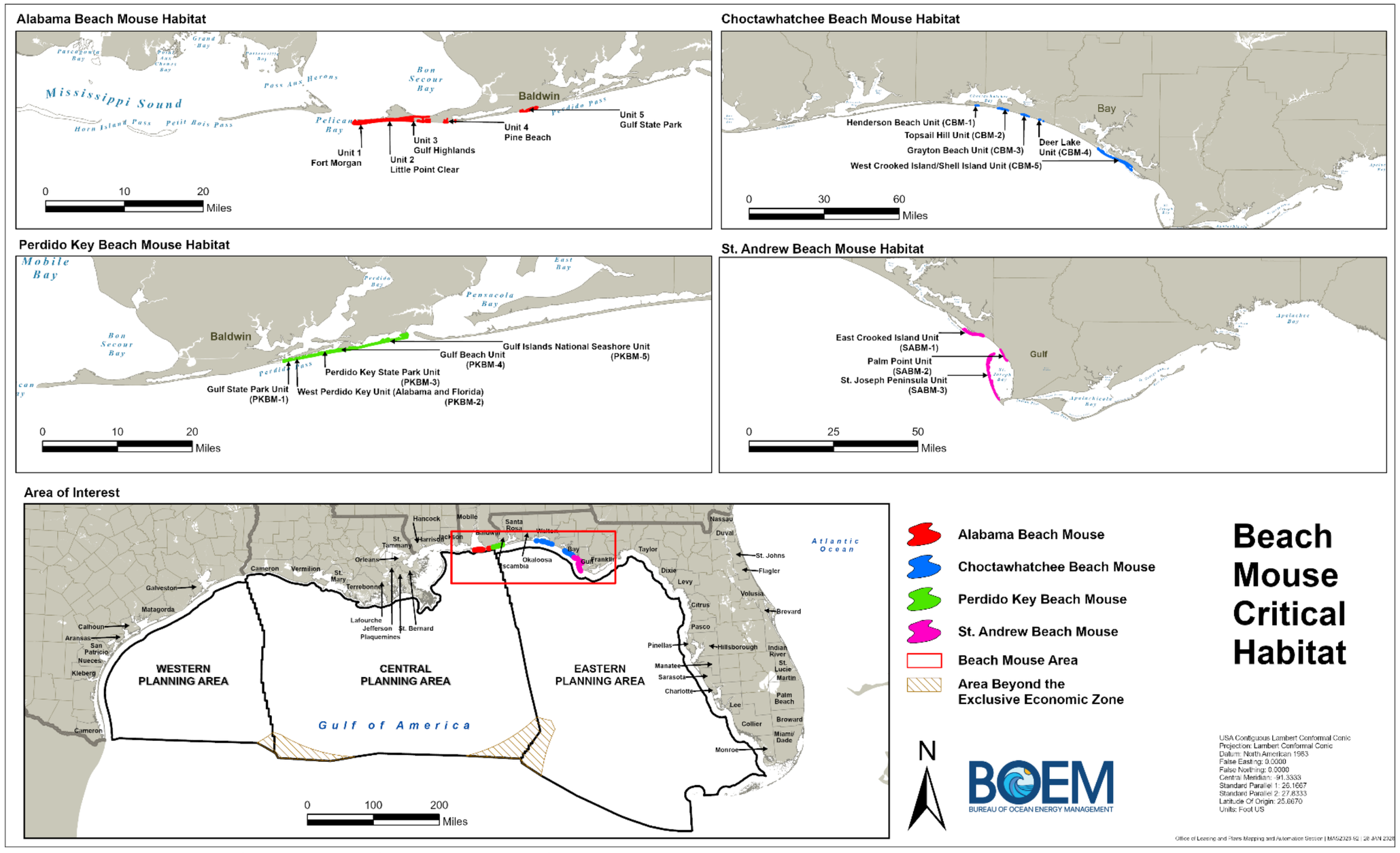


Figure 3-3. Designated Critical Habitat for ESA-listed species of beach mouse along the Gulf.
Source: BOEM - 2026. The map was created by BOEM geographers using publicly available Gulf of America Boundary data. Critical Habitat data is from the FWS.

3.2.9 Environmental and Anthropogenic Stressors

3.2.9.1 Climate-Related Factors

Ocean acidification from increased carbon dioxide absorption or sulfur and nitrogen deposition can impact pH levels, resulting in potential physiological effects among organisms and alterations to food web dynamics (Mai and Chen 2024). The changes may act additively or synergistically with other stressors and have species- and stage-specific effects. Ocean acidification can hinder the growth of calcium carbonate shells in shellfish, although responses can vary among and within species (Osborne et al. 2022). The Eastern oyster (*Crassostrea virginica*) may be particularly vulnerable under prediction scenarios (Osborne et al. 2022), causing concern for the function of this important benthic habitat-forming organism in coastal areas of the Gulf. Compared to other regions, the pH of coastal Gulf waters has not yet decreased significantly. It is expected that the Gulf region will not experience acidified coastal waters until after 2099 (Ekstrom et al. 2015). Hypoxia and riverine input can exacerbate local ocean acidification (Melzner et al. 2013; Ekstrom et al. 2015) and may contribute to lower pH values.

As global temperatures increase, glaciers melt and accelerate sea-level rise. Rising temperatures also cause changes in precipitation, evaporation, and river discharge. In conjunction with land subsidence, largely due to groundwater withdrawal, sea-level rise is of significant concern to the coastal environments of the northern Gulf (Kolker et al. 2011; Dangendorf et al. 2023). Coastal flooding and saltwater intrusion can cause shifts in community composition, possibly resulting in severe vegetation loss from the sudden shift of environmental conditions. For example, after Hurricane Harvey, patterns of massive die-off events of *S. alterniflora*, a saltmarsh grass, were observed due to the sudden conversion of a vegetated marsh to mudflat or open water (Stagg et al. 2021). The use of living shorelines that incorporate natural habitats (e.g., oysters, marsh), instead of armored shorelines (e.g., rip rap, sea walls, bulkheads) that cannot adapt to changes in sea level, has been proposed as a potential option for mitigating failing infrastructure and restoring habitat function in response to sea-level change and coastal erosion (Barry et al. 2025).

3.2.9.2 Disease

Physical and chemical factors (e.g., eutrophication and associated low DO) can contribute to stress and lead to disease and/or parasite susceptibility in coastal organisms, because significant stress can affect host resistance. Diseases and parasitic infections in the Gulf are typically restricted to certain geographic areas or are species-specific (e.g., catfish die-off of 1996), tending to exist at low levels in species populations in most cases. Few diseases cause mass mortality (Overstreet and Hawkins 2017).

Harmful algal blooms (HABs) occur when toxin-producing algae grow excessively and can cause mortality in coastal fishes and invertebrates when toxins are ingested via transference across gills or through ingestion. HABs of the toxic dinoflagellate *Karenia brevis*, also known as red

tide, commonly occur within the northern Gulf and are known to cause large fish kills (Anderson et al. 2021). Fish mortality is caused by dehydration, hemolysis, and interference in blood-clotting mechanisms, as well as neurotoxicity. In addition to causing mortality to fish, red tide blooms can also cause mortality to higher trophic levels (e.g., marine birds, sea turtles, marine mammals) through brevetoxin exposure and bioaccumulation in fish and invertebrate prey. Although red tide is common in the eastern Gulf (i.e., off Florida), *K. brevis* blooms also occur in Alabama and Texas (Overstreet and Hawkins 2017; Oh et al. 2023). Dust and associated nutrients blown into the Gulf region from African and occasionally Asian deserts, can also result in small fish kills related to other toxic dinoflagellates, in addition to *K. brevis* (Overstreet and Hawkins 2017).

Brown tide blooms, caused by the microalga *Aureoumbra lagunensis*, also occur in the Gulf coastal waters, primarily within the Laguna Madre, Texas, possibly caused by hypersaline conditions that inhibit grazers and competing algal species. The Laguna Madre was home to what is believed to be the longest continual algal bloom in history, from 1990 to 1997. Though not toxic like red tide, *A. lagunensis* can discolor water and result in shading of seagrass areas (Buskey et al. 2001; Anderson et al. 2021).

The slime mold *Labyrinthula* has been identified as the cause of "wasting disease" in seagrass beds worldwide. The disease spreads by blade-to-blade contact and can have long-lasting effects to seagrass beds. Salinity appears to be a major factor in the level of wasting disease infection observed (Blakesley et al. 2000; Bishop et al. 2017).

Coastal invertebrates, including the habitat-forming Eastern oysters, are also vulnerable to disease. For more information on disease in invertebrates, see **Section 3.5.6.7** Disease (Fish and Invertebrates).

3.2.9.3 Marine Debris, Pollution, and Runoff

Marine debris can come from both ocean- and land-based (e.g., riverine output, runoff) sources. In a study conducted over twelve barrier island sites across the northwestern and north-central Gulf, from Texas to the Florida panhandle, on average, plastics were found to overwhelmingly dominate the type of debris found in both quantity (93 percent) and mass (82 percent). Northwestern sites were found to accumulate ten times more debris per meter of coastline than north-central Gulf sites (Wessel et al. 2019). Similarly, based on the National Marine Debris Monitoring Program, sites west of the Mississippi River accumulate 6 times more marine-based debris than sites east of the River (Ribic et al. 2011). This trend is most likely due to the predominantly onshore winds and currents in the western compared to central Gulf region (Ribic et al. 2011; Wessel et al. 2019). Most plastics originate from plastic pellets (called "nurdles"), which are manufactured on a large scale in the northern Gulf, especially in Texas and Louisiana. These nurdles can be lost at the manufacturing facility and also during transport and storage (Grace et al. 2022).

Debris, such as nurdles and other plastics, can degrade and become microdebris (e.g., microplastics, <5 millimeters; mm [0.2 inches; in] in size), which can be ingested by marine organisms. Negative effects of microdebris ingestion include physical damage (e.g., internal abrasions, gastrointestinal blockages) and exposure to organic pollutants, toxins, or foreign microbes that adhere to the debris surface and lead to decreased growth, reproduction, and survival. Effects are species-specific and life-stage dependent, with a possible trend found for decreasing exposure to microdebris with distance from shore (Lestrade and Hernandez 2023). Industrialized bays along the northern Gulf appear to have higher microplastics levels than the open ocean likely due to the proximity of microplastic sources (e.g., plastic manufacturing facilities) (Grace et al. 2022).

Anthropogenic sources of metals include fossil fuel and waste burning; mining and ore processing; chemical production; and agriculture. Metals from terrestrial sources (e.g., smokestack emission, motor vehicle exhaust, and volatilization of pesticides) are transferred to coastal and estuarine water primarily through runoff and atmospheric deposition. NOAA's Mussel Watch Program monitors coastal waters in the northern Gulf for chemical contaminants and biological indicators of water quality. Based on 2022 results, most metals monitored–including copper, lead, mercury, tin, and zinc–have not displayed any indication of increasing or decreasing trends on a regional scale since 1986. In contrast, cadmium has shown a potential decrease, and arsenic and nickel appear to be increasing, although arsenic levels remain relatively low. Nickel does not appear to undergo biomagnification in the food chain and there are no current U.S. Food and Drug Administration safety levels for nickel in fish and shellfish (Dampier et al. 2022)

In terms of legacy organic contaminants, NOAA's Mussel Watch Program found that organic contaminant compound groups, including butyltins, chlordanes, chlorpyrifos, dichlorodiphenyltrichloroethane (DDT), dieldrins, endosulfans, hexachlorocyclohexane, mirex, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), have been decreasing with one exception, chlorobenzenes in Terrebonne Bay/Lake Barre, Louisiana. Chlorobenzenes are organic halogen compounds used for products like degreasers and biocides, and their prevalence in production has decreased since 1960. Generally, they evaporate rapidly into the air or are broken down by bacteria and do not bioaccumulate in the food chain. The decreasing regional trends in contamination show the effects of long-term monitoring and regulations (Swam et al. 2024).

Coastal water eutrophication can result from organic matter derived from rivers and watershed runoff due to either point sources (e.g., industrial plants, septic systems) or nonpoint discharges (e.g., agriculture). When present, eutrophication can cause mortality to marine organisms through oxygen depletion (i.e., hypoxia), toxin exposure (e.g., HABs), and/or through an individual's susceptibility to predation while ill. The Gulf Dead Zone on the OCS is one of the largest coastal hypoxic zones in the world. It is an area that receives high freshwater discharge from the nutrient-rich Mississippi and Atchafalaya Rivers, stimulating phytoplankton growth and a stratified water column (e.g., stratified temperature and/or salinity). Phytoplankton not incorporated into the food web, and the generated fecal matter, sink to the bottom waters

where anaerobic bacteria decompose the matter, causing oxygen depletion (Overstreet and Hawkins 2017). Additional details on the Gulf Dead Zone are provided in **Section 3.3.1.1**.

3.3 PELAGIC HABITATS AND COMMUNITIES

This section describes the physical and chemical characteristics of pelagic habitats in the Gulf 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 cyclones and freshwater inputs) and in some cases by the presence of anthropogenic and/or OCS 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 stable and less susceptible to large-scale variations (Dickey-Collas et al. 2017).

The pelagic zone is divided into two provinces: neritic and oceanic (**Figure 3-4**). Coastal and estuarine waters are considered part of the neritic province and span from the coast to the continental shelf break (100–200 m; 328–656 ft). The oceanic province begins at the shelf break, continuing out into the open ocean.

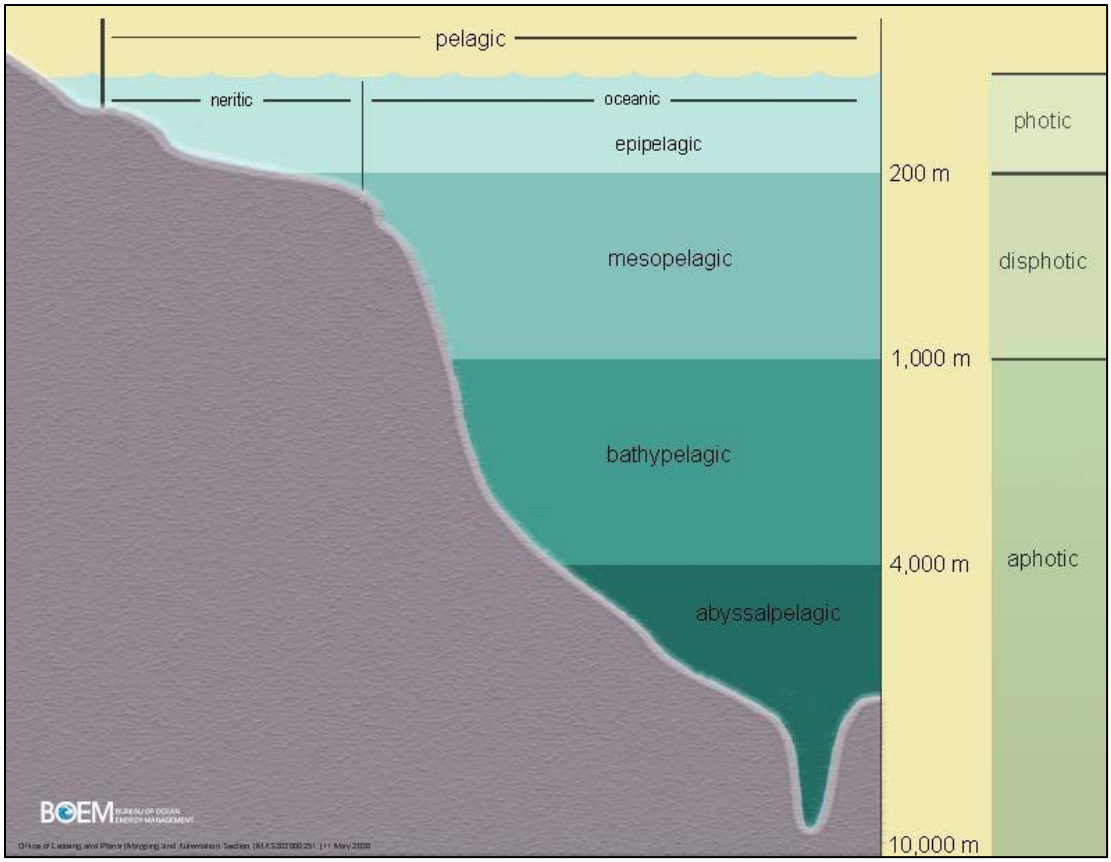


Figure 3-4. Subdivisions of the pelagic zone.
Source: Image adapted from Webb (2021).

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 (0–200 m; 0–656 ft). 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 (see **Section 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 (see **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 ocean's most complex habitats, including coral reefs, seagrass beds, and oyster reefs (see **Section 3.2**). Similarly, see the chapters on fish and invertebrate resources (**Section 3.5**), sea turtles (**Section 3.6**), marine mammals (**Section 3.7**), and birds (**Section 3.8**) for descriptions of the fauna that commonly use these habitats. In addition to sunlight, pelagic habitats and communities in the northern Gulf

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 Gulf pelagic habitats and communities. The Delta's freshwater input into the Gulf 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) increase significantly, directly and indirectly providing food for consumers at all levels of the food chain. In a report from Glaspie et al. (2024a) observing this "Dead Zone", the authors noted freshwater runoff associated with the Mississippi River and other smaller watersheds (e.g., Pearl River) may be directed to the east or west of the Gulf because of the currents or wind, possibly explaining the spread of hypoxic conditions. The spread of hypoxic conditions from Louisiana to Alabama encompasses 6,705 km^2 (2,589 mi^2), from the Chandeleur Islands south of New Orleans to as far as Mobile Bay (Glaspie et al. 2024a). 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 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, which potentially indicates the influence that frontal zones have on the reproductive success of local pelagic species (Govoni et al. 1989; Lohrenz et al. 1990; Dagg and Whitledge 1991). 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 3-5**), with varying impacts to pelagic habitats and associated communities. Hypoxia is generally defined as water with DO concentrations less than 2.8 milligram (mg) O_2/liter (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 support 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, 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. Ou and Xue (2024) demonstrated that DO dynamics and the

evolution of hypoxia are influenced by various physical processes and local biochemistry, with sedimentary oxygen consumption and vertical diffusion identified as key contributors.

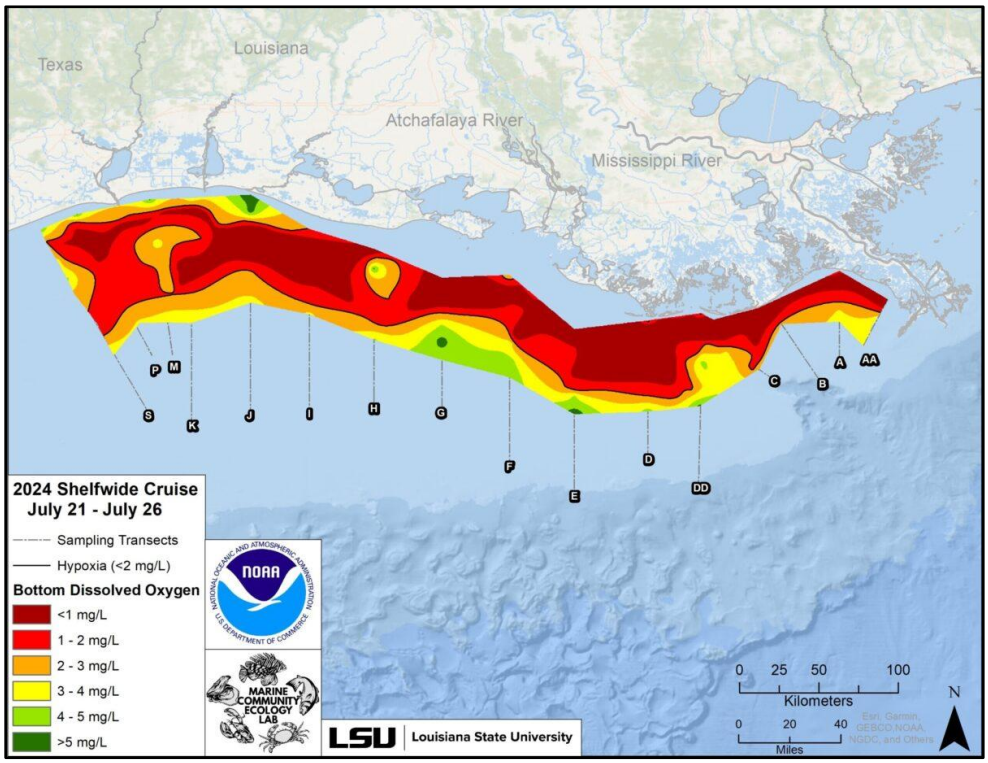


Figure 3-5. Distribution of bottom-water DO concentration for July 21–26, 2024 in the Gulf.
Note: The combined areas less than 2 mg l^{-1} and 1 mg l^{-1} are the darkest colors and outlined by the black line.
Source: Glaspie et al. 2024a.

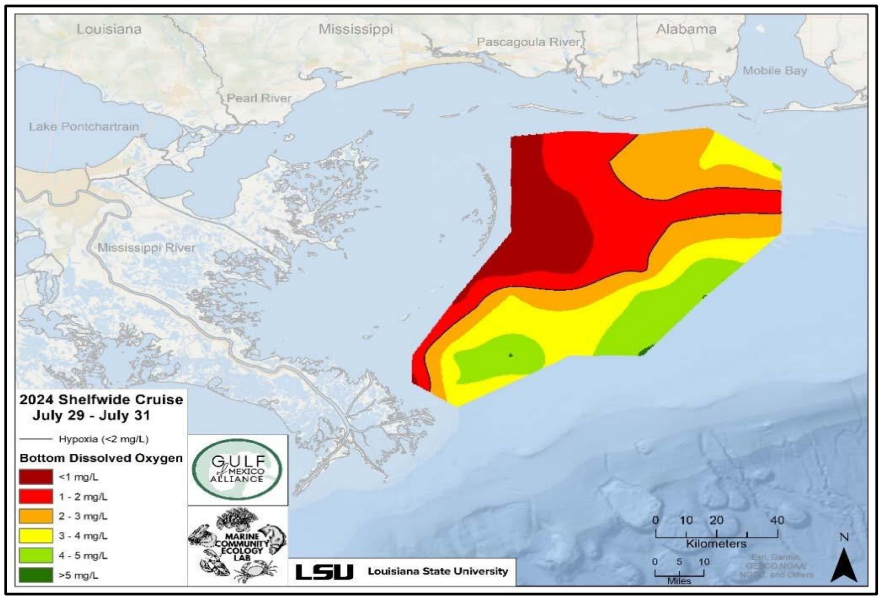


Figure 3-6. Map depicting extension of 2024 hypoxic zone in the northern Gulf, east of the Mississippi River.
Source: Glaspie et al. 2024b.

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 were 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 are 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 natural 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, the commercial shrimp trawling industry is known to alter bottlenose dolphin (Lorenz 2015) and pelagic fish feeding behavior (e.g., sharks, blackfin tuna, and yellowfin tuna). The bycatch thrown overboard from the shrimp trawling industry has become a food source for pelagic communities (Lorenz 2015). Additionally, 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, see **Section 4.3.2**.

Oil- and gas-related infrastructure in the coastal northern Gulf (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 made 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, see **Section 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). Studies have investigated the possible benefit of artificial structures, like standing oil and gas platforms, as refugia from hypoxic conditions in the Gulf (Egerton et al. 2021; McLean et al. 2022; Yu et al. 2023; Fortune et al. 2024).

Fish and invertebrates are also attracted to structural habitats. The large-scale introduction of platforms in the neritic northern Gulf 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 Gulf (Shaw et al. 2002). Moreover, the predominant taxa of post-larval and juvenile fishes collected down current of platforms are represented primarily 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. 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 3-4**). 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 m (ft)	Habitat Zone
Photic	0–200 (0–656)	Epipelagic
Dysphotic	200–1,000 (656–3,280)	Mesopelagic
Aphotic	1,000 (>3,280)	Bathypelagic Abyssopelagic Hadalpelagic

Five habitat zones are determined by depth (**Figure 3-4**). 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 zones (Webb 2021). The epipelagic zone is discussed below, while the mesopelagic, bathypelagic, and abyssopelagic zones are discussed in **Section 3.3.3** Deep-Sea Zones. Sigsbee Deep, located in the west-central Gulf, is the deepest water bottom (3,850 m; 12,631 ft) in the Gulf (Darnell and Defenbaugh 1990). As such, the Gulf has no hadalpelagic waters; therefore, it will not be further discussed. Cold temperatures, which can reach near freezing in the abyssopelagic zone, and 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 Gulf, the temperatures of epipelagic sea surface waters vary seasonally and can rise above 32°C (90°F) 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 use of available nutrients by photosynthetic organisms in neritic waters (Webb 2021). 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 Gulf 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 Gulf causes both upwelling and cross-shelf transport of nutrient-rich Mississippi River Delta waters through entrainment in mesoscale eddies (see **Figure 3-1**) south of the Mississippi outflow, south of the Louisiana-Texas shelf, and in the northwest and northeast corners of the Gulf (Ohlmann et al. 2001; Morey et al. 2003). Phytoplankton present in this zone due to nutrient availability from upwelling, entrainment in mesoscale eddies, or atmospheric deposition are eventually consumed by primary consumers (i.e., zooplankton). The zooplankton (e.g., heterotrophic dinoflagellates, foraminifera, copepods, and larval fish) are then food sources for higher trophic organisms.

Higher trophic-level organisms that occur primarily in oceanic epipelagic waters rarely encounter the coastline or the seafloor. Prey is generally scarce, and most forage over long distances. Higher trophic-level organisms are generally large and highly migratory, and some make 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) and/or an apex predator (i.e., an animal that is at the top of the food chain and has few predators).

Other animals using the epipelagic zone include marine mammals (**Section 3.7**), sea turtles (**Section 3.6**), seabirds (**Section 3.8**), and deep-sea fish (**Section 3.5**). The Gulf epipelagic waters support a diversity of marine mammal species by potentially supplying a large number of ecological niches (Baumgartner et al. 2001) 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 (see **Section 3.6**) (Haney 1986; Carr 1987; Moser and Lee 2012; Witherington et al. 2012). Also, 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 use 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 500 m (1,640 ft) in the Gulf (Teo et al. 2007). Smaller, unidentified tuna species have also been documented in deep-sea habitats (100–600 m, 328–1,969 ft) in the northern Gulf (Benfield and Kupchik 2017). Aside from fish, sperm whales have been recorded with towed hydrophone arrays making dives in excess of 500 m (1,640 ft) (Thode et al. 2002) and have even been observed with remotely-operated vehicles diving on foraging trips as far down as 1,736 m (5,696 ft) in the northern Gulf (Benfield and Kupchik 2017).

3.3.2.2 Plankton

Plankton form the base of the pelagic food chain and consist of phytoplankton and zooplankton that drift with surface currents (i.e., unable to swim against a current). Phytoplankton are single-cell, photosynthetic organisms. Their abundance and growth are influenced by the availability of light and inorganic nutrients. In the Gulf, nitrate is the primary limiting nutrient for phytoplankton, while phosphate becomes the limiting nutrient when nitrate is abundant. Common phytoplankton include diatoms and dinoflagellates (Rowe 2017).

Zooplankton are heterotrophic and can either be holoplankton, which are planktonic (i.e., drift with the currents) their entire lives, or meroplankton, which are only planktonic as larvae and potentially up to their juvenile stage. Copepods are the dominant taxa, and most zooplankton exhibit vertical migration, swimming near the surface at night and descending lower in the water column during the day. Zooplankton contribute to the flow of energy by being an intermediate step in the food chain between plankton and higher trophic-level consumers; in addition, their molted exoskeletons and fecal particles contribute to the detrital food web for deepwater benthos (Rowe 2017). Gulf zooplankton are typically most abundant nearshore and less abundant in deep water off the shelf and have a high fecundity and relatively short generation times (Daly et al. 2021).

An important component of zooplankton is ichthyoplankton, consisting of fish eggs and larvae. They are predators of the lower trophic planktonic organisms (e.g., dinoflagellates and copepods) and important prey for larger marine organisms. Ichthyoplankton are predominantly located within the upper water column, and their distribution is influenced by spawning locations and oceanographic processes (e.g., currents and temperature) (Rowe 2017).

Ichthyoplankton natural mortality is high, which can be attributed to egg quality, starvation, disease, predation, and environmental fluctuations (Dahlberg 1979).

3.3.2.3 Sargassum

Due to the depths of the oceanic province and its distance from shore, there is a lack of natural structural habitats. However, in the Gulf, *Sargassum* provides a unique floating habitat that is ubiquitous throughout the ocean epipelagic zone. *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 in length and in diameter, providing a highly dynamic structural habitat for numerous species. *Sargassum* provides numerous life functions for a variety of species and can act as a method of dispersal for some inhabitants, providing them with substratum, predator protection, and concentration of food within the pelagic zone (Gulf of Mexico Fishery Management Council 2004). *Sargassum* provides an essential habitat for several purposes and for numerous species (**Table 3-2**). For example, flying fish, 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 foraging 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).

This dynamic habitat has been observed originating from two different locations—the northwestern Gulf or northwestern Caribbean Sea—with each source using specific transport pathways (Zhang et al. 2024). *Sargassum* from the northwestern Gulf has been documented traveling east using Gulf currents and eddies, eventually entering the Sargasso Sea. The transport pathway for *Sargassum* entering the Gulf from the northwestern Caribbean Sea involves physical transport in three directions. Northward and eastward transports are driven by the Loop Current system, while westward transport is influenced by several factors: the westward extension of the Loop Current, the movement of ocean eddies, wind-driven currents, and westward currents in the northern and central Gulf (Zhang et al. 2024). Johnson et al. (2020) observed the transport of *Sargassum* from the Sargasso Sea to the Tropical Atlantic due to a North Atlantic Oscillation anomaly event. *Sargassum* has persisted in this area since 2011, despite being thought an anomaly, resulting in the "Great Atlantic Sargassum Belt".

Gower and King (2011) found a seasonal pattern with satellite imagery in which *Sargassum* originates in the northwestern Gulf in the spring of each year, forming long, narrow meandering slicks. The *Sargassum* is then advected out of the Gulf into the Atlantic Ocean east of Cape Hatteras, North Carolina by July and finally moves into the northwest Bahamas by February of the following year. Once in the Atlantic, mats accumulate in the North Atlantic subtropical gyre and are 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 Gulf organisms and *Sargassum*-associated communities in the Atlantic.

Since 2011, there has been an observed increase in frequency and magnitude of *Sargassum* blooms in the tropical Atlantic and Caribbean region, which are key origin points for *Sargassum* in the Gulf (Fidai 2024). Fidai (2024) mentions the negative impacts that may occur in relation to mass surges and increase of abundance of *Sargassum*. Large *Sargassum* blooms in the Atlantic can potentially disrupt local socioeconomic or ecosystem functions, or impact human health, with the range to affect one or several countries. The large size of blooms has capability of restricting sunlight which affects benthic communities and blocking sea turtles looking to nest due to large *Sargassum* beach landings (McGlathery 2001; Maurer et al. 2015).

Table 3-2. *Sargassum* mats: ecosystem functions and associated animals

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

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

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

Deep-sea pelagic habitat zones are here defined as those deeper than 200 m (656 ft). These zones occupy an enormous biovolume of space in which organisms can live (>billion/km^3 [mi^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 compared to 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 Gulf's total volume and contains enormous taxonomical and functional diversity (Sutton et al. 2020). It is one of the four "hyper-diverse" midwater ecosystems in the World Ocean due to the Gulf's unique geography, the combination of tropical waters and winter cooling, and the presence of a large river system (Sutton et al. 2017; Sutton et al. 2020). Much of what is known about the Gulf's deep-sea pelagic ecosystems has come from the collection or observations of meso- and bathypelagic organisms (see **Section 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 percent 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 3-4**). 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, see **Section 3.4**. Other deep-sea animals have developed combinations of physical and behavioral adaptations 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 Douglas 1995; Haddock et al. 2010).

Temperature and pressure are also important physical influences on the biology of deep-sea inhabitants. Temperature decreases with depth, while 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 10 m (33 ft) the water pressure increases by 1 atmosphere (6.6 kg/cm^2; 14.6 pounds [lbs]/in^2), 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). Consequently, deep-sea pelagic organisms are particularly sensitive to environmental disturbances and overexploitation.

3.3.3.1.1 Diel Vertical Migration

Diel vertical migration (DVM) is a behavior exhibited by organisms to reduce light-dependent mortality risk and potentially access to higher abundances of prey (Parra et al. 2019). Nocturnal and reverse DVM are two predominantly observed patterns exhibited by organisms. Nocturnal DVM is observed as the upward movement of organisms towards shallower depths at dusk and downward movement deeper into the water column at dawn (Hays 2003). The energy demands of deep-sea communities cannot be fully met by relying solely on particulate influx, such as marine snow and megafauna falls (e.g., whale falls) alone (Bianchi et al. 2013). As a result, nocturnal DVM is a key behavioral adaptation for meso- and bathypelagic organisms. This behavior helps organisms cope with the limited food availability in deep-sea habitats. DVM is 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 make them susceptible to predation by some epipelagic predators (e.g., marine mammals, large epipelagic fish, and sea birds). Reverse DVM is another observed behavior in marine organisms. At night, these organisms disperse throughout the water column. During the day, they either retreat to the very bottom (nocturnal) or move to the surface (reverse), depending on the species (Parra et al. 2019). DVM occurs in a wide range of marine and freshwater environments and in different taxonomic groups. This behavior can offer ecological advantages, such as predator evasion and increased feeding opportunities.

3.3.3.2 Deepwater Petroleum Structures

Over the past decade, the Gulf has experienced an increased emphasis on deepwater oil and gas exploration in water depths greater than 300 m (984 ft). As such, the presence of deepwater petroleum structures has become more commonplace in the Gulf. These structures can include tension-leg platforms, compliant towers, spars, drillships, floating production storage and offload platforms, and other equipment. The structures can indirectly act as fish aggregating devices, which are known 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 Gulf 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 Gulf, and they are widely dispersed. As of March 29, 2026, 59 deepwater petroleum structures had been installed in water depths greater than 305 m (1,000 ft) (BSEE

2026). For more information on the possible effects that offshore habitat modification has on pelagic habitats, see **Section 4.3**.

3.3.4 Environmental and Anthropogenic Stressors

3.3.4.1 Climate-Related Factors

Rising sea temperatures may result in distribution shifts and alter the timing of phytoplankton blooms. Warmer ocean temperatures, changes in nutrient availability, and altered circulation patterns, can lead to earlier, larger, or more frequent blooms. In the northern Gulf system, the changing dominant current system in the summer can significantly alter the distribution of shelf nutrients and types of nutrient limitations (Ou and Xue 2024). These changes result in altering the growth of phytoplankton and summer hypoxia development. Blooms initially increase oxygen levels, yet their subsequent collapse depletes oxygen in the water resulting in hypoxic dead zones that can have cascading effects on the ecosystem.

3.3.4.2 Marine Debris, Pollution, and Runoff

Marine debris in the Gulf can be attributed to land- and marine-based sources. Land-based debris may enter the Gulf through rivers, stormwater runoff, and direct disposal into the sea. Common land-based contributors include plastic waste, synthetic fibers and materials, and other consumer goods that can be carried into the ocean. For more information on land-based contributors and point source pollution, see **Section 3.2.9.3**.

Marine-based sources can be attributed to derelict fishing gear, abandoned vessels, and various debris from shipping activities. Marine debris and microplastics are of increasing concern in pelagic waters. These pollutants come from a variety of sources; Mississippi River discharge is a major input into the Gulf (Lecke-Mitchell and Mullin 1997; Wessel et al. 2016; Di Mauro et al. 2017; Kane et al. 2020). Once microplastics and marine debris are in pelagic habitats, the distribution of marine debris in the Gulf is influenced by various environmental and oceanographic factors. Ocean currents, such as the Loop Current and coastal currents, have a significant role in the accumulation of marine debris in ecosystems, beaches, and estuarine habitats. Convergence zones can act as additional accumulation points in open water habitats and in *Sargassum* mats, which often aggregate along the surface of convergence features (Lestrade and Hernandez 2023). It is generally understood that the buoyancy of debris determines what depth they can accumulate, with plastics observed on the surface and lower density debris to the sea floor or throughout the water column. Palino and Wessel (2023) conducted a study on the abundance of microplastics in the Gulf, finding that most samples were distributed from heavily populated coastal areas and transported along currents, as indicated by the spatial distribution of the samples. Microplastics were present at every sample site, with 94.8 percent of the samples taken containing plastic particles. The study also observed higher concentrations of microplastics at the surface compared to the rest of the water column, suggesting that plastic morphology varies with depth and influences vertical distribution (Palino and Wessel 2023).

3.4 Benthic Habitats and Communities

Benthic fauna inhabit the seafloor throughout the Gulf at all water depths (**Figure 3-7**). 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[8] and meiofauna[9]. Microbial communities and, within the photic zone, microalgae, macroalgae, and rooted vegetation also inhabit the seafloor. All benthic communities are trophically linked[10] and contribute significantly to global carbon cycling.

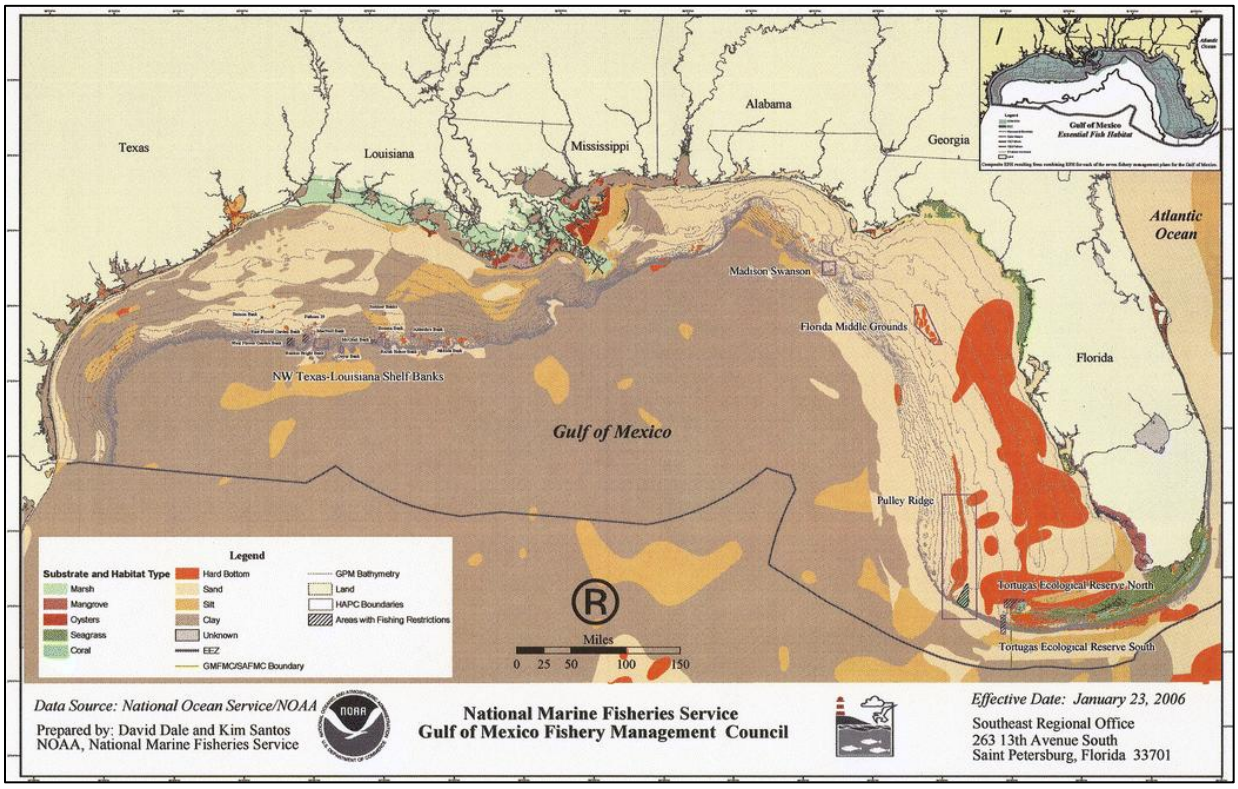


Figure 3-7. Benthic habitat in the Gulf.

Source: Benthic habitat distribution in the Gulf of Mexico (Rowe 2017 modified from Gulf of Mexico Fishery Management Council 2004; 2005).

Credit: This figure is licensed under the terms of the Creative Commons Attribution-NonCommercial 2.5 International License.

Documented benthic ecosystems in the Gulf discussed in this section include muddy, soft bottom; 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, including oyster reefs, are discussed in **Section 3.2**.

[8] Organisms greater than 1 millimeter (mm) (0.04 in) in size.

[9] Organisms between 45 micrometer (µm) and 1 mm (0.00004 and 0.04 in) in size.

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

Connectivity with areas adjacent to and within the Gulf depends on pelagic larval transport by surface currents. Most Gulf 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 Gulf region that 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, use, and removal, bottom fishing, artificial reef installation, commercial shipping (e.g., ballast water discharge and shipwrecks), and dredging.

3.4.1 Shallow Water (<300 m; 984 ft)

3.4.1.1 Shallow Coral Reefs

The Gulf shallow-water reefs occupy roughly 2,640 km^2 (1,019 mi^2) of the entire Gulf (<0.2 percent of the area), with the largest distribution along the Florida coast (Tunnell Jr. et al. 2007). The Gulf 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 113–185 km [70–115 mi] 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 Gulf that are protected under the ESA include those listed in **Appendix A**. Distribution of those listed species within the U.S. Exclusive Economic Zone (EEZ) 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 (71 FR 26852). 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 exist today (NOAA 2025; NOAA Fisheries 2025n).

On August 9, 2023, critical habitat was designated for five species of corals (Caribbean boulder star coral, lobed star coral, mountainous star coral, pillar coral, and rough cactus coral) in Florida, Puerto Rico, the U.S. Virgin Islands, Navassa Island, and the Flower Garden Banks

National Marine Sanctuary (88 FR 54026). The boulder star coral is native to the Caribbean, Gulf, 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 2025a). 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 2025i). The mountainous star coral is also native to the Caribbean and the Gulf (NOAA Fisheries 2025k).

All seven ESA-listed shallow-water Gulf corals are threatened by ocean warming, ocean acidification, unsustainable fisheries, and pollution (NOAA 2025; NOAA Fisheries 2025a; 2025i; 2025k; 2025n). Shallow-water Gulf coral reefs are at risk of decline due to habitat destruction, increased turbidity, and sedimentation (Schutte et al. 2010; Jones et al. 2015). Designated critical habitat for ESA-listed corals can be seen in **Figure 3-8**.

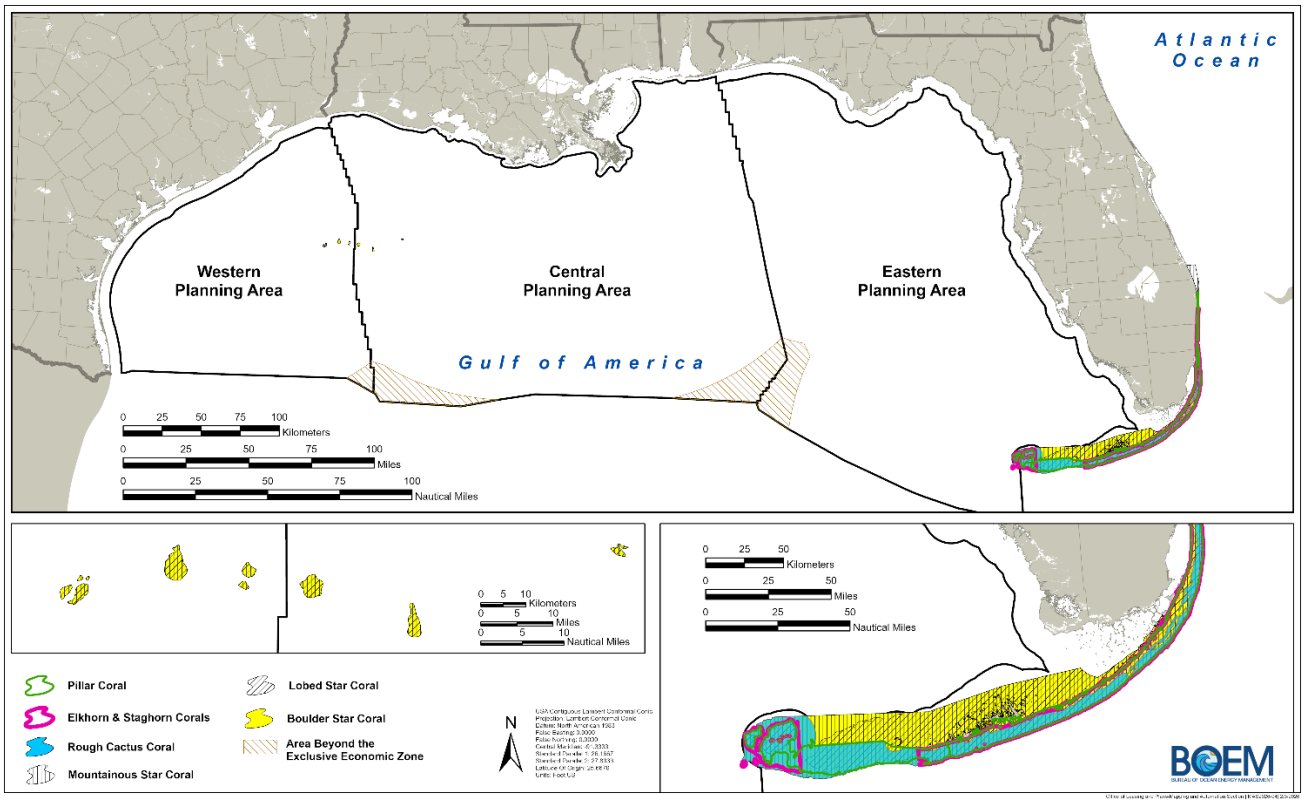


Figure 3-8. Designated critical habitat for corals in the Gulf.
Source: BOEM - 2026. Map was created by BOEM geographers. The source for the Gulf coral data is NOAA/NMFS. The source for the planning areas and other boundaries is BOEM's Technical Information Management System.

3.4.1.2 Soft-Bottom Communities

In the Gulf, 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 Gulf basin is associated with mixing due to winter cold fronts, fluvial outflow, and coastal primary production. In the Gulf, 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). For a discussion of fish and invertebrate biomass in the Gulf, see **Chapter 3.5**.

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 Gulf include polychaete worms, pericaridean and decapod crustaceans, echinoderms, mollusks, nematodes, and hydroids (Briones 2004; Rowe 2017). Species richness is generally lower compared to coastal ecological zones.

Sand shoals may represent “hotspots” of biodiversity in primarily soft-bottom regions of the Gulf and may provide refuge for benthic organisms during periods of hypoxic conditions (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 Gulf sand shoals (Grippo et al. 2009). Macrofaunal communities vary across shoals, with sand percentage being the most influential environmental parameter (Dubois et al. 2009; Gelpi Jr. 2012). Diversity and abundance increase as sediment grain size decreases and bottom-water DO increases. 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 Jr. 2012).

The Gulf 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 DO concentrations lower than 2 mg/L. In 2024, this dead zone measured ~17,365 km^2 (6,705 mi^2), the twelfth largest on record. The five-year average size of the hypoxic zone is 6,967 km^2 (4,298 mi^2). (NOAA 2024). 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 Gulf, the persistence of the hypoxic zone into 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. 2002a).

3.4.1.3 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 Gulf. 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" (Cummins Jr. 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 (Szedlmayer and Lee 2004; Fraser and Sedberry 2008; Gallaway et al. 2009; Nash et al. 2013; Johnston et al. 2015).

3.4.1.4 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 Gulf 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 (Bright et al. 1976; Rezak and Bright 1981; Berryhill Jr. 1987). There are 38 defined topographic features with special protection from offshore commercial activities in the Gulf: 22 in the WPA and 16 in the CPA. **Figure 3-9** illustrates the OCS lease blocks that contain defined topographic features in the Gulf. 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.

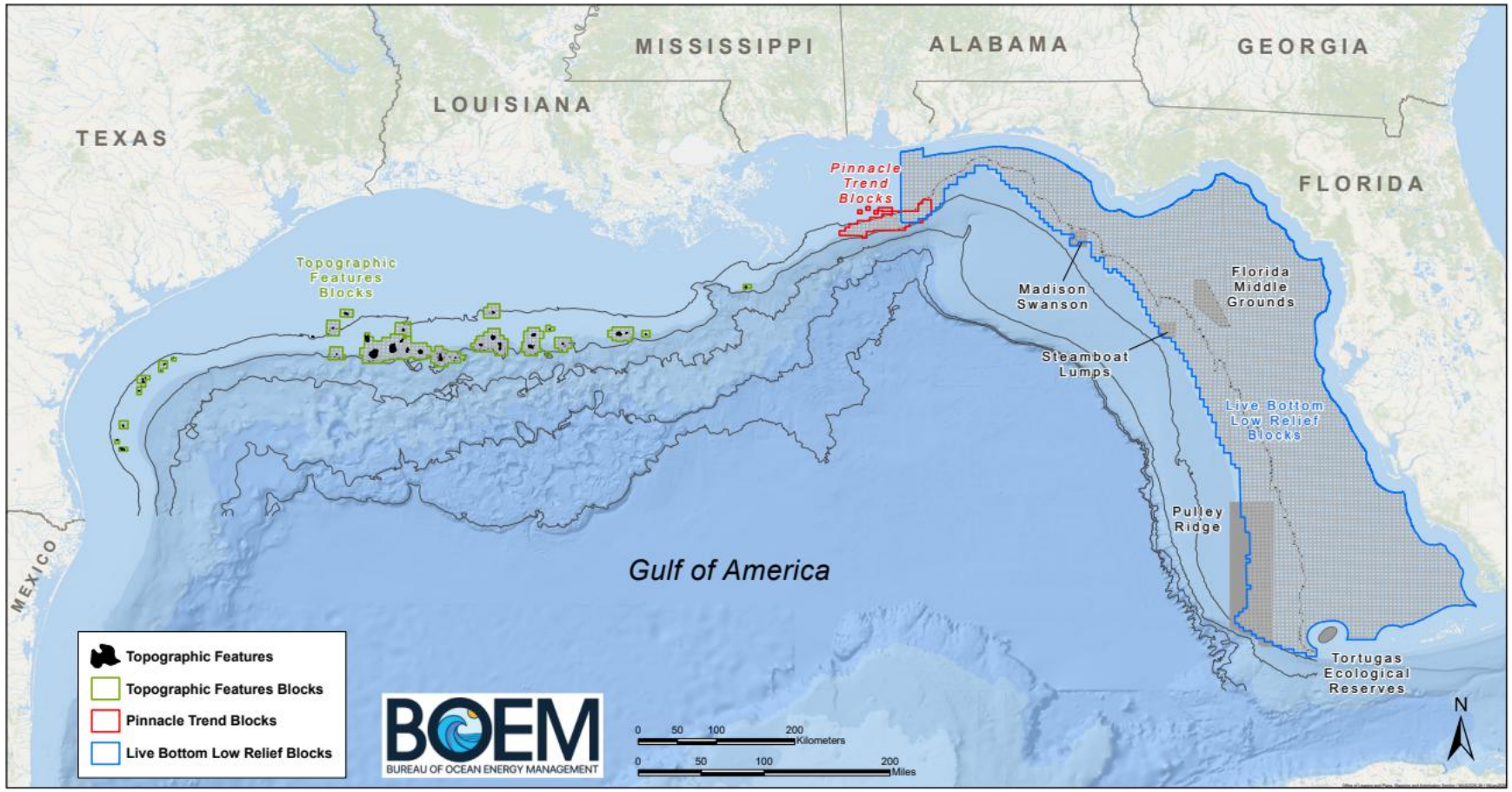


Figure 3-9. Gulf OCS blocks that contain defined topographic features.

Source: BOEM - 2026. Map was created by BOEM geographers using a publicly available Esri Topographic Basemap. The source for Topographic features, feature blocks, Pinnacle Trend Blocks, and Live Bottom Low Relief Blocks is BOEM's Technical Information Management System.

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-regulated activity areas.

Figure 3-10 delineates 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 Gulf: shelf-edge banks; midshelf banks; and South Texas banks.

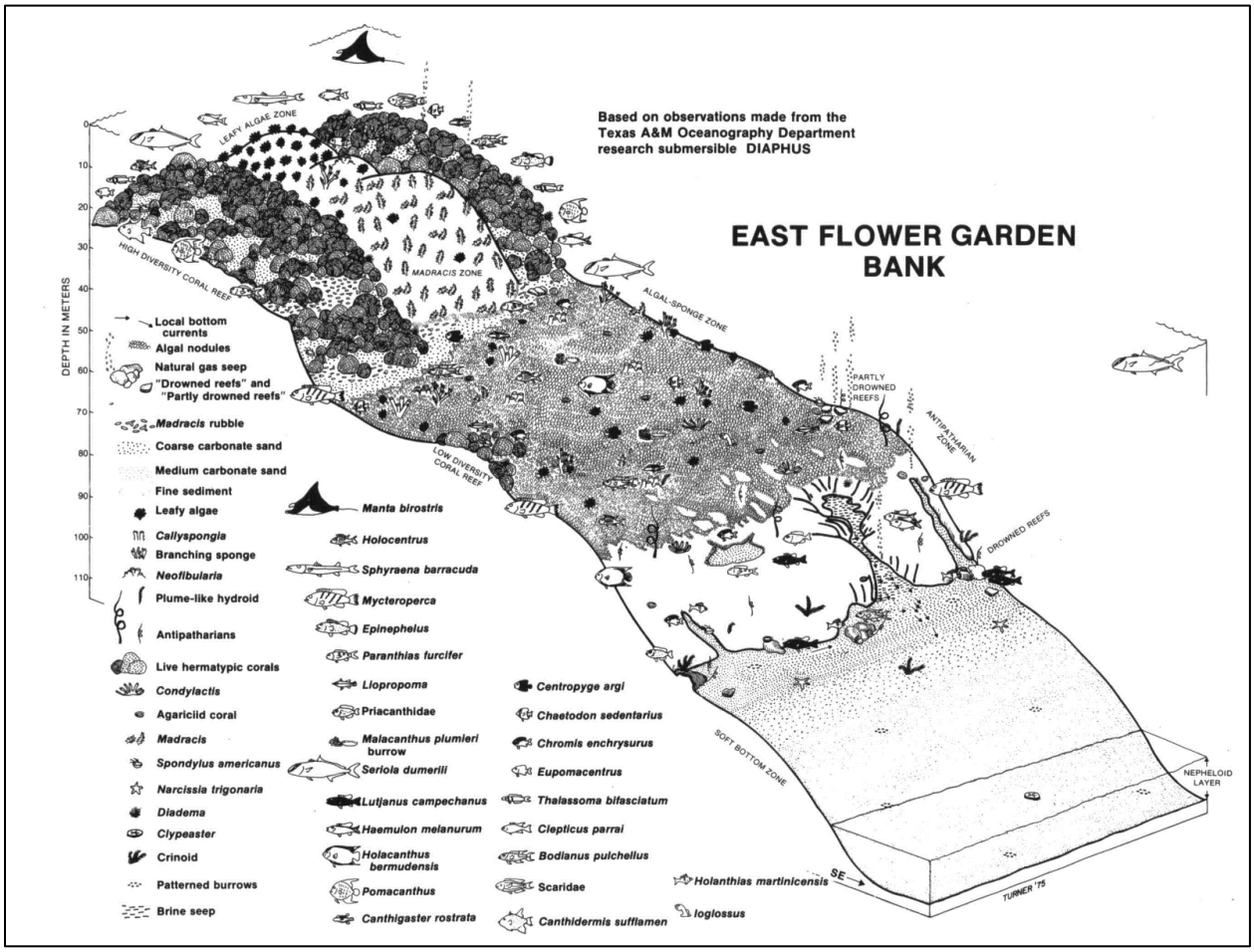


Figure 3-10. Ecological representation of common features on Gulf banks and reefs.
From: Bright et al. 1985.

3.4.1.4.1 Shelf-edge Banks (Including the Flower Garden Banks National Marine Sanctuary)

Shelf-edge banks are located between 80 and 300 m (262 and 984 ft) (**Figure 3-11**) (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 community structure on shelf-edge banks depends 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 Gulf induce oxygen and nutrient enrichment, and cross-shelf water exchange with deep water regulating temperature, salinity, and larval dispersal within and between banks (Lugo-Fernández 1998). The annual reproductive period coincides with the summer water temperature maximum in August or September (Hagman et al. 1998). For a discussion of the Gulf Large Marine Ecosystem, see **Chapter 2**.

The best known and most studied of the shelf-edge banks are located within the Flower Garden Banks National Marine Sanctuary (FGBNMS). The FGBNMS was designated in 1992 by NOAA (15 CFR 922.210). At the time it was designated, the Sanctuary consisted of only East Flower Garden Bank (EFGB) and West Flower Garden Bank (WFGB). In 1996, the midshelf bank, Stetson Bank was added to the Sanctuary. The Sanctuary was expanded in 2021 to include an additional 14 reefs and banks, increasing the total area of the Sanctuary from 145 to 414.4 km (90 to 257 mi) (Johnston et al. 2021). The banks added include Horseshoe, MacNeil, Rankin, 28 Fathom, Bright, Geyer, Elvers, McGrail, Bouma, Sonnier, Rezak, Sidner, Parker, and Alderdice Banks. EFGB and WFGB have been monitored annually since 1989 and Stetson Bank since 1993.

Because global coral reef systems are in decline, the northwest Gulf 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). Below the coral cap, gorgonians and black corals dominate the benthic community. Recent research suggests that the FGBNMS could serve as nursery habitat for one or more Mobulid (ray) species (Stewart et al. 2018). Sea turtles, marine birds, and marine mammals also make regular use of the sanctuary. For a complete species list, see the Flower Gardens Banks NMS Species List.

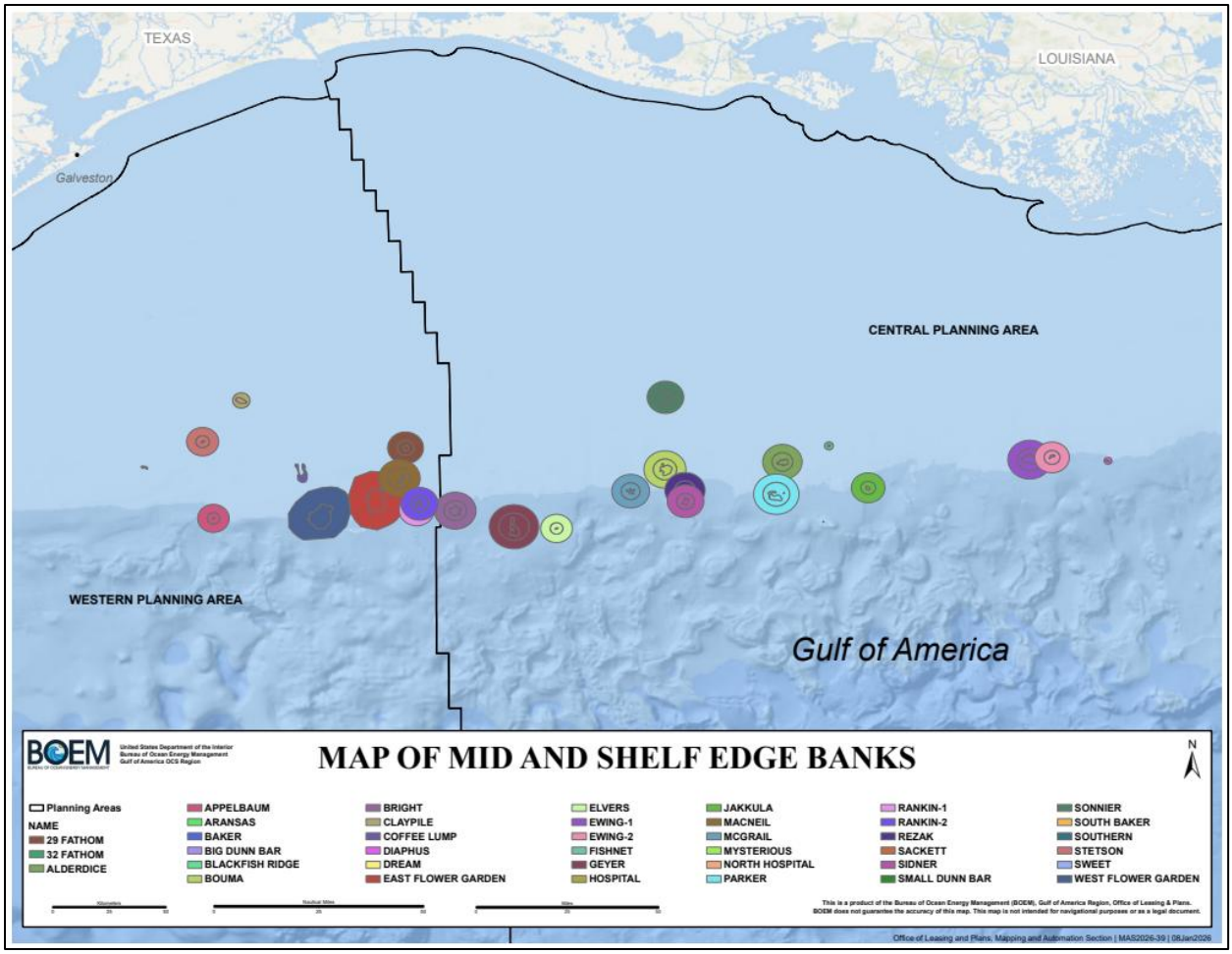


Figure 3-11. Shelf-edge and midshelf banks in the north and northwestern Gulf.
Source: BOEM - 2026. Map was created by BOEM geographers using a publicly available Esri World Ocean Basemap. The source of the Planning Areas and Topographic zones is BOEM's Technical Information Management System.

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 are 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 FGBNMS 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, 17 m (56 ft) below the sea surface. The bank is dominated by sponges, algae, and fire coral, with outcroppings of Ten-Ray Star Coral and hermatypic corals (Hickerson et al. 2012). Since monitoring began at Stetson Bank, the benthic community has transitioned from a *Millepora*-Sponge dominant community to an algal-sponge community (Nuttall et al. 2020).

3.4.1.4.2 South Texas Banks

The South Texas banks are primarily drowned Pleistocene coralgal reefs (**Figure 3-12**) (Berryhill Jr. et al. 1976; Bright et al. 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 and 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 Mollusca are the most common phyla (Nash et al. 2013).

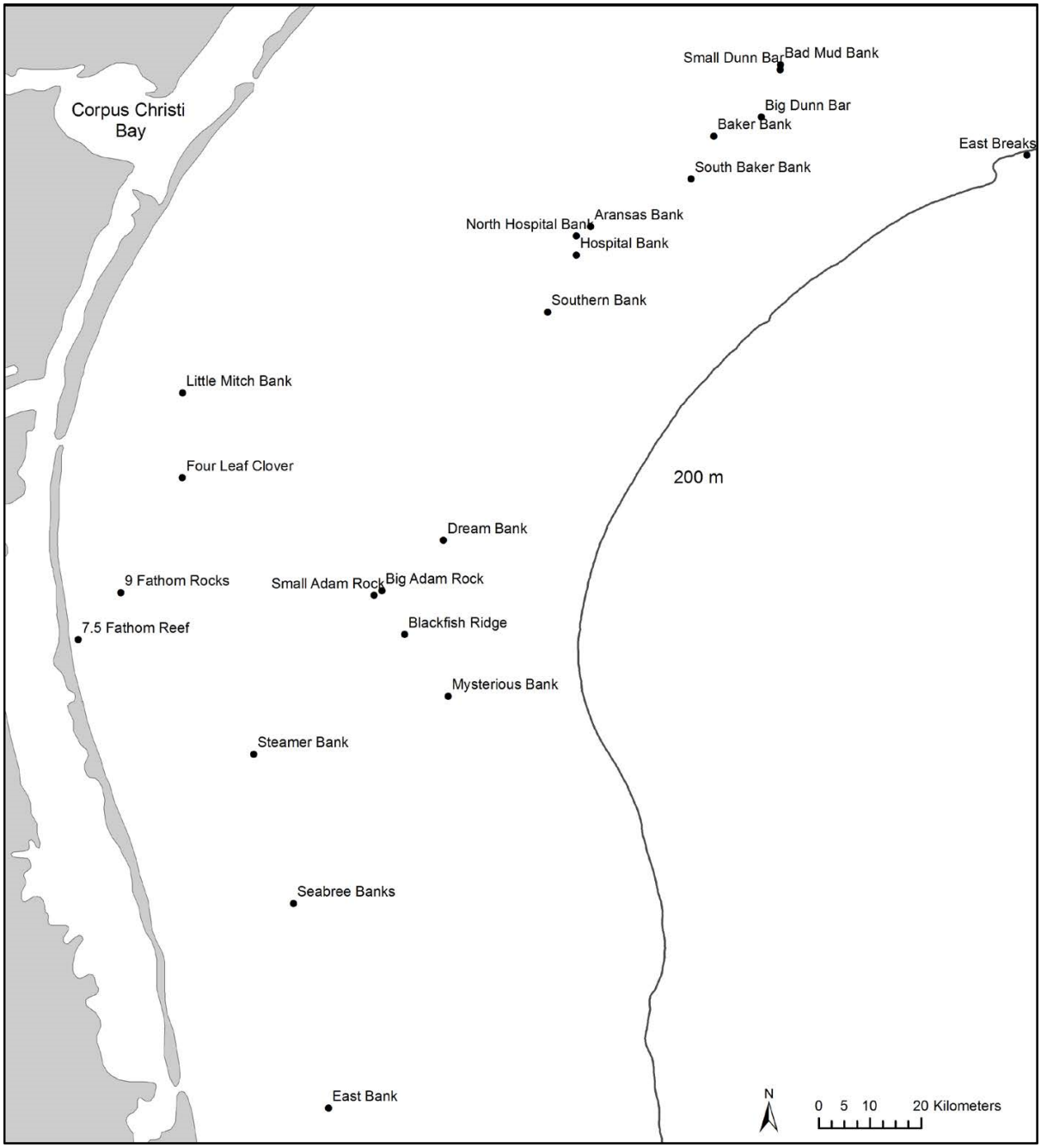


Figure 3-12. South Texas banks.
From: Nash et al. 2013.

3.4.1.4.3 Pinnacles Trend

The Pinnacles 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, Pinnacles Trend sites are dominated by the octocorals *Swiftia* sp., *Thesia nivea*, and *Hypnogorgia* sp. (Boland et al. 2017).

The Pinnacles Trend is afforded special avoidance protection by BOEM with regard to OCS activities.

One well-studied Pinnacles 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). The 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 Sun Cup Coral, which is the dominant species. Several species of soft corals (*Antipathes* spp., *Wire Coral*, 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 Pinnacles 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 Gulf 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).

3.4.1.5 Eastern Gulf Coral Reef Systems

3.4.1.5.1 Florida Middle Ground

Hermatypic coral reefs form from the midshelf 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 changes, and physical oceanographic processes (Hine et al. 2008).

The flora and fauna of the Florida Middle Ground are eurythermic and are composed 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 (Lee et al. 2002; Hine et al. 2008). The five most abundant fish species are purple reef fish, yellowtail reef fish, slippery dick, striped parrot fish, and cocoa damselfish (Coleman et al. 2005).

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]) on 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.

In the southeast corner of the northern Gulf 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 define the Florida Keys: Dry Tortugas; Tortugas Bank; and Riley's Hump. The Dry Tortugas supports sandy cays and shallow coral reefs.

3.4.1.5.2 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 Gulf 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 (1,805 ft) (Newton et al. 1987).

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 FGBNMS 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 in the FGBNMS. 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.

Trends in seawater temperature from 1990 to 2019 in EFGB and WFGB indicate that ocean temperatures at FGBNMS have been rising over the past three decades (Johnston et al. 2021). The mean sea surface salinity fluctuated considerably at both banks in 2019. Salinity data collected at both banks slightly varied. However, the salinity measurements recorded at depth

were within the acceptable limits for coral reefs in the western Atlantic (Johnston et al. 2021). A probable source of low-salinity water within these banks is a nearshore river-seawater mix from the Mississippi and Atchafalaya Rivers (Zimmer et al. 2010).

Throughout 2023, corals in Stetson Bank were exposed to prolonged high temperatures in July and August, possibly contributing to the sporadic occurrences of bleaching accounting for 16.4 to 7.6 percent of corals exhibiting signs of bleaching (O'Connell et al. 2024). Corals observed in the FGBNMS have historically exhibited low incidence of coral disease and bleaching, but long-term monitoring of the EFGB and WFGB has identified disease-like lesions on seven coral species (Johnston et al. 2023; Johnston et al. 2024). This monitoring report observed coral bleaching/paling to be less than 2 percent in 2022, however trends of increasing seawater temperature from 1990 and 2022, suggest possible bleaching events in the future. Genetic evidence from two Endangered coral species (*Orbicella* spp.) at EFGB 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).

3.4.2 Deep Water (>300 m [984 ft])

3.4.2.1 Soft-Bottom Communities

The deep sea is the largest ecosystem on Earth, including within the Gulf. When compared to habitats at higher latitudes or those in upwelling areas, it is typically oligotrophic. The variety of different habitats and temporal variations in the deep sea, including within the Gulf's deep-sea basin, contribute to its biodiversity (Ingels et al. 2016).

Soft-bottom communities are composed of several size classes defined by required sampling regimes: microbiota (<1 micrometer [µm]; 0.00004 in [bacteria and archaea to 40 µm; 0.0016 in [protists]); meiofauna (>40 µm;0.0016 in to 500 µm; 0.02 in); macrofauna (250 µm; 0.01 in to 500 µm; 0.02 in); megafauna (>1 cm; 0.4 in); and demersal fishes. For a discussion of size-class biomass and community structure, see Rowe (2017). 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 Gulf 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 (sea stars), 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, *Midgardia xandaros* (no common name), is the most common megafauna (Downey 1972).
- 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 [~6,562 ft]), and diversity in community composition is likely related to productivity, competition, and predation relative to depth (Rex 1981). Though the majority of corals in the Gulf 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 II 2009).

3.4.2.2 Hard Bottom Coral Communities

Hard substrate is found throughout the deep waters of the Gulf and is made up of either exposed bedrock or relict authigenic carbonate coral reef (Brooks et al. 2016). Both hard- and soft-bodied corals colonize deepwater substrate. 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).

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[11]; 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, 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 of smooth black coral, a black coral species, 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 zigzag coral, a branching stony coral species, 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; Sulak et al. 2007; Cordes et al. 2008; Fraser and Sedberry 2008; Hourigan 2014; NOAA 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 Gulf and the West Florida Slope at depths of 250–2,500 m (820–8,202 ft). The black coral *Leiopathes* spp. appears broadly distributed across both regions. Lophelia is found primarily on the upper slope but has been reported as deep as 3,000 m (9,843 ft).

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

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, sulfide, hydrogen, and iron II are expelled forming hydrocarbon or gas plumes. In the Gulf, hydrocarbon seeps, the majority of which are gas prone, occur along the continental 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 Gulf at the base of the Florida Escarpment in 1983 (Paull et al. 1984). Hydrocarbon seep ecosystems are composed of mosaic[12] 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 Gulf 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 Gulf seep communities tend to be large, up to several hundred meters across (MacDonald 1992). Over 330 chemosynthetic communities are confirmed in the Gulf 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 amounts of organic matter (MacDonald 2002). These mats are composed primarily of orange- or white-pigmented *Beggiatoa* spp., which function 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, sulfur compounds, or both—in the Gulf: vestimentiferan

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

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 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[13] use of sulfides. Aggregations of vesicomyid clams have been described on the Louisiana Slope (Kennicutt II et al. 1985; Rosman et al. 1987). 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).

[13] 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.

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).

Chemosynthetic invertebrates also are found in association with shipwrecks in the Gulf. Pre-20th century, the most commercially important bulk commodities shipped from the Gulf 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 three early 19th-century Monterrey Shipwrecks in the Keathley Canyon area, living chemosynthetic tube worms were found growing within the woody pulp of the hull and the remains of the cargo. And, in 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.

3.4.3 Environmental and Anthropogenic Stressors

3.4.3.1 Fisheries Interactions

Benthic ecosystems in the Gulf are home to a variety of commercially and recreationally important species that inhabit the seafloor. Species like shrimp, crabs, and various marine fish species rely on the diverse habitats within the benthic zone, including coral reefs and soft-bottom areas. Fishing practices, particularly bottom trawling and dredging, can significantly impact benthic communities by disturbing the seafloor. A common major impact of fishing on benthic habitats is the loss of habitat complexity, caused by the alteration or removal of geological and biogenic structures (Grabowski et al. 2014). These practices may cause long-term ecosystem degradation, reduce habitat complexity, and negatively affect the health of benthic environments.

Fishing activities have a range of effects on marine habitats, depending on factors such as the spatial extent of fishing, the level of fishing effort, and the type of gear used. Mobile fishing gear (e.g., trawl nets) has raised concerns due to its large-scale impact on fishing grounds, its ability to modify substrates, disturb benthic communities, and remove nontarget species. As environmental and fishing pressures have increased, the development of new gear and navigation aids has enabled access to previously unexplored regions of the OCS, slope, submarine canyons, and seamounts. These areas have been subjected to the impacts of bottom trawling and dredging.

The extent of the effects in benthic habitats depends on several factors, including the configuration of the gear, towing speed, water depth, and the type of substrate being disturbed

(National Research Council 2002). The direct impacts of trawling and dredging include the loss of erect and sessile epifauna, the smoothing of sedimentary bedforms, a reduction in bottom roughness, and the removal of taxa that provide structural habitat. Grabowski et al. (2014) conducted a comprehensive evaluation of fishing gear on benthic habitats and found that benthic substrate habitats were most vulnerable to impacts from hydraulic dredging and slightly less vulnerable to those from trawling and scallop dredging. Additionally, it was found in this study that benthic habitats were least vulnerable to fixed fishing gears. Trawl gear can crush, bury, or expose marine flora and fauna, leading to a reduction of structural diversity (Auster and Langton 1999). Additionally, fishing gear that disturbs the sediment surface can alter sediment grain size, suspend sediments, and influence sediment transport processes (Kaiser et al. 2003).

The alteration of sediment on the seafloor has a variety of effects including releasing nutrients held in the sediment; exposure of anoxic layers; release of contaminants; increasing biological oxygen demand; and smothering of feeding and respiratory organs (Barnette 2001; Kaiser et al. 2003). Bottom trawling and dredging can also resuspend and bury biologically recyclable organic material, disrupting nutrient flow within the food web (Mayer et al. 1991). Disturbance in shallow waters, including the resuspension caused by benthic disturbing fishing gear, can affect nutrient cycling and potentially lead to shifts in the abundance and type of macroalgae (Barnette 2001).

The recovery rates of benthic habitats depend on factors such as the type and extent of habitat alteration, the frequency of disturbances compared to natural changes, habitat characteristics, and the life history traits of the species involved. Recovery times can vary based on the intensity and frequency of the disturbance, the spatial scale of the affected area, and the physical characteristics of the habitat, including sediment type and hydrodynamics. A meta-analysis by Collie et al. (2000) found that recovery in biogenic (structurally complex) habitats is likely to have the longest recovery time because of the permanence of the disturbance. In contrast, due to their high recovery rate, mobile sand sediment communities can withstand 2–3 incidents of physical disturbances per year without significant changes. For some benthic habitats, physical disturbances from bottom-disturbing fishing gear can have long-lasting effects. Areas subjected to more frequent trawling and dredging can exceed a threshold above which a disturbance can result in observable, long-term ecological effects resulting in longer recovery times.

3.5 Fishes and Invertebrates

This section describes the fish and invertebrate communities present throughout the Gulf. Additional details are provided for species of ecological and economical (commercial and recreational) significance. For the purposes of this document, these resources are divided into coastal and oceanic waters with subcategories used to distinguish zones. A discussion of EFH in the Gulf, as well as Threatened and Endangered fish and invertebrate species is included in this chapter. The emphasis within each section will be on the northern Gulf, where BOEM's regulated OCS activities occur.

The Gulf has a taxonomically and ecologically diverse assemblage of fishes and invertebrates due to its unique geologic, oceanographic, and hydrographic features (see **Chapter 2**). Currently, it is estimated that the Gulf contains 1,541 fish species in 736 genera, 237 families, and 45 orders (Felder and Camp 2009). Fifty-one of these species are sharks and 42 are rays and skates (Ward and Tunnell Jr. 2017). Many fish species in the Gulf are targeted commercially and recreationally. Examples include red drum, black drum, spotted seatrout, southern flounder, tarpon, cobia, groupers, snappers, jacks, triggerfish, hogfish, tilefish, mahi-mahi, mackerels, cobia, tunas, marlin, sailfish, and sharks.

Over 13,000 species of invertebrates in 46 phyla are found in the Gulf (Felder and Camp 2009). These include Annelida (segment worms), Crustacea (e.g., amphipods, copepods, crabs, shrimp), Cnidaria (e.g., corals, anemones, hydroids, jellyfish), Dinoflagellata (protists), Echinodermata (e.g., sea stars, sea cucumbers, sea urchins, sand dollars, brittle stars), Foraminifera (amoeboid protists), Mollusca (e.g., chitons, snails, bivalves, cephalopods), and Porifera (sponges), among others. Invertebrates targeted commercially and/or recreationally in the Gulf include brown, white and pink shrimp, blue crab, stone crab, spiny lobster, bay scallop, and Eastern oyster.

Similar to fishes found along the U.S. Atlantic Coast from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, northern Gulf fishes are generally considered to be warm temperate (Carolinian) (Sherman et al. 1991). Conversely, the southerly waters of the continental shelf in the northern Gulf contain 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 Gulf 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 Gulf. Some large pelagic species found in the northern Gulf (e.g., whale sharks, giant manta ray, and bluefin tuna) occur seasonally and are highly migratory. However, continued satellite tagging efforts in the northern Gulf 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).

The spatial and temporal distribution of fishes and invertebrates in the Gulf is shaped by a combination of reproductive behavior, ontogenetic (e.g., development from egg to adult) habitat shifts, trophic dynamics, oceanographic processes, and other factors. For many species, eggs and larvae are pelagic and are transported via wind, tides, and oceanic currents (e.g., the Loop Current and associated spin-off eddies) throughout the Gulf. This is true even for many species with limited mobility as adults (including those attached to or primarily living in the benthos, such as sponges, corals, anemones, oysters, barnacles, blennies, and tilefish), as pelagic larval stages help facilitate dispersal. In the north-central Gulf, 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 1997), are found in higher densities within frontal zones proximal to the Loop Current. Upon development, some fishes and invertebrates settle into benthic or coastal habitats, while others remain in the pelagic environment. Habitat requirements can

change through ontogeny (development over an individual's lifespan), causing different life stages of certain species to occupy different habitats. For some, habitat shifts can be predominantly food-driven. For example, vertical migrations through the water column in search of prey is a behavior commonly observed in deep-sea fishes and invertebrates (Hopkins and Baird 1985; Flock and Hopkins 1992; Salvanes and Kristoffersen 2001). For highly migratory species, seasonal shifts in habitat use are correlated to reproduction and food availability. These and other processes and life histories shape the unique and diverse fish and invertebrate assemblages that occupy the wide variety of Gulf habitats.

3.5.1 Coastal Fishes and Invertebrates

In this section, coastal waters are considered those extending from inland estuaries seaward over the continental shelf. These waters are enriched by organic material exported from Gulf estuaries and rivers, and they support the greatest biomass of the coastal and pelagic zones described. Though there can be overlap (i.e. species that use the entire water column), many species in coastal waters can be found using either primarily pelagic or primarily benthic 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

This section describes fish and invertebrate resources found associated primarily with the coastal pelagic environment. "Coastal pelagic" refers to species that inhabit sunlit waters extending from the nearshore to waters over 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 fishes and invertebrates, a few of which will be discussed further (i.e., zooplankton, menhaden, and sharks).

Table 3-3. Examples of coastal pelagic fish and invertebrate taxa in the Gulf

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

Classification	Taxonomic Group	Common Name
Vertebrate	Rachycentridae	cobia
Vertebrate	Carcarhinidae	requiem sharks
Vertebrate	Sphyrnidae	hammerhead sharks
Vertebrate	Megalopidae	tarpon

Zooplankton

"Plankton" refers to all plants and animals that drift with the currents in marine and freshwater environments, and is divided into phytoplankton (microscopic, primarily photosynthetic organisms) and zooplankton (e.g., microscopic animals). Zooplankton include organisms that 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 upon development. An innumerable quantity of fish and invertebrate species inhabit the Gulf zooplankton communities. Three taxonomic groups will be described further, i.e., the Dinoflagellata, Copepoda, and larval fish and invertebrates. Each group has 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). Dinoflagellate species can be phototrophic (producing food through photosynthesis), heterotrophic (obtaining nutrients by consuming other organisms), or mixotrophic (able to photosynthesize and ingest other food sources). Some dinoflagellates form symbiotic relationships with corals (colloquially known as zooxanthellae), and 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 ecological and socioeconomic consequences in Gulf 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 (Stoecker and Govoni 1984; Schultz and Kiørboe 2009), they can act as pathways for these toxins and other anthropogenic inputs (e.g., PAHs).

Copepods (i.e., Copepoda) are small, aquatic crustaceans that are among the most numerous metazoan groups in marine ecosystems (Turner 2004), and they have 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 either predominately herbivorous or omnivorous (Kleppel 1993), feeding on detritus, phytoplankton, 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 Gulf, in a response to Mississippi River plume waters in the spring and summer (Dagg and Whitledge 1991), likely have 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 Gulf because they are predators of lower trophic-level organisms (e.g., phytoplankton, dinoflagellates, and copepods) and are prey for many others (e.g., other larval fish and invertebrates, tunicates, and cnidarians). In the northern Gulf, 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 Gulf 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 (Govoni et al. 1989; Lohrenz et al. 1990; Dagg and Whitledge 1991; Rooker et al. 2012). For more information, see **Section 3.3**.

Menhaden

Menhaden are small, planktivorous fish in the family Clupeidae, and are highly prevalent in the northern Gulf, particularly off the coasts of Louisiana and Mississippi (Lassuy 1983; Southeast Data, Assessment, and Review 2011). They represent a taxa of small, schooling fishes that link lower trophic-level (e.g., plankton) and higher trophic-level (e.g., other fishes and sharks) organisms. Menhaden likely influence the population dynamics of many predatory fish species in the northern Gulf (e.g., blacktip sharks, king mackerels, Spanish mackerels, and red drum) (Sagarese et al. 2016; Chen 2017). Three species occur in the Gulf: 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 can tolerate a range of salinities, which allows them to 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 150 mm (5.9 in) (Lewis and Roithmayr 1981).

Coastal Pelagic Sharks

The Gulf 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). Along southwest Florida, the most common coastal pelagic sharks encountered are bonnethead, blacktip, blacknose, and lemon sharks. In the northernmost region of the Gulf, populations are dominated by Atlantic sharpnose, followed by blacktip, finetooth, and bull sharks (Parsons and Hoffmayer 2007). Coastal sharks may migrate from inshore to offshore waters in response to seasonal temperature variations (Hoffmayer et al. 2006; Parsons and Hoffmayer 2007; Chen 2017). These seasonal habitat shifts are not as likely where seasonal temperature fluxes are generally less dramatic (Chen 2017). Some coastal pelagic sharks, like the sandbar shark, are known to leave the Gulf and travel into the Atlantic

(Parsons and Hoffmayer 2007). Young of the year and neonates of some shark species (e.g., Atlantic sharpnose, blacktip, finetooth, bull, scalloped hammerhead, spinner, and sandbar sharks) have been found using coastal habitats, such as barrier islands, bays, and estuaries, along the coasts of the northern Gulf 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 Gulf are managed by NMFS as part of the Atlantic Highly Migratory Species (HMS). Sharks are separated into four management units: (1) small coastal; (2) large coastal; (3) pelagic; and (4) prohibited species. Small coastal sharks include bonnetheads, Atlantic sharpnose, blacknose, and finetooth sharks. Large coastal sharks include blacktip, bull, great hammerhead, lemon, sandbar, scalloped hammerhead, silky, smooth hammerhead, spinner, nurse, and tiger sharks. Pelagic sharks include blue, porbeagle, thresher, shortfin mako, and oceanic whitetip sharks. Prohibited species include whale, basking, sand tiger, bigeye sand tiger, white, dusky, night, bignose, Galapagos, Caribbean reef, narrowtooth, longfin mako, bigeye thresher, sevengill, sixgill, bigeye sixgill, Caribbean sharpnose, smalltail, shortfin mako, and Atlantic angel sharks.

Sharks are high trophic-level predators who have 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 because of aspects of their life histories, such as slow growth, late sexual maturation, and the production of a relatively small number of offspring compared to other fishes (e.g., less than 50 offspring per single reproductive event for many species; up to a maximum of 300 for whale sharks [Cortes 2000]).

3.5.1.2 Coastal Demersals

Coastal demersal fishes and invertebrates use primarily benthic substrates or are associated with structure (natural or human-made) extending from the nearshore to waters over the continental shelf. The coastal waters of the northern Gulf are mostly low-relief, soft-bottom habitat (e.g., sands, silts, muds, and clays), but benthic hard bottom and human-made structures are scattered throughout. Some species are primarily found over either soft or hard bottom habitats, whereas others can be found using both (**Table 3-4**). Species attracted to structure, such as reef fish, can be found using natural hard bottom substrates as well as 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 (i.e., shellfish, red drum, snappers, groupers, and jacks).

Table 3-4. Examples of 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

Coastal demersal shellfish (e.g., blue crab and penaeid shrimp) are important both ecologically and economically. Ecologically they are important prey items for fishes and invertebrates and some species, like the Eastern oyster, create important benthic habitats (see **Section 3.2**). Many are economically valuable both commercially and recreationally. Targeted fisheries include penaeid shrimp (i.e., brown, white, and pink), Eastern oyster, and blue crab (**Figure 3-13**). 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 3-13. Five most economically and recreationally valuable shellfish species in the Gulf.
Note & credit: These species include the blue crab (top left; (NOAA 2020b), Eastern oyster (top right; (NOAA 2020a), brown shrimp (bottom left; (NOAA Fisheries 2025b), white shrimp (bottom center; (NOAA Fisheries 2025o), and pink shrimp (bottom right; (NOAA Fisheries 2025l).

All heavily targeted shellfish are dependent on estuaries for some or all of their life cycles and can be characterized as r-selected species. R-selected species are those that 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 Gulf bays can become sexually mature just four 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 Jr. 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 two 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 compared to slow-growing animals who produce only a few, well-developed offspring.

Commercially valuable shellfish species in the northern Gulf face many natural and anthropogenic threats. Natural perturbations, such as sea-level rise and tropical storms, threaten coastal and estuarine habitats. 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 found throughout estuaries and nearshore and offshore habitats in the Gulf. They are an important secondary consumer in shallow, coastal habitats, assisting in the regulation of primary consumer populations. They are also important to coastal economies because they form a widely popular and lucrative recreational fishery. Red drum use 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 tides and currents 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 (Bass and Avault Jr. 1975; Peters and McMichael Jr. 1987). Juvenile red drum typically exhibit very little to no movement between estuaries or regions (DuBose et al. 2024). 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 Jr. 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 2000). Recent findings have suggested that both sexes reach sexual maturity around 3 years old (Bennetts et al. 2019). In the Gulf, red drum live approximately 30 years; some individuals reach over 40 (DuBose et al. 2024). Red drum are not considered as resilient as other species with shorter life spans. Red drum stocks are currently undergoing overfishing in Louisiana (DuBose et al. 2024), but are

stable in Florida (Addis 2020). Texas has stocked hatchery-reared red drum in their coastal bays since the 1980s.

Snappers

In the Gulf, there are 16–17 species of snapper (family Lutjanidae) 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). Red snapper are arguably one of the most valuable and sought-after sport fish in the Gulf because of their popularity as a food fish. Though snappers vary in their life history attributes, they are often found in association with reefs, hard bottoms, or artificial substrates as adults. Juveniles of many species (e.g., gray snapper and goliath grouper) are often found in shallow, inshore areas associated with seagrass beds, mangroves, and inshore reefs. Some species, like red snapper, also use soft-bottom habitats (e.g., sands and/or muds) as both juveniles and adults, where they feed on sand- and mud-associated fishes and invertebrates (Gulf of Mexico Fishery Management Council 1981; Geary et al. 2007; Wells et al. 2008).

Red snapper can be found in coastal waters throughout the Gulf and are particularly prevalent in the northern Gulf 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. 2001; 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 spawning abundances occurring in the northern Gulf off central and western Louisiana (Collins et al. 2001; Chen 2017). Several species of snappers form temporary spawning aggregations where many individuals, including other species (e.g., jacks), spawn together. These fish spawning aggregations (FSAs) act as “productivity hotspots” as they attract many other marine species who come to these locations to reproduce, feed on spawning fish, or feed on nutrient-rich eggs (Grüss et al. 2018). Though some snapper and grouper species form resident spawning aggregations, others formtransient spawning aggregations (TSAs) in which adults travel outside of their home ranges to a small number of specific locations within a restricted period of time (Grüss et al. 2018). TSAs may be the only opportunity for participating individuals to reproduce, which makes TSAs particularly vulnerable to anthropogenic impacts (Grüss et al. 2018) that may cause temporary or permanent disruptions to spawning aggregations.

Red snapper larvae are planktonic and remain as ichthyofauna for approximately 30 days. Larvae are transported via currents to shallow, sandy, and muddy nearshore habitats before eventually moving into more structured habitats and deeper water with development. Their dispersal can be highly influenced by topographic barriers (e.g., Mississippi River Delta, De Soto Canyon, and the Apalachicola Peninsula) and spin-off eddies associated with the Loop Current (Johnson and Perry 2019). Genetic studies have indicated the likelihood of metapopulations for the Gulf red snapper stock: the general assumption is the existence of two primary sub-stocks

within the region (an eastern and a western stock separated roughly by the Mississippi River) (Southeast Data, Assessment, and Review 2018).

The most recent stock assessment report (Southeast Data, Assessment, and Review 2018) indicated that red snapper overfishing is not occurring, but it has not yet recovered to the Gulf-wide rebuilding target (the Gulf-wide rebuilding target was 26 percent and, as of 2018, the spawning stock biomass was 20 percent). This is a sign that steps to manage overharvesting, which is the primary threat to red snapper in the Gulf, are seeing evidence of success.

Groupers

Fishes of the family Serranidae (subfamily Epinephelinae) are found in both the tropical and subtropical Gulf waters and consist of commonly known groupers, rock hinds, and seabasses. They are slow-growing, late-maturing, long-lived demersal fish. Like snappers, groupers are structure-oriented, generally associating with hard or rocky bottoms and reefs (both natural and human-made) (see **Section 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 have important functions in food web dynamics.

Because of groupers' popularity for sportfishing and human consumption, commercial and recreational fisheries exist for groupers, lending to their considerable economic value throughout the Gulf. Currently the Gulf Council manages 15 species, and they have been divided into shallow-water and deepwater grouper complexes (Southeast Data, Assessment, and Review 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).

Generally, grouper display spawning aggregations, which are temporary gatherings of large numbers of grouper for spawning at specific times and places. These FSAs have been observed forming near outer reef edges and either vertical (pinnacles) or horizontal discontinuities (promontories) in bottom structure (Kobara et al. 2013) and in less than 200 m (656 ft) water depth (Helies et al. 2016). Often, reef species such as snapper and jack species will be observed with grouper in the same FSA. Heyman et al. (2019) concludes that shelf edges and ridges are the most suitable habitat preference for the group FSA of snapper, jacks and groupers, while midshelf obstructions are the preferred habitat for goliath grouper. Grouper spawning seasons can persist from 3 months (Nassau grouper) to as long as 12 months (yellowmouth grouper) with varying seasonality, showing no consistent pattern except for peak spawning season during the summer months (June–August) (Heyman et al. 2019).

Though harvesting both Nassau grouper and goliath grouper is prohibited, only the Nassau grouper is listed under the ESA as Threatened. Nassau groupers are long-lived, moderately sized serranid fish that inhabit shallow coastal waters as adults and are generally associated with high-relief coral reefs or rocky substrates in clear waters. Their current distribution includes Bermuda to Florida, throughout the Bahamas and Caribbean Sea (Heemstra and Randall 1993). The goliath grouper is the largest of the grouper species, weighing up to 800 lbs. Goliath grouper have been observed primarily in shallow tropical waters among coral and artificial reefs in the Gulf, Florida Keys, the Bahamas, most of the Caribbean, and most of the Brazilian coast.

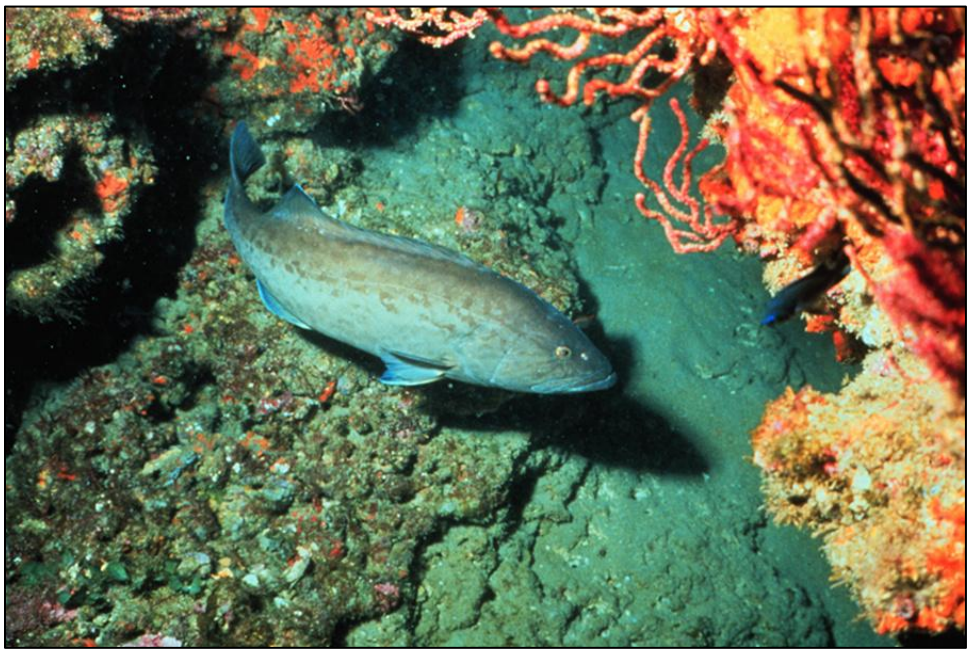


Figure 3-14. Gag grouper.
Source: NOAA Fisheries 2025c.

Gag grouper (**Figure 3-14**) are one of the most abundant and economically important reef fish in the Gulf. In 2022, commercial harvest levels exceeded 412,769 kg (910,000 lbs), valued at $5.5 million, and recreational harvest totaled 1.45 million kg (3.2 million lbs) (NOAA Fisheries 2025c). According to the most recent stock assessment, there are two stocks of gag grouper: South America and the Gulf. Both stocks are currently overfished and are subject to overfishing (Southeast Data, Assessment, and Review 2021). Adult gag grouper are commonly found inhabiting coastal structures, such as reefs and rocky bottoms or ledges at depths up to 152 m (500 ft) in the Gulf. Like many other grouper species, they are protogynous hermaphrodites, meaning they begin their lives as females then transform into males once they reach a certain size and/or age (Jory and Iversen 1989; NOAA Fisheries 2025c). The maximum age observed of gag grouper in the Gulf ranges from 31 to 33 years. The inflection age at which 50 percent of individuals transition to male is estimated to happen around 13 years with females becoming sexually mature at age 4 (Southeast Data, Assessment, and Review 2021). Coloration of gag grouper varies depending on sex and age. Generally, this species is a gray to light brown with darker wavy markings that create a marbled look on the sides of the body. Like other grouper

species, gag groupers form spawning aggregations offshore in winter from late January to mid-April in the Gulf along the continental shelf. Females spawn multiple times per season, releasing between 60,000 and 1.7 million eggs each time they spawn (Southeast Data, Assessment, and Review 2021; NOAA Fisheries 2025c). Juvenile gag groupers find shelter in seagrasses, mangroves, and oyster reefs before migrating offshore.

Jacks

Jacks (family Carangidae) are a large family of predatory marine fishes that support commercial and recreational fisheries in the Gulf, accounting for up to 5 percent of the annual marine finfish landings due to their value as bait, sportfish, and food (Mohan et al. 2017). Four species of jacks are managed by the Gulf Council under the Reef Fish Fishery Management Plan: the greater amberjack, lesser amberjack, almaco jack, and the banded rudderfish. Jacks occur worldwide and are found throughout tropical and temperate waters, occupying primarily the epipelagic water column (upper 200 m; 656 ft). They are broadcast spawners; some species spawn in offshore, pelagic waters and others spawn closer to shore. For most species, the spawning season is fairly long and generally peaks during the summer months (Cayetano and Honebrink 2000). Spawning in the wild has not been documented for most species but appears to occur repeatedly and periodically (Thresher 1984). Many species (e.g., greater amberjack, almaco jack, banded rudderfish) have young that associate with pelagic *Sargassum*, whereas others (e.g., crevalle jack) can be found in nearshore and inshore brackish waters over muddy bottoms, sandy bottoms, and seagrass beds (Pattillo et al. 1997). Juvenile and post-larval jacks in the northern Gulf were documented to have a higher abundance in areas with lower salinities, yet preferences for SST and sea surface height were found to be species- and life-stage specific. This highlights a strong correlation between physical oceanographic features and distribution of jacks in the Gulf. For some species, like the greater amberjack, schooling behavior around *Sargassum* decreases as they mature, and there is a shift from inhabiting pelagic habitats to demersal habitats (NOAA Fisheries 2025d). Adults and sub-adults are typically found in association with structured habitats (e.g., natural hard bottoms and artificial reefs), and some populations live in particular locations though others are thought to migrate and use a variety of habitats and areas throughout the year (NOAA Fisheries 2025d). Greater amberjacks are commonly targeted by fishers in the Gulf where the stock is currently listed as overfished by NOAA Fisheries.

3.5.2 Oceanic Fishes 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 HMS (e.g., tunas, oceanic sharks, and billfish). 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 on physical and biological characteristics and have evolved various adaptations to survive in the habitats where 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 200 m (656 ft); mesopelagic, which extends from 200 to 1,000 m (656 to 3,281 ft); and bathypelagic, which extends from 1,000 to 4,000 m (3,281 to 13,123 ft). Knowledge of assemblages and community structure deeper than this bound (i.e. the abyssopelagic zone) in the Gulf 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 200 m (656 ft)	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	200–1,000 m (656–3,281 ft)	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), pteropods and heteropod mollusks
Bathypelagic	1,000–4,000 m (3,281–13,123 ft)	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 Gulf, especially at or beyond the shelf edge. Epipelagics are reportedly associated with mesoscale hydrographic features, such as frontal zones, mesoscale 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 (**Section 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, such as tunas, marlin, sailfish and swordfish, 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 (Tyminski et al. 2015) and bluefin tuna (Teo et al. 2007), are known to migrate vertically down to the deep-sea zones (>200 m; 656 ft).

Tunas (Genus *Thunnus*)

Tunas (family Scombridae) are arguably one of the most ecologically important, widely occurring, and economically valuable oceanic-pelagic fishes in the Gulf. 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 Gulf.

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 Gulf, particularly in the northern Gulf where they are primarily captured (Teo and Block 2010). Peak spawning of yellowfin tuna in the north-central Gulf occurs from May to August (Pacicco et al. 2023). Yellowfin tuna fecundity increases more rapidly in larger females, which are capable of spawning daily during peak months (Pacicco et al. 2023).

The spatiotemporal distribution of yellowfin tuna in the Gulf is closely linked to the mesoscale structure and dynamics of the water column (Ramírez-Mendoza et al. 2024). Areas with moderate to high salinity (28–36 practical salinity units [psu]), SST above 29 °C (84 °F), deeper thermoclines, and proximity to fronts associated with mesoscale oceanographic features such as the Loop Current, warm-core eddies, and discharges from the Mississippi Atchafalaya River System appear to yield preferred habitats for yellowfin tuna (Cornic and Rooker 2021; Ramírez-Mendoza et al. 2024). Waters deeper than 1,000 m (3,281 ft) and off the midwestern continental shelf, highly influenced by upwelling-favorable winds over the shelf and slope from April and August, are also favorable (Ramírez-Mendoza et al. 2024).

Electronic tagging efforts have shown that adult yellowfin tuna in the northern Gulf 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 not only to the high productivity associated with the Mississippi River Delta, but also to the extensive network of oil and gas structures. Price et al. (2022) used acoustic transmitters on deepwater oil and gas structures to track tagged yellowfin in the Gulf and found that yellowfin interacted with deepwater oil and

gas structures in a manner similar to how they interact with fish aggregating devices and other geographical features. Oil and gas structures may be used as meeting points, landmarks, and stopovers within a movement corridor. The northern Gulf has been found to be an important foraging area for yellowfin tuna, while it also provides optimal conditions for larval growth and survival due to its high values of chlorophyll-a and intermediate salinities (Le-Alvarado et al. 2021). Elevated nitrogen levels near the Mississippi River plume (including those from anthropogenic sources, such as livestock production, treated wastewater, and manure) also support the retention of adult yellowfin in this region.

Although yellowfin tuna have distinct spawning areas (i.e., Gulf of Guinea, southeastern Caribbean Sea, Cape Verde, and the Gulf [of America]) and apparent heterogeneity in their distributions, they are currently considered to be a single stock for the entire Atlantic (International Commission for the Conservation of Atlantic Tunas 2018). Rooker et al. (2023) identified a high level of mixing of yellowfin tuna from nursery origins in the Gulf [of America], Caribbean Sea, Cape Verde, and the Gulf of Guinea, emphasizing the complexity of the stock structure and population connectivity of yellowfin tuna. Recruits from the Caribbean Sea were found to be important to both fisheries in the Gulf and the Mid-Atlantic Bight (Rooker et al. 2023). Additionally, trans-Atlantic migrants were identified in U.S. waters from nurseries in the Gulf of Guinea and the Cape Verde. Comparison of yellowfin tuna in the Gulf and Atlantic has shown further support of no significant differences among fishes from the two areas. An age, growth, and mortality study of yellowfin in the Gulf and Atlantic found no significant differences in mean length at age (Pacicco et al. 2021). This study analyzed otolith samples from 3,443 yellowfin tuna collected in the western Atlantic and Gulf between 2004 and 2017, revealing a significant increase in longevity (~7.5 years), with the oldest individual estimated to be 18 years old. The size distribution of individuals in the Gulf ranged from 628–1,981 mm; 25–78 in (males, females, and unknown sex), with little variation from the Atlantic population which ranged from 609–1,481 mm (24–58 in).

Bluefin tuna are the largest of the tuna species and an economically valuable sport 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 Gulf (western stock) and Mediterranean Sea (eastern stock), respectively (Block et al. 2005; Boustany et al. 2008). In the northern Gulf, 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., anticyclonic warm- and cold-core eddies) in the northern Gulf as likely nursery habitats (Cornic et al. 2017), along with other highly migratory species (e.g., billfish and swordfish) (Rooker et al. 2012).

Blackfin tuna are among the most abundant tuna species in the Gulf, yet basic information about their life history remains limited. They are the smallest of the tunas, and accounted for more than 80 percent of tuna larvae in a long-term, fishery independent study conducted in the Gulf (Gutierrez et al. 2024). Generally, blackfin tuna larvae have a high metabolic demand for fast growth, and increased prey availability often results in higher larval survival (Cornic and

Rooker 2018). Blackfin tuna larvae are found to be more abundant in areas influenced by freshwater inflows, where intermediate salinity levels (30–34 psu) and elevated nutrient levels from riverine discharges create favorable conditions. Cornic and Rooker (2018) suggest that the distribution and abundance of blackfin tuna larvae are strongly influenced by warm temperatures, such as the Loop Current and warm-core eddies, which offer favorable thermal conditions and abundant prey resources. Gutierrez et al. (2024) used an otolith-based aging method to estimate the age, growth, and mortality relationship of 393 blackfin tuna in the Gulf (84 females, 270 males, and 39 unknown sex) and determined that they exhibit slower growth and a shorter mean length at adulthood compared to other tuna species.

3.5.3 Deep-Sea Fishes and Invertebrates (Meso- and Bathypelagic Zones)

Much of what is known of deep-sea (over 200 m; 656 ft) meso- and bathypelagic fauna in the Gulf comes from a combination of trawl surveys, remotely-operated vehicle (ROV) footage, and gut content analyses. These efforts have discovered assemblages of fish and invertebrates (**Figure 3-15**) that are so diverse and abundant that the Gulf was 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, deepwater pelagic surveys conducted since the *Deepwater Horizon* oil spill resulted in the collection of 794 mesopelagic and bathypelagic fish species, ranking the Gulf 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 Sutton et al. (2017) includes many of the fish and invertebrate taxa that have been documented at various depths within the meso- and bathypelagic zones of the Gulf.



Figure 3-15. Deep-sea pelagic fish and invertebrates captured during a DEEPEND research expedition in the northern Gulf.

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Fish in the deep sea tend to grow slowly and some can live to extraordinary ages, although aging individuals has proven to be difficult, particularly for small, deep-sea pelagics (Cailliet 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 2004).

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 Gulf 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, some taxa appear to be 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 Gulf fish and invertebrate species incorporated as appropriate.

3.5.3.1 Mesopelagics

Many of the fish and invertebrate species living primarily in the mesopelagic zone undergo DVM to the epipelagic zone at night where they feed on plankton (Salvanes and Kristoffersen 2001; Widder 2010; Bianchi et al. 2013). In the northern Gulf, 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 epipelagic predators (e.g., fish, squids, night-foraging seabirds, and marine mammals) have adapted to take advantage of these migrations (Spies et al. 2016). Therefore, DVMs contribute to the transfer of energy from deep-sea ecosystems to surface waters and vice versa. East of the Mississippi River, daily variability in DVMs intensify from autumn to spring, with changes in structure over the course 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, barracudinas, 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 m (328 ft) of the epipelagic zone (Sassa and Kawaguchi 2006; Hsieh et al. 2017) and in association with Loop Current frontal zones in the Gulf (Richards et al. 1993).

Some of the most abundant and ecologically significant of these taxa in the Gulf 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 Jr. 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 migrate vertically throughout the water column, contributing to the transfer of energy. They include many taxa of crustaceans (e.g., copepods, decapod shrimps, mysids, ostracods, 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 Gulf as both predators and prey (Judkins and Vecchione 2020); they are known to be the primary prey of sperm whales in the Gulf (Baumgartner et al. 2001). Through stable isotope stomach content analyses, (McClain-Counts et al. 2017) found that invertebrates such as copepods and gelatinous organisms (e.g., salps and pteropods) are important components of mesopelagic fish diets.

3.5.3.2 Bathypelagics

The bathypelagic zone is one of the largest and least understood biomes on the planet. No sunlight penetrates 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 swim bladders (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 bathypelagic 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 1997). This finding was corroborated by a 1980s Minerals Management Service survey of deep-sea communities in the Gulf (Pequegnat 1983), where fish diversity in the mesopelagic zone increased down to 950 m (3,117 ft) water depth, and steadily decreased through the bathypelagic zone, with a drastic drop below 2,300 m (7,546 ft) water depth. More recent midwater trawl surveys in the eastern Gulf 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 percent) and decapod shrimps (17 percent) (Burghart et al. 2010). Gut content analysis 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) fed primarily 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 is still a unique assortment of fishes that are typically only found at these depths. In the Gulf, these include ceratioid anglerfishes, whalefishes, and tubeshoulders (Tolley et al. 1989; Pietsch and Sutton 2015; Novotny 2018). Both anglerfishes and whalefishes have exhibited extreme examples of sexual dimorphism, in which the female is extremely large in comparison to males (Johnson et al. 2009; Pietsch and Sutton 2015). 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). 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 greatest number of individual cephalopods has been documented in the mesopelagic zone, 95 percent of oceanic cephalopod species in the northern Gulf 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 Gulf, 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).

3.5.4 Essential Fish Habitat and ESA-Listed Threatened and Endangered Species

This section describes EFH, the process by which it is designated, and how it is managed. ESA-listed Threatened and Endangered species of fish and invertebrates present in the Gulf are also discussed, with an emphasis on the northern Gulf.

3.5.4.1 Essential Fish Habitat (EFH)

Federally managed fishes and invertebrates in the Gulf include: red drum, reef fish (31 species), coastal migratory pelagic fishes (3 species), corals (2 classes), shrimps (4 species), spiny lobster, stone crab, and highly migratory species (53 species). Most of these managed species have portions of their range and associated habitats that have been recognized by Congress as EFH, defined as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (16 U.S.C. §§ 1801 et seq.; NMFS 2007). NMFS works with the Gulf Council to designate EFH using the best available scientific information and may update designations as more information is gathered. Pursuant to Section 305(b) of the MSA (NMFS 2007), federal agencies are required to consult with NMFS on any action that may result in adverse effects to EFH. NMFS published the final rule (67 FR 2343) implementing the EFH provisions of the MSA

on January 17, 2002. NMFS further clarified the terms associated with EFH by the following definitions:

- **Waters**: Aquatic areas and their associated physical, chemical, and biological properties that are used by fish and, where appropriate, may include aquatic areas historically used by fish.
- **Substrate**: Sediments, hard bottoms, structures underlying the waters, and associated biological communities.
- **Necessary**: The habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem.
- **Spawning, breeding, feeding, or growth to maturity**: Stages representing a species' full life cycle.
- **Adverse effects**: May include direct or indirect physical, chemical, or biological alterations of the waters or substrate as well as the loss of and/or injury to benthic organisms, prey species, their habitat, and other ecosystem components. Adverse effects may be site-specific or habitat-wide impacts including individual, cumulative, or synergistic consequences of actions. Certain OCS oil- and gas-related activities authorized by BOEM may result in adverse effects to EFH and therefore require EFH consultation.

Collectively, the spatial extent of EFH designations in the Gulf encompasses most areas from coastal estuaries to the deep sea. EFH includes habitats such as the water column, wetlands, SAV, sand and mud bottoms, hard bottoms and coral reefs, and *Sargassum*. Coastal areas are important EFH for many species in the Gulf, containing highly productive waters and habitats that support a variety of species and their early life stages. Hard bottom benthic habitats such as coral reefs are also important EFH that support a large diversity of fishes and invertebrates (see **Section 3.4**). In Gulf oceanic waters, the Loop Current and its associated eddies are important for many pelagic species as they create dynamic zones and dominant circulation features with strong divergences and convergences that concentrate and transport marine fishes and invertebrates.

In addition to EFH, the Gulf Council and NMFS are responsible for identifying habitat areas of particular concern (HAPCs), which are discrete subsets of EFH (**Figure 3-16**). 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. Although the HAPC designation does not necessarily confer additional protection to an area, it can be used to prioritize conservation or as a focus for additional fishery management efforts. In 2020, Amendment 9 to the Coral and Coral Reefs of the Gulf of Mexico Fishery Management Plan was implemented (85 FR 65740), which established 21 new HAPCs for corals (13 of which have fishing restrictions), and modified

regulations for three existing HAPCs. For more information on benthic habitats, see **Section 3.4**).

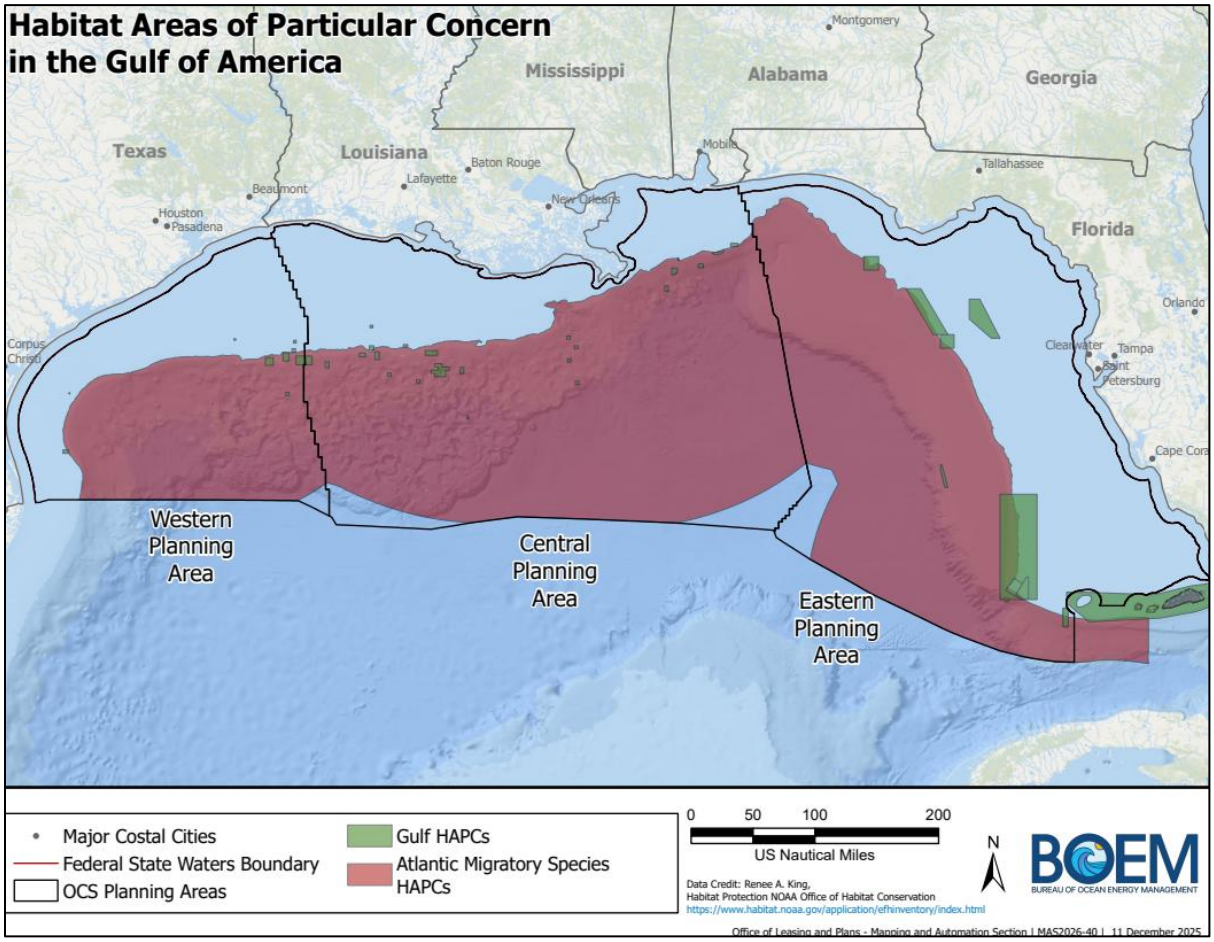


Figure 3-16. Gulf Habitat Areas of Particular Concern (HAPCs).
Source: BOEM - 2025. The HAPC datasets used in this image were downloaded in August 2025 from the NOAA Habitat Conservation website.

3.5.4.2 ESA-Listed Fish and Invertebrate Species

Several fish and invertebrate species occurring in the coastal and marine habitats of the Gulf are listed as Threatened or Endangered under the ESA. Threatened species include the Gulf sturgeon, Nassau grouper, oceanic whitetip shark, giant manta ray, queen conch, and several species of coral. The smalltooth sawfish is the only Endangered fish listed in the Gulf to date. The coral species listed under the ESA are discussed in **Section 3.4**. The critical habitat designated for ESA-listed species can be seen in **Figure 3-17**.

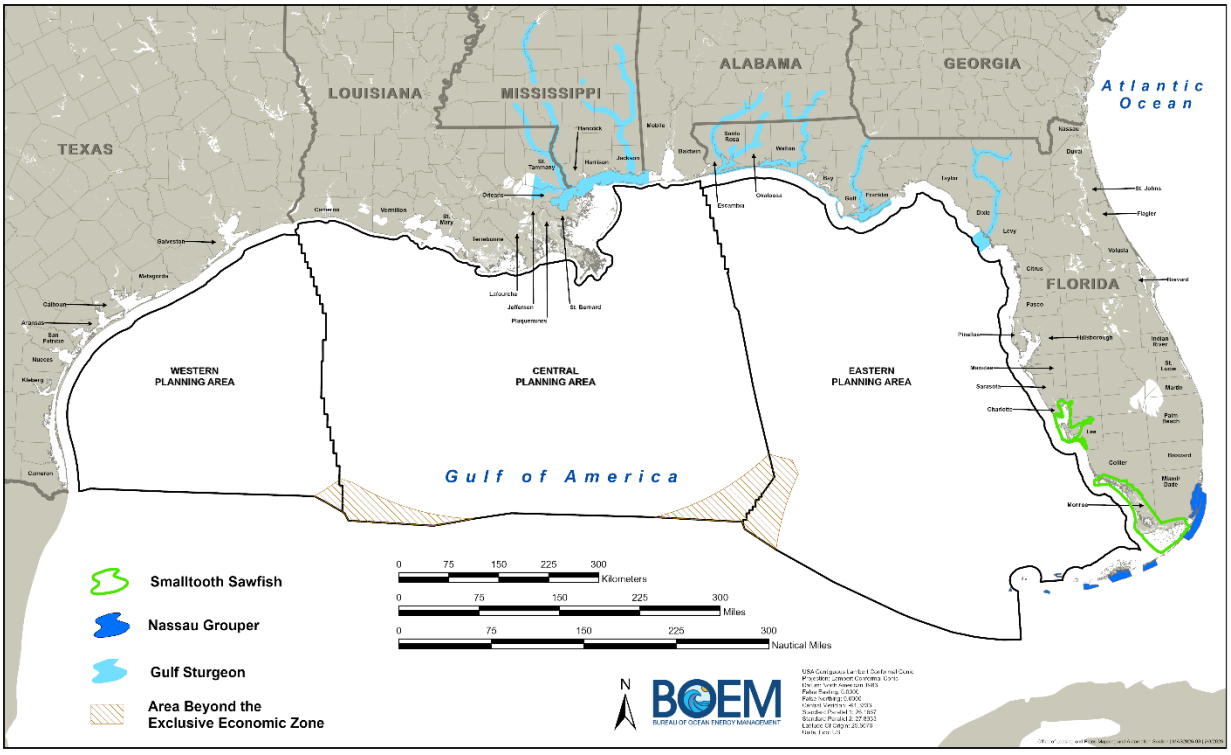


Figure 3-17. Designated critical habitat for fishes listed under the ESA.
Source: BOEM - 2026. Map was created by BOEM geographers. The source of the ESA- listed Species data is NOAA. The source for the planning areas and other boundaries is BOEM's Technical Information Management System.

3.5.4.3 ESA-Listed Threatened Species

Gulf Sturgeon

Gulf sturgeon, a subspecies of the Atlantic sturgeon, was 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 Gulf (68 FR 13370). Gulf sturgeon feed primarily within estuarine and marine systems in the northern Gulf from October to April. In 2003, 3,755 km^2 (2,333 mi^2)of estuarine and marine habitat in the Gulf were designated as critical habitat for Gulf sturgeon, along with 4,478 km^2 (2,783 mi^2) of natal river systems (68 FR 13370). Previous use of habitats and river systems east of Mobile Bay to foraging grounds in the Mississippi Sound has been identified, suggesting Gulf sturgeon travel through Alabama waters. Greenheck et al. (2023) quantified this suggested use of Mobile Bay Estuary, observing sustained use and habitat suitability from 2016 to 2021. Based on additional sampling, this study suggests that Gulf sturgeon forage in this area due to high prey richness that resembles that of a known foraging site. Although this habitat is not currently designated as critical habitat, the observed habitat use and foraging capabilities identified by Greenheck et al. (2023) warrant further consideration. Gulf sturgeon 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 (68 FR 13370). Their present range extends from Lake Pontchartrain in Louisiana to the Suwannee River in Florida. Designated critical habitat for Gulf sturgeon can be seen in **Figure 3-17**.

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 Gulf but are generally replaced by red grouper in the eastern Gulf in areas north of Key West and the Tortugas. They are considered rare or transient in the northwestern Gulf along Texas, but a first sighting of a Nassau grouper was made in the FGBNMS in September 2006 (Foley et al. 2007). NMFS designated critical habitat for Nassau grouper under the ESA in 2024 (89 FR 126). While a few locations are in the Dry Tortugas and Florida Keys, many of the critical habitat locations are largely outside the Gulf (off southeastern Florida and in the Caribbean). Designated critical habitat for Nassau grouper within the Gulf can be seen in **Figure 3-17**.

Oceanic Whitetip Shark

The oceanic whitetip shark is a large, pelagic requiem shark species that was listed as Threatened under the ESA in 2018. The oceanic whitetip shark is broadly distributed in tropical and subtropical open ocean waters globally, typically found offshore near continental shelf edges or around islands in depths greater than 184 m (604 ft), and from the surface to at least 152 m (499 ft) depth (Young and Carlson 2020). Oceanic whitetips were once common, but populations have decreased substantially over the years due to bycatch in longline fisheries and direct fisheries for the finfish trade. In the Gulf, Baum and Myers (2004) have estimated that oceanic whitetip sharks have declined by over 99 percent between the 1950s and late 1990s. Like other sharks, oceanic whitetips are generally considered vulnerable to overexploitation because of their life histories, which are characterized by a late age at maturity and low fecundity (Musick et al. 2000).

Giant Manta Ray

The giant manta ray is the world's largest ray, with a wingspan of up to 8.8 m (29 ft). Giant manta rays are slow-growing filter feeders that are globally distributed and highly migratory. However, tagging efforts in the southern Gulf (i.e., Yucatán peninsula) have indicated that regional populations likely exist with a degree of site fidelity (Marshall et al. 2011; Graham et al. 2012). They have low fecundity, birthing only one or two live young every 1–2 years (Marshall 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). Over half (60 percent) of the giant manta ray's suitable habitat is confined to the continental shelf (<200 m; 656 ft depth) and the inner continental slope of the Gulf (Romo-Curiel et al. 2022). In the northwestern Gulf, a prevalence of juvenile manta rays has been found at the FGBNMS, suggesting that the banks may function as nursery habitats for this species (Childs 2001; Stewart et al. 2018).

Queen Conch

The queen conch is a large gastropod mollusk that can be found in the subtropical waters of Bermuda and in tropical to subtropical waters throughout the Caribbean and Gulf, including the FGBNMS. As juveniles, they are usually found in association with seagrass beds. As adults, they are most often found on sandy algal flats, but can also be found over gravel, coral rubble, smooth hard coral, and beach rock bottoms (NOAA Fisheries 2025m), and are generally not found in waters deeper than 21 m (70 ft). Though queen conch have a long spawning season, they reproduce through internal fertilization and must be near a mate to reproduce (NOAA Fisheries 2025m), making them more vulnerable to anthropogenic impacts that reduce the numbers of individuals in a population. In March 2024, NOAA Fisheries listed the queen conch as Threatened throughout its range under the ESA (89 FR 11208). The queen conch is also listed under Appendix II of CITES, meaning it is considered a species that could be Threatened with extinction if trade is not closely controlled. Within the FGBNMS, the queen conch has been documented at the WFGB, EFGB, and Stetson Bank. During 2006, three juveniles were observed at Stetson Bank along with 27 adults, indicating a potential recruitment event to the bank (NOAA Fisheries 2025m).

3.5.4.4 ESA-Listed 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: 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 (74 FR 45353); however, populations became so depleted they were listed as Endangered under the ESA in 2003. Their decline is due to habitat loss and degradation, and 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 exists only 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. Designated critical habitat for smalltooth sawfish can be seen in **Figure 3-17**.

3.5.5 Fish and Invertebrate Bioacoustics

The following sections discuss the importance of sound to fishes and invertebrates, fish and invertebrate hearing anatomy, how different hearing groups are classified, and potential impacts from introduced anthropogenic sounds. Given the limited body of research available, these sections present current knowledge that includes information on species that may not occur within the Gulf but offer relevant biological and ecological insights.

3.5.5.1 The Importance of Sound to Fishes and Invertebrates

Many fishes and invertebrates produce sounds for basic biological functions like attracting a mate and defending territory. Sound production in fishes has evolved at least 33 times throughout evolutionary time, and the majority of ray-finned fishes are likely capable of producing sounds (Rice et al. 2022). Fish may produce sounds through a variety of mechanisms, such as vibrating muscles near the swim bladder, rubbing parts of their skeleton together, or snapping their pectoral fin tendons (Ladich and Bass 2011; Rice et al. 2022). Similarly, many marine invertebrates produce sounds, ranging from the ubiquitous snapping shrimp "snaps" (Johnson et al. 1947) to spiny lobster "rasps" (Patek 2002) to mantis shrimp "rumbles" (Staaterman et al. 2011). Some sounds are also produced as a by-product of other activities, such as the scraping sound of urchins feeding (Radford et al. 2008a) and even a "coughing" sound made when scallops open and close their shells (Di Iorio et al. 2012).

Some species do not appear to produce sounds, but still have acute hearing (e.g., the goldfish), which has led scientists to surmise that animals glean a great deal of information about their environment through acoustic cues, a process called "auditory scene analysis" (Fay 2009). All of the sounds in a given environment (biological, geophysical, and anthropogenic) make up the "soundscape" (Pijanowski et al. 2011). Soundscapes naturally vary over space and time, and there is increasing evidence that some fish and invertebrate species can distinguish between soundscapes of different habitats (e.g., Radford et al. 2008b; McWilliam and Hawkins 2013; Kaplan et al. 2015). In fact, some pelagic larvae may use soundscapes as a cue to orient towards suitable settlement habitat (Simpson et al. 2005; Montgomery et al. 2006; Radford et al. 2007; Vermeij et al. 2010; Lillis et al. 2015) or to induce molting into their juvenile forms (Lillis et al. 2013; Stanley et al. 2015). The unique acoustic signatures of marine habitats provide vital information to the range of species that reside within and around them.

Compared to their understanding of marine mammals, scientists have only scratched the surface in understanding the importance of sound to the vast number of extant fish and invertebrate species. Yet underwater sound is vitally important to their basic life functions, such as communicating, finding a mate, detecting prey and predators, and selecting habitat (Popper and Hawkins 2019). The ability of fishes and invertebrates to detect components of marine soundscapes could be adversely affected by the addition of noise from anthropogenic activity.

3.5.5.2 Hearing Anatomy

All fishes and invertebrates can sense the particle motion component of a sound wave (for information about particle motion, see **Appendix B**). The inner ear of fishes is similar to that of all vertebrates. Each ear has three otolithic end organs, which contain a sensory epithelium lined with hair cells, as well as a dense structure called an otolith (Popper et al. 2021). As the back-and-forth particle motion moves the body of the fish (which has a density similar to seawater), the denser otoliths lag behind, creating a shearing force on the hair cells, which sends a signal to the brain via the auditory nerve (Fay and Popper 2000). Particle motion also can occur through substrate vibration, and sediment dwelling species are believed to be able to

detect particle motion over a greater distance via the substrate, because vibrations propagate further than water-borne particle motion (Williams et al. 2021). Animals that can detect only particle motion or substrate vibration are likely to detect sounds only within a few wavelengths of a sound source, where the particle motion component of a sound wave is dominant (Urick 1983; Kalmijn 1988; Popper and Hawkins 2018).

In addition to particle motion detection, a shared trait across all fishes, some species (typically referred to as "hearing specialists") are also capable of detecting acoustic pressure (Fay and Popper 2000). Special adaptations of the swim bladder (e.g., anterior projections, additional gas bubbles, or bony parts) bring it close to the ear; as the swim bladder expands and contracts due to the change in pressure, particle motion within the body of the fish sends a signal to the ear (Popper et al. 2021). Hearing specialization is not limited to features that enhance hearing sensitivity or bandwidth (frequency), and may include adaptations for better signal discrimination, sound localization, and detection of signals among masking sounds, among others. Most hearing specialists can typically detect a broader range of acoustic frequencies (up to 3–4 kilohertz [kHz]) (Wiernicki et al. 2020; Lucke et al. 2024), but a few species can detect sounds beyond that range (Popper et al. 2021). A few species in the herring family can detect ultrasonic (>20 kHz) sounds (Mann et al. 2001), but this is considered to be very rare among the bony fishes. Another important distinction for species that do possess swim bladders is whether the swim bladder is "open" or "closed"; species with open swim bladders can release pressure via a connection to the gut, while those with closed swim bladders can only release pressure very slowly, making them more prone to injury when experiencing rapid changes in pressure (Popper et al. 2019). It should also be noted that hearing sensitivity can change with age. In some species, like black sea bass, the less distance between the ear and the swim bladder in smaller fish can mean that younger individuals are more sensitive to sound than older fish (Stanley et al. 2020). In other species, hearing sensitivity seems to improve with age (Kenyon 1996).

Invertebrate bioacoustics is a rapidly expanding field of research (Normandeau Associates Inc. 2012; Mooney et al. 2016; Popper and Hawkins 2018). Like elasmobranchs and other fishes considered to be hearing non-specialists, marine invertebrates lack a gas-filled bladder and are thus unable to detect the pressure changes associated with sound waves. However, all cephalopods and some bivalves, echinoderms, and crustaceans have a sac-like structure that develops during the larval stage called a statocyst, which includes a mineralized mass (statolith) and associated sensory hairs (e.g., crustaceans in Edmonds et al. 2016). Statocysts, which are similar to fish ears, act like accelerometers: a dense statolith sits within a body of hair cells, and when the animal is moved by particle motion, it results in a shearing force on the hair cells (Budelmann 1992; Mooney et al. 2010). In addition to statocysts, some invertebrates have epidermal hair cells which help them detect particle motion in their immediate vicinity (Budelmann 1992; Kaifu et al. 2008), comparable to lateral lines in fish (McCormick 2011). Similarly, decapods have sensory setae on their body (Popper et al. 2001), including on their antennae which may be used to detect low-frequency vibrations (Montgomery et al. 2006). The research thus far shows that the primary hearing range of most particle-motion sensitive organisms is below 1 kHz (Popper et al. 2021).

3.5.5.3 Hearing Groups

Though there is a wide variety in hearing anatomy and sensitivity among fishes and invertebrates, Popper et al. (2014) proposed three categories to describe fish hearing, which have been accepted by the scientific community (**Table 3-6**). However, Lucke et al. (2024) recently proposed subcategories within each of these groups to further delineate relative sensitivity across taxa; the authors also proposed rudimentary weighting functions. Because this is a very recent publication, it is uncertain whether (or when) the regulatory community will adopt these new hearing subcategories.

Table 3-6. Fish and invertebrate groupings based on hearing anatomy

Group	Hearing anatomy	Example species	Sensitivity to underwater sound
1	Fishes with no swim bladder or other gas chamber, invertebrates, eggs and larvae	Flatfish, Atlantic mackerel, sharks, rays, cephalopods, crustaceans, bivalves	Detect particle motion but not acoustic pressure, sensitive to sound over relatively small spatial scales, not susceptible to barotrauma. Generally capable of detecting sounds up to 1 kHz.
2[#]	Fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume	Bluefish, snapper, some tunas, Atlantic salmon, European seabass, lake sturgeon, drum, black sea bass	Detect particle motion but not acoustic pressure. May be susceptible to barotrauma due to the presence of a swim bladder. May be sensitive to sounds up to ~3 kHz.
3[*#]	Fishes in which hearing involves a swim bladder or other gas volume	Cod, European eel, squirrelfish, croaker, Atlantic herring, goldfish	Detect particle motion and acoustic pressure. May be susceptible to barotrauma. Sounds can be detected over larger spatial scales and are generally considered to be the most sensitive to impacts from anthropogenic sound. May be able to detect sounds up to 5 kHz, and in some rare cases (e.g., herring) >20 kHz.

Nomenclature based on classification in Popper et al. (2014). Example species and frequency ranges are from Wiernicki et al. (2020).

Note: Wiernicki et al. (2020) further divide Group 3 into two subgroups: (1) fishes with anterior projections of the swim bladder, which bring it closer to the ear and enhances hearing; and (2) fishes with Weberian ossicles (special bones that connect the swim bladder to the ear) representing the most sensitive of all fishes.

[#]Also note: there is no distinction within Groups 2 and 3 between fishes with open vs. closed swim bladders, though some evidence suggests that this distinction could be important when considering susceptibility to barotrauma (Popper et al. 2019).

3.5.5.4 Potential Impacts of Underwater Sound on Finfish and Invertebrates

Fishes and invertebrates may experience a range of impacts from underwater sound, depending on physical qualities of the sound source and the environment, as well as the physiological characteristics and the behavioral context of the species of interest (Pieniazek et al. 2023). Examining the short and long-term effects of low frequency sound on marine fishes

and invertebrates is critical for understanding the broad range of impacts, especially on important biological processes such as reproduction, larval development, and recruitment (Carroll et al. 2016). It is important to note that unlike mammals, whose hair cells do not regenerate, fishes are able to regrow hair cells that die or become damaged (Corwin 1981). This makes it unlikely that they could experience permanent threshold shift (PTS), an irreversible loss of hearing due to hair cell loss or other structural damage to auditory tissues (Saunders et al. 1985; Henderson et al. 2008). There are therefore no thresholds focused explicitly on auditory injury for fishes. However, fishes do experience temporary threshold shift (TTS), a relatively short-term, reversible loss of hearing following noise exposure (Southall et al. 2007; Finneran 2015), often resulting from hair cell fatigue (Saunders et al. 1985; Yost 2000). When very close to impulsive sound sources or explosions, fishes could experience barotrauma, a term that refers to a class of injuries ranging from recoverable bruises to organ damage (which could ultimately lead to mortality) (Stephenson et al. 2010; Popper et al. 2014). When the air-filled swim bladder inside the body of the fish quickly expands and contracts due to a rapid change in pressure, it can cause internal injuries to the nearby tissues (Halvorsen et al. 2011). The greater the difference between the static pressure at the site of the fish and the positive and/or negative pressures associated with the sound source, the greater the risk of barotrauma. This means that impulsive sounds like those generated by impact pile driving or seismic airguns may present a risk of injury due to the rapid changes in acoustic pressure (Hamernik and Hsueh 1991).

For marine invertebrates, exposure to near-field high-amplitude sound may cause anatomical damage and behavioral responses, although research outside of seismic airgun sources is limited (Carroll et al. 2016). A review by Cones et al. (2022) showed that data from comparable studies of similar sound types and characterizations provide evidence that acoustic impacts to bivalves tend to be more severe with increasing received levels. Jézéquel et al. (2022) identified significant differences between the auditory thresholds of juvenile and subadult giant scallops, with juveniles being more sensitive, suggesting ontogenetic differences in hearing sensitivity. Giant scallop auditory thresholds below 500 hertz (Hz) were quantified using particle acceleration and behavioral responses; the results showed best sensitivity at 100 Hz and stronger valve closures occurred with exposure to lower frequencies and higher sound levels (Jézéquel et al. 2022). Damage to invertebrate statocysts has been observed as a result of sound exposure, but it is unclear whether the hair cells can regenerate, like they do in fishes (Solé et al. 2013; Solé et al. 2017). Furthermore, most studies to date have focused on low frequency sound; however, a playback study using high-frequency stimuli (100–200 kHz sweeps) was reported to elicit a noise-induced physiological stress response in black sea urchins (Vazzana et al. 2020). As with marine mammals, continuous, lower-level sources (e.g., vessel noise) are unlikely to result in auditory injury but could induce changes in behavior or acoustic masking. Generally speaking, because particle motion is most relevant within a few wavelengths of a sound source, impacts from underwater noise on marine invertebrates is likely to occur over very small spatial scales (Urick 1983; Kalmijn 1988; Popper and Hawkins 2018).

3.5.5.4.1 Thresholds for Physical and Auditory Injury

The Sound Exposure Guidelines for Fishes and Sea Turtles (Popper et al. 2014), which became an ANSI standard (#ASA S3/SC1.4 TR-2014), have become the widely accepted thresholds for physical and auditory injury for fishes, parts of which have been accepted by the NMFS. Because hair cells in fish ears regenerate (Corwin 1981), they are unlikely to experience permanent hearing loss, but when very close to impulsive sound sources they could experience barotrauma or TTS. The thresholds for barotrauma and mortality were derived from a series of studies using a special testing apparatus that simulated signals from pile driving 10 m (33 ft) from a pile (Halvorsen et al. 2011; 2012a; 2012b; Casper et al. 2012; 2013a; 2013b). These studies also revealed that many fish recovered from TTS within 10 days of exposure. An important component of this work was the ability to simulate both the pressure and particle motion components of the sound field, which is rarely done in laboratory experiments. These studies showed that effects are greater in fishes with swim bladders than those without, and that species with closed swim bladders experienced greater damage than those with open swim bladders.

Popper et al. (2014) also provide thresholds for recoverable injury, which they define as "injuries, including hair cell damage, minor internal or external hematoma, etc." TTS is defined as any change in hearing of 6 decibels (dB) or greater that persists. (Popper et al. 2014) do not distinguish between impulsive and non-impulsive sounds; instead they provide thresholds for each sound type (explosions, pile driving, seismic airguns, sonars, and continuous sounds). That said, studies focused on pile driving are sometimes used to draw conclusions about impacts from seismic airguns, and vice versa. This is simply due to a lack of comprehensive data for each source type. The thresholds are all given in terms sound pressure, not particle motion, though many have acknowledged that these would be more appropriate (Popper and Hawkins 2018). Currently, there are no underwater noise thresholds for invertebrates, but the effect ranges are expected to be similar to those predicted for fishes in Group 1.

Table 3-7. Acoustic thresholds for fishes for exposure to seismic airguns and pile driving sounds

Fish Hearing Group	Mortality and Non-Recoverable Injury (L_{pk})	Mortality and Non-Recoverable Injury (SEL)	Recoverable Injury (L_{pk})	Recoverable Injury (SEL)	TTS (SEL)
[a]Fish without swim bladder (Group 1)	>213	>219	>213	>216	>186
[a]Fish with swim bladder not involved in hearing (Group 2)	>207	210	>207	203	>186
[a]Fish with swim bladder involved in hearing (Group 3)	>207	207	>207	203	186

Fish Hearing Group	Mortality and Non-Recoverable Injury (L_{pk})	Mortality and Non-Recoverable Injury (SEL)	Recoverable Injury (L_{pk})	Recoverable Injury (SEL)	TTS (SEL)
[a]Eggs and Larvae	>207	>210	--	--	--
[b]Fish ≥ 2 g			206	187	
[b]Fish < 2 g			206	183	

SEL = sound exposure level

[a] Popper et al. (2014) Sound Exposure Guidelines. Note that Popper et al. (2014) use the notation "SEL_{cum}," but SEL without a subscript is the preferred nomenclature, used here to describe the energy that would be accumulated over an entire pile driving event (i.e., installation of a pile). For seismic airguns, SEL_{cum} is more difficult to quantify, so the authors suggest using L_{pk} instead. See the Units of Measurement in the Acoustics Appendix (Appendix B) section for further detail.

[b] Fisheries Hydroacoustic Working Group 2008.

Regarding potential injury from explosives, Popper et al. (2014) present criteria for mortality and non-recoverable injury as a result of exposure to detonations. They note that it is difficult to disentangle the effects of the compressive forces of the shock wave (very close to the explosion) from the decompressive effect (area of negative pressure, further from the explosion), but either can lead to barotrauma or mortality in fishes. Several studies (e.g., Goertner [1978b]; Yelverton et al. [1975]) have worked with different species, with different charge sizes and water depths, all of which are important factors in predicting the effects of explosives. Yet Popper et al. (2014) derive their thresholds using data from an older study which represents the lowest amplitude that caused consistent mortality across species (Hubbs and Rechnitzer 1952). Therefore, for all fishes, regardless of hearing anatomy, the Lpk (peak pressure level) threshold for mortality and non-recoverable injury is given as a range: 229–234 dB re 1 micropascal (µPa) by Popper et al. (2014), but, in practice, 229 dB is generally used.

3.5.5.4.2 Thresholds for Behavioral Disturbance

NOAA Fisheries currently uses a sound pressure level (SPL) criterion of 150 dB re 1 µPa (dB relative to the pressure of 1 µPa) for the onset of behavioral effects in fishes (Greater Atlantic Regional Fisheries Office 2020). The scientific rationale for this criterion is not well supported by the data (Hastings et al. 2008), and there has been criticism about its use (Popper et al. 2019). Most notably, the differences in hearing anatomy among fishes suggest the use of a single criterion may be too simplistic (Popper 2023). Furthermore, a wide range of behavioral responses have been observed in the empirical studies thus far (ranging from startle responses to changes in schooling behavior), and it is difficult to ascertain which, if any, of those responses may lead to significant biological consequences. Interestingly, several studies on free-ranging fishes (Hawkins et al. 2014; Roberts et al. 2016) have observed the onset of different behavioral responses at similar received levels (Lpk-pk of 152–167 dB re 1 µPa), and Popper et al. (2019) suggest that a received level of 163 dB re 1 µPa Lpk-pk might be more

appropriate than the current SPL criterion of 150 re 1 µPa. Studies on spawning Atlantic cod showed no substantially altered behavior when exposed to distant seismic airguns at received levels between 115 and 145 dB re 1 µPa2 (McQueen et al. 2022). However, the same fish species were observed to decrease their activity levels and increase swimming depths when exposed to marine vibrator noise at the same exposure levels (McQueen et al. 2024). The authors suggest that the cod were probably more likely to be disturbed by continuous sounds than intermittent sounds. Finally, because most species are more sensitive to particle motion and not acoustic pressure, the criteria should, at least in part, be expressed in terms of particle motion. Overall, until there is further empirical evidence to support a different criterion, the 150 dB re 1 µPa SPL threshold remains in place as the interim metric that regulatory agencies have agreed upon.

3.5.6 Environmental and Anthropogenic Stressors

3.5.6.1 Noise

The potential sources of underwater noise from non-BOEM activities that may impact fishes and invertebrates include noise from natural (e.g., wind-driven waves and animal sounds) and anthropogenic sources (e.g., vessel noise from commercial shipping and fishing, inshore dredging and coastal construction). Of these, the most widespread and persistent source is vessel noise. A description of the relative presence of vessel noise in the Gulf soundscape can be found in **Section 3.7**. The most likely effects of distant and/or chronic vessel noise would be behavioral changes or acoustic masking.

Avoidance of vessels and vessel noise has been observed in several pelagic, schooling fishes, including Atlantic herring (Vabø et al. 2002), Atlantic cod (Handegard et al. 2003) and others (reviewed in De Robertis and Handegard [2013] and Pieniazek et al. [2023]). Fish may dive toward the seafloor, move horizontally out of the vessel's path, or disperse from their school (De Robertis and Handegard 2013). These types of changes in schooling behavior could render individual fish more vulnerable to predation but are unlikely to have population-level effects. A body of recent work has documented other, more subtle behaviors in response to vessel noise, but has focused mainly on tropical reef-dwelling fish. For example, damselfish antipredator responses (Simpson et al. 2016; Ferrari et al. 2018) and boldness (Holmes et al. 2017) seem to decrease in the presence of vessel noise, while nest-guarding behaviors seem to increase (Nedelec et al. 2017). There is some evidence of habituation, though: Nedelec et al. (2016) found that domino damselfish increased hiding and ventilation rates after two days of vessel sound playbacks, but responses diminished after one to two weeks, indicating habituation over longer durations. Subtle changes to social behaviors and communication, rather than dramatic effects, such as injury or mortality, are important for evaluating the potential consequences of noise on reproductive success and species survival. Data from a playback study on African cichlids showed that when exposed to pure tones of 100 Hz–2 kHz, the fish were less likely to interact with one another in territorial, courtship, or reproductive interactions, and females had a lower incidence of spawning and reduced hearing capabilities than non-exposed animals (Butler and Maruska 2020).

It is possible that vessel noise could induce physiological stress or lead to acoustic masking in fishes. Several studies have shown an increase in cortisol, a stress hormone, after playbacks of vessel noise (Wysocki et al. 2006; Nichols et al. 2015; Celi et al. 2016), but other work has shown that the handling stress of the experiment itself may induce a greater stress response than an acoustic stimulus (Harding et al. 2020; Staaterman et al. 2020). The cavitation of vessel propellors produces low frequency, nearly continuous sound that is audible by most fishes and invertebrates and could mask important auditory cues, including conspecific communication (Haver et al. 2021; Parsons et al. 2021). Stanley et al. (2017) demonstrated that the communication range of both haddock and cod (species with swim bladders but lacking connections to the ear) would be significantly reduced in the presence of vessel noise, which is frequent in their habitat in Cape Cod Bay. Vieira et al. (2021) found a reduction in acoustic energy of meagre chorusing, as well as a reduction in the ability to discriminate conspecific calls during the passage of a ferryboat, suggesting a significant masking effect of vessel noise which could impact spawning behavior (Vieira et al. 2021). Generally speaking, species that are sensitive to acoustic pressure would experience masking at greater distances than those that are only sensitive to particle motion. Rogers et al. (2021) and Stanley et al. (2017) theorize that fish may be able to use the directional nature of particle motion to extract meaning from short range cues (e.g., other fish vocalizations) even in the presence of distant noise from vessels.

The great diversity of aquatic invertebrates, compounded by a relative lack of research on vessel noise specifically, makes it difficult to draw broad conclusions about effects on this taxonomic group. However, a meta-analysis was conducted by Davies et al. (2024) to investigate how different acoustic stimuli influence aquatic invertebrates' behavior and physiology. The authors looked at 50 species being studied under a range of experimental conditions with four sound types: anthropogenic, environmental, synthetic, and music. The authors concluded that anthropogenic and synthetic sounds had detrimental effects on the animals that were exposed, while environmental sounds had slightly beneficial effects on their behavior (Davies et al. 2024). In a laboratory playback study, Putland et al. (2023) exposed three life stages of hummingbird bobtail squid to 15 minutes of vessel sound at 150 dB re 1 µPa, resulting in TTS and a decrease in ventilation rate for all life stages, which recovered in two hours. Some crustaceans seem to increase oxygen consumption (crabs: Wale et al. 2013) or show increases in some hemolymph (an invertebrate analog to blood) biomarkers like glucose and heat-shock proteins, which are indicators of stress (spiny lobsters: Filiciotto et al. 2014). Other species (American lobsters and blue crabs) showed no difference in hemolymph parameters but spent less time handling food, defending food, and initiating fights with competitors (Hudson et al. 2022). One study examined the impacts of noise on locomotor activity of burrowing animals and showed that to some extent, noise changed the way they mediate sediment dynamics (Solan et al. 2016). While there does seem to be some evidence that hearing, certain behaviors, and stress biomarkers in invertebrates could be negatively affected by vessel noise, it is difficult to draw conclusions from much of this work because it is limited to the laboratory, and in most cases, particle motion was not measured as the relevant cue.

3.5.6.2 Coastal Development and Lighting

Coastal development, which includes beachfront construction of homes, hotels, restaurants, harbors, and roads is a substantial contributor to coastal land use and/or modification not associated with BOEM-regulated activities. These developments can indirectly affect fishes and invertebrates through modification and/or loss of preferred habitat, with similar effects to those described later for BOEM-regulated activities under **Section 4.5.4** Coastal Land Use/Modification and **Section 4.5.3** Bottom Disturbance.

Artificial lighting from non-BOEM-regulated activities (e.g., from privately owned homes, hotels, public fishing piers, restaurants, and industry-related infrastructure, such as shipping and commercial fishery docks) creates lighting conditions that would not naturally occur in coastal areas. Though the effects to fish and invertebrates are not well understood, some studies suggest that artificial light can alter predator-prey interactions and negatively impact settlement site selection in coastal areas. Pathways to impact would be similar to those described for BOEM-regulated activities in **Section 4.5.7** Visual and Lighting Impacts.

3.5.6.3 Bottom Disturbance

The potential sources of bottom disturbance from non-BOEM activities that may impact fishes and invertebrates include vessel and buoy anchoring, moorings, military operations, artificial reef emplacement, dredging (e.g., for canals and harbors, or the harvest of sediment resources in state waters for beach restoration), trawling, and mass wasting. Of these, coastal dredging, either for new waterways or maintenance of existing waterways, is likely the bottom-disturbing activity most impactful to fishes and invertebrates. Potential effects to fishes and invertebrates are similar to those described for BOEM-regulated bottom-disturbing activities (e.g., physical crushing and increased turbidity; see **Section 4.5.3** Bottom Disturbance).

3.5.6.4 Fisheries Interactions

Commercial and recreational fishing directly affect the abundances of fish and invertebrates in the Gulf, although improvements in fishery management techniques and science have been able to improve stock levels for many commercially and recreationally valuable species. Several gear types, such as longlines (surface and bottom) and trawls (bottom and midwater), can result in the bycatch and mortality of many species that are important both ecologically as predators and/or prey and socioeconomically (e.g., juvenile red snapper, Atlantic croaker, and bluefin tuna). This can result in potential damage to future year-classes, reduce prey availability, and damage benthic habitat for many Gulf fish and invertebrate species. It is likely that a combination of factors including overfishing, bycatch in fishing gear, and other anthropogenic factors contribute to declines in populations (Diamond et al. 2000).

3.5.6.5 Vessel Strike

Vessel strikes to fishes and invertebrates may result from vessels not associated with BOEM-regulated activities, such as commercial shipping, recreational boating and fishing, commercial fishing, and cruise ships. Though larval fish and invertebrates with limited mobility may experience mortality from vessel strike, or may be temporarily displaced by vessel wake, the majority of the strike risk would be to large, surface-feeding fishes such as whale sharks. The potential impacts would be similar to those from vessels associated with BOEM-regulated activities and can be found discussed in more detail in **Section 4.5.9.4** Strikes and Collisions.

3.5.6.6 Climate-Related Factors

Higher water temperatures associated with increased carbon dioxide lead to sea-level rise, sea ice loss, increased ocean stratification, deoxygenation and eutrophication of coastal waters, and altered patterns of ocean precipitation, circulation, and freshwater input (Doney et al. 2012; Rodgers 2021). These factors disproportionately affect coastal areas, which is problematic for organisms such as shallow-water corals. Impacts to coastal habitats (e.g., coral reefs) have indirect effects to fish and invertebrates that rely on and use these habitats for foraging, reproduction, shelter, and cleaning stations (e.g., sharks and rays). Warming waters can lead to changes in size structure, spatial range, and seasonal abundance of organisms; they can also affect the distribution of parasites, pathogens, and invasive species, intensifying their proliferation and expanding their ranges (Marcogliese 2008; Doney et al. 2012). The introduction of nonnative species into the Gulf is well documented and includes both aquatic fish and invertebrates (e.g., Asian tiger shrimp and lionfish), which threaten ecosystems through competition, habitat displacement, and/or predation of endemic species.

Potential changes to spawning and migration behaviors of highly migratory species may also occur (Muhling et al. 2011). Northward expansions of tropical and subtropical fish species have been observed in the Gulf, which have potential to alter the ecology of existing ecosystems including food web and habitat interactions (Fodrie et al. 2010; Fujiwara et al. 2019; Purtlebaugh et al. 2020).

In addition to warming waters, excess carbon dioxide in the atmosphere is absorbed by the oceans, reducing ocean pH (i.e., ocean acidification) and carbonate ion concentrations, as well as altering the levels of calcium carbonite saturation. Experimental evidence suggests that changes in these levels may impair the ability of corals, calcareous phytoplankton, as well as the ability of larval mollusks and echinoderms to maintain their calcium carbonite skeletons (Orr et al. 2005; Hoegh-Guldberg et al. 2017), which has negative implications for fish and invertebrate habitat availability and trophic pathways (Doney et al. 2012).

Land loss, sea-level rise, and major storm effects can alter estuarine and coastal habitats which support a wide variety of fishes and invertebrates at various life stages. Important recreational and commercial fishes and invertebrates, including red drum, black drum, spotted seatrout,

southern flounder, blue crab, and penaeid shrimps, use estuarine habitats for some, or all, of their life cycle.

3.5.6.7 Disease

A variety of diseases impact fishes and invertebrates in the Gulf. As described in the previous section, warming waters may increase the proliferation of pathogens and subsequent disease in marine fishes and invertebrates. One of the challenges in determining the degree and extent of disease among fish and invertebrates is that impacted individuals may be more susceptible to predation, leading to their mortality and thus making the determination of disease prevalence difficult to discern. Additionally, compounded environmental factors may make it difficult to attribute mortality solely to disease, as is the case with harmful algal blooms (HABs) which not only produce toxins but also cause oxygen depletion in the marine environment (Overstreet and Hawkins 2017). Some diseases manifest through altered behavior, skin lesions, or other visible abnormalities, whereas others may remain less detectable externally.

The most prevalent toxic algae and their associated toxins in the Gulf include *Alexandrium monilatum* (goniodomin A), *Karenia brevis* (brevetoxins), *Karlodinium veneficum* (karlotoxins), *Prymnesium parvum* (prymnesins), and *Akashiwo sanguinea* (surfactants). *Cochlodinium polykrikoides* (ichthyotoxins), and raphidophyte species such as *Chattonella marina, Heterosigma akashiwo,* and *Fibrocapsa japonica* are other potential ichthyotoxic species (Overstreet and Hawkins 2017). *Karenia brevis* causes probably the most well-known HAB in the Gulf, known as “red tide”. These blooms are triggered by a combination of optimal environmental conditions for algal growth (e.g., temperature, light), and nutrient influxes (particularly nitrogen and phosphorus). These reddish blooms may result in large mortalities of fish and are also known to cause respiratory irritation and contact dermatitis in humans. Fish may undergo mortality when their gills encounter toxins (released when *K. brevis* cells lyse), when they ingest dinoflagellate cells, or when they ingest other contaminated biota (Overstreet and Hawkins 2017). Contaminated fish may exhibit vigorous twisting/corkscrew swimming, contractions, tail curvature, loss of equilibrium, slow and irregular opercular movements, quiescence, and sudden convolution leading to mortality (Kimm-Brinson and Ramsdell 2001).

Fish may have lesions (occasionally referred to as “red sore”, “tail rot”, “fin rot”, or “mouth rot”) as a result of predator wounds, trawling or other fishing activities, undesirable water quality, internal or external parasites, plasmid or viral infections, and bacterial infections. These lesions are particularly susceptible to new or secondary bacterial infection. *Vibrio* and *Pseudomanas* infections are most common, with several other types (e.g., *Aeromonas*, *Flexibacter*) present in lower salinity conditions. In addition to visible lesions, fish may exhibit exophthalmia (referred to as “bugeye”) in response to bacterial infection. However, exophthalmia may result from a variety of causes. Bacterial infections may result in rare but large mortality events (Overstreet and Hawkins 2017).

Viral infections (several strains) may result in lymphocystis in fish, wherein connective tissue cells in the skin hypertrophy and result in large, tumorous growths. These growths may be

external or occur internally on organs. Lymphocystis typically only affects a small number of individuals, but a wide variety. Fishes of the family Sciaenidae (drums) are most commonly affected by lymphocystis (Overstreet and Hawkins 2017). Though viruses may contribute to large mortality events, mortality may also be attributed to stress or some other condition.

Fungal infections may also present as ulcerative skin lesions in fishes. These lesions have been observed in striped mullet, silver mullet, black drum, sheepshead, and silver perch. There is less known about fungal infections in the higher-salinity offshore environment, although one study suggested that a fungal infection identified in the swim bladder and kidney of a red snapper individual may have been acquired during deflation of the swim bladder (using a hypodermic needle) after fishing capture (Overstreet and Hawkins 2017).

Gulf invertebrates also undergo a variety of disease stressors. Penaeid shrimps can undergo viral infections; more than 25 species of viruses have been documented (Overstreet and Hawkins 2017). Microsporidia, a phylum of unicellular spore-forming parasites related to fungi, also infect penaeid shrimps in the Gulf and can result in mass mortality events (Overstreet and Hawkins 2017). Black gill disease, which can be caused by a variety of sources including chemical irritants, viruses, bacteria, and fungi, but mostly attributable to ciliates, presents as darkened, damaged gill tissue and can cause mortality events in penaeid shrimps. For blue crabs, shell disease can occur when bacteria or fungi gain entrance to shells, manifesting as orange, brown, or black lesions. Stress from those lesions can prevent crabs from molting and result in mortality. For Eastern oysters, *Perkinsus marinus* (previously known as *Dermocystidium marinum,* or, for short, “dermo”) is the most impactful parasitic agent in the Gulf. The impact of *P. marinus* varies from location to location according to freshwater inflow, salinity, temperature, genotype of the infectious agent, and possibly on interaction with specific contaminants (Overstreet and Hawkins 2017; Silvy et al. 2020). *P. marinus* can cause reduced feeding, growth, and reproduction in oysters and increase their vulnerability to predation. *Vibrio* bacteria is also known to infect Eastern oysters and can cause larval mortality and also concentrate in adult tissues, posing a health risk for human consumption (Overstreet and Hawkins 2017).

3.5.6.8 Marine Debris, Pollution, and Runoff

Marine debris, pollution, and runoff from sources not associated with BOEM-regulated activities may include fresh water, wastewater, stormwater runoff, gray water from vessels, chemical wastes, nutrients (e.g. nitrogen and phosphorus), dredged material, and other materials (e.g., trash, including plastics). These inputs can alter habitat suitability for fishes and invertebrates. Pathways to impact would be similar to those described for BOEM-regulated activities and can be found discussed in more detail in **Section 4.5.2** Discharges and Wastes, **Section 4.5.9.1** Accidental Releases, and **Section 4.5.9.3** Marine Trash and Debris.

3.6 SEA TURTLES

Five species of sea turtles occur in the Gulf: the loggerhead turtle; green turtle; hawksbill turtle; Kemp's ridley turtle; and leatherback turtle. All are ESA-listed as Threatened or Endangered. The Northwest Atlantic Ocean Distinct Population Segment (DPS) of loggerhead turtle Figure 3-18and the North Atlantic DPS of green turtle are ESA-listed as Threatened. 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 are federally designated under the ESA as critical habitat for loggerhead turtles (79 FR 39856) (**Figure 3-18**). On July 19, 2023, NMFS proposed to designate specific areas in the marine environment as critical habitat for six of the DPS of green sea turtle (88 FR 46572). Proposed critical habitat includes nearshore areas, extending from the mean high-water line to a depth of 20 m (66 ft), along the coasts of Florida, Texas, North Carolina, Puerto Rico, U.S. Virgin Islands, California, Hawai'i, American Samoa, Guam, and the Commonwealth of Northern Mariana Islands for both North and South Atlantic DPSs. It also includes *Sargassum* habitat, from a depth of 10 m (33 ft) to the outer boundary of the U.S. EEZ in the Gulf (88 FR 46572). 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.

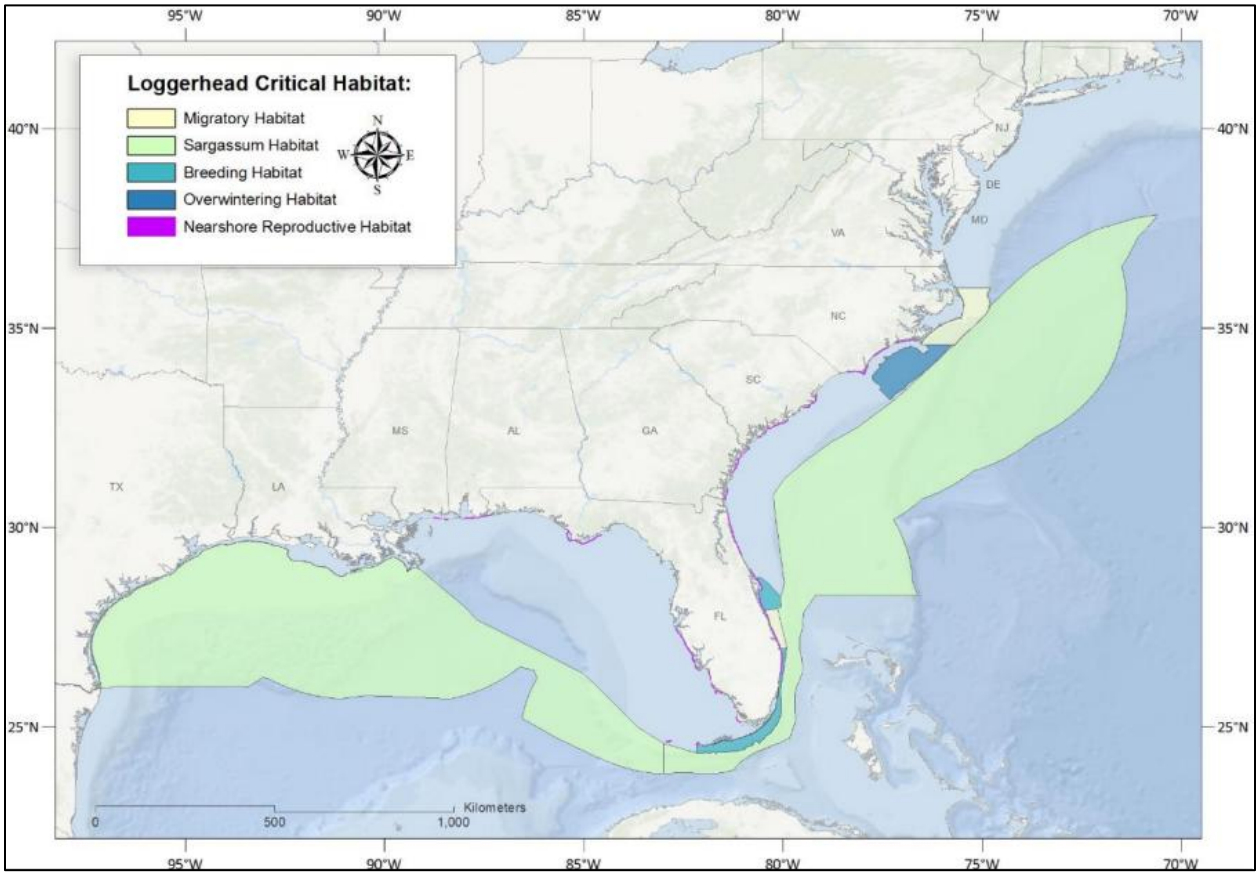


Figure 3-18. Loggerhead turtle critical habitat.

Source: Map of the critical habitat for the Northwest Atlantic Ocean Distinct Population Segment of loggerhead turtle (NOAA Fisheries 2022).

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, Gulf, and Caribbean Sea. Important marine habitats for sea turtles in the Gulf include nesting beaches, estuaries and embayments, nearshore hard substrate areas, and the Gulf Stream (Valverde and Holzwart 2017). There is a diversity in habitat use across species (Hart et al. 2018), geographic regions (Hatase et al. 2002; Hart et al. 2018), and among individuals (Vander Zanden et al. 2010). Lamont and Johnson (2021) and Siegfried et al. (2021) identified species and habitat as the best indicators for size distribution, including artificial habitats such as reefs, jetties, and piers along with marine ecosystems. Loggerheads and larger turtles, such as leatherbacks, were documented in coastal bay seagrass meadows; green and smaller turtles were found in nearshore sand-bottom habitats. This habitat is believed to be optimal for immature Kemp's ridley and loggerhead turtles (Lamont and Johnson 2021; Shaver et al. 2022). Among these habitats, the Gulf Stream System strongly influences recruitment to sea turtle nesting aggregations, affecting the overall population structure (Lasala et al. 2023). Similarly, in the Gulf, the Loop Current connects with the Gulf Stream after passing near the western coast of Florida, which may explain the increased nesting observed along Florida's western coast compared to other Florida rookeries (Lasala et al. 2023).

Barrier islands and mainland beaches in the Gulf also provide important nesting habitat for sea turtles (Valverde and Holzwart 2017). The significance of barrier islands as a nesting habitat is underscored by recent studies highlighting the Chandeleur Islands, Louisiana, which play a crucial role in supporting populations of loggerheads and Kemp's ridleys. This chain of barrier islands benefits from protection through the Breton National Wildlife Refuge, and their remote location helps limit access to anthropogenic disturbances (Lamont et al. 2023b; Welsh et al. 2023). These islands provide undisturbed sandy habitats for nesting sea turtles, a resource that is increasingly rare due to climate-related factors (**Section 3.6.8.5**) and coastal development (**Section 3.6.8.2**). These species rely on coastal (**Section 3.2**) and pelagic waters (**Section 3.3**) for foraging needs (Fritts et al. 1983a; 1983b; Collard 1990; Bjorndal 1997; Godley et al. 2008; NMFS and FWS 2015).

Roberts et al. (2022), using data from a 10-year time period, examined the time different species of sea turtles spend in the top 2 m (7 ft) of the water column. Turtles were captured and tagged in the northern Gulf in locations along the Florida, Alabama, Mississippi, Louisiana, and Texas coasts. The study evaluated environmental and oceanographic parameters to assess if these parameters were predictive for time at surface, and developed a model to examine the potential connection between turtle dive time and ocean frontal zones (Roberts et al. 2022). The results of the study indicate that that Kemp' ridley sea turtles spent on average 18 percent of their time at surface with no seasonable variability. Loggerhead sea turtles spent on average 16 percent of their time at surface, peaking during summer (Roberts et al. 2022). Green sea turtles spent an average of 19 percent of their time at surface, peaking during summer. The time at surface peaks for both loggerhead and green sea turtles coincided with nesting season

(Roberts et al. 2022). Modeling results seemed to support surface use during fronts for loggerheads and green turtles. The frontal surface use was thought to be associated with increased productivity in these areas (Roberts et al. 2022). The loggerhead and Kemp's ridley times at surface are similar to numbers previously reported.

The northeastern Gulf is an important foraging ground during the developmental stages for both loggerheads and green sea turtles (Wildermann et al. 2019). For instance, seagrass beds provide foraging habitat for sea turtles (Ward and Tunnell Jr. 2017). *Sargassum* mats provide food and protection from predation for a wide spectrum of fauna, including juvenile sea turtles (Dooley 1972; Casazza and Ross 2008). 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 to 100s of km; 6.2 to over 62 mi] regions of persistent frontal activity, i.e., Gulf Stream), then use the habitat as foraging grounds and protection during their pelagic "lost years" (juvenile years during 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 are known for their large head and powerful jaws that enable them to feed on hard-shelled prey, such as whelks and conch. Loggerheads are a large species: an adult may weigh 91–159 kg (200–350 lbs), and have a slightly heart-shaped carapace length of 0.76–1.06 m (2.5–3.5 ft) (NOAA Fisheries 2025j). Adults and sub-adults typically have a pale yellowish plastron and a reddish-brown carapace covered by non-overlapping scutes that meet along the seam lines. Hatchling loggerheads are mostly dark brown with a yellowish-tan plastron and flippers with white to white-gray margins. Loggerheads go through eight distinct life stages. The Recovery Plan for the Northwest Atlantic Population identified specific ecosystems for each stage: (1) egg (terrestrial zone), (2) hatchling stage (terrestrial zone), (3) hatchling swim frenzy and transitional stage (neritic zone), (4) juvenile stage (oceanic zone), (5) juvenile stage (neritic zone), (6) adult stage (oceanic zone), (7) adult stage (neritic zone), and (8) nesting female (terrestrial zone) (NMFS and FWS 2008). Loggerheads are long-lived, reaching sexual maturity at between 20 and 38 years of age, and can live to 70 to 80 years or more (NOAA Fisheries 2025j).

Loggerhead turtles range from tropical to temperate regions globally, with nine DPSs. The Gulf is an important area for this species. Loggerheads are one of the most commonly occurring sea turtle species in the Gulf, with critical habitat designations for beaches and coastal waters in Florida, Alabama, and Mississippi (**Figure 3-18**). The northeastern Gulf coastline represents 90 percent of the nesting habitat for the Northwest Atlantic subpopulation of loggerhead turtle (Ceriani and Meylan 2017).

In the Gulf, loggerhead turtles have been sighted primarily in waters above the continental shelf, although many surface sightings have occurred in the outer slope beyond the 1,000 m (3,281 ft) 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 nonnesting years, adult females from U.S. beaches are distributed in waters off the eastern U.S., Gulf, Bahamas, Greater Antilles, and Yucatán (Conant et al. 2009).

Loggerheads are the most observed turtle in FGBNMS; the majority of sightings are at the EFGB (Hickerson 2001). In 2000, a population of large juvenile loggerheads was documented residing in and moving near the EFGB and WFGB (Hickerson 2000). Hatchlings and/or post-hatchlings, large juveniles, and adults are present at FGBNMS (Hickerson 2000); large juveniles appear to be the most common, while hatchlings and/or post-hatchlings sometimes pass through on *Sargassum* mats (Hickerson 2001). FGBNMS reefs may provide a temporary residence for juveniles approaching maturity as they prepare to move to adult feeding areas (Office of National Marine Sanctuaries 2008). Loggerheads use the shallow reef crest to rest and forage on deeper areas of the reef (Hickerson 2000). They have been documented to show strong site fidelity (Hickerson and Peccini 2000). Loggerheads are typically observed in FGBNMS during the late afternoon or night, resting under ledges or coral heads (Office of National Marine Sanctuaries 2008). For instance, they have been observed feeding on sponges at Stetson Bank. They have also been observed on the surface catching a breath (Office of National Marine Sanctuaries 2008).

Loggerheads mate in late March through early June in the southeastern U.S. They migrate to their natal beaches to mate (NMFS and FWS 2023). The mean clutch size for loggerheads is 100–126 eggs per nest, with an average of 4.1 nests/nesting individuals per nesting season (Murphy and Hopkins 1984; NMFS 2013).

Benscoter et al. (2022) quantified the number of nesting loggerhead sea turtle females that were <87 cm (34 in) curved carapace length notch (CCL-n). A CCL-n of >87 cm (34 in) has been previously used as the size classification for reproducing females and is used in the estimates provided in the Recovery Plan for the Northwest Atlantic Ocean population (NMFS and FWS 2008). Nesting loggerhead females were evaluated at three sites that represent different segments of the Northwest Atlantic population: Gulf Shores, Alabama; Dry Tortugas National Park; and Everglades National Park, which each represent an individual Recovery Unit (RU) (Benscoter et al. 2022). The CCL-n of the smaller-sized nesting loggerhead females ranged from 74.0–86.9 cm (29–34 in). Thirteen percent of the loggerheads nesting on beaches at the three sites were smaller than the standard size considered to be a reproductive female for this species in this region (Benscoter et al. 2022). The smaller reproductive females behaved differently than their larger counterparts; specifically, they exhibited shorter migration distances and migrated along shallower depths compared to the larger (>87 cm (34 in) CCL-n) reproductive females. The authors hypothesize that the smaller sizes of nesting loggerhead females in the three RUs in the Northwest Atlantic may be indicative of slower growth rates and/or maturation at younger ages, which may represent a shorter juvenile stage for these turtles.

The Northwest Atlantic DPS nesting trend appears to be stable (i.e., not increasing or decreasing) for over twenty years (NMFS and FWS 2023). 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 Jr. 1988). In the western Atlantic, loggerhead sea turtles nest in southeast U.S. and Wider Caribbean Region beaches (NMFS and FWS 2023). In the Gulf, major nesting areas include some coastal beaches in Mississippi, Alabama, and Florida. Reproductive adult females return to their original hatching site to nest. In a study by Ceriani et al. (2019), nest counts from 1989 to 2018 were collected on core beaches representing the Peninsular Florida RU (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) and the bulk of the Northern Gulf RU. The results of this study suggest that despite the fluctuation in nest counts over this thirty-year period, a strong population recovery has not occurred. Florida is considered to be the most important loggerhead nesting area in the world; the Florida Peninsula RU (NMFS and FWS 2008) accounts for approximately 89 percent of all nesting effort in the Northwest Atlantic Ocean DPS (Ceriani et al. 2019).

The Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) gathered broad-scale information on the distribution and abundance of sea turtles in the Gulf to inform seasonally- and spatially-explicit density estimates for priority species (Lamont and Hart 2023). For loggerhead turtles, GoMMAPPS found that turtle density was highest in shallow waters near the shore in the northeastern Gulf and central Gulf with a rapid decline in waters deeper than 100 m (328 ft). This study also revealed that SSTs influenced turtle density (Lamont and Hart 2023). Before GoMMAPPS, satellite tracking efforts with adult female loggerheads showed that northern Gulf loggerheads exhibit relatively low nesting site fidelity to both within (i.e., inter-nesting) and among (i.e., re-migration) nesting seasons (Hart et al. 2013; 2014). The satellite-tracked females remained in the northern and northeastern Gulf during the inter-nesting period, moving as far as 2,837 km (1,763 mi) during that approximately two-week period and depositing successive nests that were more than 400 km (249 mi) apart (Hart et al. 2013). After completing the nesting season, all tracked females remained within the Gulf and most traveled to foraging locations in southwest Florida and the northern Gulf (Hart et al. 2014). These foraging areas also have potential to overlap with several anthropogenic activities, including shipping vessels, oil and gas platforms, shrimp trawlers, and deepwater aquaculture (Hart et al. 2018; Farmer et al. 2022).

Loggerhead juvenile developmental habitat is in the open ocean (NMFS and FWS 2023). Offshore, they reside for months in the oceanic zone on *Sargassum* floats, generally along the Loop Current and the west coast of Florida. Hart et al. (2020) and Sloan et al. (2022) identified the Big Bend region off the northwest Florida coast as a crucial year-round foraging site for migrating post-nesting loggerheads from several DPSs. The West Florida Shelf features highly productive and biologically diverse marine habitats, which have become crucial foraging grounds for this species (Hart et al. 2020). This research suggests the importance of nearshore habitats on the Gulf continental shelf, which function as long-term and year-round foraging hotspots for multiple sea turtle species, indicating the significance of these areas as critical

habitat (Hart et al. 2020) (**Figure 3-18**). Additionally, this study identified a range of individual variation in home range size; larger home ranges were in greater water depths.

Foraging location depends on life stage and foraging strategy (NMFS and FWS 2023). 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 in neritic habitats commonly forage in nearshore coastal waters, coastal inlets, sounds, bays, estuaries, lagoons, and along the continental shelf during the spring, summer, and fall months from Cape Cod, Massachusetts to Florida, and into the Gulf; during winter, they are found off the coast from North Carolina to Florida (NMFS and FWS 2023). Juveniles are omnivorous; they forage on crabs, mollusks, jellyfish, and vegetation at or near the surface (Dodd Jr. 1988). Subadult and adult loggerheads forage primarily in coastal areas 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 Gulf 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.

Iverson et al. (2020) identified migration corridors of post-nesting female adult loggerhead turtles in the Gulf and Florida Straits, and overlaid the corridors on shipping density, commercial line fishing, and shrimp trawling data. This yielded hotspots in the Florida Straits, off the northwest Florida coast, and off the Tampa Bay coast. Loggerheads migrated in neritic and oceanic waters, with some leaving the Gulf (Iverson et al. 2020). Neritic waters west of Florida and in the Florida Straits were observed to be high-use migration corridors, with migration mainly occurring in July and August.

In 2022, a mass mortality event for loggerhead sea turtles occurred in Texas, resulting in 441 recorded beach-cast strandings (Stacy et al. 2024). This number represents only a fraction of the at-sea mortality, suggesting that the total number of affected turtles may have been in the hundreds or thousands (Stacy et al. 2024). The recorded number of turtles stranded were found in diminished nutritional condition, exhibiting signs of secondary infections and heavy parasitism. Though various chronic conditions and intense parasitism accounted for several strandings, the majority could not be linked to any clear primary or underlying causes (Stacy et

al. 2024). By excluding other causes, environmental factors including degradation of habitat and changes in prey availability were the primary considerations. The main potential contributing cause of this mass mortality event was considered to be a limitation in food resources, as evidenced by the nutritional deprivation consistent with clinical and postmortem findings (Stacy et al. 2024). Additionally, the recovery of live-stranded sea turtles with dietary support further supported this conclusion. Stacy et al. (2024) indicated that limitations in the abundance and distribution of prey were due to the large hypoxic zone (dead zone) that forms in the Gulf each summer (**Section 3.2.9** and **3.3.1.1**). This zone reduces the levels of DO in aquatic ecosystems beyond what most species need to survive, significantly disrupting these ecosystems and leading to increased mortality, reduced growth, diet shifts, and changes in migration patterns in species affected (Stacy et al. 2024). The first peak in loggerhead strandings in Texas occurred in the spring of 2022, which does not correspond temporally or spatially with cold stunning events.

3.6.2 Kemp's Ridley Sea Turtle

Kemp's ridley turtles are the smallest of all sea turtles, growing up to 0.6 m (2 ft) in carapace length and weighing (32–45 kg) 70–100 lbs. This species' coloration varies during development from the gray-black dorsum and plastron of hatchlings, a gray-black dorsum with a yellowish-white plastron as post-pelagic juveniles, and then to the lighter gray-olive carapace and cream-white or yellowish plastron of adults (NOAA Fisheries 2025g). Kemp's ridley turtles have triangular-shaped heads, slightly hooked beak, and shells that are typically as wide as they are long. They are estimated to have a lifespan comparable to other sea turtle species, reaching sexual maturity around 7 to 15 years of age and potentially living for at least 30 years (Turtle Expert Working Group 1998; NOAA Fisheries 2025g).

Kemp's ridley habitat consists largely of sandy and muddy areas in shallow, nearshore waters less than 37 m (120 ft) deep, although they can also be found in deeper offshore waters. Kemp's ridley turtles are one of the most commonly occurring sea turtle species in the Gulf, which is their primary range. However, they are considered the most endangered sea turtle species globally. The Kemp's ridley turtle has a more restricted distribution through its life stages relative to other sea turtle species. Data suggests that Kemp's ridleys are found mainly in coastal Gulf 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).

Kemp's ridley nesting is limited predominately to western Gulf beaches, mainly in Tamaulipas, Mexico (NMFS and FWS 2015). Nesting sites in the U.S. include primarily Texas, and occasionally Florida, Alabama, Georgia, South Carolina, and North Carolina (NMFS and FWS 2015). Nearshore Gulf waters likely provide important developmental habitat for juveniles. Gredzens and Shaver (2020) observed the foraging behavior of adult female Kemp's ridleys, finding that they preferentially selected nearshore foraging areas in the northern Gulf. These turtles demonstrated fidelity to these regions, migrating back to the same foraging sites they had used previously. 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 Gulf. The Texas-Louisiana Shelf and off the Mississippi River Delta in the northern Gulf have been identified as heavily used foraging areas for adult Kemp's ridleys, as well as new areas being observed along the Atlantic coasts of Florida and Georgia (Gredzens and Shaver 2020).

Juvenile and subadult Kemp's ridleys have been found along the Eastern Seaboard of the U.S. (Epperly et al. 2007) and in the Gulf (NMFS and FWS 2015). Atlantic juveniles and sub-adults travel northward in the spring as waters warm to feed in the productive, coastal waters of Georgia through New England, then returning southward with the onset of winter to escape the cold (Ogren 1989; NMFS and FWS 2015). Gredzens and Shaver (2020) suggested that oceanic circulation patterns may influence the dispersal of hatchlings, affecting where individuals recruit to forage as adults. These circulation patterns may explain the preferential use of the northern Gulf. Along the Louisiana coast, immature Kemp's ridleys migrate to warmer nearshore waters during winter months (Coleman et al. 2016).

The only historic nesting sites for Kemp's ridleys in the world are found along the Gulf coast of northern Mexico (Shaver 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, in the state of Tamaulipas (NMFS and FWS 2015). Hatchlings leave the nest at night and actively swim offshore into the anticyclonic Mexican Current and into the northern Gulf. 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. Between 1997 and 2009, the number of nests observed globally increased significantly, reaching nearly 20,000 nests worldwide, compared to just 705 nests recorded in 1985 (NPS 2018). This trend was also observed on the Texas coast with an increase of Kemp's ridleys nests from 6 to 209 between 1996 and 2012. This increasing trend, however, has not been long lasting and since 2010 has been fluctuating at reduced levels (NPS 2018). In the Gulf, juvenile and/or subadult Kemp's ridleys occupy shallow, coastal regions. Little is known of the movements of the post-hatching, planktonic stage within the Gulf, 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 a 20- to 60-cm (8- to 24-in) straight-line carapace length are found in nearshore coastal waters, including Gulf and Atlantic estuaries.

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 Gulf, though occasionally swim into the Atlantic along the U.S. East Coast (NMFS and FWS 2015). Pelagic-stage, neonatal Kemp's ridleys presumably feed on available *Sargassum* and associated infauna or other epipelagic species found in the Gulf (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).

The northern Gulf has been recorded as a high-use foraging area for post-nesting Kemp's ridley turtles, which have showed high fidelity to this area (Gredzens and Shaver 2020; Sasso et al. 2021; Shaver et al. 2022). Weber et al. (2023) conducted a stable isotope study to investigate the foraging ecology of Kemp's ridley turtles, providing insights into the trophic and spatial dynamics of this species. The study revealed a significant difference in isotopic values between smaller and larger size classes, indicating that different sizes of Kemp's ridleys occupy distinct spatial and trophic niches. Larger turtles displayed a wider range of isotopic values, suggesting greater plasticity in their foraging strategies (Weber et al. 2023). In contrast, smaller Kemp's ridleys, still in the juvenile stage, appeared to forage at lower trophic position compared to the larger class size. This difference suggests that the two classes may prefer different prey items or use different habitat communities within the same foraging area (Weber et al. 2023).

A study by Garrison et al. (2020) found that dive-surface behaviors for Kemp's ridleys in the northern Gulf indicated important seasonal, diurnal, and spatial effects on time at 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.

Variation in dive behavior in sea turtles has been documented relative to body size (Hays et al. 2004)**.** Larger turtles may have greater lung capacity that may allow them to remain submerged longer and dive deeper than smaller turtles (Hays et al. 2004). Sasso and Witzell (2006) found that juvenile Kemp's ridleys in the Ten-thousand Islands, Florida spent 94 percent of their time submerged, which is a much greater proportion of time than was documented during GoMMAPPS for the relatively larger Kemp's ridleys tagged in the northern Gulf (54 percent) (Rappucci et al. 2023). The Ten-thousand Islands is a chain of islands and mangrove islets along the southwest Florida coast characterized by shallow water and soft-bottom habitats, whereas the Kemp's ridleys tracked for GoMMAPPS were captured and tracked primarily in deeper waters of the open Gulf. Along with the habitat type, body size of Kemp's ridleys differed between turtles tracked for GoMMAPPS (Rappucci et al. 2023) (mean 57.8 cm; 22.8 in, range 40.3–67.8 cm; 15.9–26.7 in CCL) and those tracked in the study by Sasso and Witzell (2006) (mean 46.2 cm; 18.2 in, range 40.2–54.1 cm; 15.9–21.3 in CCL).

3.6.3 Green Sea Turtle

The green sea turtle is the largest of the hardshell marine turtles, with a typical adult weighing 136–226.8 kg (300–350 lbs) and growing to a straight carapace length of 91–122 cm (3–4 ft) (NOAA Fisheries 2025e). Green sea turtles have a smooth carapace with four pairs of lateral (or costal) scutes, five scutes running down the middle and a single pair of elongated prefrontal scales between the eyes (NOAA Fisheries 2025e). Green turtles that are found throughout the Gulf belong to the North Atlantic DPS along with other populations found in the Caribbean and North Atlantic Ocean (81 FR 20058; NMFS and FWS 2007). There are 11 DPSs listed under the ESA, covering over 80 countries where they nest and more than 140 countries where they live.

Green sea turtles live in nearshore tropical and subtropical waters where they generally feed on marine algae and seagrasses. They have specific foraging grounds and may make large migrations between these forage sites and nesting beaches.

Green sea turtle breeding season occurs in late spring in the nearshore waters of the nesting beaches. Mature females migrate to return to their natal beaches to nest, typically occurring every two to five years, while males are known to reproduce every year (NOAA Fisheries 2025e). 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). The two largest nesting populations are found at Tortuguero, on the Caribbean coast of Costa Rica, and Raine Island, on the Pacific Coast of Australia along the Great Barrier Reef. The Gulf coast and offshore waters are important nursery habitats for green turtles of Mexican origin. Shamblin et al. (2023) connected mitochondrial DNA markers between green turtle nesting populations and juvenile foraging aggregations indicating that juvenile green turtles in the Gulf were of Mexican origin, possibly from nesting populations from Campeche, Yucatán, and Quintana Roo.

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 to 115 eggs. Eggs incubate for approximately two months before hatching. Hatchling green sea turtles are approximately 5 cm (2 in) in length and weigh approximately 25 grams (g) (0.9 ounces [oz]). Survivorship at any nesting site is greatly influenced by the level of anthropogenic stressors.

The post-hatchling, pelagic-stage individuals are thought to be omnivorous (NMFS and FWS 2007). Green sea turtles exhibit particularly slow growth rates of about 0.20–0.42 cm (0.08–0.17 in) per year (Omeyer et al. 2017). Once the juveniles reach approximately 20–25 cm (8–10 in) carapace length, they leave the pelagic habitat and travel to nearshore foraging grounds, such as protected lagoons and open coastal areas rich in sea grass and marine algae. Green turtles spend most of their lives in coastal foraging areas, where they consume mainly marine algae and seagrass, though some populations also forage highly on invertebrates (NMFS and FWS 2007). Coastal foraging areas and oceanic habitats are used by oceanic-stage juveniles, migrating adults, and, on some occasions, by green turtles foraging in the oceanic zone (NMFS and FWS 2007).

Age at sexual maturity for green turtles is estimated to be between 20 and 40 years, and they can live for 70 years or more (NOAA Fisheries 2025e). 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 2007). Foraging has been observed during the inter-nesting period, with these sites typically located close to the nesting sites to minimize energy expenditure (Sloan et al. 2022). While in coastal habitats, green turtles exhibit site fidelity to specific foraging and nesting grounds, and they are capable of “homing in” on these sites if displaced (McMichael et al. 2003; Hart et al. 2013). Foraging areas along the northern Gulf include shallow, coastal waters with sufficient benthic vegetation such as seagrass.

Reproductive migrations of Florida green turtles to hotspot locations such as Cape Sable, Florida Bay, and the Marquesas Keys have been identified. The core nesting areas have seagrass beds, which also function as foraging sites when forage is available. Research has identified Florida's Big Bend region, a northern Gulf marine hotspot, as key nearshore foraging habitats for green turtles during inter-nesting and foraging periods from their nesting beaches (Hart et al. 2020; Sloan et al. 2022).

GoMMAPPS turtle tracking revealed use of nearshore northern Gulf habitat during the breeding season, the use of migratory pathways that included stopover areas in seagrass habitat along the eastern Gulf, and residence at foraging areas located primarily in the Florida Keys (Lamont et al. 2023a). These sites have also been linked to existing Marine Protected Areas (MPAs). MPAs for protected seagrass habitats provide foraging resources during the inter-nesting, along migratory pathways and at foraging home ranges (Lamont et al. 2023a). Lamont et al. (2023a) identified 23 MPAs that were used during migration in the northern Gulf during green turtle migration.

During migration, some turtles were observed visiting Cape Sable along their migration route and others remained in the area for longer periods of time before initiating migration (Sloan et al. 2022). While individual behavior was observed during migration and nesting season, there was a strong site fidelity to Cape Sable, identifying it as a core use area (Sloan et al. 2022). Migration to core use areas were observed to occur in shallow waters close to the shoreline, hypothesized to reflect the oceanic drift experienced by the individuals during their earlier years as hatchlings (Sloan et al. 2022).

3.6.4 Hawksbill Sea Turtle

The hawksbill sea turtle is small to medium sized, with adults weighing 45–68 kg (100–150 lbs) and ranging 61–107 cm (2–3.5 ft) in carapace length. The carapace of hawksbills typically has seated edges with overlapping scutes consisting of irregular color combinations of amber, orange, yellow, red, black, and brown (NOAA Fisheries 2025f). Due to this coloration, known as "tortoise-shell", hawksbills are illegally hunted for their highly sought-after shells. The plastron of a hawksbill is typically yellow, and its head is elongated, tapering to a point, which gives it a hawk-like appearance. This beak-like mouth is specially adapted for feeding, allowing hawksbills to reach into crevices and spaces within coral reefs to find sponges, their primary food source as adults, and other invertebrates. Hawksbill turtles have an unknown lifespan but are estimated to live to 50 years or more and reach sexual maturity at 20–35 years of age, depending on resource availability (NOAA Fisheries 2025f).

In the continental U.S., hawksbill turtles have been documented along the East Coast as far north as Massachusetts and along all Gulf Coast states, though they are found primarily along Florida and Texas. Hawksbills spend time in pelagic and coastal areas but use a variety of habitats during different stages of their life cycle; this species is primarily tropical and subtropical, inhabiting nearshore foraging grounds, especially healthy coral reefs (NOAA Fisheries 2025f). Hawksbill turtles can be found living in nearshore habitats in all the world's

major oceans, specifically between the latitudes of 30°N and 30°S (NOAA Fisheries 2025f). Their movement patterns are not fully understood, but it is believed hawksbills can be found in coastal waters of more than 108 countries by using a mixed migration strategy (NMFS and FWS 2013a).

Nesting occurs on sandy beaches throughout the tropics and subtropics in at least 70 countries. Reproductive females undertake periodic (usually nonannual) migrations to their natal beach to nest every 2–5 years (NMFS and FWS 2013a). 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. Though nesting occurs along the beaches throughout the world's oceans, and the most nesting occurs on beaches of the Caribbean Sea, hawksbill nesting is rare on northern Gulf beaches (Mays and Shaver 1998; FWS 2015a). Like other species of sea turtles, hawksbills exhibit strong fidelity in their choice of nesting sites (NMFS and FWS 2013a). Females nest an average of 3–5 times per season, and the mean clutch size is 130 eggs (NMFS and FWS 2013a). Post-nesting females have been presumed to travel less than 200 km (124 mi), while others have been documented migrating distances exceeding 2,000 km (1,243 mi) (NMFS and FWS 2013a). Throughout her lifetime, a female hawksbill turtle may lay between 9 and 60 clutches of eggs, totaling 1,170 to 7,800 eggs (NMFS and FWS 2013a).

Hawksbills exhibit slow growth rates that often vary within and among populations because of such factors as prey quality and abundance, foraging habitat, duration of foraging season, population density, and resource competition (NMFS and FWS 2013a). Hawksbills growth rates vary depending on their location, with growth rates of 2–4 cm (0.8–1.6 in) per year in the Caribbean, with other sites averaging over 5 cm (2 in) per year (NMFS and FWS 2013a). To generate straight carapace length (SCL)-at-age and somatic growth data, Avens et al. (2021) conducted skeletochronical analysis for hawksbills stranded along U.S. coastlines. Juveniles transitioned from oceanic to neritic habitat at 1–3 years old and mean SCLs of 23–24cm (9–9.4 in) (range 15.7–35.0 cm; 6–14 in). The estimated initial ages at maturation for this population, based on the initial nesting female SCLs, ranged from 15–25 years (Avens et al. 2021). Somatic growth showed significant variation depending on size, age, and stranding location, with no notable association to sex or calendar year.

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 20–30 cm (7–12 in) in SCL (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 (NMFS and FWS 2013a). 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 (NMFS and FWS 2013a). 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 Gulf may prevent hawksbills from establishing a substantial population in this area.

3.6.5 Leatherback Sea Turtle

Leatherback turtles are the largest turtle in the world and the only species of sea turtle that lack scales and a hard shell. Named for their tough skin, leatherback turtles are the most pelagic of all sea turtles, and have the widest distribution range of any sea turtle. Leatherbacks are primarily black, with rubbery skin and pinkish-white coloring on its underside. The carapace of this species is made up of small, interlocking dermal bones beneath thick 3.8 cm (1.5 in) leathery, oil-saturated connective tissues, which rest on a supportive layer of connective tissue and fat, as well as the deeper skeleton. The carapace features seven ridges running its length and tapers to a blunt point. An adult leatherback turtle can weigh anywhere from 340–454 kg (750–1,000 lbs) with a CCL often exceeding 1.5–1.8 m (5–6 ft). Another distinguishing feature of this species is the length of its front flippers. Compared to other sea turtles, their front flippers are proportionally longer, and their paddle-shaped back flippers contribute to a unique body shape, specifically adapted for long distance foraging migrations (NOAA Fisheries 2025h).

Leatherback distribution and nesting grounds are found in the waters of the Atlantic, Pacific, and Indian Oceans; the Caribbean Sea; and the Gulf (NMFS and FWS 2013b). The leatherback is the most abundant sea turtle in waters over the northern Gulf continental slope (Mullin and Hoggard 2000). Leatherbacks appear to use the continental shelf and slope habitats in the Gulf (Collard and Ogren 1990). The area of Mississippi Canyon to De Soto Canyon, especially near the shelf edge, appears to be an important habitat for leatherbacks in the northern Gulf (Mullin and Hoggard 2000). Leatherbacks have frequently been sighted in the Gulf during autumn, summer, and winter (Mullin and Hoggard 2000; Sasso et al. 2021). Sasso et al. (2021) identified leatherback turtle migration and foraging behavior during the autumn and winter months along the west Florida continental shelf. Turtles migrating along the shelf appeared to forage while in route; turtles migrating across the central Gulf followed more direct southward routes until reaching the continental shelf in the southern Gulf (Sasso et al. 2021). These movement patterns highlighted the passage between Cuba and the Yucatán as a crucial migration corridor, linking nesting beaches in Central and South America to the Gulf. The area's high usage and its relevance to nesting sites make it an important region for leatherback migration (Sasso et al. 2021).

GoMMAPPS observed leatherback turtles during all seasons, but nearly all sightings in winter and spring were east of the mouth of the Mississippi River (Rappucci et al. 2023). Sightings usually occurred more frequently in offshore waters with lower chlorophyll-a concentrations. Leatherback density was higher in offshore waters deeper than 50 m (164 ft) (Rappucci et al. 2023). The effect of the distance from continental shelf edge shows higher density in the middle of the continental shelf. The SST effect reflects the higher densities and wider distribution throughout the area observed in the summer and fall with lower density in the central northern Gulf during the winter (Rappucci et al. 2023). The regional east-west shelf

factor indicated differences in leatherback turtle densities between the areas east and west of the mouth of the Mississippi River, with overall density being higher in the eastern area.

Evans et al. (2021) found that the Gulf is an important destination for leatherbacks from the Caribbean coast of Central America with seasonal movements between high-use habitats within the Gulf. Leatherbacks nesting along the Caribbean coast of Costa Rica and Panama used four distinct passages to leave the Caribbean Sea, using habitats in both the tropical Gulf and temperate North Atlantic Ocean. Leatherbacks use three primary areas within the Gulf, all of which are connected by a shared corridor: northeastern Gulf along the panhandle side of Florida, south of Louisiana, and southern Gulf in the bay of Campeche, Mexico (Evans et al. 2021). The use of these corridors and the primary driver to use the Gulf could be attributed to the locations encountered by drifting hatchlings in the ocean current. The Caribbean Current would be the first current that is strong enough to push hatchling leatherbacks from their nesting beaches along the Caribbean coast of Central America into the Gulf via the Loop Current, before traveling into the North Atlantic Ocean (Evans et al. 2021). Leatherbacks are known to be suited to a wide range of temperatures through unique character traits that allow them to live in cold water, allowing them to travel further than any other sea turtle species (NMFS and FWS 2013b). These character traits include a countercurrent circulatory system (Greer et al. 1973), a thick layer of insulating fat (Davenport et al. 2009), gigantothermy (Paladino et al. 1990), and the ability to increase their body temperature through increased metabolic activities (Bostrom et al. 2010).

Leatherbacks grow faster than hard-shelled turtles and are a long-lived species (over 50 years), with an estimated age of sexual maturity reported at about 9–20 years (Zug and Parham 1996; NOAA Fisheries 2025h). 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 (NMFS and FWS 2013b; FWS 2015c). 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 Gulf beaches (Florida Fish and Wildlife Conservation Commission 2020). Female leatherbacks have been observed with fertility for up to 25 years (Hughes 1996). 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, little is known about the juvenile life stage. Eggs typically hatch after 60 to 65 days. The hatchlings display white striping along the ridges of their backs and on the edges of their flippers, weigh around 43–57 g (1.5–2 oz), and measure approximately 5–8 cm (2–3 in) in length with front flippers that are as long as their bodies. Hatchlings experience rapid growth, with reported rates ranging from 6.4–70.1 cm (2.5–27.6 in) in length, averaging an estimated 32 cm (12.6 in) per year (Jones et al. 2011). While other sea turtle species remain in pelagic waters and *Sargassum*, there are no records to indicate this is consistent with leatherbacks. The period from hatching to approximately 10 years later, when females return to the nesting beach, is referred to as the “lost years” because so little information is available (Carr 1987).

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 their 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 (NMFS and FWS 2013b). Their distribution appears to depend on distribution of their prey, which consist mostly of jellyfish and other pelagic gelatinous organisms, such as tunicates (Eckert et al. 1989; Evans 2006). The northern Gulf has been recorded as a high-use foraging area for leatherback turtles, because they show high fidelity to this area (Gredzens and Shaver 2020; Sasso et al. 2021; Shaver et al. 2022). Adults have been tracked foraging in the Gulf on cannonball jellies and moon jellies (Evans 2006). Additionally, physical oceanic features such as convergence zones and eddies have been identified as key foraging areas, because they create conditions that concentrate leatherback prey (Sasso et al. 2021). Adult leatherbacks are deep divers, with estimated dives to depths over 1,000 m (3,281 ft), but they may come into shallow waters if there is an abundance of jellyfish (Eckert et al. 1989).

3.6.6 Sea Turtle Bioacoustics

As applicable, discussion of turtles outside of the Gulf OCS is included as a proxy for Gulf sea turtles, representing the best available information at this time.

3.6.6.1 The Importance of Sound to Sea Turtles

Though the general importance of sound to sea turtles is not well understood, a growing body of knowledge suggests that sea turtles use sound in a multitude of ways. Sea turtles may use sound for navigation, locating prey or preferred habitat, predator avoidance, and environmental awareness (Piniak et al. 2016). They occupy different ecological niches throughout their life cycle, each characterized by unique acoustic conditions. Few studies report sound production in sea turtles, despite sea turtles' ability to hear sounds in both air and water. Cook and Forrest (2005) found that nesting leatherback sea turtles produce sound when breathing in air; this work suggested the sound was a by-product of labored breathing rather than a communication signal. Sea turtle embryos and hatchlings have been reported to make airborne sounds, thought to be produced for synchronizing hatching and nest emergence (Ferrara et al. 2014a; 2014b; 2019; McKenna 2016; Monteiro et al. 2019). Charrier et al. (2022) noted the production of 10 different underwater sounds in juvenile green sea turtles, including those within and above the frequency range of hearing reported for this species. A more comprehensive understanding of sound production and hearing is needed in sea turtles; the growing available information thus far suggests sound may be important to these animals.

3.6.6.2 Hearing Anatomy

In general, sea turtle auditory perception is thought to occur through a combination of both bone and water conduction rather than air conduction (Lenhardt et al. 1983; Lenhardt et al. 1985). The outermost part of the sea turtle ear, or tympanum, is covered by a thick layer of skin covering a fatty layer that conducts sound in water to the middle and inner ear. This is a

distinguishing feature from terrestrial and semi-aquatic turtles. This thick outer layer makes it difficult for turtles to hear well in air, but it facilitates the transfer of sound from the aqueous environment into the ear (Ketten et al. 1999). The middle ear has two components that are encased by bone, the columella and extracolumella, which provide the pathway for sound from the tympanum on the surface of the turtle head to the inner ear consisting of the cochlea and basilar membrane. This arrangement enables sea turtles to hear low-frequency sounds while underwater. The middle ear is also connected to the throat by the Eustachian tube. Because there is air in the middle ear, it is generally believed that sea turtles detect sound pressure rather than particle motion. Vibrations can also be conducted through the bones of the carapace to reach the middle ear. Based on studies of semi-aquatic turtles, Christensen-Dalsgaard et al. (2012) speculated that the sea turtle ear may not be specialized for bone conduction, but rather that sound-induced pulsations may drive the tympanic disc if the middle ear cavity is air-filled. A detailed description of sea turtle auditory anatomy and different hearing capabilities of each species are available in section three of Reese et al. (2023).

Hearing in sea turtles has been measured through electrophysiological and/or behavioral studies in both air and water on a limited number of life stages for each of the five species. In general, sea turtles hear best in water between 100–750 Hz, do not hear well above 1 kHz, and are generally less sensitive to sound than marine mammals (Papale et al. 2020; Reese et al. 2023). Though there are still substantial data gaps on hearing sensitivity across species and throughout ontogeny, there is data on loggerhead hearing capabilities at the post-hatchling (Lavender et al. 2012; 2014), juvenile (Bartol et al. 1999; Lavender et al. 2012; 2014), and adult stages (Martin et al. 2012).

Recent research indicates that sea turtles exhibit a pronounced sensitivity to low-frequency sounds, overlapping with the range of sound documented for anthropogenic noise sources (Muirhead et al. 2025). For example, in a study on 13 juvenile Kemp's ridley turtles, low-frequency specialists Muirhead et al. (2025) found that Kemp's ridleys have the greatest hearing sensitivity within the frequency range of most industrial noise. Critical uncertainties remain about how sea turtles use acoustic cues in their natural environments and the extent to which environmental factors, such as temperature, influence potential masking effects and sea turtles' auditory perception of the environment.

Table 3-8. Hearing capabilities of sea turtles

Sea Turtle Species	Age Class	Hearing[a] Range of Audibility (Hz)	Hearing[a] Range of Highest Sensitivity (Hz)	Source
Green (*Chelonia mydas*)	Juvenile	50–1,600	200–400	(Ridgway et al. 1969; Bartol and Ketten 2006; Piniak et al. 2012b; 2016)
Hawksbill (*Eretmochelys imbricata*)	Hatchling	50–1,600	400	(Piniak 2012)

Sea Turtle Species	Age Class	Hearing[a] Range of Audibility (Hz)	Hearing[a] Range of Highest Sensitivity (Hz)	Source
Kemp's ridley (*Lepidochelys kempii*)	Juvenile	100–500[b]	100–500[b]	(Bartol and Ketten 2006)
Leatherback (*Dermochelys coriacea*)	Hatchling	50–1,200	300	(Piniak 2012; Piniak et al. 2012a)
Loggerhead (*Caretta caretta*)	Post-Hatchling[c]	50–1,100	200	(Bartol et al. 1999; Lenhardt 2002; Martin et al. 2012; Lavender et al. 2014)
Loggerhead (*Caretta caretta*)	Juvenile	50–1,100	50–800	(Bartol et al. 1999; Lenhardt 2002; Martin et al. 2012; Lavender et al. 2014)
Loggerhead (*Caretta caretta*)	Adult	35–1,131	100–400	(Bartol et al. 1999; Lenhardt 2002; Martin et al. 2012; Lavender et al. 2014)

[a] Data adapted from Papale et al. (2020) and Reese et al. (2023) based on highest and lowest frequency of underwater audibility that was reported for each species including both auditory evoked potential and behavioral studies.

[b] Only in-air measurements are available for Kemp's ridley sea turtles.

[c] Post-hatchling refers to the size classification given to hatchlings when they reach a straight maximum length of 5cm.

3.6.6.3 Potential Vulnerabilities to Sea Turtles from Underwater Sound

As with marine mammals, sea turtles may experience a range of effects from underwater sound, including non-auditory injury, auditory injury, TTS, behavioral changes, acoustic masking, or increases in physiological stress. The potential effects will depend on the physical qualities of the sound source and the environment, as well as the physiological characteristics and the behavioral context of the species of interest. Sound from activities such as pile driving, seismic surveys, and drilling could have effects on sea turtles given the overlap between sea turtles' hearing range and the frequency range of these sound sources, yet there is extremely limited data on how their behavior and physiology are affected. A comprehensive review of the potential effects of noise on sea turtles can be found in Nelms et al. (2016) and Reese et al. (2023).

Though there is no direct evidence of PTS occurring in sea turtles, recently evidence of underwater noise-induced TTS in a freshwater turtle species has been recorded and suggests turtles may be more sensitive to sound than previously understood (Mannes et al. 2023; Salas et al. 2023). In red-eared sliders, Salas et al. (2023) reported the mean predicted TTS onset was 160 dB re 1 µPa2 s. There was individual variation in the susceptibility to TTS and the magnitude of threshold shift and recovery rate, which was non-monotonic and occurred on time scales ranging from < 1 h to > 2 days post-exposure (Mannes et al. 2023; Salas et al. 2023). TTS also has been demonstrated in red-eared sliders based on a 24 hour exposure that resulted in a sound exposure level of 160 dB re 1 µPa2 s, where all animals showed a decrease in hearing

sensitivity immediately after exposure but a full recovery 3–5 hours after exposure (Mannes et al. 2023; Salas et al. 2023).

Salas et al. (2024) found that underwater noise pollution can also induce TTS in the hearing of Eastern painted turtles, revealing their vulnerability to noise-induced hearing loss and the potential consequences for their survival and ecological roles. Exposure to band-limited continuous white noise resulted in significant TTS at frequencies of 400 and 600 Hz, with higher sensitivity and greater shifts observed at the latter frequency. This frequency-dependent reaction parallels the findings in other freshwater species, indicating that similar auditory sensitivities could be typical within the Emydidae family. Research in marine mammals suggests that prolonged or repeated exposure to sound levels sufficient to induce TTS without recovery time can lead to auditory injury including PTS, so the same could be true for turtles and other vertebrates (Southall et al. 2007). Few studies have looked at hair cell damage in reptiles, and do not indicate precisely if sea turtles are able to regenerate injured sensory hair cells (Warchol 2011). Further research is necessary to explore TTS across additional turtle species and different types of sound sources, to enable informed conservation strategies to mitigate the effects of noise on both freshwater and marine turtles.

In terms of behavioral responses, a recent study by Kastelein et al. (2023) found that sea turtles exposed to synthetic sounds including Helicopter Long-Range Active Sonar and killer whale vocalizations exhibit responses to high-amplitude, low-frequency sounds between 0.2 and 1 kHz, characterized by increased swimming speed and changes in swimming patterns. Responses were influenced by the sounds' spectrum, frequency modulation, and the turtles' behavioral state, particularly to sounds within the turtles' hearing range. Most notable reactions occurred at sound pressure levels exceeding 151 dB re 1 µPa, suggesting that the radius of disturbance areas around most anthropogenic sound sources is smaller for turtles than for marine mammals (Kastelein et al. 2023).

Though several studies have examined physiological responses of sea turtles to physically stressful events (e.g., incidental or directed capture in fishing nets, cold stunning, handling, transport, etc.), no research to date has been published on potential stress responses in sea turtles to elevated environmental noise (Reese et al. 2023). Stress response studies characterizing physiological (stress/hormone) responses to sound are ongoing to estimate potential acoustic impacts on sea turtles from industry sound sources. Elevated levels of corticosterone have been observed in Kemp's ridley sea turtles and green turtles in response to stressful stimuli such as ground transport for rehabilitation and disease (Aguirre et al. 1995; Hunt et al. 2016). Other physiological impacts due to chronic stress include immunosuppression (Milton and Lutz 2003). Samuel et al. (2005) demonstrated that anthropogenic sound levels from boating and recreational activity near Long Island, New York were over two orders of magnitude greater than when compared with the periods of lowest human activity, and suggested exposure to such levels could affect sea turtle behavior. Chronic exposure to anthropogenic noise may result in increased stress responses in sea turtles, which could have direct consequences on individual fitness (Reese et al. 2023). The soundscapes and subsequent noise effects presently experienced by sea turtles in biologically important habitats, and their

behavioral and physiological responses, may be variable and in general are still not well understood.

Few empirical data are available to form regulatory thresholds for sea turtle sound exposure. For several years, the regulatory community accepted the recommendations of Popper et al. (2014) and used their thresholds for fishes without swim bladders as a proxy for sea turtles. NMFS adopted work by the U.S. Navy which now serves as the foundation of present-day thresholds for sea turtles. Dual criteria (Lpk and SEL have been suggested for auditory injury (AUD INJ) and TTS, along with auditory weighting functions published by Accomando et al. (2025) used in conjunction with SEL thresholds for AUD INJ and TTS. The behavioral threshold recommended in the GARFO acoustic tool Greater Atlantic Regional Fisheries Office (2020) is an SPL of 175 dB re 1µPa (McCauley et al. 2000; Finneran et al. 2017) (**Table 3-9**). These thresholds apply to all life stages.

3.6.6.3.1 Thresholds for Auditory Injury

As a conservative approach, Popper et al. (2014) recommended using thresholds developed for fishes without swim bladders for sea turtles in response to impulsive sounds. In earlier phases of the U.S. Navy Acoustic Criteria and Thresholds Analysis, the U.S. Navy also agreed, that, while still unsatisfactory, data from fish provided a better analogy due to similar hearing range and that the functioning basilar papilla in the turtle ear is dissimilar to the functioning cochlea in mammals (Finneran et al. 2017). However, more recently the U.S. Navy has modified their criteria and thresholds based on data on TTS for freshwater turtles (Salas et al. 2024). There is no direct data for auditory injury in sea turtles; therefore the difference between TTS onset and auditory injury onset criteria is based on trends seen in terrestrial mammal data. As a result, new criteria and thresholds for the onset of TTS and AUD INJ have been developed for Phase 4, incorporating the best available science (Accomando et al. 2024; 2025).

Table 3-9. Sea turtle AUD INJ thresholds from the Phase 4 U.S. Navy report for impulsive and non-impulsive sounds

Metric	AUD INJ	TTS
Impulsive SEL (dB re 1 µPa^{2}s) (weighted)	184	169
Impulsive Lpk (dB re 1 µPa)	230	224
Non-impulsive SEL (dB re 1 µPa^{2}s) (weighted)	198	178

Source: Accomando et al. 2025.

3.6.6.3.2 Thresholds for Behavioral Disturbance

There are limited data pertaining to behavioral responses of sea turtles to anthropogenic noise. Several publications have attempted to examine sea turtle's immediate behavioral responses to seismic airgun noise. McCauley et al. (2000) observed that one green turtle and one loggerhead turtle in an open water pen increased swimming behaviors in response to a single seismic airgun at received levels of 166 dB re 1 µPa and exhibited erratic behavior at received levels

greater than 175 dB re 1 µPa. Other empirical work has shown a range of responses, but NMFS developed sea turtle behavioral criteria based on these studies by McCauley et al. (2000). The sound level at which sea turtles are expected to exhibit a behavioral response to both impulsive and non-impulsive sound is a received SPL of 175 dB re 1 µPa (McCauley et al. 2000; Finneran et al. 2017).

Newly published research detailing the behavioral reactions of sea turtles to noise (Kastelein et al. 2023) has emerged; however, the SPL root-mean-square (rms) thresholds established by NMFS for behavioral disturbance during Phase 3 remain unchanged in Phase 4. For instances involving single and multiple explosions, SEL-based thresholds exist that align with the thresholds used for assessing behavioral responses of marine mammals to similar explosive events.

Table 3-10. Sea turtle behavioral response thresholds from the Phase 4 Navy report

Source	dB SPL rms (unweighted)	dB SEL (cumulative; weighted)
Airguns	175	-
Pile driving	175	-
Sonar ≤ 2kHz	175	-
Explosives	-	164

Note: Weighted cumulative SEL thresholds in dB re 1 µPa^{2}s and unweighted SPL rms thresholds in dB re 1 µPa. The root-mean-square and sound exposure level calculations based on duration defined by 5% and 95% points along the cumulative energy curve and captures 90% of the cumulative energy in the impulse.
Source: Accomando et al. 2024.

3.6.6.3.3 Thresholds for Non-Auditory Injury

For both sea turtles and marine mammals, NMFS has adopted criteria used by the U.S. Navy to assess the potential for non-auditory injury from underwater explosive sources as presented in Finneran et al. (2017); Accomando et al. (2025). The criteria include thresholds for the following non-auditory effects: mortality, lung injury, and gastrointestinal injury. The critical explosive parameters tied to these criteria are peak pressure (L_{pk}) and positive impulse (J_0), sometimes just referred to as impulse. Based on work by Goertner (1982), Yelverton et al. (1973), the U.S. Navy has identified the similitudes in **Table 3-11** as the threshold for the occurrence of these impacts. Unlike auditory thresholds, these depend on an animal's mass and depth.

Table 3-11. U.S. Navy impulse and peak pressure threshold equations for predicting potential auditory injury to sea turtles from explosives

Impact Assessment Criterion	Threshold
Onset Mortality—Impulse	$103M^{1/3}(1+ D/10.1)^{1/6}$ Pa-s
Onset Injury (Non-auditory)—Impulse	$47.5M^{1/3}(1+ D/10.1)^{1/6}$ Pa-s

Impact Assessment Criterion	Threshold
Onset Injury (Non-auditory)—Peak Pressure	Lpk of 237 dB re 1 µPa

Note: *M* is animal mass (kg), and *D* is animal depth (m).
Source: Accomando et al. 2025.

3.6.7 Environmental and Anthropogenic Stressors

3.6.7.1 Noise

In the Gulf, several anthropogenic noise sources are present and may affect sea turtles in a variety of ways. For example, sounds from shipping vessels, naval exercises, and coastal construction are prevalent at different levels across the geographic area. The most notable and widespread noise source is vessel noise, due to the prevalence of commercial shipping, fishing, and recreational boating activities.

Despite growing concerns about the effects of vessel noise on marine ecosystems, comprehensive investigations focused on the effects to sea turtles are quite limited. Key areas lacking adequate research include the specific frequencies of shipping noise and dynamic positioning (DP) that may cause behavioral changes in sea turtles, their responses to continuous versus intermittent noise, and the long-term effects of noise exposure on their foraging, nesting, and migratory patterns. There is a need for studies that evaluate the synergistic effects of shipping noise combined with other stressors, such as habitat degradation and changes in climate-related factors.

Most existing studies primarily concentrate on larger marine mammals, leaving a substantial gap in understanding how sea turtles, which have unique auditory capabilities and higher prevalence in nearshore areas, are affected by the increasing presence of vessel operations in the Gulf. For information on sea turtle bioacoustics, see **Section 3.6.6**.

3.6.7.2 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 may 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.

3.6.7.3 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 (not BOEM- or BSEE-regulated) that is not disposed of properly can create hazards to sea turtles. Sea turtles may suffer injury and death from these types of marine debris. NMFS released a report on data collected by the Sea Turtle Stranding and Salvage Network from Alabama, Mississippi, and Louisiana 2015–2019 (Howell et al. 2021). Well-known threats to sea turtles, such as interactions with fishing gear (e.g., hooking, entanglement, and gastrointestinal injuries from ingestion) and marine debris, were identified as being a cause of mortality.

Sea turtle bycatch occurs in the Gulf, especially from 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 18 m [59 ft] 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 Jr. et al. 1996; Epperly and Teas 2002; Shaver et al. 2013). Caillouet Jr. et al. (1996) found a significant positive correlation between turtle stranding rates and shrimp fishing intensity in the northwestern Gulf. 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).

According to NMFS' 2015–2019 stranding report (Howell et al. 2021), almost half (49 percent) of stranded sea turtles showed no apparent outside abnormalities that resulted in the conclusion of suspected forced submergence due to sediment being found in the respiratory tract and the high frequency of finfish ingestion when necropsies were performed. These strandings exhibited strong, constant seasonal patterns, peaking during spring and continuing during the summer, which is consistent with commercial fisheries who use trawls and purse seines (Howell et al. 2021).

Historically, the shrimp trawl fishery has caused sea turtle bycatch (Benaka et al. 2019) and mortalities, though the implementation of turtle excluder devices (TEDs) has helped to reduce mortality (Valverde and Holzwart 2017). To reduce fishery impacts to turtles, NMFS has required the use of TEDs 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 TEDs throughout the shrimp fishing industry, gear improvements continue to be introduced. 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).

3.6.7.4 Vessel Strike

Vessel strikes are a poorly studied threat to sea turtles. 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 (km/h) (2.5 miles per hour [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). According to the NMFS 2015 to 2019 stranding report, sea turtles with significant trauma were the second most frequent category of stranding (18 percent) and were most common among green sea turtles (Howell et al. 2021). The foremost kind of trauma documented was vessel strikes, which were frequently observed near areas with high vessel traffic.

3.6.7.5 Climate-related Factors and Ocean Acidification

Coastal areas, some of which are important habitats for sea turtle nesting, are increasingly at risk due to the impacts of rising global temperatures, which are projected to contribute to sea-level rise and increased storm surge activity, posing significant threats to nesting suitability and reproductive success (Morton 2003; Lyons et al. 2020). These changes heighten the likelihood of coastal flooding, erosion, and habitat degradation (Morton 2003; Lyons et al. 2020) (**Section 3.2**). The frequency and intensity of storms, along with sea-level rise, may inundate and damage coastal and estuarine habitats, particularly affecting suitable nesting areas on barrier islands (Morton 2003; Martins et al. 2022), though more data is needed to know if both storm frequency and severity would increase.

The combined threat of coastal erosion and development leads to narrower beaches, a phenomenon known as “coastal squeeze” (Mazaris et al. 2009; Lyons et al. 2020; 2022). As beaches become increasingly threatened by flooding and erosion, access to suitable sandy nesting sites may diminish. Female sea turtles must locate sandy beach habitats to dig nests and lay eggs in undisturbed areas throughout the incubation period (Lyons et al. 2022). The selection of nest sites by nesting females is critical and can significantly influence the fate of their offspring (Martins et al. 2022). Research indicates that nests located in areas with higher moisture content are more susceptible to producing hatchlings with lower fitness, potentially contributing to increased mortality rates among these hatchlings compared to those from drier nests (Martins et al. 2022; Rivas et al. 2023). As the threats of sea-level rise and beach retreat escalate, there is growing concern that females may nest at lower elevations and closer to the

high-water line. This behavior raises the risk of increased density in nesting areas, which could lead to greater susceptibility to depredation and disease transmission (Lyons et al. 2020).

Nest placement is critical not only due to the risks of flooding and predation but also for determining the sex of the hatchlings. Hatchling sex is influenced by the temperature during embryonic development: warmer nests typically produce more females (Hays et al. 2023). Increases in temperature may lead to the creation of bias sex ratios, which could have significant population-level impacts (Laloë et al. 2014; Gatto et al. 2021; Hays et al. 2023). Synthesis and modeling studies using regional (Catron et al. 2023) and worldwide (Hays et al. 2023) nesting data and projected global temperature information project population decreases through different mechanisms. However, competition for mates tends to balance operational sex ratios (Jennions and Fromhage 2017). Relying solely on sex ratios based on nest incubation temperature may not be the best method for assessing the over-feminization of a population or the impact of temperature on the sea turtle population in the long term (Santidrián Tomillo 2022). Additionally, factors surrounding key demographic parameters (e.g., male breeding rates and sex-specific survival) need further investigation to properly project the impacts of temperature on the sea turtle population (Maurer et al. 2021).

3.6.7.6 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 (FP); viral, bacterial, and mycotic (fungal) infections; parasites (internal or external); and other environmental health problems (e.g., hypothermic stunning). Howell et al. (2021) identified 4 percent of all sea turtle strandings observed from 2015 to 2019 exhibited poor nutritional condition. This report observed various degrees of fat atrophy in Kemp's ridleys in Louisiana, which can be linked to prey abundance, prey availability, and environmental conditions. Poor nutritional condition in sea turtles can increase their susceptibility to diseases. Other stressors, such as increased ocean noise levels, can increase susceptibility to disease (Kight and Swaddle 2011). Further, temperature increases may act additively or synergistically with marine diseases. Host-pathogen relationships are sensitive to environmental conditions; thus, temperature increases can affect disease risk (Burge et al. 2014).

FP, 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). A long-term monitoring study by Guzmán-Hernández et al. (2024) identified turtles with FP tumors are more susceptible to entanglement in fishing lines and have a reduced ability to swim, dive, locate, capture and swallow food, and avoid predators. It has been reported in all sea turtle species, though its precise cause(s) is unknown (NMFS and FWS 2007; 2013a).

3.6.7.7 Marine Debris, Pollution, and Runoff

In the U.S., about 80 percent of marine debris washes into the ocean from land-based sources and 20 percent is from ocean sources (USEPA 2017). Pollutants released into streams, rivers, bays and estuaries can enter the open ocean where they can stress marine life, including sea turtles. Sea turtles are a long-lived species and can accumulate high concentrations of chemicals throughout their lifetimes. Through their long migratory routes, sea turtles may be exposed to and accumulate large amounts of pollutants from different areas. Pollution, including point and nonpoint 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.

Some species show special sensitivity to different pollutant exposure, like green sea turtles, by assaying immunological and physiological effects (Arienzo 2023). In addition, plastics have been found inside deceased sea turtles (Gregory 2009; Schuyler et al. 2016). Toxins directly harm the organisms that ingest them, and they can also have impacts further up the food chain through biomagnification (Gray 2002). Toxicity can vary with water quality and among species. The toxicity of pollutants is influenced by several factors, such as the developmental stage, dietary factors, physiology, and biochemical functions of sea turtles. Therefore, although filter-feeding benthic organisms may be the first to encounter toxic chemicals, these compounds can also contaminate sea turtles.

HABs have been identified to impact sea turtle health and be influenced by ocean temperature (Nederlof et al. 2024). The commonly used term “red tide” refers to the HAB created by the dinoflagellates, *Karenia brevis*, that produces neurotoxins referred to as brevetoxins (**Section 3.2.9.2**). HABs have been recorded occupying a wide range of distribution from Texas to as far north as North Carolina’s Atlantic coast. Rising temperatures and anthropogenic stressors are believed to influence HABs in terms of frequency, distribution, duration, and impact. For sea turtles, the primary threat from brevetoxins comes from ingesting contaminated sea water or from foraging on toxin-laden prey, such as seagrasses, crustaceans, and fish. Some prey species can accumulate high concentrations of toxins in their tissues, which may persist even after the HAB has dissipated. The effects of brevetoxin exposure in sea turtles range from moderate to severe, with some cases leading to mortality (Nederlof et al. 2024). Moderate symptoms include neurological effects, such as loss of muscle coordination, circling, head bobbing, difficulty submerging, muscle twitching, and myoclonus. More severe cases are characterized by lethargy, partial to complete paralysis, unresponsiveness, and seizures (Nederlof et al. 2024). Symptoms such as loss of coordination, circling behavior, and difficulty submerging can impair a sea turtle’s ability to forage and avoid predators, while lethargy and paralysis compromise their swimming and breathing. Exposure to brevetoxins may also heighten the risk of accidental mortality through entanglement, boat strikes, and increased vulnerability to predation due to reduced mobility.

Marine debris affects marine habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking) (Gall and Thompson 2015; Senko et al. 2020). Sea

turtles, such as leatherbacks, juvenile loggerheads, and juvenile green turtles, which spend significant portions of their life cycle in the pelagic environment, can eat or become entangled in marine debris. 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 (Gall and Thompson 2015; Senko et al. 2020).
If entangled and involuntarily submerged by marine debris, the physiological stress the turtle goes through can require additional time to rest and recover at the surface to replenish the oxygen stores consumed while it had been involuntarily submerged (Senko et al. 2020). Marine debris found on beaches can block nesting attempts and impede hatchlings from reaching the sea, potentially increasing their susceptibility to predation (Senko et al. 2020).

Schuyler et al. (2016) projected more than half (52 percent) of the world's sea turtles have already ingested plastic material, finding that oceanic life-stage sea turtles are at the highest risk of marine debris ingestion. For sea turtles of all age classes, especially juveniles, ingestion of plastic pollution can lead to impactions, obstructions, or perforations in the gut, resulting in intestinal blockage and dietary dilution, which can impact feeding ability and cause injury or death (Senko et al. 2020). Navarathna et al. (2023) identified microplastics in the stomach and intestinal contents of Kemp's ridley sea turtles through a gut analysis conducted from turtles collected along Mississippi's coast. Of the 10 turtles analyzed, over 60 microplastics were found in the stomach contents, and more than 136 were found in the intestinal contents. These findings suggest that sea turtles are ingesting microplastics directly or indirectly, likely through the consumption of lower trophic-level species such as crabs, other crustaceans, or fish, possibly as a result of opportunistic feeding (Navarathna et al. 2023). Because there are few data on marine debris in the Gulf, it is difficult to draw conclusions as to the precise extent of the problem and its impacts on sea turtle populations.

3.7 MARINE MAMMALS

The marine mammal species found in the northern Gulf are diverse and distributed throughout the Gulf waters. The Gulf's marine mammals include members of the taxonomic order Cetacea, including suborders Mysticeti (i.e., baleen whales) and Odontoceti (i.e., toothed whales), and the order Sirenia (i.e., manatee). There are species that have been reported from Gulf waters either by sighting or stranding that, due to their rarity (i.e., uncommon in the Gulf and/or are not included in the most recent NMFS regional Marine Mammal Stock Assessment Reports [SARs]), are not considered in this document. These species include: the blue whale; North Atlantic right whale; and Sowerby's beaked whale, all of which are considered extralimital in the Gulf; and the humpback whale, fin whale, sei whale, and minke whale, all of which are considered rare occasional migrants in the Gulf. Twenty-one species of cetaceans and one species of Sirenia regularly occur in the Gulf and are identified in the NMFS SARs (Hayes et al. 2025).

3.7.1 Distribution and Trends

Most marine mammal distributions vary widely across the northern Gulf; little is known about each species' breeding and calving grounds, and any general patterns of Gulf-wide movement. Several species (i.e., Rice's whale, sperm whale, and bottlenose dolphin) have presumed year-round resident populations in the Gulf (Harrison et al. 2023; Hayes et al. 2025). The distribution and abundance of cetaceans within the northern Gulf is strongly influenced by various mesoscale oceanographic circulation patterns and other factors that influence feeding behaviors. These patterns are driven primarily by river discharge (mainly from the Mississippi River), wind stress, and the Loop Current and its derived circulation phenomena (**Chapter 2**). Marine mammals may focus their foraging efforts on these prey-abundant 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 (Dooley 1972; Casazza and Ross 2008). Besides factors influencing feeding behaviors, little is known about other factors that may influence marine mammal distribution in the northern Gulf.

There is little information on marine mammal use of or sightings within FGBNMS. Most marine mammal species commonly found in the Gulf are not common in the vicinity of FGBNMS (NOAA 2012a). Beaked whales, Atlantic spotted dolphins, and bottlenose dolphins are found within the coral cap region of the FGBNMS (up to 40 m [130 ft] deep) (National Ocean Service 2024), though observations have been rare (NOAA 2012a). Also, Rice's whales and pantropical spotted dolphins may be found within FGBNMS.

3.7.2 Unusual Mortality Events

Under the Marine Mammal Protection Act (MMPA), 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." Active and closed UMEs with updated information can be found at the NOAA Fisheries website; information is generally updated regularly. There are currently no active UMEs in the Gulf.

3.7.3 ESA-Listed Marine Mammal Species

Two cetacean species, the sperm whale and the Rice's whale, regularly occur in the Gulf and are listed as Endangered under the ESA. The Florida manatee, a subspecies of the West Indian manatee, is listed as Threatened under the ESA and has designated critical habitat in Florida (82 FR 16668). The MMPA protects all marine mammals, regardless of ESA status. NMFS is charged with protecting all 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 (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 Caribbean Sea. They are widely distributed throughout continental slope and oceanic waters in the northern Gulf (Fulling et al. 2003; Mullin et al. 2004; Mullin and Fulling 2004; Maze-Foley and Mullin 2006; Mullin 2007; Garrison and Aichienger Dias 2020; Hayes et al. 2021; Rappucci et al. 2023) in all seasons (Mullin et al. 1994; Hansen et al. 1996; Mullin and Hoggard 2000). As deep divers, sperm whales generally inhabit oceanic waters at depths greater than 1,000 m (3,280 ft). 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 Gulf sperm whale population is unknown, but they are believed to live at least 60 years.

NMFS considers sperm whales in the Gulf as a distinct stock in their Marine Mammal SAR (Hayes et al. 2025), which was last updated in 2020 for sperm whales (Hayes et al. 2021), and research supports this distinction from the Atlantic and Caribbean stocks (Jaquet 2006; Gero et al. 2007; Jochens et al. 2008). Regarding current population trend, there were no significant differences between surveys conducted in 2003, 2004, 2009, 2017, and 2018 (Hayes et al. 2021). No discernable seasonal migrations have been observed, though a range of Gulf-wide movements have occurred (Jochens et al. 2008; Hayes et al. 2021). The status of sperm whales in the northern Gulf, relative to optimum sustainable population (OSP), is unknown (Hayes et al. 2021). There is no statistically significant trend in population size for this stock in the northern Gulf (Hayes et al. 2021).

The low-salinity, nutrient-rich water from the Mississippi River contributes to an enhanced primary and secondary productivity in the north-central Gulf, which may explain the presence of sperm whales in the area (Davis et al. 2000b; 2002; Jochens et al. 2008). The continental margin in the north-central Gulf is only 20 km (12 mi) wide at its narrowest point, and the ocean floor descends quickly along the continental slope, reaching a depth of 1,000 m (3,281 ft) within 40 km (25 mi) of the coast. This unique area of the Gulf brings deepwater organisms within the influence of coastal fisheries, contaminants, and other human impacts on the entire northern Gulf (Davis et al. 2000b). Consistent sightings, satellite tracking, strandings, and historical whale catches indicate that sperm whales occupy the northern Gulf 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 500–2,000 m (1,641–6,562 ft) deep, and represent a resident population (Davis and Fargion 1996; Jefferson and Schiro 1997; Davis et al. 2000b; 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 Gulf, it is not known whether females leave the Gulf to mate or whether males sporadically enter the area to mate with females, which would make this an important area for sperm whale reproduction. Mullin et al. (2022) examined the projected movements of sperm whales identified in the Gulf through the use of photo identification via

fluke photos. Comparisons have demonstrated individuals with movements of up to 6,200 km (3,852 mi) (Mullin et al. 2022).

Spatial density models developed from the GoMMAPPS study dataset showed spatial distribution changes for sperm whales in the Gulf (Garrison et al. 2023b). A notable change was an increase in sperm whale density in the central Gulf. During 2003, 2004, and 2009 surveys, there were many sperm whale sightings in the northeastern Gulf in waters with relatively high chlorophyll-a content and to the north of the Loop Current or a separated Loop Current eddy (Rappucci et al. 2023). During the 2017 and 2018 GoMMAPPS surveys, waters with higher sea surface height anomaly and generally lower surface water productivity dominated the northern Gulf, and sperm whale sightings occurred primarily in the central and western Gulf, and were less frequent in the northeastern Gulf. The selected spatial density model predicted higher sperm whale densities in waters with low surface velocity, less influenced by the Loop Current or Loop Current eddies (Rappucci et al. 2023). The positive effect of SST was primarily associated with higher densities during summer months and the overall low density observed in the winter. This model indicates that sperm whales occurred in highest densities in deeper slope waters that were less influenced by the Loop Current or Loop Current eddies, and during summer months (**Figure 3-19**) (Rappucci et al. 2023). The variability in the oceanographic conditions in the northern Gulf between the 2003–2009 and 2017–2018 surveys likely account for the observed shifts in spatial distribution and lower sperm whale density in the northeastern Gulf.

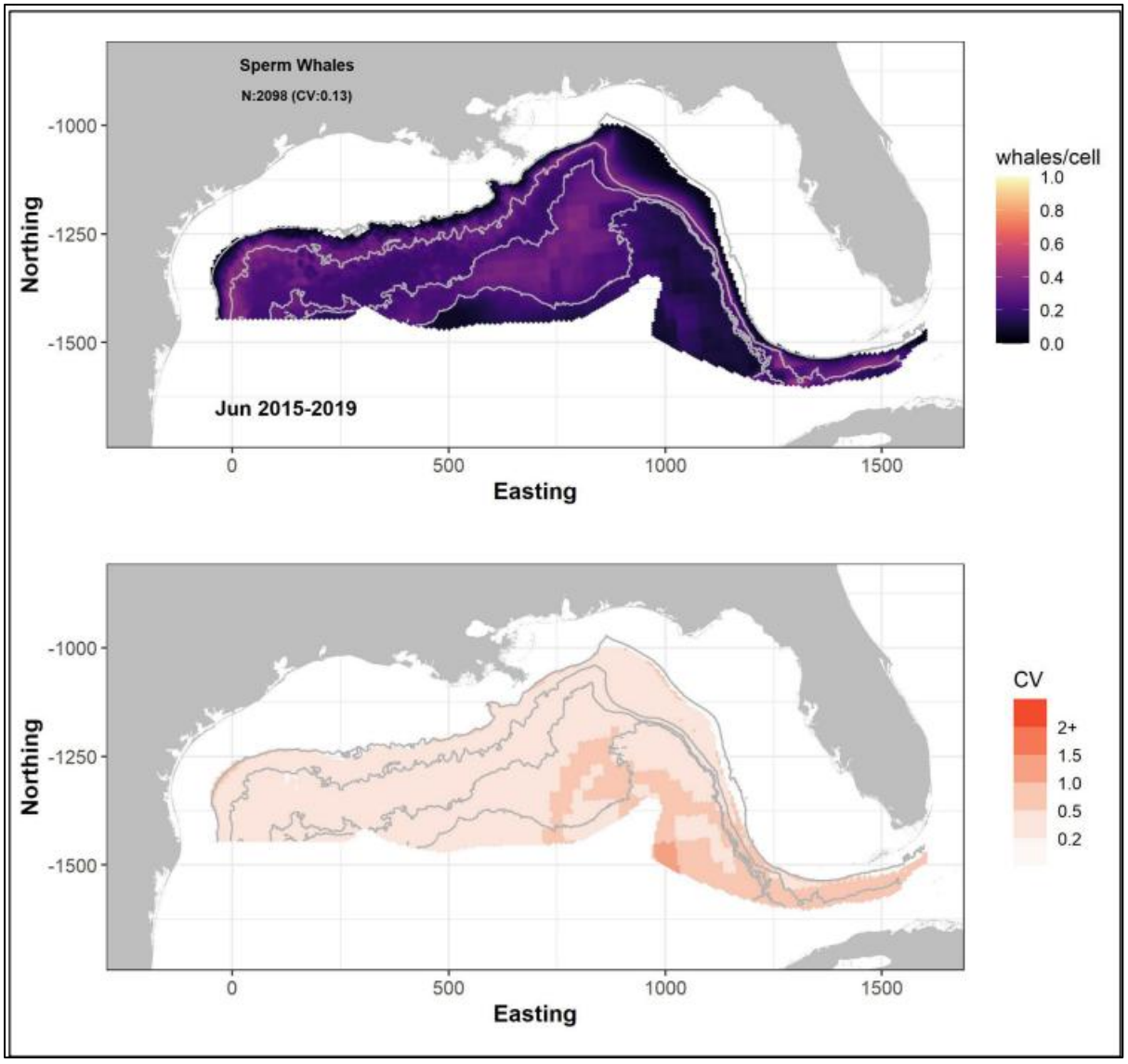


Figure 3-19. Projected density model for sperm whales in the northern Gulf for the months of June 2015–2019.
From: Garrison et al. 2023a.

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 400 m (1,312 ft), followed by approximately 8 minutes of resting at the surface (Papastavrou et al. 1989). However, dives of over 2 hours and deeper than 3.3 km (2.1 mi) have been recorded (Watkins et al. 1993), and individuals may spend extended periods at the surface to recover. Sperm whales dive to depths exceeding 610 m (2,000 ft) to feed, primarily in canyons (Waring et al. 2016).

Mathew and Sidorovskaia (2023) investigated the foraging and social behavior of sperm whales in the northern Gulf by analyzing their vocalizations through passive acoustic monitoring. The study found that sperm whales spent about 40 percent of their vocal time on foraging, followed by about 30 percent of their vocal time spent on socializing. Approximately 17 percent of the

sperm whale's vocal time was spent traveling at sea (Mathew and Sidorovskaia 2023). The authors suggested that the time budget analysis can be used as an indicator to assess the behavioral ecology of sperm whales. The study also found that the northern Gulf is an important habitat for sperm whales, with the presence of a relatively consistent population throughout the year (Mathew and Sidorovskaia 2023).

Morano et al. (2020) performed a large-scale passive acoustic survey of sperm whales along the eastern Gulf continental shelf following the *Deepwater Horizon* oil spill and response. Sperm whales were shown to exhibit a seasonal occurrence pattern in the region, with seasonal movements to other regions, which are likely not directly influenced by the oil spill. Seasonal occurrence was shown to be highest during summer and lowest during winter. Results suggest other factors (not the *Deepwater Horizon* oil spill) influence sperm whale occurrence. In addition, Li et al. (2021) analyzed passive acoustic datasets in the northern Gulf from approximately 16, 40, and 80 km (10, 25, and 50 mi) away from the *Deepwater Horizon* oil spill site. Data were collected in 2007, 2010, 2015, 2016, and 2017. A comparison was made between the abundances of sperm whales before and after the oil spill. The results show that sperm whales were present in the region throughout the entire monitoring period during spill cleanup. The results also indicated that the density of sperm whales at the site closest to the spill increased between 2010 to 2015, likely due to prey field recovery.

Sperm whales 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). 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. 2000b). Evidence of ingested stones, sand, sponges, and other non-food items suggests they forage on or near the seafloor (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 Gulf. 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 resident baleen whale in the northern Gulf is the Rice's whale, previously referred to as the Gulf of Mexico Bryde's whale. Recent evidence shows that the population previously known as Bryde's whales in the northern Gulf is a newly identified species of baleen whale, Rice's whale (86 FR 47022; Rosel et al. 2021). Research shows that they are geographically, demographically, and genetically isolated from all other balaenopterid lineages, leading to their recognition as separate species (Rosel et al. 2021; Soldevilla et al. 2022b). On August 23, 2021, NMFS published a direct final rule in the *Federal Register* (86 FR 47022): "Endangered and Threatened Wildlife and Plants; Technical Corrections for the Bryde's Whale (Gulf of Mexico

Subspecies)." NMFS revised the common name to the Rice's whale, the scientific name to *Balaenoptera ricei*, and the description of the listed entity to the entire species. The changes to the taxonomic classification and nomenclature do not affect the species' listing status under the ESA or any protections and requirements arising from its listing. This rule became effective on October 22, 2021.

NMFS proposed in the *Federal Register* to designate critical habitat for the Rice's whale (88 FR 47453) (**Figure 3-20**). The currently proposed designation includes waters from the 100-m (328-ft) isobath to the 400-m (1,312-ft) isobath in the Gulf from the Texas-Mexico border east to the boundary between the South Atlantic Fishery Management Council and the Gulf Council (50 CFR 600.105(c)) off of Florida (88 FR 47453).

The Rice's whale is among the most endangered large whale species in the world. The Rice's whale northern Gulf Marine Mammal SAR was last updated in 2022 by Hayes et al. (2023), incorporating the data reported by Garrison et al. (2020). Regarding current population trend, there were no significant differences between surveys conducted in 2003, 2004, 2009, 2017, and 2018 (Hayes et al. 2023). The status of Rice's whales in the northern Gulf, relative to OSP, is unknown (Hayes et al. 2023). There is no statistically significant trend in population size for this stock (Hayes et al. 2023).

The majority of Rice's whale detections are limited to the northeastern Gulf along the continental shelf between roughly 100- and 400-m (328- and 1,312-ft) depth; they have been less frequently detected in the western, central, and southern Gulf (Garrison et al. 2024b; NOAA Fisheries 2026). During vessel surveys conducted from 2003 to 2019, Rice's whales were primarily observed in the northeastern Gulf near the 220-m isobath (Rappucci et al. 2023). Rice's whales have also been observed in the western Gulf. For example, one confirmed Rice's whale was observed in the western Gulf near the shelf break off the coast of Texas during a summer 2017 survey (Rappucci et al. 2023). In addition, in April 2024, two Rice's whales were observed in the western Gulf, 55 nmi off the coast of Corpus Christi, Texas during an aerial survey in April 2024 (NOAA Fisheries 2026). A habitat suitability model developed by Farmer et al. (2022) and a density surface model developed by Garrison et al. (2024b) indicate suitable Rice's whale habitat along the Gulf continental shelf break. Predicted densities and occurrence of Rice's whales remain highest in their northeastern Gulf habitat (Farmer et al. 2022; Garrison et al. 2024b).

Additional research has identified an expansion in Rice's whale suitable habitat throughout the Gulf, though sightings have been concentrated predominantly around the 200-m (656-ft) isobath in the northeastern Gulf (Soldevilla et al. 2022b; Garrison et al. 2024b). There have been acoustic detections of Rice's whale calls in the northwestern and north-central Gulf, with no observed seasonality (Soldevilla et al. 2022b; Soldevilla et al. 2024). Passive acoustic monitoring (PAM) recorded Rice's whale vocalizations from the western Gulf along the continental shelf break south of the FGBNMS (EFGB and WFGB sites, both offshore the FGB located off Louisiana) (Soldevilla et al. 2022b). Overlapping calls were recorded at both of the FGBNMS sites (Soldevilla et al. 2022b). There may be fewer or more sporadically spaced Rice's

whales in the northwestern Gulf compared to the northeastern Gulf (Soldevilla et al. 2022b), though regular occurrence of Rice's whale calls were detected near two northwestern Gulf sites (Soldevilla et al. 2024). Soldevilla et al. (2024) detected Rice's whale long-moan calls year-round at the High-frequency Acoustic Recording Package WFGB site. Additionally, the long-term PAM study, through identifying their call types, has identified the first evidence of Rice's whale occurrence in Mexican waters, demonstrating that this species has a transboundary range including both U.S. and Mexican waters of the Gulf (Soldevilla et al. 2024).

Rappucci et al. (2023) used Rice's whale and unidentified baleen whale sightings from 12 vessel surveys between 2003 and 2019 to develop a detection function because there was an insufficient number of sightings during the GoMMAPPS surveys to derive a reliable detection function. Thus, Rappucci et al. (2023) handled density and abundance estimation for Rice's whales differently than for other Gulf cetaceans due to their limited distribution and rarity. The selected spatial density model from the GoMMAPPS study indicated that Rice's whale density was highest in shallow waters and with intermediate bottom temperatures between 10° C and 19 °C (50–66 °F) and intermediate surface chlorophyll-a concentrations (Rappucci et al. 2023). The combination of physical characteristics, and resulting predicted higher numbers of Rice's whales, occurred primarily in their northeastern Gulf habitat. There is some seasonal variability in predicted density associated with changes in water column characteristics (Garrison et al. 2023b; Rappucci et al. 2023). Research indicates that the locations of these sightings are linked to specific environmental features, such as temperature and salinity, which are associated with the upwelling of nutrient-rich water from the shelf break (Garrison et al. 2024b).

Rice's whales appear to forage during the day near the seafloor (150- to 250-m [492- to 820-ft] water depth) on the upper continental slope of their northeastern Gulf habitat where *Ariomma bondi*, a schooling fish, also appears to primarily occur (Kiszka et al. 2023). Rice's whales are likely selective predators, mostly foraging on high-energy content prey, particularly *A*. *bondi* (Kiszka et al. 2023). Other prey that are relatively abundant in Rice's whale habitat were found to have a lesser contribution. A study by Kok et al. (2023) suction-tagged two Rice's whales to collect information on diving kinematics and foraging behavior. It found that these whales engaged mainly in lunge-feeding near the seafloor, and partially in the water column and at the sea surface. This study also indicated that bottom foraging occurred primarily during the day with prolonged surface resting at night. There is limited research and little information available on the feeding ecology of Rice's whale, particularly because strandings are extremely rare and observing their foraging behavior is challenging because they do not forage at the surface (Kiszka et al. 2023). The limited range for Rice's whales and their prey makes them particularly sensitive to environmental changes due to climate-related factors (e.g., increased ocean temperatures; ocean acidification) as well as vulnerable to anthropogenic disturbances such as vessel traffic, fishing gear, and offshore development (**Section 3.7.6**).

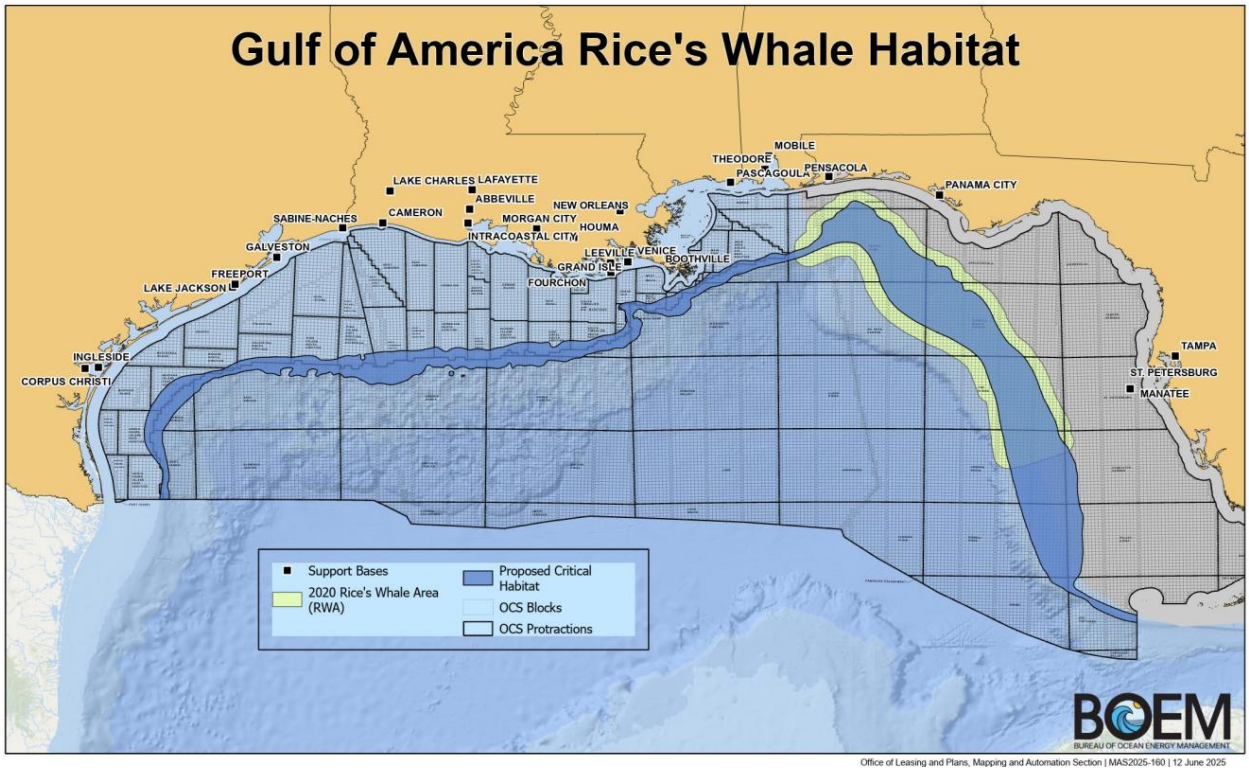


Figure 3-20. Rice's whale habitat.
Source: BOEM - 2025. Map was created by BOEM geographers. The source of the species data is NOAA/NMFS. The source for the planning areas and other boundaries is BOEM's Technical Information Management System.

3.7.3.3 Sirenians

The Florida manatee, which ranges from the northern Gulf to Virginia, is one of two subspecies of the West Indian manatee; the other is the Antillean manatee. The Florida manatee has designated critical habitat in inland waterways in four northeastern Florida coastal counties: Brevard, Duval, St. Johns, and Nassau (41 FR 41914). The most recent abundance estimates for manatees can be found on the Florida Fish and Wildlife Conservation Commission's website (Florida Fish and Wildlife Conservation Commission 2025). The West Indian manatee is ESA-listed as Threatened throughout its range and the Florida manatee has critical habitat, finalized in 1977, in Florida (**Figure 3-21**) (41 FR 41914; 42 FR 47840; 82 FR 16668). As of January 14, 2025, the Florida manatee is proposed to be listed as Threatened and the Antillean manatee as Endangered, which would replace the current Threatened species listing of the West Indian manatee (90 FR 3131). On September 24, 2024, FWS proposed critical habitat revisions for the Florida manatee (89 FR 78134). This proposed rule would remove 105,154 ha (259,842 ac) from the current Florida manatee critical habitat designation and add 485,071 ha (1,198,639 ac) in Florida to that critical habitat designation (89 FR 78134).

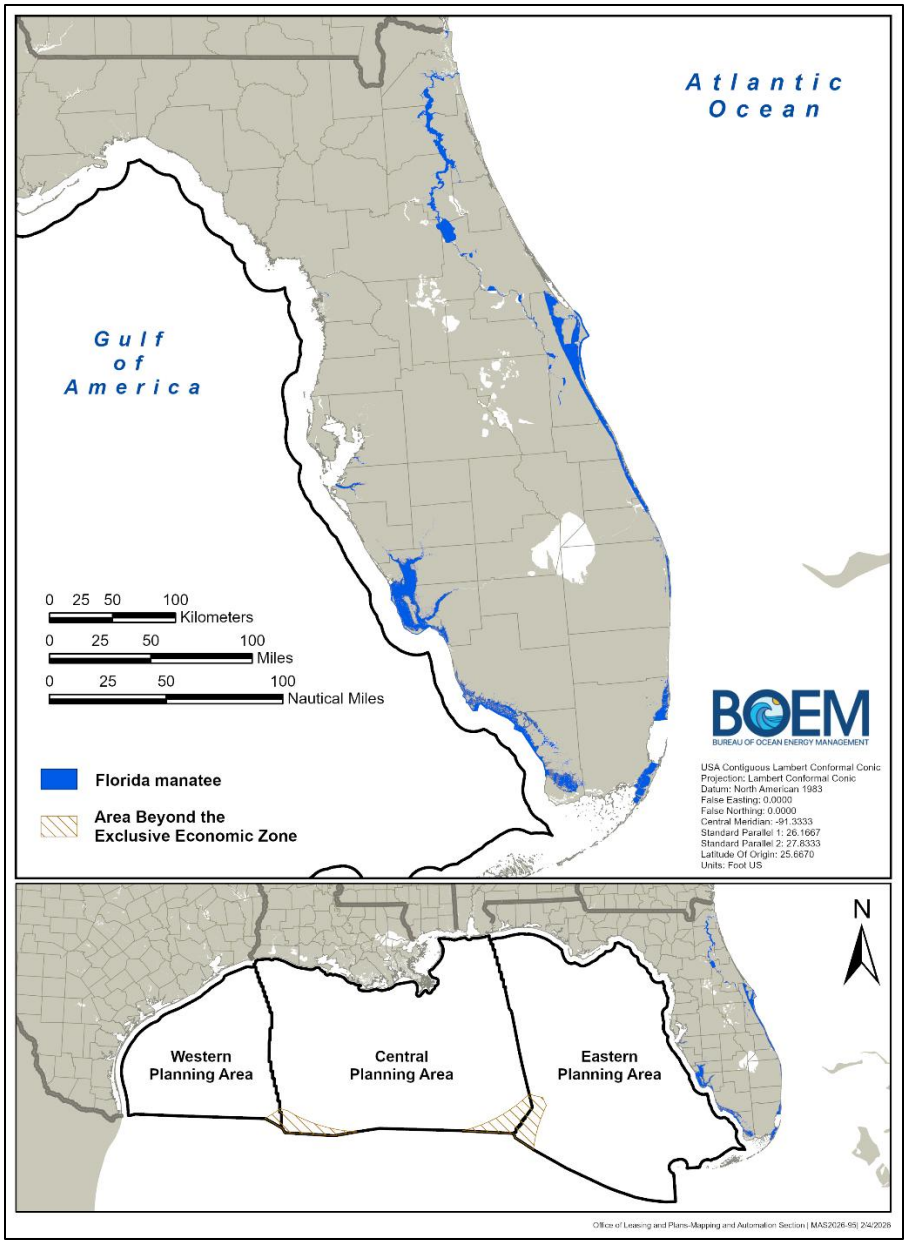


Figure 3-21. Florida manatee critical habitat.
Source: BOEM - 2026. Map was created by BOEM geographers. The source of the species data is FWS. The source for the planning areas and other boundaries is BOEM's Technical Information Management System.

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.

- The Northwest Unit that occupies the Florida Panhandle south to Hernando County, Florida (FWS 2014c). Manatees from the Northwest Unit are more likely to be seen in the northern Gulf, and they can be found as far west as Texas; however, most sightings are in the eastern Gulf (Fertl et al. 2005).

The Florida manatee has been documented all along the Gulf in nearshore waters, typically less than 4 m (13 ft) deep and within 1,000 m (3,281 ft) of the shore (Slone et al. 2022). They are most 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). Preferred coastal and riverine habitats (e.g., near the mouths of coastal rivers) are used for resting, mating, and calving (FWS 2001; 2007a).

Slone et al. (2022) tagged manatees in northwestern Florida, and manatees were tracked traveling as far west as Lake Pontchartrain, Louisiana, and as far south as Tampa Bay, Florida. Foraging areas were relatively shallow, mainly from 0.25–1.25 m (8.82–4 ft) at mid-tide. The highest density of manatee resource use was close to wetlands and estuaries where foraging resources are found, and resource use peaked in the summer (Slone et al. 2022). Traveling corridors were generally in depths greater than 3 m (9.8 ft), with highest traveling movement rates in the spring and fall. Manatees travelled more often within the intracoastal waterway, where available, rather than the open Gulf (Slone et al. 2022).

Manatee movements in the northern Gulf are characterized primarily by their need to return to protected warm water refuges in Florida each winter. This is realized by long migrations in the spring westward away from Florida's refuges. 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, ultimately depending on seagrasses and other aquatic or shoreline vegetation for forage (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. Failure to return to Florida's warm waters in the fall would likely lead to cold stress and death (Bossart et al. 2003; Laist et al. 2013; Hardy et al. 2019), barring rescue. 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 due to habitat loss and fragmentation and entanglements in fishing gear. Manatees are also susceptible to pathogens or toxins (e.g., red tide events). OCS oil- and gas-related activities in the Gulf are not likely to conflict with manatee movements or behavior due to the distance from shore and water depths greater than where manatees would be found (Slone et al. 2022).

3.7.4 Other Protected Marine Mammal Species

Nineteen out of 20 toothed cetaceans (including beaked whales and dolphins) that regularly occur in the Gulf are not ESA-listed. However, the MMPA 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. 2000b). Occurrence is primarily in the northern Gulf along the continental shelf edge and deeper waters off the continental shelf (Mullin et al. 1991; Rappucci et al. 2023). At sea, it is difficult to differentiate dwarf sperm whales from pygmy sperm whales due to their small body size and "logging behavior" while at the surface; therefore, sightings are often grouped together as "*Kogia* spp" (Rappucci et al. 2023). GoMMAPPS modeling indicates that *Kogia* spp. occur in highest densities in deep slope waters that are less influenced by the Loop Current or Loop Current eddies, after surveys conducted during 2003, 2004, 2009, 2017, and 2018 (Rappucci et al. 2023). Very little is known about the species, and most studies have been conducted on stranded individuals.

In the Gulf, 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 Gulf, they are broadly distributed in waters deeper than 1,000 m (3,281 ft) over the lower slope and abyssal landscapes (Davis et al. 1998; Davis et al. 2000b). Beaked whales were seen in the Gulf in all seasons during GulfCet aerial surveys (Mullin and Hoggard 2000). Sightings observed through two independent survey teams identified bimodal depth distribution with high densities in the central and western Gulf between the 1,000 and 2,000 m (3,281 to 6,562 ft) isobaths and in the deeper waters of the central Gulf (Rappucci et al. 2023). When the model is projected onto the southern Gulf, high beaked whale densities are predicted in the southeastern Gulf in the Yucatán and Florida Straits (Rappucci et al. 2023). Beaked whale species that may occur within the Gulf are usually observed singly or in small groups of individuals (Jefferson et al. 2008a). There are no known beaked whale hot spots in the Gulf (Würsig 2017). As a group, they are poorly studied because of their low availability at the surface and the challenge of seeing them at the surface, though they are thought to be deep-diving animals because they feed on deepwater cephalopods and fish (Jefferson et al. 2008a; Würsig 2017; Rappucci et al. 2023).

Three species of *Mesoplodon* are known to occur in the Gulf based on sighting and stranding data and are considered provisional stocks: Gervais' beaked whale, Blainville's beaked whale, and Cuvier's beaked whale (Würsig et al. 2000b; Waring et al. 2014). Sowerby's beaked whale is considered extralimital in the Gulf. Gervais' beaked whale appears to be widely, though sparsely, distributed across temperate to tropical waters worldwide (Jefferson and Schiro 1997). Blainville's beaked whale is distributed throughout temperate and tropical waters worldwide, but it is not considered common (Würsig et al. 2000b). Cuvier's beaked whale is widely, though sparsely, distributed throughout temperate and tropical waters worldwide

(Würsig et al. 2000b). They are sighted in the Gulf in all seasons in water depths typically greater than 500 m (1,640 ft) (Maze-Foley and Mullin 2006).

Fourteen members of the Family Delphinidae (dolphins) are known to occur in the Gulf. 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. 2000b; 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 Gulf. Bottlenose dolphins occur in a diverse range of habitats, including within estuaries, shallow continental shelf waters, OCS waters, and deep waters over the inner continental slope (Garrison et al. 2024a). Associated with this diverse range of habitats is a diverse range of residency and movement patterns observed among sympatric bottlenose dolphin populations (Garrison et al. 2024a). Dolphins in Barataria Basin in Louisiana were confirmed to be genetically differentiated from those in adjacent coastal waters (Speakman et al. 2022). Further, genetically distinct stocks of bottlenose dolphins were identified along the Texas coast, with a high degree of genetic differentiation among adjacent stocks (Garrison et al. 2024a).

There appears to be multiple stocks of common bottlenose dolphins in the northern Gulf: a coastal stock (16–67 m [52–210 ft]) and an offshore stock (about 250 m [820 ft]) (Duffield et al. 1983; Hoelzel et al. 1998; Rosel et al. 2009; Rappucci et al. 2023; Garrison et al. 2024a). 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 offshore stock of bottlenose dolphins has been sighted in waters near a shelf break with majority of sightings occurring in the northeastern Gulf and in waters that are less influenced by the Loop Current or Loop Current eddies. The inshore stock of bottlenose dolphins occurred more frequently in areas with higher chlorophyll-a concentrations, with lower densities further from shore and in lower productivity areas. Density within this stock of bottlenose dolphin was seen to decline rapidly in waters greater than 100 m (328 ft) depth (Rappucci et al. 2023). Additionally, Garrison et al. (2024a) assessed bottlenose dolphin stock structure in the Gulf that consists of a complex suite of oceanic, continental shelf, coastal, and estuarine stock along the Texas coast. Results observed individuals in estuarine waters and in coastal waters identifying two types of genetic markers, suggesting that bottlenose dolphins in coastal waters of Texas are genetically different from those in the Texas bays, sounds, and estuaries (Garrison et al. 2024a).

Bottlenose dolphins are opportunistic feeders, foraging on a wide variety of fishes, cephalopods, and shrimp while using a variety of techniques to detect, pursue, and capture prey (Davis and Fargion 1996; Jefferson and Schiro 1997; Quigley et al. 2022). Quigley et al. (2022) documented benthic foraging behavior opportunistically of bottlenose dolphins in the Barataria Basin in the northern Gulf between 2010 and 2019. Common bottlenose dolphins were observed engaging in a previously unidentified behavior, termed drilling or drill feeding: a dolphin positions itself nearly vertically in shallow water and thrashes its flukes across the surface, presumably enabling foraging for prey in the below substrate (Quigley et al. 2022). Most observations of drill feeding occurred near the shore, along the interior of the barrier

islands, such as Grand Isle and western Grand Terre Island, and near marsh islands in the southwestern area of the estuary. This behavior was not observed in the central, open water sites of the study area's largest water bodies, such as Barataria and Caminada Bays. Large mud plumes were observed across drilling observations, suggesting a potential association with this behavior and sediment type (Quigley et al. 2022). Drill feeding occurred during all seasons.

Mills et al. (2024) observed that the ship channel in Aransas Pass functions as a natural bottleneck for prey species moving between the Gulf and Corpus Christi Bay that may attract and sustain bottlenose dolphins despite the threat of anthropogenic threats in this busy vessel port. This study analyzed the relationship among behavioral states and environmental and geographical variables, overall identifying behavioral hotspots. Despite the daily anthropogenic stressors, bottlenose dolphins seem to engage in all behavioral states closer to features of the industrialized area (i.e., deeply dredged channels, human-engineered seawalls) over natural features (i.e., mangroves, natural seagrass beds) (Mills et al. 2024).

Since 1987, cetacean strandings in Alabama have provided decades of valuable insights into the spatial, temporal, and demographic patterns of strandings in this unique area, which connects the eastern and western Gulf coastlines (Russell et al. 2022). Multiple distinct hotspots of cetacean strandings in the north-central Gulf (e.g., Alabama) have been identified; bottlenose dolphins are the most reported (Russell et al. 2022). These hotspots may be influenced by such factors as bathymetry, geography, human population density, and sources of mortality, such as increased fishing activity. Changes in bathymetry along coastlines, along with currents, riverine discharge, and wind speed and direction, can all impact stranding patterns in specific ways (Russell et al. 2022). Further analysis showed that bottlenose dolphin strandings were most frequent in the spring (March–May). Females and juveniles were more likely to strand during the calving season (January–April) compared to the non-calving season, possibly due to mortality events related to birthing or reproductive events (Russell et al. 2022).

Bloodgood et al. (2023) identified cetacean stranding from 2015 to 2020 in Alabama to determine the cause of death in bottlenose dolphins directly following the *Deepwater Horizon* oil spill. Human interaction is one of the main causes of mortality in marine mammals, and infectious diseases, like morbillivirus and *Brucella*, are ongoing threats for offshore cetaceans in the Gulf. Bloodgood et al. (2023) observed 19 out of 108 bottlenose dolphin strandings resulted in the presence of infectious diseases; 6 of those dolphin samples containing *Brucella*. This study indicated signs of endemicity of Brucella in cetaceans in the Gulf that can ultimately result in a decrease of reproductive success and subsequently affect population dynamics.

The Atlantic spotted dolphin, Risso's dolphin, rough-toothed dolphin, spinner dolphin, striped dolphin, and false killer whale are found in tropical to temperate waters (Miyazaki and Perrin 1994; Perrin et al. 1994a; 1994b; Perrin and Gilpatrick Jr. 1994; Jefferson and Schiro 1997). The Atlantic spotted dolphin is endemic to the Atlantic Ocean (Perrin and Gilpatrick Jr. 1994; Jefferson and Schiro 1997). They are one of the most commonly observed cetaceans in U.S. continental shelf waters, including the Gulf, where the Northern Gulf Stock resides (Viricel and Rosel 2014). The continental shelf genetic cluster, one of four distinct clusters of the Atlantic

spotted dolphin, comprises three groups: animals inhabiting shelf waters in the western North Atlantic, the eastern Gulf, and the western Gulf (Viricel and Rosel 2014). These dolphins habitually occur in waters at or less than 200 m (656 ft) where most sightings have occurred in 100 m (328 ft) water depth contours, particularly off the Florida shelf (Würsig 2017). They occur as far north as 50°N latitude (though typically to about 40°N latitude) and about 25°S latitude. Their general habitat range overlaps with that of continental slope bottlenose dolphins (Würsig 2017).

Surveys conducted between 2017 and 2018 document the presence of Atlantic spotted dolphins across the continental shelf and oceanic waters (Rappucci et al. 2023). They were observed in all seasons; higher densities were typically found on the OCS near the shelf break, with high occurrences in the northeastern Gulf, south of the Florida Panhandle, where deeper waters are located relatively close to shore (Rappucci et al. 2023). Within oceanic waters, the Atlantic spotted dolphin was rarely observed in the shelf break waters of the northern Gulf, with additional sightings recorded in both the eastern and western regions of the northern Gulf (Rappucci et al. 2023). The dolphins of the genus *Stenella* are not deep divers; they typically feed within the top several 100 m (328 ft) of the water surface, often on mesopelagic prey that move towards the surface at night (Würsig 2017). Stenellids are highly social animals and are often in groups of hundreds to thousands of animals, though group sizes can widely differ. In addition, stenellids often occur in interspecies aggregations (Würsig 2017).

Surveys conducted during 2003 to 2009 observed sightings of spinner dolphins and striped dolphins in the central-eastern and northern Gulf, particularly in areas with a relatively high chlorophyll-a content and north of the Loop Current (Rappucci et al. 2023). Risso's dolphins were observed more frequently in waters with intermediate surface chlorophyll levels, with higher densities in the northern and southern portions of the Gulf, and some sightings occurring in the Loop Current waters. This suggests that this species inhabits a diverse range of habitats across the continental slope of the northern Gulf (Rappucci et al. 2023).

Fraser's dolphin has a worldwide distribution in tropical waters. They are known to feed on a wide variety of fishes, cephalopods, crustaceans, and benthic invertebrates (Perrin et al. 1994a; Jefferson and Schiro 1997). In the Gulf, 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. 2000b). Species including false killer whales, pygmy killer whales, and melon-headed whales ("blackfish") were observed throughout the waters of the northern Gulf, with sightings primarily concentrated in the central and western regions, particularly in deeper waters off the continental shelf (Davis and Fargion 1996; Rappucci et al. 2023). 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). Limited information is available on this combined group of species because of the relatively small number of encounters and the lack of fit with dynamic environmental parameters, likely reflecting the rarity of these species in the GoMMAPPS study (Rappucci et al. 2023).

The short-finned pilot whale is distributed in tropical to temperate waters worldwide (Jefferson and Schiro 1997). They feed predominantly on squid, with fishes being consumed occasionally (Würsig et al. 2000b). Aggregations of short-finned pilot whales are commonly associated with other cetacean species (Maze-Foley and Mullin 2006). High densities of short-finned pilot whales are found to occur primarily in inner continental slope waters of the northwestern Gulf that are less influenced by the Loop Current or Loop Current eddies. When the model selected in GoMMAPPS was applied to the southern Gulf, it suggested high densities of pilot whales extending into the southwestern Gulf and the Bay of Campeche (Rappucci et al. 2023).

The pantropical spotted dolphin is considered the most common cetacean in the Gulf (Würsig 2017). These dolphins occur in tropical and subtropical waters from the equator to approximately 40°N latitude and 30°S latitude. They occur on the upper slope in waters of 100 m (328 ft), as well as their primary habitat, waters greater than 100 m (328 ft) and into the open abyssal zone of the Gulf (Würsig 2017). They are found in large groups, often over 100 dolphins per group. They feed on mesopelagic and epipelagic fishes, crustaceans, and squid, in addition to surface-dwelling flying fishes in some areas (Würsig 2017).

3.7.5 Marine Mammal Bioacoustics

As applicable, discussion of marine mammals outside of the Gulf is included as a proxy for Gulf marine mammals, representing the best available information at this time.

3.7.5.1 The Importance of Sound to Marine Mammals

Marine mammals are highly dependent on acoustic cues as a primary means of communicating and assessing their environment. Sound travels faster and farther in water (~1500 m/s; 4,921 ft/s) than it does in air (~350 m/s; 1,148 ft/s), making this a reliable mode of information transfer across large distances and in dark environments where visual cues are limited. Sound plays an essential role in critical activities like breeding, navigating, avoiding predators, foraging, and maintaining social structure. Marine mammals glean information from a range of acoustic signals, including ambient sounds produced on coral reefs, the low-frequency rumble associated with approaching storms, and the vocalizations of other marine fauna. Additionally, toothed whales use echolocation clicks to navigate their surroundings and locate prey (Madsen and Surlykke 2013).

3.7.5.2 Hearing Anatomy

Like terrestrial mammals, the auditory anatomy of marine mammals generally includes the inner, middle, and outer ear (Ketten 1994). Not all marine mammals have an outer ear, but if it

is present, it funnels sound into the auditory pathway. The middle ear acts as a transformer, filtering and amplifying the sound. The inner ear is where auditory reception takes place. The key structure in the inner ear responsible for auditory perception is the cochlea, a spiral-shaped structure containing the basilar membrane, which is lined with auditory hair cells. Specific areas of the basilar membrane vibrate in response to the frequency content of the acoustic stimulus, causing hair cells mapped to specific frequencies to be differentially stimulated and send signals to the brain (Ketten 1994). Though the cochlea and basiliar membrane are well conserved structures across all mammalian taxa, there are some key differences in the auditory anatomy of terrestrial versus marine mammals. Marine mammals have the unique need to hear in aqueous environments. Amphibious marine mammals (including seals, sea otters, and sea lions) have evolved to hear both in air and under water, and all except phocid pinnipeds have external ear appendages. Cetaceans do not have external ears, do not have air-filled external canals, and the bony portions of the ear are much denser than those of terrestrial mammals (Ketten 1994).

All marine mammals have binaural hearing and can extract directional information from sound. However, the pathway that sound takes into the inner ear is not well understood for all cetaceans and may not be the same for all species. For example, in baleen whales, bone conduction through the lower jaw and skull is likely to play a role in hearing (Cranford and Krysl 2015) transferring vibrations to the tympanic bullae, which each vibrate at different frequencies. This is believed to be the way in which baleen whales experience directional hearing (Morris et al. 2025). Odontocetes have a fat-filled portion of the lower jaw which is thought to funnel sound towards the ear (Mooney et al. 2012). Hearing tests have been conducted on several species of odontocetes, while only two adolescent individuals of the same baleen whale species (minke whale) have ever been tested (Houser et al. 2024). Therefore, most understanding of baleen whale hearing comes from examining the ears of deceased whales (Erbe et al. 2016; Houser et al. 2017).

Many marine mammal species produce sounds through vibrations in their larynx (Frankel 2002). In baleen whales, for example, air in the lungs and laryngeal sac expands and contracts, producing vibrations and sounds within the larynx (Frankel 2002). Baleen whales produce low-frequency sounds that can be used to communicate with other animals over great distances (Clark and Gagnon 2002). Differences in sound production among marine mammals varies, in part, with their use of the marine acoustic environment. Toothed whales hunt for their prey using relatively high-frequency (10s of kHz) echolocation signals. To produce these signals, they have a specialized structure called the “melon” in the top of their head that is used for sound production. When air passes through the phonic lips, a vibration is produced, and the melon helps transmit the vibration from the phonic lips to the environment as a directed beam of sound (Frankel 2002). It is generally believed that if an animal produces and uses a sound at a certain frequency, its hearing sensitivity will at least overlap those frequencies. An animal’s hearing range is likely much broader than this, as they rely heavily on acoustic information–beyond the signals they produce themselves–to understand their environment.

3.7.5.3 Functional Hearing Groups

Marine mammal species have been classified into functional hearing groups based on similar anatomical auditory structures and frequency-specific hearing sensitivity obtained from hearing tests on a subset of species (Finneran et al. 2017; NMFS 2018; Southall et al. 2019). For those species for which empirical measurements have not been made, the grouping of phylogenetic and ecologically similar species is used for categorization. This concept of marine mammal functional hearing groups was first described in 2007 by Southall et al. After a few updates based on newer studies and science (Southall et al. 2019), NMFS (2024a) now recognizes at least eight functional hearing groups, i.e., low-frequency cetaceans, high-frequency cetaceans, very-high frequency cetaceans, sirenians, phocids in air, phocids in water, other marine carnivores in air, and other marine carnivores in water, described in Southall et al. (2019). The NMFS has the regulatory authority over the protection of cetaceans, and most pinnipeds species, and the functional hearing groups for Gulf species are provided in **Table 3-12**. The FWS oversees the protection of sirenians and other marine carnivores (i.e., polar bears, walruses, and sea otters).

Table 3-12. Marine Mammal Functional Hearing Groups from the NMFS 2024 technical guidance

Hearing Group	Generalized Hearing Range* (hertz to kilohertz)
Low-frequency (LF) cetaceans (baleen whales)	7 Hz to 36 kHz
High-frequency (HF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz
Very-high frequency (VHF) cetaceans (true porpoises, *Kogia*, river dolphins, *Cephalorhynchid*, *Lagenorhynchus cruciger & L. australis*)	200 Hz to 165 kHz
Sirenians	250 Hz to 72 kHz

*Represents the generalized hearing range for the entire group as a composite (i.e., all species within the group), where individual species' hearing ranges may not be as broad. Generalized hearing range chosen based on ~65 dB threshold from composite audiogram, previous analysis in NMFS (2018), and/or data from Southall et al. (2007; 2019). Additionally, animals are able to detect very loud sounds above and below that "generalized" hearing range.

Since the last publication summarizing the best available information on marine mammal functional hearing groups (Southall et al. 2019), a formative study on hearing in baleen whales was conducted. In a bay off Norway, auditory brainstem response tests were performed on two adolescent minke whales in-situ (Houser et al. 2024). The upper limit of their hearing range was determined to be between 45 and 90 kHz, substantially higher than previously thought. Because this study was conducted while the NMFS technical guidance was being updated, this information did not inform the 2024 technical guidance.

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, along with Rice's whales, are classified as low-frequency cetaceans (7 Hz–36 kHz) (NMFS 2024a). 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 100–900 Hz and discrete pulses at 700–900 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 Rice's whales.

A study by Soldevilla et al. (2022a) used sonobuoys and passive acoustic tagging to validate the source of potential call types and to characterize Rice's whale calls. During concurrent visual and acoustic surveys, acoustic-directed approaches were conducted to obtain visual verifications of sources of localized sounds. Of 28 acoustic-directed approaches, 79 percent led to sightings of balaenopterid whales, of which 10 could be positively identified as Rice's whales (Soldevilla et al. 2022a). Long-moan calls, downsweep sequences, and tonal-sequences are attributed to Rice's whales, based on these matches. A potential new call type, the low-frequency downsweep sequence, is characterized from tagged Rice's whale recordings (Soldevilla et al. 2022a).

Tenorio et al. (2023) found that Rice's whales studied via PAM in the northeastern Gulf produced a variety of vocalizations that could be used for individual identification and location tracking. These vocalizations may also be used to identify the presence of aggregations of Rice's whales in a specific area. Rice's whales were found to be present mainly in shallow waters and their vocal activity increased during the winter months (Tenorio et al. 2023).

The sperm whale is classified within the high-frequency cetacean functional hearing group (150 Hz–160 kHz) (NMFS 2024a). 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). These codas have distinct patterns and appear to be culturally transmitted (Watkins and Schevill 1977; Whitehead and Weilgart 1991; Rendell and Whitehead 2001). Gulf sperm whales comprise a distinct acoustic clan, rarely encountered outside of the Gulf (Rendell and Whitehead 2003; Gordon et al. 2008; Antunes 2009). 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, though they are classified within the very-high frequency cetacean functional hearing group (200 Hz–165 kHz) (NMFS 2024a). 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 (Ridgway and Carder 2001; Cook et al. 2006; Finneran 2009), 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 high-frequency cetaceans with functional hearing of approximately 150 Hz–160 kHz (NMFS 2024a). Because 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.

3.7.5.4 Potential Vulnerabilities: Marine Mammals and Underwater Sound

The importance of sound to marine mammals, consequently, means there is potential for adverse effects from unwanted sounds, such as anthropogenic noise. Depending on the level of exposure, the context, and the type of sound, potential effects of underwater sound on marine mammals may include non-auditory injury, auditory injury (e.g., permanent hearing loss), temporary hearing loss, behavioral changes, acoustic masking, or increases in physiological stress (OSPAR Commission 2009). Each of these effects is discussed below.

Non-auditory Injury: Non-auditory physiological injury is possible for very intense sounds or blasts, such as explosions. This kind of effect is possible only during detonation of explosives in decommissioning or in the rare case of occurrence of unexploded ordnances. Although many marine mammals are able to adapt to large changes in pressure–such as by a deep foraging dive–the shock waves produced by explosives expose the animal to rapid and great changes in pressure. These pressure changes cause a rapid expansion of air-filled cavities (e.g., the lungs) for which there is no compensation. This forces the surrounding tissue or bone to move beyond its limits and may lead to tears, breaks, or hemorrhaging. The extent and severity to which such injury will occur depends on several factors including the size of these air-filled cavities, ambient pressure, how close an animal is to the blast, and how large the blast is (Finneran et al. 2017). In extreme cases, this can lead to severe lung damage that can directly kill the animal; a less severe lung injury may indirectly lead to death due to an increased vulnerability to predation or the inability to complete foraging dives.

Auditory Injury and Temporary Hearing Loss: An animal's auditory sensitivity to a sound depends on the spectral, temporal, and amplitude characteristics of the sound (Richardson et al. 1995). When exposed to sounds of significant duration and amplitude (typically within close range of a source), marine mammals may experience noise-induced threshold shifts and auditory injury (AUD INJ), which includes but is not limited to PTS. TTS often results from hair cell fatigue (Saunders et al. 1985; Yost 2000). While experiencing TTS, the hearing threshold

rises, meaning that a sound must be louder to be detected. Prolonged or repeated exposure to sounds at levels that are sufficient to induce TTS–without adequate recovery time–can lead to auditory injury including PTS (Southall et al. 2007; Finneran 2015). Research suggests that some odontocete species may have mechanisms to selectively reduce their hearing sensitivity when provided with a precursory cue that an intense sound is just about to arrive, which may help to protect themselves from auditory injury or TTS (Nachtigall and Supin 2013).

Behavioral Impacts: When exposed to underwater sound, marine mammals may show varying levels of behavioral disturbance ranging from no observable response to overt behavioral changes. They may flee from an area to avoid the noise source, change their vocal activity, stop or change foraging behaviors, or change their typical dive or social behavior, among other responses (National Research Council 2003a). The implications of behavioral disturbance can range from temporary displacement of an individual, to long-term consequences on a population, such as a reduction in fitness related to decreased foraging success. Studies have shown that noise level alone often fails to reliably predict behavioral responses because several contextual factors have a role in whether and how an animal will respond (Richardson et al. 1995; Southall et al. 2007; Ellison and Frankel 2012; DeRuiter et al. 2013; Gomez et al. 2016). Some of these factors include: (1) the exposure context (e.g., behavioral state of the animal, habitat characteristics), (2) the biological relevance of the signal (e.g., whether the signal is audible, whether the signal sounds like a predator), (3) the life stage of the animal (e.g., juvenile, mother and calf), (4) previous experiences of the animal (e.g., is it a novel sound source), (5) sound properties (e.g., duration of sound exposure, sound pressure level, sound type, mobility/directionality of the source), and (6) physical properties of the medium that may affect how the sound propagates (e.g., bathymetry, temperature, salinity) (Southall et al. 2021). It is also possible that marine mammals may become habituated (show a reduced response) or sensitized (show an increased response) when repeatedly exposed to sounds (Bejder et al. 2009). Over the course of a habituation process, individual tolerance levels will increase, whereas tolerance levels will conversely decrease as individuals become sensitized to specific stimuli (Bejder et al. 2009). Variability exists across species and among individuals, resulting in variable thresholds of disturbance (see Richardson et al. 1995; Gomez et al. 2016 for a review). Because of these many factors, behavioral impacts are challenging to both predict and measure; this remains an active field of study in marine mammal bioacoustics.

Auditory Masking: 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 because there is noise present in the same frequency band. In other words, masking occurs when a noise source overlaps in time, space, and frequency with a signal of interest and obscures an animal's ability to hear it (Richardson et al. 1995; Clark et al. 2009). Auditory masking may occur over larger spatial scales than noise-induced threshold shift or behavioral disturbance. Masking can reduce an individual's "communication space," (the range at which it can effectively transmit and receive acoustic cues from conspecifics) or "listening space" (the range at which it can detect relevant acoustic cues from the environment). A growing body of research is focused on the risk of masking from anthropogenic sources, the ecological significance of masking, and what anti-masking strategies may be used by marine

mammals (Scheifele et al. 2005; Clark et al. 2009; Holt et al. 2009; Branstetter and Sills 2022). This understanding is essential to fully address masking in NOAA regulation (not under BOEM's authority) or mitigation approaches (Erbe et al. 2016). In the interim, most assessments only consider the overlap in frequency between the sound source and the hearing range of marine mammals.

Physiological stress: The presence of anthropogenic noise, even at low levels, can increase physiological stress in marine mammals (Wright et al. 2007; Kight and Swaddle 2011). For example, responses to stress may change various hormone levels (including cortisol, corticosterone, aldosterone, catecholamines, reproductive hormones, thyroid hormones, among others) (Watt et al. 2021), and animals may exhibit increased respiration rates, an increase or decrease in heart rate (Williams et al. 2022), or changes in other bodily functions. With prolonged stress from noise, these physiological changes may be tied to lower reproductive rates or decreased fertility, compromised immune function (Rolland et al. 2012), or disrupted metabolic regulation, leading to accelerated aging or slowed growth. It can be difficult to observe or sample these responses in wild animals. Several methods have emerged that allow for reliable measurements in marine mammals (Hunt et al. 2014) and may include sampling through blood, saliva, blubber, feces, urine, or the blow produced by a whale, or tagging animals with heart rate monitors (Rolland et al. 2005). The impact of physiological stress on an individual or population can be exacerbated by other factors, such as the age or condition of the animal (e.g., undergoing stress during a critical life stage such as reproduction, or while its health is already compromised) or its vulnerability from other stressors (e.g., food scarcity, habitat loss).

The effects of anthropogenic sound on marine life have been studied for more than half a century. In that time, it has become clear that this is a complex subject with many interacting factors and extreme variability in response from one sound source to another and from species to species, and even within species (i.e., individuals may have markedly different responses to a similar exposure). However, some general trends have emerged from this body of work. First, the louder and more impulsive (see **Appendix B**) the received sound is, the higher the likelihood that there will be an adverse physiological effect, such as auditory injury or TTS. These impacts generally occur at relatively close distances to a source, in comparison to behavioral effects, masking, or increases in stress, which can occur wherever the sound can be heard. Second, the hearing sensitivity of an animal plays a major role in whether it will be affected by a sound or not, and there is a wide range of hearing sensitivities among marine mammal species. Regulation to protect marine life from anthropogenic sound has formed around these general concepts (**Section 4.1.2**).

3.7.5.4.1 Thresholds for Auditory Injury

The MMPA and ESA are the two statutes that are most relevant when considering potential harm from anthropogenic noise on marine mammals (**Section 4.1.2**).

The MMPA prohibits the "take" of marine mammals, defined as the harassment, hunting, capturing, killing, or an attempt of any of those actions on a marine mammal (16 USC 1362). This act requires that an incidental take authorization be obtained from the NMFS for the incidental take of marine mammals as a result of anthropogenic activities. MMPA regulators divide the effects on marine mammals that could result in a take into Level A and Level B, defined as follows:

Level A: Any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild.

Level B: Any act of pursuit, torment, or annoyance that has the potential to disturb a marine mammal or marine mammal stock in the wild by causing a disruption of behavioral patterns including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but that does not have the potential to injure a marine mammal or marine mammal stock in the wild (16 USC 1362).

With respect to anthropogenic sounds, NMFS publishes acoustic thresholds, otherwise known as "Acoustic Guidance," to delineate the sound levels at which potential takes could occur (NMFS 2024a). Level A takes include auditory injury, whereas Level B takes include behavioral effects as well as TTS. The current regulatory framework used by NMFS for evaluating an acoustic take of a marine mammal involves assessing whether the animal's received sound level exceeds a given threshold. For Level A, this threshold differs by functional hearing group, but for Level B, the same threshold is used across all marine mammals.

The current NMFS (2024a) injury (Level A) thresholds consist of dual criteria of Lpk and 24 hour-cumulative SEL thresholds for both impulsive and non-impulsive sources (**Table 3-13**). These criteria, along with information about source levels and sound propagation, are used to predict the potential distance from a sound source within which injury may occur. Whichever criterion results in the largest distance is generally used, to be most conservative. The SEL thresholds are frequency-weighted, which means that the sound is filtered based on the frequency-specific hearing sensitivity of the functional hearing group, de-emphasizing the frequencies at which the animals are less sensitive (see **Section 3.7.5.3** for the frequency range of hearing for each group). The frequency-weighting functions are described in detail in NMFS (2024a).

Table 3-13. The acoustic thresholds for onset of auditory injury and temporary threshold shift for marine mammals for both impulsive and non-impulsive sound sources

Marine Mammal Functional Hearing Group	Effect	Impulsive Source L_{pk} (dB re 1 µPa)	Impulsive Source Weighted SEL_{24h} (dB re 1 µPa²s)	Non-Impulsive Source Weighted SEL_{24h} (dB re 1 µPa²s)
Low-frequency cetaceans	AUD INJ	222	183	197
Low-frequency cetaceans	TTS	216	168	177
High-frequency cetaceans	AUD INJ	230	193	201
High-frequency cetaceans	TTS	224	178	181

Marine Mammal Functional Hearing Group	Effect	Impulsive Source L_{pk} (dB re 1 µPa)	Impulsive Source Weighted SEL_{24h} (dB re 1 µPa²s)	Non-Impulsive Source Weighted SEL_{24h} (dB re 1 µPa²s)
Very-high frequency cetaceans	AUD INJ	202	159	181
Very-high frequency cetaceans	TTS	196	144	161
Sirenians	AUD INJ	225	186	200
Sirenians	TTS	219	171	180

AUD INJ = auditory injury

TTS = temporary threshold shift

Note: L_{pk} values are unweighted within the generalized hearing range of marine mammals (i.e., 7 Hz to 160 kHz): Values presented for SEL use a 24-hour accumulation period unless stated otherwise and are weighted based on the relevant marine mammal functional hearing group (Accomando et al. 2024). Underwater thresholds are in dB re 1 µPa = decibels relative to 1 µPa; dB re 1 μPa^2s = decibels relative to 1 µPa squared second; whereas thresholds in air are in dB re 20 µPa = decibels relative to 20 µPa; dB re 20 μPa^2s = decibels relative to 20 µPa squared second. Non-impulsive sources can also be compared to the Lpk criteria if there is a chance of exceedance.

From: NMFS 2024a.

Auditory Injury from Explosives: The supersonic shock wave from an explosion transitions into a normal pressure wave at a range determined by the weight and type of the explosive used. The range to the TTS and auditory injury threshold are greater than these radii, so the normal impulsive TTS and auditory injury thresholds (**Table 3-13**) are applicable for determining auditory injury impacts NMFS (2024a).

3.7.5.4.2 Thresholds for Behavioral Disturbance

NMFS currently uses a threshold for behavioral disturbance (Level B) of 160 dB re 1 µPa SPL for nonexplosive impulsive sounds (e.g., airguns and impact pile driving) and intermittent sound sources (e.g., scientific and non-tactical sonar), and 120 dB re 1 µPa SPL for continuous sounds (e.g., vibratory pile driving, drilling, etc.) (70 FR 1871). This is an "unweighted" criterion that is applicable for all marine mammal species. Unlike with SEL-based thresholds, the accumulation of acoustic energy over time is not relevant for this criterion, meaning that a Level B take can occur even if an animal experiences a received SPL of 160 dB re 1 µPa very briefly in one instance.

Though the Level B criterion is generally treated as a binary step function (i.e., no effect less than the threshold, always an effect at the threshold or higher), as alluded to previously, numerous factors determine whether an individual will be affected by a sound, resulting in substantial variability even in similar exposure scenarios. In particular, it is recognized that the context in which a sound is received affects the nature and extent of responses to a stimulus (Southall et al. 2007; Ellison and Frankel 2012). Another, more gradual step function for Level B harassment was introduced by Wood et al. (2012) considering some of this complexity: it delineates proportions of exposed individuals that would experience behavioral disturbance at different received levels. These probabilistic thresholds reflect the higher sensitivity that has

been observed in beaked whales and migrating mysticete whales (**Table 3-14**). Currently, this step function provides an additional approach for calculating Level B takes for certain species groups. The M-weighting functions (frequency-weighting curves to account for hearing sensitivity differences of marine mammals), described by Southall et al. (2007) and used for the Wood et al. (2012) probabilistic disturbance step thresholds, are different from the weighting functions in NMFS (2024a), previously mentioned. The M-weighting was specifically developed for interpreting the likelihood of audibility, whereas the NMFS (2024a) weighting functions are used to predict the likelihood of auditory injury.

Table 3-14. Probabilistic disturbance $L_{p,rms}$ thresholds (M-weighted) dB re 1 µPa used to predict a behavioral response.

Marine Mammal Group	120	140	160	180
Porpoises/beaked whales	50%	90%	-	-
Migrating mysticete whales	10%	50%	90%	-
All other species/behaviors	-	10%	50%	90%

Note: Probabilities are not additive and reflect single points on a theoretical response curve.
From: Wood et al. 2012.

Behavioral Disturbance from Explosives: Because the duration is so short, NMFS does not anticipate that single blast events within a 24-hour period would induce behavioral effects as long as the exposures are below the onset of TTS thresholds for frequency-weighted SEL and peak pressure level. Only short-term startle responses are expected as far as behavioral responses. For multiple detonations, the threshold applied for behavioral effects is that same TTS threshold minus 5 dB (see **Table 3-13** for TTS threshold values).

3.7.5.4.3 Thresholds for Non-Auditory Injury

Shock waves associated with underwater detonations can induce non-auditory physiological effects, including mortality and direct tissue damage (i.e., severe lung injury, slight lung injury, and gastrointestinal [G.I.] tract injury). The magnitude of the acoustic impulse, measured in pascal-seconds (Pa-s), is the integral of the positive-pressure shock pulse over time and serves as the threshold to predict non-auditory lung injury and mortality. Because lung capacity or size is generally directly related to the size of an animal, body mass is one parameter used to predict the likelihood of lung injury. Additionally, the depth of the animal is used, as this represents the ambient pressure conditions of the animal, as a scaling parameter for lung volume. G.I. tract injury potential is identified using the peak sound pressure level and is considered to occur beginning at levels of 237 dB re 1 µPa. The U.S. Navy established thresholds to assess the potential for mortality and slight lung injury from explosive sources based on a modified Goertner Equation (Finneran et al. 2017). This model is recommended by NMFS for predicting injury impacts to marine mammals from explosives (**Table 3-15**).

Table 3-15. U.S. Navy impulse and peak pressure threshold equations for estimating mortality or injury due to explosives in marine mammals

Impact Assessment Criterion	Threshold
Onset Mortality - Impulse	$103M^{1/3}(1+ D/10.1)^{1/6}$ Pa-s
Onset Injury (Non-auditory) - Impulse	$47.5M^{1/3}(1+ D/10.1)^{1/6}$ Pa-s
Onset Injury (Non-auditory) – Peak Pressure	L_{pk} of 237 dB re 1 µPa

Note: Where M is animal mass (kg) and D is animal depth (m).
From: Accomando et al. 2025.

3.7.5.4.4 General Approach to Acoustic Exposure Modeling

To predict the number of individuals of a given species that may be exposed to harmful levels of sound from a specific activity, a series of modeling exercises is conducted. First, the sound field of a sound-generating activity is modeled based on characteristics of the source (e.g., source level, frequency, directionality, beamwidth, deployment depth, array characteristics) and the physical environment (e.g., sediment type, sediment layers, sound speed, bathymetry). From the sound field, the range to the U.S. regulatory acoustic threshold isopleths can be predicted. This approach is referred to as acoustic modeling. By overlaying the marine mammal density information for a certain species or population in the geographical area of the activity, the number of animals exposed within the acoustic isopleths is then predicted. This is called exposure modeling. Some models further incorporate animal movement to make more realistic predictions of exposure numbers. Animal movement models may incorporate behavioral parameters including swim speeds, dive depths, course changes, or reactions to certain sound types, among other factors. Exposure modeling may be conducted for a range of scenarios including different seasons, energy (e.g., size of airgun array or pile driving hammers), mitigation strategies (e.g., 6 dB versus 10 dB of attenuation), and levels of effort (e.g., size of the survey).

3.7.6 Environmental and Anthropogenic Stressors

3.7.6.1 Noise

The underwater soundscape in the Gulf is dominated by sounds from anthropogenic activities, including geophysical (seismic) exploration and commercial shipping noise (Wiggins et al. 2016; Frasier et al. 2024b). Due to the highly industrialized environment, the ambient sound levels in the Gulf below 1 kHz are very high, and, while this may be more pronounced in the summer, there is little difference spatially because low-frequency sources persist over long distances (Amaral et al. 2022). Numerous other sources of anthropogenic activity in the Gulf produce sound, as well, including commercial and recreational fishing, dredging, coastal and offshore construction, mineral exploration in offshore areas, U.S. Navy sonar activity, and ocean research activities. There are also many non-anthropogenic sources of sound in the area, including biological sounds from marine mammals and fish, as well as geological and weather-related (e.g., hurricanes, wind, rain) sound (Jones et al. 2025).

Many of the biological and abiotic sounds in the Gulf are natural sounds that most animals are accustomed to. However, just because a sound is natural, does not mean it will not have an adverse effect on a receiver. For example, the sound of a predator may increase the physiological stress of the individual being hunted. Or, during a hurricane with stronger than usual wind conditions, masking may be more likely to occur for animals trying to communicate with conspecifics. These are examples of interactions with natural underwater sounds with which animals have evolved to live. For information on marine mammal bioacoustics, see **Section 3.7.5**. As applicable, discussion of marine mammals outside of the Gulf is included as a proxy for Gulf marine mammals, representing the best available information at this time.

The U.S. Navy uses low (<1kHz, LFAS) and mid-frequency (1–10 kHz, MFAS) sonar in the Gulf to detect and track submarines, and to locate mines. Historically there have been numerous cases of navy sonar use linked to marine mammal strandings, primarily beaked whales, in the Gulf (D'Amico et al. 2009; Finneran et al. 2017) and around the world. It is difficult to assess why these strandings occurred, as it is not until a stranding happens that researchers become aware and can investigate the situation, which is usually too late to understand the exact situation the whale was in before it stranded. These strandings may have occurred because the sound may have disoriented the animals causing them to behave outside their normal behaviors, increased their stress levels, or rendered the animals unable to navigate or communicate effectively. As a result, a robust research program, largely focused on behavioral effects, now exists to better understand the effects of U.S. Navy activities (McCarthy et al. 2011; Manzano-Roth et al. 2016; Harris et al. 2017). One consistent finding from these studies is that animals tend to leave the vicinity when naval sonar is in use, ceasing whatever activity in which they were previously engaged. One study found that, in beaked whales, the playback of killer whale calls elicited the same response as naval sonar (Tyack et al. 2011). The animals stopped making foraging echolocation clicks and took an unusually long time to ascend from their deep foraging dives. The authors hypothesized that due to the similarity in frequencies, the whales may have mistaken the sonar sound for a predator.

Vessel Noise

Vessel noise in the Gulf comes primarily from large container ships and other shipping vessels that come in and out of port through the Gulf. Source levels for large container ships can range from 177 to 200 dB re 1 µPa·m or more (McKenna et al. 2013) with most energy concentrated below 1 kHz. This low-frequency noise from merchant ships can travel extremely far distances and has been shown to be detectable at 125 km (78 mi) from the source (Aulanier et al. 2017). A recent assessment of the underwater soundscape in the Gulf between 2018 and 2020 reported vessel traffic as the second (after airgun noise) major source of anthropogenic noise in the region, with vessel activity being present between 10–100 percent of the time, and a greater presence in the summer months (Amaral et al. 2022). Due to the chronic presence of vessel noise in the Gulf, marine mammals may experience behavioral or acoustical changes, masking, and/or an increase in physiological stress. In an environment where vessel activity is present for substantial periods of time, vessel noise likely functions as a chronic stressor for many marine mammals in the Gulf.

Behavioral changes have been observed in marine mammals as a result of vessel noise exposure. Reviews of the literature on marine mammals and vessel noise (Richardson et al. 1995; Erbe et al. 2019) revealed that changes in behavior vary widely across species. These responses have ranged from flee responses at long ranges and longer, deeper dives (Finley 1990; Martin et al. 2023) to increases in swim velocities in beluga whales (Finley 1990), humpbacks (Sprogis et al. 2020), and narwhals (Williams et al. 2022). Dolphins have shown longer inter-breath intervals (Nowacek et al. 2001) and dolphin pods have shown increased breathing synchrony (Hastie et al. 2003). Humpback whales have shown changes in respiration rates (Sprogis et al. 2020). Changes to foraging behavior, which can have a direct effect on an animal's fitness, have been observed in killer whales (Holt et al. 2021) in response to vessel noise.

Some marine mammals may change their acoustic behaviors in response to vessel noise, either due to a sense of alarm or in an attempt to avoid masking. For example, fin whales (Castellote et al. 2012) and belugas (Lesage et al. 1999) have altered the frequency characteristics of their calls in the presence of vessel noise. When vessels are present, bottlenose dolphins increased the number of whistles (Buckstaff 2004; Guerra et al. 2014), sperm whales decreased the number of clicks (Azzara et al. 2013), and humpbacks and belugas completely stopped vocal activity (Finley 1990; Tsujii et al. 2018). Some species may change the duration of vocalizations (fin whales shortened their calls - Castellote et al. 2012) or increase call amplitude (killer whales - Holt et al. 2009) to avoid acoustic masking. Holt et al. (2015) found that as bottlenose dolphins increased the amplitude of their calls, metabolic rates increased by 20–50 percent. Although this study was not tied directly to exposure to vessel noise, it provides insight about the potential energetic cost of vocal changes (i.e., increases in vocal effort such as louder, longer, or increased number of calls). Understanding the scope of acoustic masking is difficult to observe directly, but several studies have modeled the potential decrease in "communication space" when vessels are present (Clark et al. 2009; Erbe et al. 2016; Putland et al. 2017). For example, Putland et al. (2017) showed that during the closest point of approach (<10 km; 6 mi) of a large commercial vessel, the potential communication space of Bryde's whale was reduced by 99 percent compared to ambient conditions.

Finally, several studies have demonstrated a correlation between low-frequency anthropogenic noise and physiological stress in baleen whales. Rolland et al. (2012) showed that fecal cortisol levels (an indicator of stress) in North Atlantic right whales decreased following the 9/11 terrorist attacks, when vessel activity was significantly reduced. Similar responses have been observed in humpback whales (Pallin et al. 2022) and narwals (Watt et al. 2021). On daily and monthly timescales, gray whales have also shown changes in adrenal stress depending on vessel activity (Lemos et al. 2022). Interestingly, North Atlantic right whales do not seem to avoid vessel noise nor vessel presence (Nowacek et al. 2004), yet they may incur physiological effects (e.g., stress), as demonstrated by Rolland et al. (2012). Understanding unobservable effects, such as physiological changes, is especially important in the absence of observable effects. In some cases, animals may stay in an area where they are exposed to a stressor like chronic vessel noise because the benefits (e.g., prey availability, habitat suitability) outweigh the cost to the animal (e.g., Nehls et al. 2024).

3.7.6.2 Coastal Development and Lighting

An increase in built infrastructure (e.g., residential areas, industrial centers, ports, hotels, resorts, marinas, docks, seawalls, bridges, and roads) may affect habitat used by coastal marine mammals (e.g., coastal dolphins and manatees). Coastal construction can degrade or destroy coastal habitats and degrade water quality by increased sedimentation and pollutant runoff, affecting coastal marine mammals if ingested (e.g., via prey consumption). Dolphins have been shown to stop feeding though continue socializing in habitat degraded by coastal bridge construction (Weaver 2021). Marine mammals are not expected to be vulnerable to lighting, because they typically rely more on acoustic cues.

3.7.6.3 Fisheries Interactions

Different marine industries add gear into the ocean, and commercial or recreational fishing comprises one of the most common sources (NMFS 2025a). Commercial fishery interactions are a threat to marine mammals because they may be injured or killed by commercial fishing gear, notably through entanglement. Active fishing line and gear used in commercial and/or recreational fisheries, which are managed by NMFS (i.e., outside of BOEM and BSEE regulatory authority), can pose entanglement and ingestion risks to marine mammals (Wells et al. 1998; Jog et al. 2022). 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 traps; lines; lines and buoys; nets and monofilament line from commercial and recreational fishing boats (NMFS 2025a), and discarded strapping bands and ropes from a variety of vessels. For example, Rice's whales' foraging behavior of high-power circling along the seafloor before lunging upward may increase the risk for encountering and becoming entangled in bottom longline fishery gear, which is the most prevalent type of fishery in their primary northeastern Gulf habitat (Soldevilla et al. 2017; Kok et al. 2023). Fisheries bycatch of marine mammals has also occurred in the Gulf, such as from pelagic longline fisheries and shrimp trawl fisheries (Benaka et al. 2019). See **Section 3.7.6.6** for further information on fisheries interactions from marine debris.

3.7.6.4 Vessel Strike

All marine mammals are vulnerable to accidental vessel strikes. However, some marine mammal species may be more vulnerable than others to possible vessel strike with all vessels operating at speed, including primarily slow-moving species (e.g., manatees) or those that spend extended periods of time at the surface (e.g., Rice's whales), and deep-diving species (e.g., sperm whales) while on the surface (Vanderlaan and Taggart 2007). For example, Rice's whales may spend up to 88 percent of their time at night, and 70 percent of their time overall, within 15 m (39 ft) of the ocean surface (Soldevilla et al. 2017), making them particularly vulnerable to collisions with large vessels (Stevens et al. 2024). Deep-diving sperm whales are also vulnerable to vessel strikes because of the surface period they require (several minutes) to

recover from extended, deep dives (Laist et al. 2001; Vanderlaan and Taggart 2007; Fais et al. 2016b). Sperm whales have been shown to be unable to outmaneuver a fast vessel approaching under stratified water conditions, which is when sound propagation is strongly anisotropic resulting in reduced warning times of approaching vessels (Gannier and Marty 2015).

Accidental vessel strike could result in marine mammal injury, mortality, or no apparent effect (Laist et al. 2001; Van Waerebeek et al. 2007; Vanderlaan and Taggart 2007; Pace 2011). Vessel strike from non-OCS activities has been implicated in injuries and fatalities for several large whale species (Laist et al. 2001; Van Waerebeek et al. 2007; Vanderlaan and Taggart 2007; Pace 2011). Three fundamental components are essential to understanding and assessing vessel strike risk to any marine mammal population: (1) distribution, occurrence, and habitat selection of the population; (2) dive and surface behavior of individuals; and (3) vessel characteristics, activity, and mitigation measures (Stevens et al. 2024). Further, several factors affect the risk and severity of vessel strike to marine mammals, including species type, speed, health, and behavior of the animal; and the path, speed, size, and number of vessels (Laist et al. 2001; Vanderlaan and Taggart 2007; Martin et al. 2016). Vessel speed and size are of note when assessing strike risk (Stevens et al. 2024; Garrison et al. 2025).

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 (>80 m [262 ft]) at higher speeds; 89 percent of ship strike records show that vessels were moving at >14 knots (kn) (16 mph). They also concluded that the majority of collisions appear to occur either 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).

Manatees are slow moving and are often struck by smaller boats (FWS 2001). Vessel strikes are the leading cause of human-induced mortality for manatees, and many manatees bear prop scars from contact with vessels (Gerstein et al. 1999; Lightsey et al. 2006). 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. The vast majority of strikes result from recreational and fishing vessels. Though manatees are less common in the western Gulf, they have been seen more frequently, and increased sightings indicate that there is a potential for risks to this species from vessel traffic. In regions with vessel traffic, open water travel paths for manatees present an increased risk of watercraft strikes, leading to injury or mortality. Vessel activity throughout the northeastern Gulf, where Rice's whales typically reside and where manatees undertake seasonal movements along the northern Gulf Coast, could put both of these species at risk.

NMFS has documented at least two instances of Rice's whales showing evidence of vessel strikes: a dead lactating adult female found in Tampa Bay, Florida in 2009 with injuries indicative of blunt trauma resulting from a large object (Hayes et al. 2023), and a free-swimming whale in the northeastern Gulf in 2019 with a severely deformed spine, also

consistent with a vessel strike (Rosel et al. 2021; Hayes et al. 2023). Neither incident was linked to oil- and gas-related activities.

3.7.6.5 Climate-Related Factors and Ocean Acidification

Climate-related factors can influence or act synergistically with other IPFs on marine mammals, depending on the geographic location and season. Several uncertainties exist on how these factors can affect marine mammals (Evans and Bjørge 2013; Silber et al. 2017), though 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). Warming waters can affect the timing of annual events such as plankton blooms (important food source for baleen whales [e.g., Rice's whale]), migration, and reproduction in some species, potentially disrupting predator-prey relationships, with cascading effects throughout the food web (Ullah et al. 2018). Some research also suggests that ocean acidification from rising carbon dioxide levels could potentially decrease sound absorption in oceans, thereby causing amplified levels of ambient noise (Gazioğlu et al. 2015). Further, increased sea surface temperatures likely enhance the magnitude and frequency of HABs and their associated toxins (O'Neil et al. 2012).

Lettrich et al. (2023) conducted a trait-based climate vulnerability assessment for 108 marine mammal stocks in the western North Atlantic, Gulf, and Caribbean Sea. Marine mammals are expected to respond to climate-related factors with shifting distribution, changes in abundance, and/or changing phenology. Primary drivers of high climate exposure include temperature, ocean pH, and DO, with effects mediated through prey and habitat parameters (Lettrich et al. 2023). Temperature, ocean pH, and DO indicated as a heavy influence for more than two-thirds of stocks analyzed in this study. Further, Lettrich et al. (2023) found that marine mammals in the Gulf, such as bottlenose dolphins and Rice's whales, could be at risk from habitat degradation, prey availability changes, and increased human activities exacerbated by climate-related factors.

3.7.6.6 Marine Debris, Pollution, and Runoff

Marine debris affects marine habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking) (Gall and Thompson 2015; Senko et al. 2020). 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 (Moore et al. 2009; Gall and Thompson 2015; Senko et al. 2020). Research indicates that marine mammal entanglement affects all age classes, leading to reduced forage ability, disrupted swimming performance, and increased energy costs, ultimately hindering overall efficiency in daily activities (Gall and Thompson 2015; Senko et al. 2020). Entangled marine mammals may drown or starve due to being restricted by gear, suffer physical trauma and systemic infections, and/or be hit by vessels due to an inability to avoid them. Data on marine debris in some locations of the Gulf is lacking; therefore, it is difficult to

draw conclusions as to the full extent of the problem and its effects on marine mammal populations.

Microplastics and macroplastics have been shown to affect marine mammals directly and indirectly (Alava et al. 2023). Attraction to plastic pollution can occur in several ways, including (1) through curiosity and naivety in juvenile marine mammals, (2) to use as resource needs such as nesting material, shelter, or resting platforms, (3) to seek prey that is entangled in plastic, and (4) by the odor of biofouled plastic, which may be mistaken for food (Senko et al. 2020). Marine debris ingestion can lead to intestinal blockage, which can affect feeding ability and lead to injury or death (Gall and Thompson 2015; Senko et al. 2020). Plastics have been found inside deceased marine mammals (Gregory 2009).

Debris, such as plastics, can degrade and become microdebris (e.g., microplastics, <5 mm; 0.2 in in size), which can be ingested by the pelagic community, causing physical effects including metabolic and toxicity effects on a variety of marine organisms, including marine mammals (Parolini et al. 2023). Negative effects of microdebris ingestion include physical damage (e.g., internal abrasions, gastrointestinal blockages), pseudo-satiation, and exposure to organic pollutants, toxins, or foreign microbes that adhere to the debris surface and can lead to decreased growth, reproduction, and survival. Effects would be species-specific and life-stage dependent, with a possible trend found for decreasing exposure to microdebris with distance from shore in the Gulf (Lestrade and Hernandez 2023). Navarathna et al. (2023) analyzed stomach and intestinal contents of bottlenose dolphins from the Mississippi Gulf coast, finding >134 total microplastics in the stomach and intestinal contents of the 10 dolphin samples, three of which tested positive for the presence of perfluoro-octane sulfonate. Navarathna et al. (2023) determined that since bottlenose dolphins are coastal residents who spend the entire year in the Gulf, they could be used as a bioindicator to track microplastic contamination in the Gulf. Marine animals at high tropic levels can consume plastics and/or microplastics either directly or indirectly from lower trophic-level species.

NOAA Fisheries 2019–2024 National Reports on large whale entanglements observed confirmed cases of live entangled animals and cases involving deceased animals (floating or tangled) (NMFS 2022b; 2022a; 2023; 2024c; 2025a). There were no documented, confirmed large whale entanglements in the Gulf during this time. During 2019, 2020, and 2021, over 50 percent of identified entangling debris involved gear directly used in commercial or recreational fishing (e.g., buoys with identifiable marks, traps, nets, and monofilament line), and the remaining cases involved line that could not be attributed to a source (NMFS 2022b; 2022a; 2023). In 2022, fishing gear represented 40 percent of confirmed cases, while the remaining cases involved line that could not be attributed to a source (NMFS 2024c). In 2023, fishing gear represented 50 percent of confirmed cases, while the remaining cases involved line that could not be attributed to a source (NMFS 2025a). In 2024, fishing gear represented approximately 48 percent of confirmed cases, while the remaining cases involved line or line and buoys that could not be directly attributed to a source (NMFS 2025b).

Discharges and wastes have the potential to modify suitable habitat for marine mammals (Morton 2003). Pollutants released into streams, rivers, bays and estuaries can enter the open ocean where they cause stress to marine life, including marine mammals. Pollution, including point and nonpoint 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. HABs, including brown and red tides, occur almost every year in Gulf waters (**Section 3.2.9.2**). These blooms could kill, displace, or cause respiratory or reproductive issues in marine mammals (Fire et al. 2008). Bottlenose dolphins and manatees are most at risk from nearshore discharges and wastes. Because other marine mammals are not expected to be found in coastal waters, they are less likely to be affected by nearshore pollution. Prey species also affect the influence of pollution on marine mammals. Toxins directly harm the organisms that ingest them but can also have effects 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. 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).

3.8 BIRDS

Birds from 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 Gulf region. Haney et al. (2025) identified 56 taxa associated with open shelf, slope, and pelagic (federal) waters, 41 primarily coastal taxa (state and federal waters), and 20 sea and diving duck taxa. High marine bird richness in the northern Gulf reflects (1) a temperate–tropical gradient supporting diverse year-round habitats, (2) varied geographic origins of species, and (3) a largely enclosed basin. 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 each spring (3-week peak; April 22–May 13) and fall (~4-week period; September 25–October 15) (Russell 2005). Alternatively, some seabird species live primarily offshore, except during their breeding season. These pelagic birds, including shearwaters, storm-petrels, boobies, gannets, jaegers, gulls, and terns (Duncan and Havard 1980), rely on offshore waters for food and rest at stopover sites. The remaining species found in the Gulf region are located within coastal and inshore habitats.

Species abundance in the Gulf 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 Gulf 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 Gulf is an essential area for migratory birds, because three of the four major flyways occur within the Gulf (the Central, Mississippi, and Atlantic Flyways) (**Figure 3-22**). These flyways are used by migratory birds, many converging within the diverse coastal and terrestrial habitats in the northern Gulf which is an important area for migratory species that travel in large numbers in the fall and spring (Russell 2005). Roughly 40 percent of all North American migrating waterfowl and shorebirds use the Mississippi Flyway (FWS 2013a; USGS 2018). The Mississippi Flyway includes the states of Alabama, Arkansas, Indiana, Illinois, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Ohio, Tennessee, and Wisconsin, and the Canadian provinces of Saskatchewan, Manitoba, and Ontario (FWS 2026a). 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).

Other species rely on the area as they move into the coastal habitats of the northern Gulf for their wintering period. Many occur in the terrestrial habitats of the region and are not likely to be impacted by the same program-related vulnerabilities that coastal and marine birds encounter. Bird count data collected from 1965 to 2011 show that wintering coastal birds in the northern Gulf are declining. Twenty species have experienced a decline of about 2 percent, 65 percent of whose ranges are centered in the Gulf (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 at the center of their core habitat into the northern Gulf (Niven and Butcher 2011).

3.8.1 Important Bird and Biodiversity Areas

Important Bird and Biodiversity Areas (IBAs) are identified through the National Audubon Society's IBA Program in the U.S. as a global effort (i.e., BirdLife International) to identify and conserve areas that are vital to birds. These are non-binding designations and do not carry any legal authority as official FWS designations (i.e., critical habitat). The IBAs provide important specific habitat to one or more bird species, and include but are not limited to sites for breeding, wintering, or migrating birds (BirdLife International 2025). 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 over 65 IBAs along the Gulf Coast (National Audubon Society 2025). These are primarily managed to provide essential habitat for conservation including protection for both resident and migratory bird species (FWS 2025).

3.8.1.1 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 (78 FR 65844). The MBTA protects bird species that are also protected by the ESA or the Bald and Golden Eagle Protection Act.

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 12,000 km (7,457 mi) in one migration trip (Helmers 1992). The Gulf is an important area for migratory birds, as three of the four major flyways occur within the Gulf (i.e., the Central, Mississippi, and Atlantic Flyways (**Figure 3-22**). Stopover sites can also function as temporary shelters from inclement weather. Adequate stopover sites allow migratory birds to arrive at their final destination in good health (Helmers 1992).

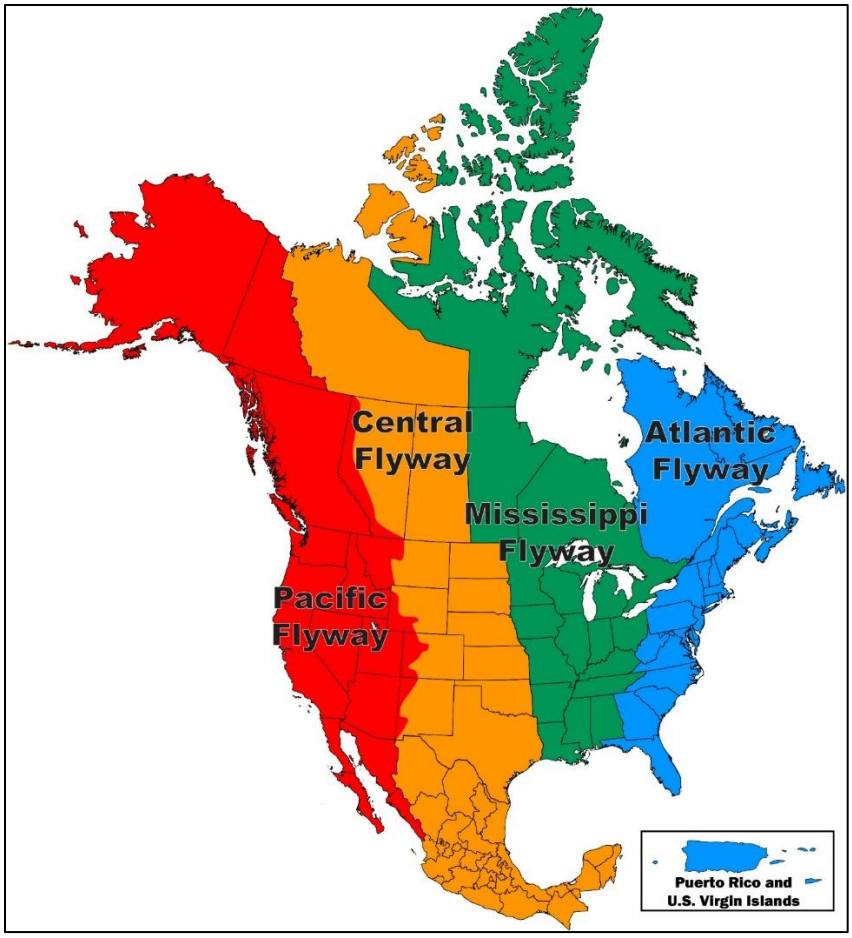


Figure 3-22. The four bird migration routes (flyways) in North America.
From: FWS 2026a.

3.8.2 Non-Listed Species of Birds

Both resident and migratory bird species are found in the Gulf. Resident species are present throughout the year and do not migrate. Migratory species either migrate through the area or use the Gulf Coast states for breeding or wintering grounds. Important stopover sites are found in the Gulf for those migrating. Trans-Gulf migrant birds include species of shorebirds, wading birds, and terrestrial birds. Every spring vast numbers of landbirds migrate northward through the Gulf 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 again through the Gulf.

Several hundred species of birds are present within and adjacent to the Gulf and include species from several different bird groups. Passerines and near-passerines (e.g., kingfishers and woodpeckers) are found in the Gulf, as well as raptors, seabirds, waterfowl, shorebirds, and wading/marsh birds. Bird species within a family share common physical and behavioral characteristics. Rather than detailing each species in the Gulf, the following sections summarize the characteristics of bird families, whose members share similar life histories, habitat

requirements, and behaviors; therefore, they share similar vulnerabilities to BOEM-regulated activities.

3.8.2.1 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 use the Gulf 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 Gulf, representing many of the breeding and wintering birds within Gulf Coast states.

3.8.2.2 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 use coastal freshwater and saltwater habitats.

3.8.2.3 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 Gulf 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 that span the Gulf, while others are found only in specific portions of the Gulf. Some species never come ashore along the Gulf Coast. The population ecology of seabirds leaves them susceptible to impacts because 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 2001). Prey availability to seabirds depends on the depths at which prey occurs relative to predator foraging techniques. Also, prey may be driven to the surface and concentrated 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 Gulf include petrels, shearwaters, gannets, boobies, cormorants, and gulls. Diving seabirds can reach depths of several meters for long durations (seconds to minutes). For example, in the Gulf, diving birds like common loons, northern gannets, and brown pelicans use diverse

foraging strategies with dive times ranging from a few seconds to over a minute. These behaviors are primarily daylight-dependent, with high-intensity hunters like the common loon dedicating roughly 60 percent of their day to foraging (Kenow et al. 2023).

The GulfCet II program collected biological oceanography data to determine the environmental patterns and oceanographic processes affecting seabirds in the northern Gulf (Davis et al. 2000b). Terns, storm-petrels, shearwaters, and jaegers were the most frequently sighted seabirds in deep water (>300 m; 964 ft). 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 Gulf 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.

Gleason et al. (2025) observed spatial and temporal patterns of seabird abundance using two survey platforms in the northern Gulf, 2017–2020. Aerial and vessel seabird surveys were conducted in coastal and continental shelf waters, and deeper waters off the continental shelf out to the EEZ, from roughly Brownsville, Texas to the Florida Keys. Forty-seven species of seabirds were identified across survey platforms, years, and seasons. Most of the seabird species observed were not considered as local to the northern Gulf. Rather, they were affiliated with breeding locations from the northern migrant-continental interior-Arctic, southern Gulf, and the Caribbean. For 24 seabird species with a sufficient number of detections, there was distribution within and across seasons and years. Data presented represents the most spatially and temporally extensive seabird surveys in the northern Gulf to date. Understanding seasonal variation in species composition and distribution is particularly relevant to better understanding potential effects from future offshore energy development. Improved, standardized monitoring of seabird assemblages in the northern Gulf, including vessel surveys, tagging, and long-term time series, can establish critical baselines to evaluate environmental variability and anthropogenic impacts (e.g., offshore energy, vessel traffic) (Michael et al. 2023).

Generally, seabirds occur in low densities over most of the ocean and are patchily distributed (i.e., 10 birds/km^2; 0.4 mi^2). Higher densities correlate with *Sargassum* lines, upwellings, convergence zones, thermal fronts, salinity gradients, and high plankton productivity areas (Ribic et al. 1997; Davis et al. 2000a). 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.

3.8.2.4 Waterfowl

Waterfowl species that occur in the coastal and inshore waters of the northern Gulf 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 greater scaup, bufflehead, and common goldeneye are common diving duck species in freshwater and estuaries in the Gulf. 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 Gulf based on their habitat preferences. The order Gaviiformes (i.e., loons) can also be found in coastal Gulf waters. Sea duck diet can consist of fish, mollusks, and small invertebrates (Sibley 2000).

3.8.2.5 Shorebirds

Shorebirds (i.e., Charadriiformes) are a large group of birds, including sandpipers (Scolopacidae), plovers (Charadriidae), oystercatchers (Haematopodidae), and avocets and stilts (Recurvirostridae), that use coastal Gulf habitats for nesting, feeding, and resting. Forty-three shorebird species occur in the Gulf during their migration or wintering periods; 28 of these species rely on northern Gulf coastlines to fuel their migrations to their near-Arctic breeding grounds (Henkel and Taylor 2015). Six shorebird species (American oystercatcher, snowy plover, Wilson's plover, willet, killdeer, and black-necked stilts) breed in the Gulf (Helmers 1992). The Lower Mississippi and western Gulf Coast are rich habitats for a variety of shorebirds. The Gulf Coast provides some of the most important shorebird habitats, 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 Gulf coastline (Morrison et al. 2001; Morrison et al. 2006). Environmental degradation of shoreline habitats, industrial and recreational development of breeding and wintering habitats, 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).

3.8.2.6 Wading and/or Marsh Birds

Wading/marsh birds are a diverse group of birds in the four orders Ciconiiformes, Gruiformes, Pelecaniformes, and Podicipediformes. They use most of the coastal aquatic habitats found in the northern Gulf, 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 Gulf. 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 year-round reliance on coastal aquatic habitats.

3.8.3 ESA-Listed (Threatened or Endangered) Species

Nine federally protected bird species (eight as of 2026) occur in the northern Gulf: Cape Sable seaside sparrow (CSSS); Mississippi sandhill crane, piping plover, rufa red knot, roseate tern, whooping crane, wood stork (delisted in 2026), eastern black rail, and black-capped petrel. Species are listed as either Threatened or Endangered. Listed species are considered and analyzed through ESA consultation with the FWS. These seven species are present in the northern Gulf: Mississippi sandhill crane, piping plover, rufa red knot, whooping crane, wood stork, eastern black rail, and the black-capped petrel. Five species are found in or adjacent to the WPA and CPA where they are more vulnerable to potential impacts from the IPFs of BOEM-regulated activities as there are higher activity levels in the WPA and CPA. Two (CSSS and roseate tern) of the listed species are found exclusively in Florida, where they are less vulnerable to BOEM-regulated activities. The Everglade snail kite, a medium-sized raptor, is present in Florida and adapted to feed almost exclusively on freshwater apple snails (FWS 2023b). Though this is an ESA-listed species, it is not discussed further because it is far removed from current BOEM-regulated activities or potential oil spills.

There are designated critical habitat (**Figure 3-23**) for five protected species that occur in the Gulf: CSSS, Mississippi sandhill crane, piping plover, whooping crane, and Everglade snail kite. A critical habitat rule has been proposed for the rufa red knot, including designations for coastal wintering areas of the Gulf Coast states (88 FR 22530).

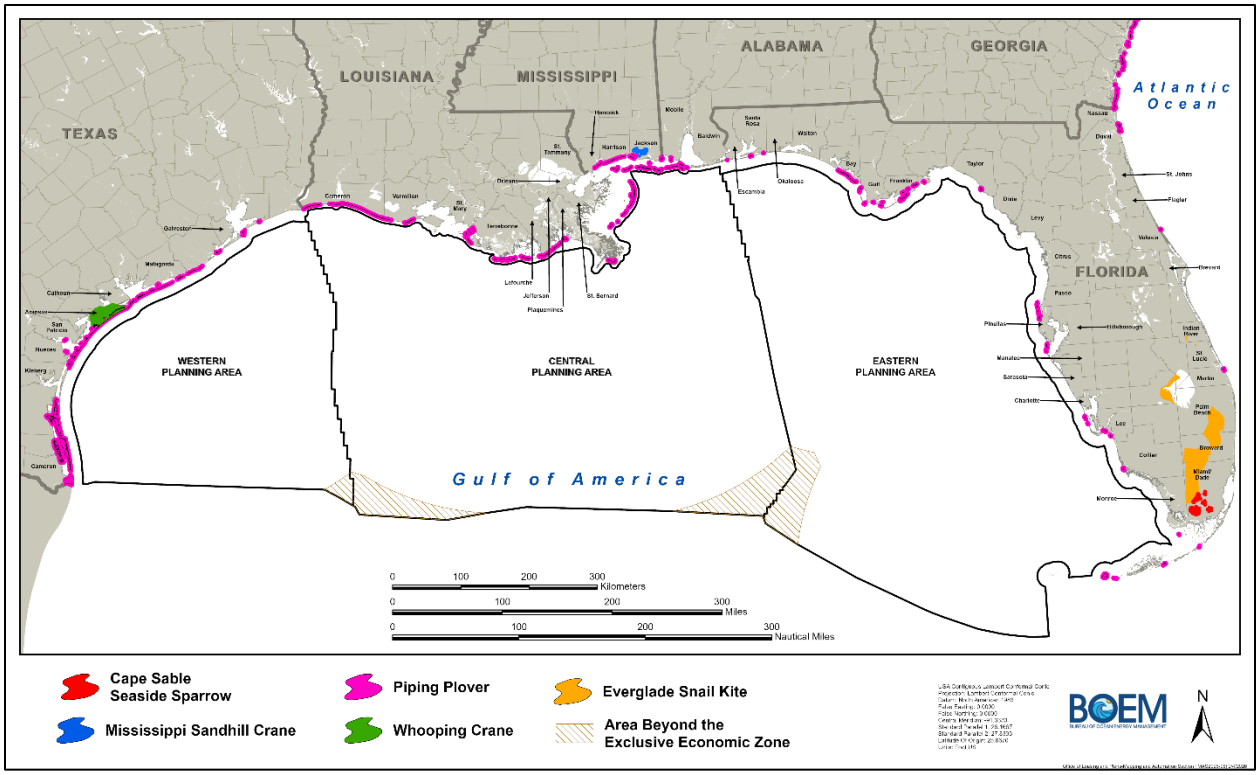


Figure 3-23. Bird critical habitat.
Source: BOEM - 2026. Map was created by BOEM geographers. The source of the species data is FWS. The source for the planning areas and other boundaries is BOEM's Technical Information Management System.

As with the Everglade snail kite, other listed species occur in the coastal Gulf, but are not explored further in this document because they rely more on terrestrial habitats or are not commonly documented in the northern Gulf OCS.

3.8.3.1 Cape Sable Seaside Sparrow (CSSS)

The Cape Sable seaside sparrow (CSSS), 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 CSSS on May 18, 1999. The most recent Five-Year Review: Summary and Evaluation, a process required by the ESA, was completed in June 2023. The review concluded that while three of the six subpopulations of the CSSS population showed signs of stability, overall, the population has declined and has not increased in number. Surveys conducted from 2015 to 2021 revealed fluctuations in subpopulation sizes, but the CSSS population continues to decline, and its status remains unchanged (FWS 2023a). The review estimated the total population size for all six subpopulations in 2021 was 2,448 individuals, which is consistent with figures reported since 1993, typically ranging between 2,416 and 4,068 individuals. The most substantial decline occurred in 1993, when the population dropped by nearly half, from an estimated 6,576

individuals in 1992 to 3,312 individuals. Subpopulation A was particularly impacted, with the decline attributed to flooding in the area between 1993 and 1995 (FWS 2023a).

The CSSS 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 CSSS' 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 (42 FR 40685) and revised in 2007 (72 FR 62736).

During their nesting period, the CSSS 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 CSSS 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 CSSS' preferred nesting habitat are flooding at higher water levels and for longer periods, leading to lower nesting success (Nott et al. 1998; Van Houtan et al. 2010).

3.8.3.2 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 (38 FR 14678) 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 (40 FR 27501). The Interstate-10 corridor jeopardized the existence of this population; however, a settlement agreement resulted in the Mississippi Department of Transportation purchasing 793 ha (1,960 ac) for habitat, and an interchange was built (Valentine Jr. and Lohoefener 1991). The Mississippi Sandhill Crane National Wildlife Refuge in Jackson County, Mississippi, represents 74 percent of the total critical habitat (Valentine Jr. and Lohoefener 1991). As of June 2024, the wild population of Mississippi sandhill cranes stands at 174 individuals: 67 males, 72 females, and 35 cranes of unknown sex (FWS 2024b). This represents the highest population estimate of the subspecies observed in the wild since 1993. The population growth can be largely attributed to the protection of much of its habitat within 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 2014a). 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.

3.8.3.3 Piping Plover

Three populations of the piping plover, a small migratory shorebird, were federally listed on December 11, 1985, and are protected under the MBTA (FWS 2013b). The two populations that winter along the Gulf Coast are the Great Lakes (Endangered) and the Great Plains (Threatened) populations (50 FR 50726). The most recent Five-Year Review was completed in December 2024, with recommendations that their status remains unchanged (FWS 2024c). The piping plover is also a state species of conservation concern in all Gulf Coast states. The growth in the Great Lakes piping plover population, from 55 breeding pairs in 2011 to 80 pairs in 2023, demonstrates the effectiveness of ongoing recovery efforts but major threats like habitat degradation, predation and anthropogenic disturbance remain (FWS 2024c). 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(July 10, 2001; 66 FR 36038). 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 2012a). This reliance on upper beach areas for food places them 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.

All piping plovers are considered Threatened when on their wintering grounds (66 FR 36038). As high as 75 percent of all breeding piping plovers may winter in the Gulf (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. This species also exhibits a high degree of fidelity to their wintering areas. Gratto-Trevor et al. (2016) observed 100 percent fidelity of the piping plovers that were observed in their wintering grounds were resighted either on or within 6 km (3.7 mi) of the same beach where they were originally banded between 2010 and 2016. Habitats used by wintering piping plovers along the Gulf include beaches, mudflats, sand flats, algal flats, and wash over 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 and 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 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).

3.8.3.4 Rufa Red Knot

The rufa red knot subspecies was listed as Threatened on January 12, 2015 (79 FR 73706) 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 and breed in the Arctic; the rufa subspecies occurs along Gulf Coast during fall migration and 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 15,000 km (9,300 mi), 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, and in the Gulf the decline can be contributed to harmful algal blooms (red tide) (Newstead et al. 2024).

Specifically, within the Gulf region, wintering birds are found primarily in Florida and Texas but have been observed in Louisiana and Alabama. 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. In 2023, a critical habitat rule was proposed for the rufa red knot that includes designations for coastal wintering areas of the Gulf Coast states (88 FR 22530).

3.8.3.5 Roseate Tern

The roseate tern is a worldwide species that is divided into five recognized subspecies. Two subspecies occur in the Gulf: the Northeastern North American (Northeast Distinct Population Segment [DPS]) and the Caribbean (Caribbean DPS) populations. Both populations were listed as Endangered and Threatened, respectively, on November 2, 1987. Recovery plans for the Northeastern and Caribbean populations were completed on November 5, 1998, and September 24, 1993, 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 attributed mostly to chick predation by the herring gull and the 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 (i.e., 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 2011). 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 (52 FR 42064). 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 (52 FR 42064; Gochfeld et al. 1998).

After their migration over the open ocean from the West Indies and South America, the Northeastern roseate tern population breeds in the northeastern U.S. and eastern Canada (Kirkham and Nettleship 1987). The Caribbean population's migration is less understood. 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. According to the most recent Five-Year Review for the roseate tern, the exact number of Caribbean roseate tern breeding pairs is unknown, but it is suggested they have experienced an overall decline between 2010 and 2021 (FWS 2022b). In Florida, the number of breeding pairs has fluctuated between 6 to 233 over the past decade (FWS 2022b).

3.8.3.6 Whooping Crane

Whooping cranes are found only in North America and in only three locations (Canadian Wildlife Service and FWS 2007; FWS 2009b). The whooping crane was federally listed as Endangered on March 11, 1967 (32 FR 4001) 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 (76 FR 6066) and Florida (66 FR 33903) represent nonessential, experimental populations (NEP). Pursuant to Section 10(j) of the ESA, the Secretary of the Interior may designate a reintroduced population established outside the species' current range, but within its historical range, as an experimental population. Such designation affords management flexibility by permitting the population to be treated as Threatened, regardless of the species' classification elsewhere within its range (76 FR 6066). Critical habitat (established in 1978) along the Gulf Coast is within the Aransas National Wildlife Refuge in Texas (43 FR 20938).

The whooping crane currently exists in the wild as one self-sustaining population, the Aransas-Wood Buffalo National Park Population. Scientists have released, experimental, nonessential populations in several states including Florida and Louisiana. Twelve captive sites contribute to the captive breeding and release program (FWS 2012b). 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 to range from 308 birds from the FWS 2014–2015 annual survey of their wintering grounds in the coastal marshes of Texas (FWS 2015d) to 504 birds from the FWS 2018–2019 annual survey (FWS 2018b). Preliminary FWS survey analyses estimated the Aransas-Wood Buffalo population of whooping cranes at 557 individuals during the 2024–2025 wintering period (Butler et al. 2025). 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 (43 FR 20938).

3.8.3.7 Wood Stork

The U.S. breeding population of the wood stork was listed as Endangered on February 28, 1984 (49 FR 7332). The species was formally down-listed to Threatened on July 30, 2014, on the recommendation of the Five-Year Status Review in 2007. This was due to a population increase and expansion of the breeding range (75 FR 57426). On February 10, 2026, FWS removed the Southeast U.S. DPS of the wood stork from the list of Endangered and Threatened species (91 FR 5826). FWS determined that the Southeast U.S. DPS had recovered, and the threats to it are being effectively managed such that the DPS no longer meets the criteria for Endangered or Threatened species under the ESA. 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 the 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 year-round residents of Florida and Georgia. They feed in freshwater marshes, narrow tidal creeks, or flooded tidal pools (FWS 2015e). Their diet consists primarily 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), and breeding no longer occurs in Louisiana, Mississippi, and Alabama (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 the ability of breeding pairs to track resource availability (i.e., food), therefore, not all colonies are occupied every year (Kushlan and Frohring 1986; Bryan Jr. and Robinette 2008). 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, where some mixing of U.S. and Mexican populations may occur (Bryan Jr. and Robinette 2008).

3.8.3.8 Eastern Black Rail

In April 2010 the FWS received a petition to list 404 aquatic, riparian, and wetland species from the southeastern U.S. On September 27, 2011, the FWS published a 90-day finding on 374 of the petitioned species, including the eastern black rail, indicating that listing may be warranted (76 FR 59836). On October 9, 2018, the FWS proposed to list the eastern black rail as Threatened (83 FR 50610). A final rule to the listing of the eastern black rail was published on October 8, 2020, with an effective date of November 9, 2020 (85 FR 63764). There is currently no critical habitat established for eastern black rail (FWS 2020). The eastern black rail is a migratory species and protected under the MBTA (FWS 2013b).

The eastern black rail is a subspecies of the black rail and is a small and cryptic wetland dependent subspecies. The eastern black rail relies on salt, brackish, and freshwater marsh habitats that can be tidally or non-tidally influenced (83 FR 50610). Within these habitats the birds use the transition zone between the emergent wetlands and the upland interface (85 FR

63764) that is vegetated by emergent plants, including rushes, grasses, and sedges. The eastern black rail requires dense vegetative cover, made up of fine-stemmed emergent plants that form a dense canopy or cover. If scrub densities become too high, the habitat may become unsuitable. The eastern black rail uses areas of moist or flooded soils with, or adjacent to, shallow waters (<6 cm; 2.4 in). The eastern black rail forages on small aquatic and terrestrial invertebrates, especially insects and seeds (FWS 2018a). (83 FR 50610). Migration of the eastern black rail is poorly understood. Within the Gulf region, wintering and resident birds are found primarily along the Texas coast, the western Louisiana coast, and the Gulf Coast of Florida (83 FR 50610; FWS 2018a). Eastern black rail sightings in the other Gulf Coast states would be considered a vagrant or as an accidental migrant.

Based on the best available data, there are currently no precise population estimates for this subspecies. However, over the past 10 to 20 years, the U.S. population has experienced declines of 75 percent or greater. In 2017, pre-Hurricane Harvey, population estimates along the upper Texas coast were estimated at 1,299 individuals (FWS 2018a). The upper Texas coast was significantly impacted by flooding from Hurricane Harvey, and the eastern black rail are expected to have experienced population declines from related impacts. Between 355 and 815 breeding pairs are estimated to reflect the Atlantic, Florida Atlantic, and Gulf Coasts populations (FWS 2018a). Again, those areas were impacted by multiple hurricane events after those estimates.

3.8.3.9 Black-Capped Petrel

On December 28, 2023, the FWS published the final rule listing the black-capped petrel as Endangered under the ESA as of January 29, 2024 (88 FR 89611). The black-capped petrel nests on the island of Hispaniola and spends the rest of its life at sea. Recent studies have confirmed occurrences of black-capped petrels in the northern Gulf, which extends the known pelagic seabird range (Jodice et al. 2021).

The FWS determined that the black-capped petrel is Endangered due to the following threats: habitat loss due to deforestation and forest fires, and predation by nonnative mammals. Other factors that currently have a lesser impact on the species, or may affect it in the future, include impacts such as collisions or disorientation and grounding from lighting from onshore development, offshore oil and gas infrastructure and activities, and communication towers (88 FR 89611). Natural storm intensity and frequency, resulting in flooding of burrows and erosion of suitable nesting habitat, are also expected to affect the species. Historically, human predation for consumption and other natural disasters (i.e., earthquakes and volcanic eruptions) affected the viability of the species.

A portion of the black-capped petrel's range extension overlaps with BOEM's action area. Jodice et al. (2021) documented several observations in BOEM's action area, the majority of which were in the eastern Gulf and concentrated in the EPA and a small number of observations west of the Mississippi River. Due to the presidential withdrawal of most of the

EPA, OCS oil- and gas-related activity in the eastern Gulf are generally low, reducing the potential overall for interaction with black-capped petrel.

3.8.4 Bird Bioacoustics

The research thus far suggests that birds have a relatively restricted hearing range for airborne noise. Most of the species discussed in this section are not found in the Gulf and should be considered as general information on bird bioacoustics. Generally, aerial hearing sensitivity in non-nocturnal terrestrial birds occurs at frequencies between about 1 and 5 kHz, with absolute (best) sensitivity often approaching 0–10 dB SPL at the most sensitive frequency, which is usually in the region of 2–4 kHz (Dooling 1980; 1982; 1992; Dooling et al. 2019; 2000; Dooling and Popper 2007; Dowling et al. 2017). The importance of in-air acoustic cues for aquatic birds is well-documented (e.g., Searby et al. 2004; Lengagne et al. 2010). Recent psychoacoustic and electrophysiological in-air hearing tests have been completed on multiple species of diving seabirds including: great cormorants, long-tailed ducks , harlequin ducks, ruddy ducks, marbled murrelets, common murres, Atlantic puffins, surf scoters, white-winged scoters , black scoters, lesser scaups, common eiders, red-throated loons, and northern gannets, which share peak hearing sensitivities between 1.0 and 3.5 kHz (Therrien 2014; Crowell et al. 2015; Crowell 2016; Maxwell et al. 2016; 2017; Larsen et al. 2020; Mooney et al. 2019; 2020; Smith et al. 2023a; 2023b).

The body of research on underwater hearing in diving birds is still emerging but growing steadily. The most substantial data come from studies on great cormorants and various sea duck species. Underwater hearing thresholds have been obtained in the following five species of marine birds: the great cormorant (Johansen et al. 2016; Hansen et al. 2017; Larsen et al. 2020), the long-tailed duck (Therrien 2014; McGrew et al. 2022), the surf scoter (McGrew et al. 2022), the common eider (McGrew et al. 2022), and at a single frequency (1 kHz) for the common murre (Hansen et al. 2023). Auditory sensitivity varied amongst the species tested, spanning over 30 dB in the frequency range of best hearing, with sensitivity in great cormorants comparable to seals and toothed whales at lower frequencies (1-4 kHz; Hansen et al. 2017). Playback studies show that gentoo penguins, African penguins, and common murres can react negatively to underwater sounds (Frost et al. 1975; Cooper 1983; Pichegru et al. 2017; Anderson Hansen et al. 2020; Sørensen et al. 2020), even though there is no data on underwater hearing thresholds from these species with the exception of the common murre. One additional study has shown that gentoo penguins can exhibit Pavlovian conditioning to underwater sound playbacks paired with fish rewards (Rasmussen et al. 2022). Current studies indicate diving bird species have the most sensitive underwater hearing in the 1–4 kHz range (e.g., Hansen et al. 2017; McGrew et al. 2022), which follows the frequency range of best hearing sensitivities of birds in air.

There are currently no regulatory thresholds related to seabird exposure to underwater noise, and no studies exist of bird hearing loss due to underwater sound exposures because birds require air. One exception is the marbled murrelet, for which an auditory injury threshold of 202 dB re 1 µPa2s was derived for underwater pile driving noise through an expert convened

workshop (Science Applications International Corporation 2011). Studies of in-air based hearing threshold shifts in terrestrial birds are limited and show that the frequency of exposure is the hearing frequency most likely to be affected (Saunders and Dooling 1974; Niemiec et al. 1994; Ryals et al. 1999; Dooling and Popper 2007; U.S. Navy 2018). The existing studies indicate that birds are more resistant to hearing loss and auditory damage from acoustic exposures compared to mammals (e.g., Saunders and Dooling 1974; Ryals et al. 1999; Dooling et al. 2019). This is partly because avian species, in contrast to mammals, exhibit the biological ability to achieve complete regeneration of inner ear sensory hair cells following acoustic trauma or age-related decline. This restorative process facilitates a return to pre-auditory thresholds within approximately four to five weeks and functions effectively across both terrestrial and aquatic environments (Sato et al. 2024; Miranda Portillo et al. 2025; Takeuchi et al. 2026).

Vocalizations are essential to seabirds in-air, and research on seabirds using underwater vocalizations for communication, foraging, or navigation is ongoing. There is evidence that at least three species of penguins (king penguins, macaroni penguins, and gentoo penguins) produce short duration (mean = 0.06 s) underwater vocalizations during feeding dives (Thiebault et al. 2019).

3.8.5 Environmental and Anthropogenic Stressors

3.8.5.1 Noise

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). Birds are known to have a relatively restricted hearing range for airborne noise, with acute sensitivity occurring in the range of 1 to 5 kHz (Dooling and Popper 2007). Less is known about the auditory hearing range of birds underwater; however, some studies suggest their greatest hearing sensitivity underwater ranges from 1 to 3 kHz (Crowell et al. 2015; Hansen et al. 2017; McGrew 2019). Military activities, including training overflights, occur in designated areas offshore that also function as seabird habitat. The U.S. Air Force and U.S. Navy conduct most military operations in the Gulf in areas federally designated for training, research, testing, and evaluation activities. A study found that weapons testing noises had no significant effects on bald eagle activity or reproduction (Brown et al. 1999). Aircraft noise can also affect birds, but studies have shown that bird exposure to frequent, low-level military jet aircraft and simulated mid- to high-altitude sonic booms resulted in some short-term behavioral responses with little effect on reproductive success (Ellis et al. 1991).

Noise could be a stressor for marine and coastal birds in the Gulf. Elevated noise from human activities, such as shipping, construction, and recreational boating, can interfere with essential behaviors like altering communication patterns, foraging efficiency, adult and nestling physiology, reproductive success, migration, and habitat usage during breeding (Injaian et al. 2018).

Communication is essential to birds. Noise can mask vocalizations used for mate attraction or territorial defense, leading to disrupted social interactions (Wright et al. 2013a). Reponses to anthropogenic noise can vary across species and can depend on characteristics of the sound source; however, a common behavioral response across species is aversion (e.g., flushing, flying or swimming away). Senzaki et al. (2020) examined how two major sensory pollutants–anthropogenic noise and artificial nighttime light–impact the reproductive timing (phenology) and fitness (nest success, hatching success, clutch failure) of 142 bird species across the contiguous United States. Overall, nest success was negatively correlated with noise exposure among birds nesting in forested or otherwise closed habitats (Senzaki et al. 2020). Further, birds with lower-frequency vocalizations delayed nesting under noisy conditions, likely because low-frequency anthropogenic noise masks their songs, affecting mate communication (Senzaki et al. 2020). Additionally, Injaian et al. (2018) suggests that if noise exposure alters parental behavior during the breeding period, long-term impacts, such as altered nestling physiology and reduced survival rates are likely to occur. Impacted nestling physiology during early developmental stages has been observed resulting in negative life-long consequences, possibly leading to population-level effects (Injaian et al. 2018).

Data, though limited, suggest that seabirds are not particularly sensitive to sounds below 1 kHz. Avian species can regenerate the inner ear sensory hair cells; this allows a return to pre-auditory thresholds within approximately four to five weeks and functions effectively across both terrestrial and aquatic environments (Sato et al. 2024; Miranda Portillo et al. 2025).

3.8.5.2 Coastal Development and Lighting

Ongoing and projected wetland loss results in the loss of essential habitats for coastal and marine birds. Wetlands serve as vital breeding and nesting grounds for adult birds and rearing grounds for juveniles. These habitats provide drinking water, feeding habitat, resting habitat, shelter, and community opportunities for several species of birds. As discussed in Section 4.3.1.1 of the GOM Oil and Gas SID, historical wetland loss due to Mississippi River hydromodification would be improved by wetland creation from Atchafalaya River sediments through coastal restoration and hurricane protection programs. Habitat (e.g., wetland) loss, alteration, and fragmentation associated with building, factory, and road construction are mitigated by USACE and state wetland permitting regulations to decrease harming sensitive bird habitat. Non-consumptive beach recreation that could impact birds includes bird-watching activities, riding in all-terrain vehicles, and walking and jogging with pets. All forms of beach use may cause birds to become stressed and fly away, with varying degrees of response for individual species.

Lighting could impact birds and, in the Gulf region, state oil and gas structures provide sources of artificial lighting in state waters. Attraction to artificial lighting could impose energetic costs to individual birds as well as collision risk with the structures, which could result in injury or mortality. Artificial lighting at night can disorient birds, especially offshore migrators. Poor weather conditions (e.g., fog, precipitation, and low cloud cover) could further increase birds' attraction to lighting, especially at dusk or during a full moon (Rodríguez and Rodríguez 2009; Miles et al. 2010).

Major sources of lighting on or near marine environments during the night include vessels, lighthouses, light-induced fisheries, and coastal construction. Light pollution can have detrimental negative effects for the ecosystem, ultimately disturbing the natural behavior and physiological processes of many different species. Light pollution can potentially affect birds by disrupting development, altering activity patterns, and interfering with hormone-regulated processes, such as the internal circadian rhythm (Poot et al. 2008; Dominoni 2015). One of the most commonly observed effects of light pollution on birds is attraction to artificial light sources followed by disorientation often resulting in collision with these artificially lit structures and shifting temporal behavior.

Avians are highly sensitive to light pollution because of their wide range of photoreceptors. Located in several tissues, birds' photoreceptors are in the retina of the eye, the brain, and the pineal gland, all of which use opsin-based photopigments to detect and transduce light (Dominoni 2015). Due to their wide variety of photoreceptors, the circadian rhythm of birds is more complex than that of mammals. Photoreceptors found in the eyes, the hypothalamus, and pineal gland are all sensitive to light and are involved in the expression and regulation of circadian rhythms. The presence of artificial light modifying the daily rhythm of birds is widely known as an ecological effect of light pollution, because light is the most important synchronizer of the avian circadian clock. Dominoni et al. (2013) demonstrated the addition of light at night is a major source of modification of daily patterns. Additionally, artificial light can disrupt the magnetic compass of migratory birds when exposed to bright white or red light resulting in severe disorientation and possible collision of the artificially lit structure (Poot et al. 2008).

3.8.5.3 Fisheries Interactions

Commercial fisheries may incidentally entangle and drown or otherwise injure birds during fishing operations, or from lost or discarded fishing gear (Manville II 2005; Bull 2007; Brothers et al. 2010). Seabird bycatch was considered a major cause for declines in many species of seabirds worldwide (Cooper et al. 2001; Melvin and Parrish 2001). The longline fisheries in the Gulf target primarily pelagic tuna and swordfish, bottom sharks, and reef species. Within the region, the total incidental seabird bycatch for the bottom longline fisheries was one gull of unidentified species, two brown pelicans, one herring gull, and two unidentified seabirds from 2005 to 2008; for the pelagic fishery, it was one brown pelican and two unidentified seabirds from 1992 to 2005 (BOEM 2012). A global assessment of fisheries bycatch (1990–2008), using empirical data across seabirds, marine mammals, and sea turtles and major gear types (gillnets,

longlines, trawls), indicates that the Gulf exhibits the lowest recorded level of seabird-fishery interaction compared globally (Lewison et al. 2014). In the Gulf, seabird bycatch in trawl fisheries is likely underestimated due to limited monitoring, underscoring the need for better reporting and mitigation measures to reduce seabird mortality (Lewison et al. 2014). In the Gulf, seabird bycatch in trawl fisheries is likely underestimated due to limited monitoring, underscoring the need for better reporting and mitigation measures to reduce seabird mortality (Phillips et al. 2024).

Both NMFS and FWS have taken proactive steps to mitigate losses through modifications to the equipment used, fishery closures in certain areas, time-of-year and time-of-day closures by some states, and use of fishery observers (Melvin et al. 1999; Cooper et al. 2001; Melvin and Parrish 2001). With changes in policy, procedures, and techniques, cumulative impacts to future bird bycatch of longline fisheries on marine birds in the northern Gulf should be much reduced. There is likely overlap among many species of seabirds, their prey, and some fisheries. Fisheries may impact certain seabird populations by removing preferred prey or may alter food web dynamics by removing top-level predators (e.g., bluefin and yellowfin tuna) (Furness 2003). In addition, substantial quantities of bycatch (i.e., nontarget species) are discarded as waste overboard and, though detrimental to the ecosystem as a whole (Crowder and Murawski 1998; Harrington et al. 2005), may actually benefit some species of seabirds (Furness 2003; Votier et al. 2004). Overharvest of some fish populations, particularly top-level predatory fishes, appears to be occurring at unprecedented levels worldwide (Myers and Worm 2003). Unfortunately, the loss of these top-level predators can have unknown and potentially dramatic effects on marine food web dynamics and the ocean ecosystem as a whole, including seabird populations reliant on various species of smaller prey fish (Furness and Camphuysen 1997; Piatt and Harding 2007).

3.8.5.4 Vessel Strike

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 Gulf regional estimates for annual mortality rates for vehicle or building bird strikes, or 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 1.3–4.0 billion birds per year (Loss et al. 2013). Cat predation mainly impacts small birds (e.g., passerines).

3.8.5.5 Climate-Related Factors

Though temperature-related impacts on birds are difficult to predict, they may influence birds' ecology through changes in habitat ranges (Mustin et al. 2007; Jodice et al. 2021), increased risk of predation and competition, exposure to different prey and parasites, shifts in seasonal events (e.g., breeding and migration) that force life cycles out of synchrony with prey sources, changes to local food webs, and/or habitat alterations (Butler and Taylor 2005; Wormworth and Mallon 2006; Tillmann and Siemann 2011; Liebezeit et al. 2012; Wauchope et al. 2017).

With temperature increases specific species can shift to new habitat ranges (Mustin et al. 2007), because range area contractions are expected to occur more frequently than range area expansions. 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. This could lead to impacts on marine and coastal bird prey. Biodiversity is vital to the ecosystems that support all bird life (McDaniel and Borton 2002). The frequency and intensity of hurricanes may increase, which could possibly worsen damage to important breeding and wintering habitats in the northern Gulf (NOAA 2023).

3.8.5.6 Disease

Wildlife diseases have impacted North American migratory bird populations for decades. Notable diseases include avian botulism, avian influenza, avian cholera, and West Nile virus (FWS 2026b). All of these have contributed to population declines and mortality events among migratory bird species. The emergence and global spread of the A/goose/Guangdong/1/1996 (H5N1), a strain of avian influenza (HPAI), in wild migratory birds has established the highly pathogenic avian influenza as a persistent threat to wildlife, requiring coordinated approaches that address both wild and domestic bird populations (Ramey et al. 2022). The 2022 H5N1 avian influenza outbreak caused widespread mortality across North Atlantic northern gannet colonies, resulting in major population declines and reduced breeding success while highlighting the growing threat of HPAI to seabird conservation (Lane et al. 2024).

Other emerging infectious diseases are a threat to native bird species and a substantial cause of nearshore and coastal bird mortality (Newman et al. 2007). Diseases, such as the West Nile virus, can have widespread and long-term effects on landbird populations (LaDeau et al. 2007; George et al. 2015). The majority of the studies on West Nile cover continental level estimates; however, estimates can be qualitatively extrapolated to other species, as well as the northern Gulf, where West Nile virus and potentially other infectious diseases would be expected to have severe impacts on avian populations.

3.8.5.7 Marine Debris, Pollution, and Runoff

Any accidental marine debris from vessels and structures offshore presumably drifts ashore, remains within coastal waters, or eventually sinks. These materials may include lost or discarded fishing gear such as gill nets and monofilament lines, which cause the greatest overall damage to birds (Tasker et al. 2000; Dau et al. 2009; Ryan et al. 2009). Coastal and marine birds are commonly entangled in discarded trash and debris (Robards et al. 1995). Many species readily ingest small plastic debris, either intentionally or incidental to consuming prey. Interaction with plastic materials may lead to debilitating injuries or even death (Pierce et al. 2004).

Non-OCS-related activities and natural processes that can impact marine water quality include bilge water discharges from large ships and tankers, and coastal pollutants that are transported away from shore, including runoff, river input, sewerage discharges, industrial discharge, and

natural seepage of oil and gas. There is a wide variety of contaminant inputs into coastal waters bordering the Gulf (USEPA 2012). Contaminants from non-OCS pollution of coastal waters resulting from municipal, industrial, and agricultural runoff and discharge may have acute or chronic, lethal, or sublethal impacts to avian populations in the Gulf. The dominant pollution source is the large volume of water from the Mississippi River, which drains over two-thirds of the contiguous United States, creating a zone of hypoxia offshore at the continental shelf (Rabalais and Turner 2001; Rabalais et al. 2002a; 2002b).

3.9 OTHER SPECIES

3.9.1 Bat Species

There are 1,400 species of bats in the world; the U.S. has approximately 48 of these species with additional species in the U.S. territories in the Pacific and Caribbean. Bats have a crucial role in pollinating over 300 species of fruit. While primarily terrestrial, some bat species have been documented in Gulf Coast states or even crossing into the Gulf during migration or foraging. Among these are and not limited to the hoary bat, Florida bonneted bat (see below for critical habitat), northern yellow bat, eastern red bat, Seminole bat, northern long-eared bat, and tricolored bat. These species face various threats, both on land and during migration. Overall, habitat loss and pesticide exposure pose significant risks to their populations.

The northern long-eared bat and tricolored bat are especially vulnerable. The northern long-eared bat is classified as Endangered under the ESA (87 FR 73488), and the tricolored bat is proposed to be listed as Endangered (September 14, 2022; 87 FR 56381) due to white-nose syndrome and habitat loss. Both also face habitat degradation and pesticide exposure. While the hoary bat, northern yellow bat, red bat, and Seminole bat currently lack specific listing status, they may still be affected by habitat fragmentation and disturbance during migration. Conservation efforts strive to address these threats and protect the habitats and migratory pathways of these bat species, ensuring their continued survival and ecological contributions across the Gulf Coast states. The Florida bonneted bat has a few areas of critical habitat designated near the Gulf coast in southern Florida (see **Section 3.6.2.5**; **Figure 3-24**). None of the other bats species above have critical habitat identified in the Gulf or adjacent coastlines.

In Louisiana, the tricolored bat, northern long-ear bat, Seminole bat, hoary bat, and Eastern red bat are all found to be residents of the coastline and surrounding areas. Stevens et al. (2020) identified that, while more bat species were caught during the summer than during the winter, there was considerable activity of all bat species during the winter, identifying a positive relationship between community-level bat activity and warmer temperatures. This suggests the flexibility of many bat species to respond to warmer temperatures in the winter.

Most bat species in North America are insectivorous. Though bats exhibit prey specialization and preferences, most species opportunistically feed on various insects during their lifetime, because local diets shift seasonally in response to changing prey availability (Neuweiler 1989; Lacki et al. 2007). Beyond insect availability, the physical morphology of bats fundamentally

shapes their foraging ecology and prey selection strategies. Morphological characteristics including body mass, skull dimensions, jaw structure, and wing configuration directly influence foraging behavior in insectivorous bats. Large-bodied Myotis species with elongated ears typically forage within dense vegetation where their enhanced hearing aids in detecting prey amid cluttered environments. In contrast, species that commonly forage over open freshwater possess compact bodies and shorter ears optimized for less acoustically complex habitats (Fenton and Bogdanowicz 2002; Lacki et al. 2007). Wing morphology determines flight characteristics, with wing size and shape dictating both flight speed and maneuverability, thereby influencing preferred foraging zones. These adaptations ensure that bats maintain hearing acuity while emitting high-intensity echolocation signals.

Bats can serve as natural reservoir hosts for numerous pathogens and can harbor and transmit various viruses, including, but not limited to, rabies, Hendra, Nipah, Menangle, coronaviruses, and Ebola virus (Calisher et al. 2006; Schneeberger and Voigt 2016). Calisher et al. (2006) suggests that because bats were among the earliest mammalian species to develop, they have robust immune systems that allow them to carry some viruses asymptomatically without becoming severely ill. Additionally, their migratory behavior, colonial roosting patterns, and high population densities act as major drivers of viral persistence and spread by facilitating efficient pathogen transmission both within colonies and across species (Hayman et al. 2013).

It is not typical for these nocturnal bat species to be present offshore or around oil- and gas-related activities because they prefer to stay elevated for ease of flying. Though more research is needed in the offshore environment, it does not prevent a reasonable vulnerability assessment. Habitat loss and fragmentation, predation, and white-nose syndrome for roosting and foraging bats remain the overarching threat to bat species. In general, none of the known factors affecting bat populations would be related to BOEM-regulated activities or potential oil spills.

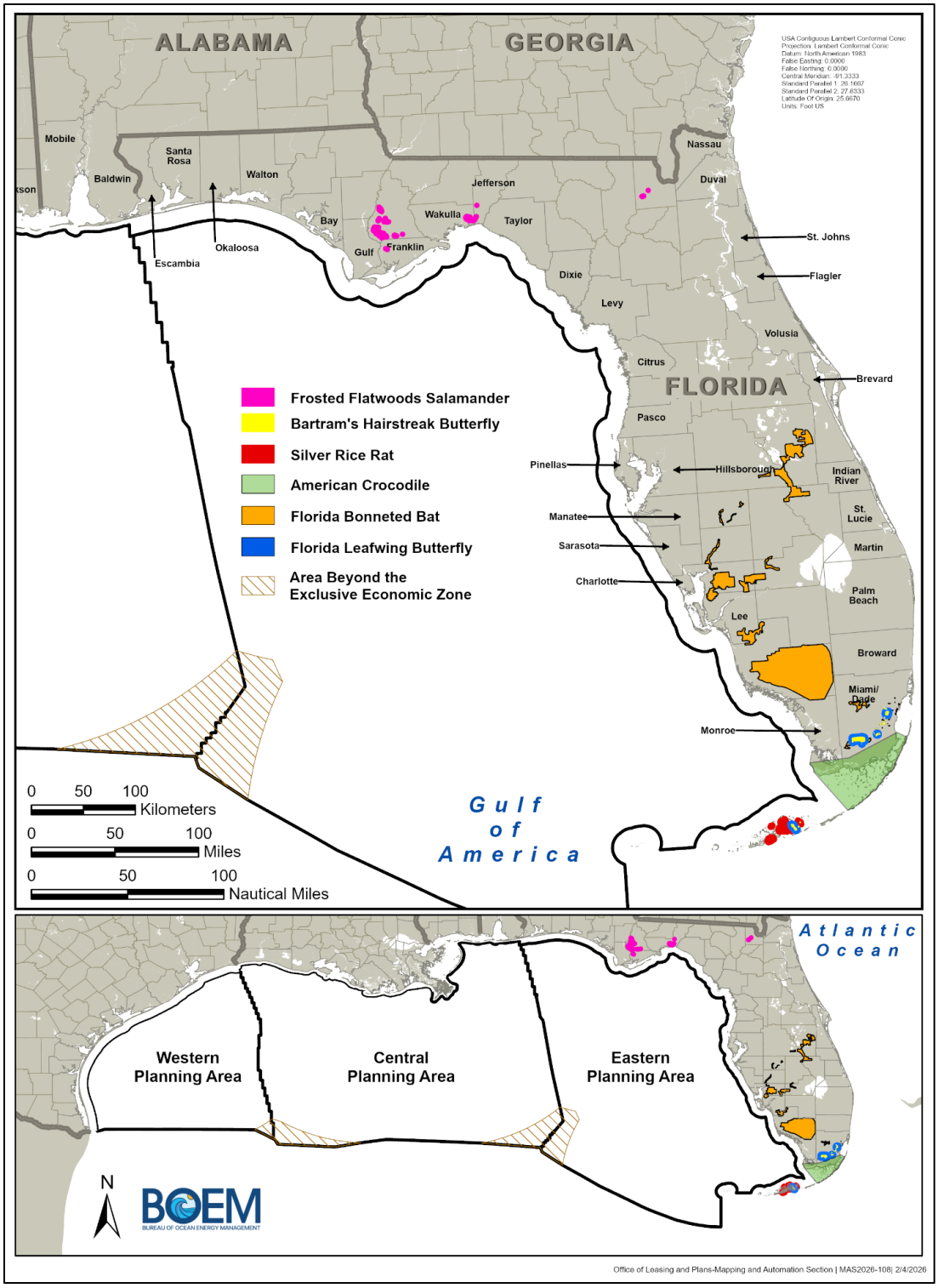


Figure 3-24. Other ESA-listed species with critical habitat within coastal areas.
Source: BOEM - 2026. Map was created by BOEM geographers. The species data source is the FWS. The data source for planning areas and other boundaries is BOEM's Technical Information Management System.

3.9.2 Other ESA-Listed Species with Critical Habitat

3.9.2.1 Frosted Flatwoods Salamander

On April 1, 1999, the FWS listed the frosted flatwoods salamander as Threatened under the ESA (64 FR 15691), and designated critical habitat on February 10, 2009 (74 FR 6700). The following are the primary constituent elements of the physical or biological features essential to conservation (the full list can be found in 74 FR 6700):

(1) Breeding habitat. Small (generally less than 0.4 to 4.0 ha (less than 1 to 10 ac), acidic, depressional standing bodies of freshwater (wetlands) that:

   a. Are seasonally flooded by rainfall in late fall or early winter and dry in late spring or early summer;

   b. Are geographically isolated from other water bodies;

   c. Occur within pine flatwoods-savanna communities;

   d. Are dominated by grasses and grass-like species in the ground layer and overstories of pond-cypress, blackgum, and slash pine;

   e. Have a relatively open canopy, necessary to maintain the herbaceous component that serves as cover for flatwoods salamander larvae and their aquatic invertebrate prey; and

   f. Typically have a burrowing crayfish fauna, but, due to periodic drying, the breeding ponds typically lack large, predatory fish (for example, *Lepomis* (sunfish), *Micropterus* (bass), *Amia calva* (bowfin)).

(2) Non-breeding habitat. Upland pine flatwoods-savanna habitat that is open, mesic woodland maintained by frequent fires and that:

   a. Is within 457 m (1,500 ft) of adjacent and accessible breeding ponds;

   b. Contains crayfish burrows or other underground habitat that the flatwoods salamander depends upon for food, shelter, and protection from the elements and predation;

   c. Has an organic hardpan in the soil profile, which inhibits subsurface water penetration and typically results in moist soils with water often at or near the surface under normal conditions; and

   d. Often have wiregrasses as the dominant grasses in abundant herbaceous ground cover, which supports the herbivorous invertebrates that serve as a food source for the flatwoods salamander.

(3) Dispersal habitat. Upland habitat areas between non-breeding and breeding habitat that allows for salamander movement between such sites and that is characterized by:

a. A mix of vegetation types representing a transition between wetland and upland vegetation (ecotone);

b. An open canopy and abundant native herbaceous species;

c. Moist soils as described in PCE 2; and

d. Subsurface structure, such as that created by deep litter cover or burrows, which provides shelter for salamanders during seasonal movements.

Tide-driven saltwater intrusion increasingly threatens these amphibians which prefer longleaf pine flatwoods terrestrial habitat and isolated, seasonally inundated freshwater breeding habitat. As demonstrated by Hurricane Michael, intense storm surges pose a severe and growing danger to their survival (FWS 2019). None of the known factors affecting frosted flatwoods salamander populations would be related to BOEM-regulated activities or potential oil spills.

3.9.2.2 Bartram's Hairstreak (or Scrub-Hairstreak) Butterfly

On September 11, 2014, the FWS listed the Bartram's hairstreak (or scrub-hairstreak) butterfly as Endangered under the ESA (79 FR 49023), and designated critical habitat on August 12, 2014 (79 FR 47180). The primary constituent elements of the physical or biological features essential to conservation consist of:

(1) Areas of pine rockland habitat, and in some locations, associated rockland hammocks and hydric pine flatwoods;

(2) Competitive nonnative plant species in quantities low enough to have minimal effect on survival of Bartram’s scrub-hairstreak butterfly;

(3) The presence of the butterfly’s hostplant, pineland croton, in sufficient abundance for larval recruitment, development, and food resources, and for adult butterfly nectar source and reproduction;

(4) A dynamic natural disturbance regime or one that artificially duplicates natural ecological processes (e.g. fire, hurricanes or other weather events, at appropriate intervals) that maintains the pine rockland habitat and associated rockland hammock and hydric pine flatwood plant communities;

(5) Pine rockland habitat and associated rockland hammock and hydric pine flatwood plant communities that allow for connectivity and are sufficient in size to sustain viable populations of Bartram's scrub-hairstreak butterfly; and

(6) Pine rockland habitat and associated rockland hammock and hydric pine flatwood plant communities with levels of pesticide low enough to have minimal effect on the survival of the butterfly or its ability to occupy the habitat.

These butterflies are not present in coastal habitats but prefer pine rocklands throughout their life cycles. The pesticides used to control salt marsh mosquitoes that are applied using aerial and ground-based methods present a potential risk to nontarget species (e.g., butterflies herein). Increasingly frequent storm surges and king tide events (episodic disturbances that drive severe coastal erosion and soil salinization) are likely to accelerate the conversion of pine rocklands to mangrove communities by inundating root zones with salt water (FWS 2024a). None of the known factors affecting Bartram's scrub-hairstreak butterfly populations would be related to BOEM-regulated activities or potential oil spills.

3.9.2.3 Silver Rice Rat

On April 30, 1991, the FWS listed the silver rice rat as Endangered under the ESA (56 FR 19809), and designated critical habitat on August 31, 1993 (58 FR 46030). The following primary constituent elements of the physical or biological features essential to conservation consist of:

(1) areas containing contiguous mangrove swamps, saltmarsh flats, and buttonwood transition vegetation. These vegetational types, as well as freshwater cattail marshes, contain the primary constituent elements in critical habitat for the silver rice rat. These vegetational types can be generally identified by the presence of the following species:

- Mangrove swamp containing red, black (, and white mangroves and buttonwood;
- Salt marshes, swales, and adjacent transitional wetlands containing saltwort, perennial glasswort, saltgrass, sea oxeye , keygrass, and coastal dropseed; and
- Freshwater marshes containing cattails, sawgrass, and cordgrass.

Saltmarsh habitats occupied by silver rice rats are regularly inundated by spring tides and, to varying extents, by storm tides. The severity of threats from unpredictable natural events, including hurricanes and associated storm surge, may be amplified by the species' small population size and restricted geographic range (FWS 2021). None of the known factors affecting silver rice rat populations would be related to BOEM-regulated activities or potential oil spills.

3.9.2.4 American Crocodile

On March 20, 2007, the FWS reclassified the American crocodile as Threatened under the ESA (72 FR 13027) in Florida, and designated critical habitat on September 24, 1976 (41 FR 41914). The were no primary constituent elements of the physical or biological features essential to conservation listed for critical habitat. In Florida, the American crocodile occurs primarily in coastal areas, occupying brackish, freshwater, and marine aquatic habitats and adjacent upland shorelines (FWS 2022a). Natural habitats include mangrove swamps and mangrove-lined bays, creeks, and inland swamps that are protected from wave and wind exposure. The estimated population in Florida for 2021 was between 1306 and 3,150 individuals (FWS 2022a). The known current threats to this species are and not limited to habitat loss associated with changes in mangrove vegetation, frequency of cold weather events, hurricanes and nest success, hydrologic changes influencing salinity intrusion, and genetic variability. None of the known factors affecting American crocodile populations would be related to BOEM-regulated activities or potential oil spills.

3.9.2.5 Florida Bonneted Bat

On October 2, 2013, the FWS listed the Florida bonneted bat as Endangered under the ESA (78 FR 61004), and designated critical habitat on March 7, 2024 (89 FR 16624). The following are the primary constituent elements of the physical or biological features essential to conservation. The full list can be found in 89 FR 16624.

(1) Habitats with sufficient darkness that provide for roosting and rearing offspring. Such habitat provides structural features for rest, digestion of food, social interaction, mating, rearing of young, protection from sunlight and adverse weather conditions, and cover to reduce predation risks for adults and young, and is generally characterized by:

   a. Live or dead trees and tree snags, especially longleaf pine, slash pine, bald cypress, and royal palm, that are sufficiently large (in diameter) and tall and that have cavities of a sufficient size for roosts; and

   b. Live or dead trees and tree snags with sufficient cavity height, spacing from adjacent trees, and relative canopy height to provide unobstructed space for Florida bonneted bats to emerge from roost trees; this may include open or semi-open canopy and canopy gaps.

(2) Habitats that provide adequate prey and space for foraging, which may vary widely across the Florida bonneted bat's range, in accordance with ecological conditions, seasons, and disturbance regimes that influence vegetation structure and prey species' distributions. Foraging habitat may be separate and relatively far from roosting habitat. Essential foraging habitat consists of sufficiently dark open areas in or near areas of high insect production or congregation, commonly including, but not limited to:

   a. Freshwater edges and freshwater herbaceous wetlands (permanent or seasonal);

   b. Prairies;

   c. Wetland and upland shrub; and/or

   d. Wetland and upland forests.

(3) A dynamic disturbance regime (e.g., fire, hurricanes, forest management) that maintains and regenerates forested habitat, including plant communities, open habitat structure, and temporary gaps, which is conducive to promoting a continual supply of roosting sites, prey items, and suitable foraging conditions;

(4) A sufficient quantity and diversity of habitats to enable the species to be resilient to short-term impacts associated with disturbance over time (e.g., drought, forest disease). The ecological communities the Florida bonneted bat inhabits differ in hydrology, fire frequency and/or intensity, climate, prey species, roosting sites, and threats, and include, but are not limited to:

   a. Pine rocklands;

   b. Cypress communities (cypress swamps, strand swamps, domes, sloughs, ponds);

   c. Hydric pine flatwoods (wet flatwoods);

   d. Mesic pine flatwoods; and

   e. High pine.

(5) Habitats that provide structural connectivity where needed to allow for dispersal, gene flow, and natural and adaptive movements, including those that may be necessitated by climate change. These connections may include linear corridors such as vegetated, riverine, or open-water habitat with opportunities for roosting and/or foraging, or patches (i.e., stepping stones) such as tree islands or other isolated natural areas within a matrix of otherwise low-quality habitat; and

(6) A subtropical climate that provides tolerable conditions for the species such that normal behavior, successful reproduction, and rearing of offspring are possible.

Florida bonneted bats forage in a variety of open habitats, including pine and hardwood forests, agricultural areas, golf courses, and residential neighborhoods, and they roost in pine tree cavities, beneath barrel roofing tiles, and in bat houses. They use forests, freshwater wetlands, open freshwater edges, and urban areas (78 FR 61004). Florida bonneted bats are the largest non-hibernating bat in Florida and are also not known to forage in saltwater areas. Some threats include disease, predation (i.e., nonnative constrictor snakes) and coastal squeeze, which happens when rising sea levels force habitats to shift landward, but coastal development prevents natural migration, resulting in reduced roosting and foraging habitat for bats (78 FR 61004). None of the known factors affecting Florida bonneted bat populations would be related to BOEM-regulated activities or potential oil spills.

3.9.2.6 Florida Leafwing Butterfly

On September 11, 2014, the FWS listed the Florida leafwing butterfly as Endangered under the ESA (79 FR 49023), and designated critical habitat on August 12, 2014 (79 FR 47180). The following primary constituent elements of the physical or biological features essential to conservation consist of:

(1) Areas of pine rockland habitat, and in some locations, associated rockland hammocks and hydric pine flatwoods;

(2) Competitive nonnative plant species in quantities low enough to have minimal effect on survival of the Florida leafwing butterfly;

(3) The presence of the butterfly's hostplant, pineland croton, in sufficient abundance for larval recruitment, development, and food resources, and for adult butterfly roosting habitat and reproduction;

(4) A dynamic natural disturbance regime or one that artificially duplicates natural ecological processes (e.g., fire, hurricanes or other weather events, at appropriate intervals) that maintains the pine rockland habitat and associated rockland hammock and hydric pine flatwood plant communities;

(5) Pine rockland habitat and associated rockland hammock and hydric pine flatwood plant communities sufficient in size to sustain viable Florida leafwing populations; and

(6) Pine rockland habitat and associated rockland hammock and hydric pine flatwood plant communities with levels of pesticide low enough to have minimal effect on the survival of the butterfly or its ability to occupy the habitat.

These butterflies are not present in coastal habitats but prefer pine rocklands throughout their life cycles. The pesticides used to control salt marsh mosquitoes are applied using aerial and

ground-based methods and present a potential risk to nontarget species (e.g., butterflies herein). Increasingly frequent storm surges and king tide events (episodic disturbances that drive severe coastal erosion and soil salinization) are likely to accelerate the conversion of pine rocklands to mangrove communities by inundating root zones with salt water (FWS 2023c). None of the known factors affecting Florida leafwing butterfly populations would be related to BOEM-regulated activities or potential oil spills.

3.9.3 Vulnerability Assessment

The likelihood of any vulnerability in coastal and offshore waters resulting from BOEM-regulated OCS activity is reduced by both the distance from a potential spill or production area and the likely small concentration of contaminants that may result from OCS oil and gas activities, that could be expected to reach the critical habitat area onshore. The above-listed species are often found in sheltered bays, on shallow banks, and in estuaries, freshwater wetlands or river mouths, making the likelihood of vulnerability even more remote. For this reason, these species are not included for further analysis in this vulnerability assessment.

4 RESOURCE VULNERABILITY ANALYSIS

4.1 INTRODUCTION

This chapter explores the vulnerabilities of Gulf 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 Gulf region. Unlike NEPA analyses, no assumptions are made about the extent, timing, and potential locations of OCS conventional 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 or marine mineral activities. There are general IPFs typical of offshore oil and gas and marine mineral activity that manifest regardless of activity levels and location. This report aims to determine the general vulnerability of the Gulf region's biological resources to these activities and better inform future analyses, assessments, and consultations, as well as identify areas of future study.

Critical mineral extraction is authorized as a BOEM-regulated activity that could occur on the OCS. Critical mineral extraction activities remain in the developmental phase and are considered prospective activities within the Gulf region. Though a vulnerability analysis is not included in this document for critical mineral extraction, the IPFs associated with such activities are provided in **Table 4-1** and assumed to be similar to conventional energy.

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 individual to population levels. Vulnerabilities to an IPF may exist even though lease stipulations, Notices to Lessees and Operators (NTLs), Protocols, Project Criteria, Conditions of Approvals (COAs), and/or other guidance from BOEM may prevent or reduce the IPF from affecting the resource. Existing laws and regulations do prevent vulnerabilities among 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 [nominal], 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 anywhere from the individual to population level.

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, Notices to Lessees, Protocols, Project Criteria, Condition(s) of Approval(s) and/or other guidance from BOEM may prevent or reduce the IPF from affecting the resource. Existing laws and regulations *do* prevent vulnerabilities among IPFs and resources (see **Section 4.1.2**). 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 have the potential to create IPFs (e.g., vessel traffic or geophysical surveying).

Impact/Effect: 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 routine basis during a BOEM-regulated activity and are unintentional by nature (e.g., reasonably foreseeable spills of fuel, crude oil, or other chemicals resulting from accidents, weather events, and collisions, and their response procedures). Vessel strikes, unintentional release of trash and marine debris, and entanglement and entrapment are also 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 BOEM-regulated activities have been grouped into categories based on previous and ongoing assessments and outreach efforts, which are continuously being revised. The IPF categories listed in this document closely align with those in the *Programmatic Description of the Potential Effects from Gulf of Mexico OCS Oil- and Gas-Related Activities: A Supporting Information Document,* which details how oil and gas operations in the Gulf may interact with physical, biological, and human resources (see Gulf of Mexico OCS Oil- and Gas-Related Activities SID [BOEM 2023]). 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 about what constitutes unwanted or undesirable intrusions of sounds. Noise can have negative effects on biological resources and environmental quality through several pathways, including direct auditory injury, acoustic masking, and/or other behavioral disruptions. The severity of impact depends on many factors, including, but not limited to, the frequency range of the sound, the type and intensity of sound, as well as the hearing abilities of the species of interest. For more details on the physics of noise, see **Appendix B.** For approximate hearing ranges of marine species and frequency ranges of various common anthropogenic sources, see **Figure 4-1**.

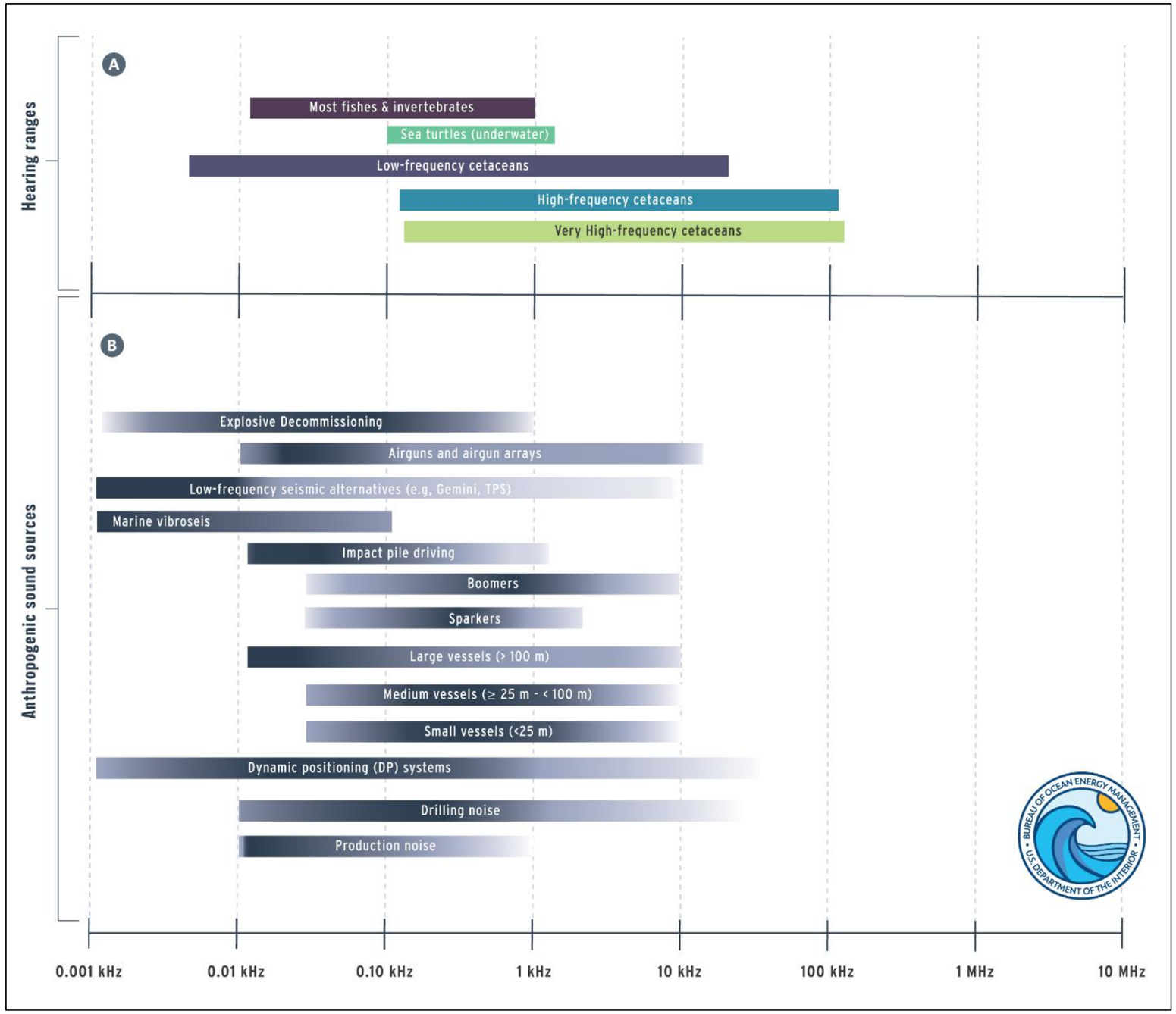


Figure 4-1. Approximate hearing ranges of marine species and frequency ranges of various anthropogenic sound sources.

(A, top panel) Approximate hearing ranges of marine species; (B, bottom panel) 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.

Source: BOEM. Graphic was created using information from Popper et al. (2014), Lucke et al. (2024), NMFS (2024a), and Center for Marine Acoustics (2023).

Note: This figure is a simplified representation and not all-inclusive of every sound source. The sound sources included are those that are of potential concern and common; there may be others not depicted. These frequencies are approximate ranges, and sources may vary based on operations. The frequency axis of both plots shows kHz in a logarithmic scale.

- **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 USCG regulations.
- **Bottom Disturbance:** Physical disturbance to the seafloor that can be caused by a variety of BOEM-regulated activities. Examples include anchoring, drilling, trenching, jetting, and pipe and cable disturbing actions that are associated with BOEM-regulated activities.
- **Coastal Land Use and/or Modification:** 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 would be 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 and Pollution:** This refers to the release of gaseous or particulate pollutants into the atmosphere from stationary sources, vessels, vehicles, or aircraft, which can affect air quality, criteria air pollutants[14], and associated resources. These emissions can occur onshore and offshore and include those from helicopters, vessels, stationary engines (e.g., generators), and equipment leaks (i.e., fugitive emissions).
- **Lighting and Visual Impacts:** The structural presence and associated lighting in both the onshore and offshore environment.
- **Seawater Use and/or Uptake (Impingement):** This refers to activities that involve the physical extraction of seawater or the disturbance of marine minerals or sediments to be used for offshore development, including desalinization, jetting, cooling of drilling equipment during oil production, ballast water, fire suppressant, and anti-fouling measures for vessel and platform maintenance.

[14] The USEPA-defined criteria pollutants released by OCS sources include carbon monoxide, nitrogen dioxide, fine particulate matter of 2.5 μ in diameter, particulate matter 10 μ or less, and sulfur dioxide.

- **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, and hydrogen sulfide and sulfurous petroleum releases.
- **Release Response**: This refers to the response and cleanup efforts of unintended or accidental releases into the environment, including the use of dispersants, mechanical removal (e.g., booms), and controlled burning.
- **Strikes and Collisions:** These terms describe the unintended accidental collision between OCS-associated vessels with structures or other vessels, including collisions between two vessels, allisions (when a vessel strikes a stationary object, such as a vessel that is not underway or an artificial structure), and vessels running aground. This also includes moving vessels and/or vehicles striking biota or natural habitat above or below the water's surface, and aerial species.
- **Entanglement and Entrapment:** Entanglement occurs when marine wildlife accidentally becomes caught in or tangled by debris or equipment. Entrapment occurs when an animal is being physically confined or trapped by an object or structure, like submerged structures, debris, or moon pools.

Table 4-1. Examples of BOEM-regulated activities associated with each impact-producing factor category

Examples include activities from oil and gas exploration and production and marine minerals extraction and use. Each program listed may not be linked to every activity example.

Activity or Event Type	Impact-Producing Factor	Activity Related to OCS Energy and Mineral Exploration and Production	Associated Program(s)
Routine Activities	Noise	◦ Geological and geophysical active acoustic sources ◦ Vessels (including DP) ◦ Aircraft ◦ Drilling and production ◦ Trenching Construction (including both onshore and offshore) ◦ Structure removal (including explosives) ◦ Dredging ◦ Vibration ◦ Pile driving ◦ Sonar	◦ Oil and Gas ◦ Marine Minerals (e.g., Sand) ◦ Marine Minerals (Offshore Critical Minerals)
Routine Activities	Discharges* and Wastes	◦ Operational wastes and discharges (including brine and hydrostatic test-water discharge) ◦ Drilling muds and cuttings ◦ Produced water ◦ Well treatment, workover, and completion fluids ◦ Production solids and equipment ◦ Bilge ballast and fire water ◦ Cooling water (temperature differential) ◦ Deck drainage (stormwater) ◦ Domestic and sanitary wastes ◦ Minor and/or Miscellaneous discharges ◦ Onshore disposal of waste generated offshore ◦ Dredge outwash	◦ Oil and Gas ◦ Marine Minerals (e.g., Sand) ◦ Marine Minerals (Offshore Critical Minerals)
Routine Activities	Bottom Disturbance	◦ Drilling infrastructure emplacement (subsea equipment) and maintenance ◦ Anchoring ◦ Geological and geophysical coring ◦ Geological and geophysical ocean bottom nodes ◦ Decommissioning and/or structure removal (including clearance surveys) ◦ Dredging ◦ Sediment removal ◦ Pile driving ◦ Pipeline and cable emplacement and maintenance (jetting)	◦ Oil and Gas ◦ Marine Minerals (e.g., Sand) ◦ Marine Minerals (Offshore Critical Minerals)

Activity or Event Type	Impact-Producing Factor	Activity Related to OCS Energy and Mineral Exploration and Production	Associated Program(s)
Routine Activities	Coastal Land Use and/or Modification	◦ Construction facilities and/or fabrication yards ◦ Support and transportation facilities ◦ Processing facilities ◦ Pipeline landfalls ◦ Vessel traffic ◦ ◦ Sand and gravel placement ◦ Navigation dredging and/or maintenance ◦ Port expansion	◦ Oil and Gas ◦ Marine Minerals (e.g., Sand) ◦ Marine Minerals (Offshore Critical Minerals)
Routine Activities	Offshore Habitat Modification and/or Space Use	◦ Offshore infrastructure emplacement (e.g., pipelines, platforms, etc.) ◦ Decommissioning and/or structure removal ◦ Placement or removal of coastal infrastructure ◦ Vessel presence (aspects other than noise and collisions) ◦ Scour protection ◦ Geological surveys ◦ Dredging ◦ Engines (e.g., vessels, platforms)	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)
Routine Activities	Air Emissions and Pollution	◦ Drilling ◦ Pile Driving ◦ Dredging ◦ Vessel Operations ◦ 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	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)
Routine Activities	Lighting and Visual Impacts	◦ Offshore structures ◦ Safety lighting ◦ Vessel presence	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)
Routine Activities	Seawater Use/Uptake (Impingement)	◦ Ballast and fire water ◦ Cooling water ◦ Jetting ◦ Anti-fouling (vessel and platform maintenance)	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)

Activity or Event Type	Impact-Producing Factor	Activity Related to OCS Energy and Mineral Exploration and Production	Associated Program(s)
Accidental Events	Entanglement/ Entrapment	◦ Diver lines ◦ Surveys (e.g., airgun strings, ROV) ◦ Construction equipment (e.g., crane cables) ◦ Moorings ◦ Ocean bottom nodes ◦ Moon pools ◦ Trawling (e.g., fishery surveys and site clearance)	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)
Accidental Events	Accidental Releases into the Environment	◦ Oil and/or chemical spills and associated response from pipelines, wells, or vessel operations ◦ Non-routine air emissions (e.g., loss of well control, non-routine equipment venting and emergency flaring) ◦ Marine vessel collisions ◦ Marine trash and debris release	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)
Accidental Events	Release Response	◦ Chemical dispersant use ◦ Mechanical removal (e.g., booms) ◦ Controlled burning	◦ Oil and Gas
Accidental Events	Strikes and Collisions	◦ Vessels or other vehicles striking other vessels, human-made structures, wildlife, or habitat above or below the water's surface	◦ Oil and Gas ◦ Marine Minerals (e.g., sand) ◦ Marine Minerals (Offshore Critical Minerals)

*All discharges to the Gulf fall under the Clean Water Act, which is implemented by the USEPA through NPDES permitting.

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 Gulf region. The following sections of this chapter describe each resource and 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 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 region

An X indicates a vulnerability between that IPF-resource combination and not necessarily a direct or indirect impact. The subsequent sections of this chapter provide a rationale for these vulnerability determinations.

Resource	Noise	Discharges and Wastes[1]	Bottom Disturbance	Coastal Land Use and/or Modification	Offshore Habitat Modification and/or Space Use	Air Emissions[2] and/or Pollution	Lighting and Visual Impacts	Seawater Use and/or Uptake (Impingement)	Accidental Events[3]
Coastal Habitats and Communities	X	X	X	X	-	X	X	X	X
Pelagic Habitats and Communities	X	-	-	-	X	-	-	X	X
Benthic Habitats and Communities	X	X	X	-	X	-	X	X	X
Fish and Invertebrate Resources	X	X	X	X	X	-	X	X	X
Sea Turtles	X	X	X	X	X	X	X	X	X
Marine Mammals	X	X	X	X	X	X		X	X
Birds	X	-	-	X	X	-	X	-	X

[1] USEPA Water Quality Standards; Section 301(a) of the Clean Water Act (CWA), 33 U.S.C. 1311(a), makes it unlawful for any person to discharge any pollutant, except in compliance with other CWA 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 Treaty and the Marine Debris Act, 33 U.S.C. 1951 et seq., and regulations imposed by various agencies, including the USCG and USEPA.

4.1.2 Regulatory Compliance

To authorize activity on the OCS, BOEM must comply with environmental statutes, regulations, and executive orders to carry out its mission. BOEM is responsible for oil and gas leasing, exploration, and development plan approval and administration, environmental studies, NEPA analyses, resource evaluation, and economic analysis. BOEM reviews and approves plans for OCS exploration and development. Federal laws govern the OCS leasing program (i.e., the Outer Continental Shelf Lands Act [OCSLA]) and the environmental review process (i.e., NEPA). In implementing their responsibilities under the OCSLA, BOEM and BSEE must consult with numerous federal departments and agencies that have authority to govern and maintain ocean resources pursuant to other federal laws. Those federal entities include but are not limited to the USCG, USEPA, USACE, FWS, and NOAA through NMFS. For more information about the environmental statutes, regulations, and executive orders with which BOEM must comply, see BOEM's *Gulf of America OCS Regulatory Framework* (BOEM 2025).

Table 4-3. Existing regulatory requirements and protective measures that reduce the potential for injury

Regulatory Requirement or Mitigating Measure[1]	Enforcing Agency	Sources of Potential Injury Reduced or Avoided	Supporting References and Sections
OCSLA	BOEM BSEE	Noise; Offshore Habitat Modification/Space Use; Air Emissions and Pollution; Discharges and Wastes; Accidental Events	◦ 30 CFR 550, 551, 580 and 585; ◦ 30 CFR 250.1727(g)
ESA	BOEM, BSEE, NOAA Fisheries	Noise; Accidental Events (Strikes and Collisions; Marine Trash and Debris; Entanglement and Entrapment)	◦ 16 U.S.C. 1531 et seq.
MMPA	NOAA Fisheries	Noise (i.e., geophysical surveys)	◦ 16 U.S.C. 1361 et seq.; ◦ 50 CFR 217 Subpart S, and ◦ (89 FR 31488)
Topographic Features Stipulation	BOEM BSEE	Bottom Disturbance; Discharges and Wastes; Accidental Events (Release Response)	◦ NTL 2009-G39, Biologically-Sensitive Underwater Features and Areas; ◦ Sections 5.10 and 7.6 of the SID (BOEM 2023)
Live Bottom Stipulation	BOEM BSEE	Bottom Disturbance; Discharges and Wastes; Accidental Events (Release Response)	◦ NTL 2009-G39, Biologically-Sensitive Underwater Features and Areas; ◦ Sections 5.10 and 7.9 of the SID (BOEM 2023)
Protected Species Stipulation	BOEM BSEE	Noise; Accidental Events (Strikes and Collisions; Marine Trash and Debris; Entanglement and Entrapment)	◦ The latest Protected Species Stipulation at the time of this report publication can be found at this BOEM website. For updates, see the BOEM Lease Sale web page.
Ancillary Activity Reporting and Notification Requirements	BOEM BSEE	Noise, Bottom Disturbance	◦ 30 CFR 550.207–210
Hard bottom habitat and chemosynthetic communities avoidance mitigations	BOEM BSEE	Bottom Disturbance	◦ NTL 2009-G39, Biologically-Sensitive Underwater Features and Areas; ◦ NTL 2009-G40, Deepwater Benthic Communities; ◦ Sections 5.10, 6, and 7.9 of the SID (BOEM 2023)
Magnuson-Stevens Fishery Conservation and Management Act (EFH Consultation)	NOAA	Bottom Disturbance; Noise	◦ 50 CFR 600
CWA Section 402, the NPDES for Regions 4 and 6, and Section 404	USEPA, USACE	Coastal Land Use and/or Modification; Discharges and Wastes; Accidental Events	◦ Sections 2 and 5.11 of the SID (BOEM 2023); ◦ 33 U.S.C. 1251; ◦ 40 CFR 125 M

Regulatory Requirement or Mitigating Measure[1]	Enforcing Agency	Sources of Potential Injury Reduced or Avoided	Supporting References and Sections
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), MARPOL Annex V Treaty	International Maritime Organization (IMO); USCG	Discharges and Wastes; Accidental Events	◦ See the USCG website about MARPOL; ◦ 33 U.S.C. 1901–1915; ◦ 33 CFR A; ◦ Sections 2.2, and 2.9.1.7 of the SID (BOEM 2023)
Marine Protection, Research, and Sanctuaries Act	USEPA	Discharges and Wastes	◦ 33 U.S.C. 1401 et seq.; ◦ MARPOL Annex V, implemented by 33 CFR 151; ◦ 33 U.S.C.1901–1915
National Marine Sanctuaries Act (NMSA) – FGBNMS, including NMSA 304(d)	NOAA	Bottom Disturbance; Noise	◦ 15 CFR 922 L; ◦ 16 U.S.C. 1434(d)
BSEE Decommissioning Requirements[15]	BOEM BSEE	Bottom Disturbance; Noise; Accidental Events (Strikes and Collisions; Entanglement and Entrapment)	◦ 30 CFR 250.1740–250.1743; ◦ Section 2.3.1.3 of the SID (BOEM 2023); ◦ NTL 2019-G05; ◦ 30 CFR Q
Vessel General Permit[2]	USEPA	Discharges and Wastes	◦ (78 FR 21938). ◦ See the USEPA 2013 Vessel General Permit and Interim Requirements.
Ballast Water Treatment Regulations	USCG	Discharges and Wastes	◦ USCG Ballast Water Management Program (33 CFR part 151)
Marine Plastic Pollution Research and Control Act	USCG	Accidental Events (Marine Trash and Debris)	◦ 33 U.S.C. 1901; ◦ Sections 2.9.1.7 and 4.4.5.2.3 of the SID (BOEM 2023)
Coastal Zone Management Act	NOAA, states	Coastal Land Use and/or Modification	◦ 16 U.S.C. 1251 and ◦ 15 CFR 930
Marine Debris Research, Prevention, and Reduction Act	USEPA, USCG	Accidental Events (Marine Trash and Debris)	◦ 33 U.S.C. 1901; ◦ Sections 2.9.1.7 and 4.4.5.2.3 of the SID (BOEM 2023)

[15] Regulation and enforcement of these laws are conducted by USEPA, USCG, NOAA, and BSEE to protect water quality and prevent unreasonable degradation of OCS waters in the Gulf.

Regulatory Requirement or Mitigating Measure[1]	Enforcing Agency	Sources of Potential Injury Reduced or Avoided	Supporting References and Sections
National Contingency Plan (CWA, Oil Pollution Act, National Oil and Hazardous Substances Pollution Contingency Plan)	USCG; USEPA; state, regional, and local governments	Accidental Events (Accidental Releases; Release Response)	◦ 40 CFR 300; ◦ Oil Pollution Act of 1990 (33 U.S.C. 2701–2762; ◦ CWA Section 311; ◦ 33 U.S.C. 1321; ◦ 40 CFR 110.3; ◦ MARPOL Annex I, as implemented in the U.S. at 33 CFR 151.10), National Response Framework; ◦ Executive Orders 12580 and 12777; ◦ Secretary's Order 3299
BSEE Marine Trash and Debris Prevention Program	BSEE	Accidental Events (Marine Trash and Debris)	◦ Title 30, CFR 250.300, Pollution Prevention16; ◦ Sections 2.9.1.7 and 4.4.5.2.3 of the SID (BOEM 2023); ◦ See the BSEE Marine Debris Program webpage.
Clean Air Act (CAA) Amendments of 1990 (e.g., National Ambient Air Quality Standards [NAAQS] pursuant to the CAA through OCSLA)	USEPA; BOEM	Air Emissions and Pollution	◦ Section 4.1.2.2; ◦ 40 CFR 55; ◦ Sections 2.1 and 6 of the SID (BOEM 2023)
Visual Flight Rules Nera Noise-Sensitive Areas	Federal Aviation Administration (FAA)	Accidental Events (Strikes and Collisions)	◦ FAA: AC No: 91-36D (Kaulia 2004)
MBTA	FWS	Coastal Land Use and/or Modification; Offshore Habitat Modification and/or Space Use	◦ 78 FR 65844

[1] See Chapter 6 of the SID (BOEM 2023) for conditions of approval commonly applied to oil and gas activities at the post-lease stage.

[2] VIDA was enacted on December 4, 2018, to regulate incidental discharges from commercial vessels. VIDA authorized the USEPA and the USCG to develop standards of performance for vessel discharges and to implement, monitor, and enforce regulations. Vessel Incidental Discharge National Standards of Performance were published in the *Federal Register* on October 26, 2020, for comment. Currently, the USEPA is developing a Supplemental Notice to the proposed rule for the standards. Vessel General Permit requirements remain in place until the standards are finalized and USCG implementing regulations in place.

[16] Regulation and enforcement of these laws are conducted by USEPA, USCG, NOAA, and BSEE to protect water quality and prevent unreasonable degradation of OCS waters in the Gulf.

4.1.2.1 Water Quality Regulations

Rules and regulations addressing water quality (e.g., in support of the CWA, MARPOL, and others; see **Table 4-3**) are implemented to minimize the impact of discharges from offshore oil and gas operations and vessel activities on water quality in OCS waters of the Gulf. These requirements include compliance with multiple federal statutes, international agreements, and agency regulations designed to prevent unreasonable degradation of the marine environment.

Before permit issuance, ocean discharges must be evaluated against the USEPA's published criteria for determination of unreasonable degradation. Unreasonable degradation is defined in the NPDES regulations (40 CFR 125 M; 125.1211e) as the following:

- significant adverse changes in ecosystem diversity, productivity, and stability of the biological community within the area of discharge and surrounding biological communities;
- threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms; and
- loss of aesthetic, recreational, scientific, or economic values, which is unreasonable in relation to the benefit derived from the discharge.

Permit GMG290000[17] was reissued in 2023 and is more restrictive than its predecessor permit, offering greater protection to the environment.

One of the ten factors specified at 40 CFR 125.122 for determining unreasonable degradation is the composition and vulnerability of the biological communities that may be exposed to such pollutants, including the presence of unique species or communities of species; the presence of species identified as Endangered or Threatened pursuant to the ESA; or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain (USEPA 2023). As noted above, the degradation of ambient water quality is not anticipated with regulatory compliance subject to the terms of NPDES permits issued by the USEPA under the CWA. Operational discharges are diluted and dispersed when released in offshore areas, so any exposure would be intermittent and temporary and not expected to directly or indirectly affect any species. For more information on the environmental statutes, regulations, and executive orders BOEM must comply with, see BOEM's *Gulf of America OCS Regulatory Framework* technical report (BOEM 2025).

[17] The NPDES General Permit for New and Existing Sources and New Discharges in the Offshore Subcategory of the Oil and Gas Extraction Point Source Category for the Western and Central Portion of the Outer Continental Shelf of the Gulf of Mexico (May 11, 2023).

4.1.2.2 Air Quality Regulations

The National Ambient Air Quality Standards (NAAQS), established by the CAA Amendments of 1990, address six criteria air pollutants that can be harmful to both public health and the environment: carbon monoxide, nitrogen oxides, sulfur dioxide, suspended particulates, total hydrocarbons, and volatile organic compounds. The USEPA set these standards, with primary standards focusing on protecting the health of "sensitive" populations, such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. These standards are found on the USEPA NAAQS Table website.

Among particulate matter, fine particulate matter ($PM_{2.5}$) and course particulate matter (PM_{10}) are of concern due to their ability to travel long distances and pose inhalation risks to human health (USEPA 2026). The USEPA's regulations also monitor volatile organic compounds (VOCs) as they are precursors to ozone formation. In addition to the criteria pollutants, BOEM also assesses other pollutants, such as nitrogen oxides, sulfur oxides, ammonia, hazardous air pollutants, and greenhouse gases, because these contribute to the formation or presence of criteria air pollutants.

BOEM has jurisdiction over OCS air emissions from sources it authorizes in the Gulf west of 87.5°W longitude (off the coasts of Texas, Louisiana, Mississippi, and Alabama). Under OCSLA, BOEM must have regulations "for compliance with the national ambient air quality standards pursuant to the Clean Air Act (42 U.S.C. 7401 et seq.), to the extent that activities authorized under this subchapter significantly affect the air quality of any State" (43 U.S.C. 1334(a)(8)). Under BOEM's regulations, in order to receive approval for an oil and gas exploration or development plan, lessees must provide "[t]ables showing the projected emissions of criteria air pollutants, volatile organic compounds (VOC), and total suspended particulates (TSP)" for the proposed activities (30 CFR 550.218, 550.249). The projected emissions are estimates based on the type of equipment used. BOEM's regulations then rely upon an exemption emissions threshold (EET), based on projected emissions and distance from shore to determine if a plan's emissions will have significant impacts on air quality (30 CFR 550.303(d)). If a source did exceed the EET, the operator would conduct air quality modeling (using an approved model) to assess whether its emissions would significantly affect onshore air quality by comparing the projected emissions to "significance levels" established by EPA (30 CFR 550.303(e), (f); see 40 CFR 51.165(b)(2)). If a significance determination is made, further requirements would apply; the requirements would depend on if the impacted onshore location is in an attainment or a nonattainment area (30 CFR 550.303(g)).

4.1.3 Mitigation Strategies

BOEM implements mitigation strategies to minimize or eliminate the potential of environmental impacts associated with OCS activities including oil and gas plans, pipeline

applications (installation and decommissioning), oil and gas structure removals, and G&G applications. Such mitigations include, but are not limited to, those applied at the leasing stage through lease stipulations or at the post-lease stage pursuant to the Bureaus' authority under OCSLA (43 U.S.C. §§ 1331 et seq.). BOEM and BSEE also develop mitigations applied to regulated activity for the protection of benthic communities and habitat, in part due to requirements under existing EFH consultations. These mitigation measures are integral to BOEM's program ensuring that post-lease operations are consistently conducted in an environmentally responsible manner. The adopted mitigation framework follows the preference: avoid; minimize; and mitigate through alternative methods. Mitigations are integrated throughout leasing processes and are continuously updated to reflect changes in requirements through environmental consultations, regulations, new technology, new information and/or publications, and new methods of operation. Additionally, BOEM applies site-specific mitigation efforts during the planning and approval stages. Discussion of commonly applied mitigation measures for oil and gas activities can be found in Chapters 6 and 7 of the SID.

4.2 COASTAL HABITATS AND COMMUNITIES

Coastal habitats of the northern Gulf (e.g., marsh, beaches, barrier islands, SAV, mangroves, oysters, intertidal flats) support diverse biological communities. The following subsections describe how IPFs from BOEM-regulated activities may affect these coastal habitats and communities.

4.2.1 Noise

Many marine species that make up coastal communities are sensitive to underwater sound. Descriptions of hearing capabilities and potential impacts of underwater noise can be found in **Sections 4.5.1** Noise [Fish and Invertebrates], **4.6.1** Noise [Sea Turtles], **4.7.1 Noise** [Marine Mammals], and **4.8.1** Noise [Birds].

Most BOEM-related activities in the Gulf occur offshore, so noise from those activities would not affect coastal communities. However, noise from onshore construction, pipeline laying, or vessel traffic could still occur in coastal areas. It has been shown that species, such as crabs, oysters, mussels, and shrimp, are capable of perceiving low-frequency sounds (e.g., Aguilar de Soto et al. 2013; Roberts et al. 2015; Charifi et al. 2017). 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. 2013; Lillis et al. 2015; Stanley et al. 2015). Although these animals use natural acoustic cues for basic life functions, they are unlikely to be disturbed by most anthropogenic noise sources if they are beyond a few wavelengths from the source, because particle motion does not propagate that far (Urick 1983; Kalmijn 1988; Popper and Hawkins 2018). Larger, pressure-sensitive species like manatees, coastal dolphins and turtles, could experience behavioral disturbance from vessel traffic as they pass through coastal areas, but within very shallow areas like mangrove habitats and estuaries, low-frequency sounds will not propagate due to the "low-frequency cutoff" (Urick 1983).

4.2.2 Discharges and Wastes

Vessels conducting BOEM-regulated activities use coastal ports and waterways during transit to and from the OCS, which can result in discharges of ballast water, cooling water, and wastes (e.g., sanitary wastes, bilge) into coastal waters, possibly affecting local water and habitat quality. However, discharges and wastes resulting from routine coastal activities are regulated and generally expected to be localized and dissipate quickly. The dispersion and dilution of the discharges is influenced by a variety of factors, including the discharge composition, discharge rate, discharge point (e.g., depth, direction), and oceanographic conditions (e.g., currents, winds, waves temperature, salinity) (Beyer et al. 2020).

Many operational discharges from BOEM-regulated activities, 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 and are either transported to shore or diluted and discharged according to USEPA regulations (e.g., NPDES permits in support of the CWA; for more detail, see **Section 4.1.2** and **Table 4-3**). Though offshore produced-water discharges can extend over 2 km (1.2 mi) from the source, the majority of the ecological impacts occur within 200–300 m (656–984 ft) of the source (Cordes et al. 2016) and are, in most cases, too distant to pose a threat to coastal communities and habitats.

However, some activities (e.g. vessel transit, dredging for marine minerals) may result in discharges closer to shore. Cooling water discharge (e.g., from vessels) can result in a temporary elevation of water temperature, which may negatively impact organisms that are unable to avoid the discharge plume. Also, pipeline in-situ hydrostatic testing may occur when pipelines are placed into service or during repair activities to verify a pipeline's structural integrity. During this testing, pipelines are typically filled with seawater treated with chemicals (e.g., biocides) to prevent corrosion. After pressure testing, the test-water is either collected (e.g., frac tank) and disposed of onshore or discharged into the water column in accordance with NPDES permit requirements (for more detail, see **Section 4.1.2** and **Table 4-3**). If cooling water or test-water is discharged into the water column, changes in water quality could result in mortality or physiological effects to organisms unable to avoid the plume. However, any effects from these discharges would be expected to be localized and temporary due to current and tidal mixing.

Ballast water can transport plants, animals, and microorganisms, potentially introducing nonnative species. However, to prevent the spread of aquatic nuisance species, the USCG implements a Ballast Water Management Program (see **Table 4-3**) that applies the provisions of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended by the National Invasive Species Act of 1996. Aquatic Nuisance Prevention and Control Act of 1990, as amended by the National Invasive Species Act of 1996.

During coastal dredging, the outwash of excess materials can result in sediment plumes extending out from the area of physical dredging. This sediment resuspension temporarily increases turbidity that could result in the clogging and damaging of appendages and feeding

structures (Berry et al. 2003) and/or reduce light penetration, which could impede photosynthesis of seagrasses or affect predator-prey dynamics of fishes and invertebrates (e.g., for visual predators). However, areas affected by sediment deposition from the outwash plume would generally be limited to a few hundred meters from the outwash point (i.e., discharge chute) (Newell et al. 1998; Hitchcock and Bell 2004).

Due to wetland protection regulations, such as section 404 of the CWA (see **Section 4.1.2** and **Table 4-3**), no new waste disposal sites are expected to be developed in wetlands. If improperly monitored and controlled, some seepage or discharges from existing onshore sources, such as waste sites, ports, or oil storage sites into adjacent wetland areas can occur, potentially resulting in changes to soil chemical composition and/or vegetation injury or mortality.

4.2.3 Bottom Disturbance

4.2.3.1 Anchoring

Most BOEM-regulated operations are distant from coastal habitats. When in coastal areas, associated vessels are usually moored at established ports (i.e., generally, no anchoring is anticipated). However, anchoring and spudding within coastal habitat could be associated with pipeline and/or cable installation and repair and dredging. Temporary anchoring and associated cable sweeps would result in bottom disturbance and the generation of turbidity plumes near the seafloor. Coastal benthic habitats (e.g., oyster reefs, seagrass beds) could be crushed or buried by anchoring, and scars could remain on the seafloor. Habitat within the anchor's footprint would also be unavailable while the anchor is in place. Further, increased turbidity could result in the clogging and damaging of appendages and feeding structures of coastal organisms (Berry et al. 2003) and/or reduce light penetration, which could impede photosynthesis for seagrasses or affect predator-prey dynamics for fishes and invertebrates (e.g., visual predators).

4.2.3.2 Pipeline and Cable Emplacement

Many existing OCS pipelines make landfall on the shorelines of barrier islands and wetlands (Johnston et al. 2009). Installation of pipelines in or near wetland habitats could lead to hydrologic alteration, disturbance, fragmentation, and loss of wetlands (Ko and Day 2004a). Impacts from pipeline and cable emplacement could be long term and could affect the associated biological communities, such as coastal bird species, that rely on these habitats for nesting and feeding (see **Section 4.8.3** and **Section 4.8.4**). These vulnerabilities may be greater in the EPA, where the absence of existing infrastructure and pipelines means that newly installed pipelines would be more likely to disturb previously intact habitats. However, much of the EPA is currently withdrawn from leasing (see **Section 1.2**).

At least two studies have shown a connection between land loss and existing pipelines. As discussed in **Section 3.2**, coastal land loss is already an issue of immense concern in the Gulf, and pipeline and cable emplacement may exacerbate this loss. One study indicated that

existing pipelines have caused direct land loss, averaging 2.43 ha (6 ac) per linear km/0.6 mi of pipeline for the 1955–1978 period (Baumann and Turner 1990). However, Baumann 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 in the coastal zone of the Gulf: (1) upland trenching; (2) jetting; (3) building flotation canals; (4) push-pull ditching; and (5) directional drilling. Of these, flotation canals have the most harmful effects because of their large habitat disturbance. Push-pull ditching can be used to 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 most favored technique and is considered less impactful to sensitive habitats. By using directional drilling, pipeline installation can occur without having to cut through shore facings, minimizing any erosion and surface habitat disturbance. Impacts are limited to the access and staging sites for the equipment. At present, directional drilling is required almost without exception for crossing barrier island and shore faces. Typically, the installation of new pipelines that make landfall is rare. When pipelines do make landfall, there are mitigating measures from regulatory programs (e.g., section 404 of the CWA; see **Section 4.1.2** and **Table 4-3**) and environmental consultations (e.g., ESA) that may be applied, including compensatory mitigation.

In coastal areas where pipelines and cables cannot be buried to required regulatory depths due to substrate conditions (e.g., shallow bedrock), they may be armored to prevent susceptibility to impact (such as fishing trawls, anchors). Armoring can use materials such as concrete mattresses or boulders. Because most of the coastal seafloor in the Gulf is flat sand, silt, and mud, the addition of rock or concrete would change the nature of the seabed habitat. Adding hard surfaces, vertical relief, and habitat complexity could lead to increases in faunal diversity (Langhamer 2012; Taormina et al. 2018). This conversion of soft bottom to 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.

4.2.3.3 Dredging

Maintenance dredging of navigation channels and canals is USACE-regulated and routinely conducted, in part, to support OCS activities. Occasionally a channel would be dredged ahead of its normal maintenance schedule to accommodate the transport of large OCS platforms. Dredging for beach nourishment is a BOEM-regulated activity on the OCS. Dredging of OCS sand resource areas (i.e., borrow areas) in the Gulf is typically completed using either a hopper or cutterhead dredge, and generally occurs at depths of less than 50 m (164 ft). Images and additional description of these dredge types can be found in Section 2.3.2.5 of the GOM Oil and Gas SID.

Trailing suction hopper dredges (TSHD) are the most common type of hopper dredge used for shoreline restoration projects that use OCS sediments, due to factors such as water depth, project size, and oceanographic conditions typical of OCS borrow areas. TSHD are self-propelled, with the unique ability to perform suction dredging while in motion, and do not require an anchor to dredge. They are often used at coastal inlets and offshore but cannot be used in confined or shallow water areas because of their size and draft. Fitted with powerful pumps, TSHD draw sediment from the surface of the seafloor through intake pipes, called "dragarms" and store it in the hoppers. A typical hopper dredge contains two dragarms, one on either side of the vessel. Each dragarm is equipped with a suction mouth called a "draghead" that is dragged across the seabed during dredging operations. While dragarms are usually large in diameter, their size depends on the type of sediment (particularly grain size) being targeted. A slurry of water and sediment is generated from the plowing of the draghead "teeth," using high pressure water jets and suction pumps. The dredged slurry is distributed within the vessel's hopper, allowing solids to settle out and the water portion of the slurry to be discharged from the vessel during operations through its overflow system. When the hopper has a full load, dredging stops, and the ship travels to either an in-water placement site, where the dredged material is discharged through the bottom of the ship by opening doors on the bottom of the hull, or to an area of coastline targeted for beach nourishment, where the material is rehydrated and transported to the shore through a pipeline.

The cutterhead dredge is another common type of dredge for shoreline restoration projects, typically excelling in larger borrow areas with deep shoals. Cutterhead dredges are capable of dredging a wide variety of sediments due to their wide range of cutting head power. During operation, the vessel swings port and starboard alternately, passing the cutter through bottom material until proper depth is achieved. The dredge advances by "walking" itself forward on two spuds located at the stern. Swing anchors are also used for positioning and are located ahead of the dredge, connected by wire ropes. The cutterhead dredge has rotating blades or teeth to break up or loosen the bottom material so it can be drawn through the intake pipe. Cutterheads feature various edge configurations designed for different sediment types, including adapter edge, toothed edge, serrated edge, and plain edge designs. These edge configurations incorporate different blade or teeth shapes that are selected based on project-specific sediment characteristics. Cutterhead dredges have accurate bottom and side slope cutting capability but require an extensive array of support equipment, including boats (e.g., crew, work, and survey) and barges. Their operational limitations also include restricted mobility, long mobilization and/or demobilization times, inability to work in high wave action and currents, and impracticality for use in high traffic areas.

The selection of dredge type is based largely on transit distance, dredge availability, site conditions (e.g., wave and/or current action, vessel traffic), and cost. If the distance from the proposed borrow areas to the placement site is long and not conducive to piping dredged material directly from the borrow area to the placement site, and a cutterhead dredge is used, scows will be needed for dredged material transport. This is not the case with hopper dredges, which are self-propelled and can be used to transport sediment.

Dredged material can be used to enhance and create coastal wetlands, after the material has been tested for the presence of contaminants. The USACE New Orleans District dredges an average of 60 million m^3 (78 million yd^3) of material annually during maintenance dredging of federal navigation channels; approximately 38 percent of that is used for the beneficial use of the dredge materials program (USACE 2014). The USACE reported that, over a recent period of 20 years, approximately 12,545 ha (31,000 ac) of wetlands were created with dredged materials, most of which were 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. E.O. 11990 (42 FR 26961) 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. Because of the USACE's policy of beneficial use of dredged material, increased emphasis has been placed on the use of dredged material for marsh creation.

Regardless of the type of dredge, dredging can affect water quality. Bottom disturbance from dredging can suspend materials, increasing turbidity and causing negative impacts for coastal biota (e.g., altered predator-prey interactions, clogging of gills and/or reduced respiration, abrasions; see other resource sections for further detail). Dredging would result in increased turbidity and probable sedimentation within 200–600 m (656–1,969 ft) of a dredge site, with moderate impacts extending up to 3 km (1.9 mi) (Pickens et al. 2020). For TSHD, increased turbidity can occur from two primary sources: the draghead and the discharge of hopper overflow. For cutterhead dredges, turbidity is primarily generated only at the seafloor by the cutterhead (MMS 2004). The duration of increased total suspended solid concentrations could vary widely and would depend on sediment grain size and other components (e.g., organic detritus, debris content), among other factors (Pickens et al. 2020). Resuspension of sediments at the borrow area after dredging can also occur; in one case, sediment resuspension was documented for up to 1.5 years post-dredging (Pickens et al. 2020). Suspended material could also result in increased sedimentation in the area, potentially smothering immobile or low mobility benthos. The combined impacts of increased turbidity, physical removal, and burial from dredging activities could disturb and destroy seagrass beds (Kenworthy and Fonseca 1996; Erftemeijer and Lewis III 2006).

4.2.3.4 Geotechnical Surveys

Geotechnical surveys are performed in offshore and coastal waters to assess the sediment type and characteristics that will be encountered during various OCS activities (e.g., for pipeline and cable installation, sediment borrow for shoreline restoration). Geotechnical surveys use shallow-bottom coring and surface sediment sampling devices, such as cone penetration tests (CPTs), piston and/or gravity cores, vibracores, rotary borings, sediment profile imagers, and grab samplers. Disturbance of the seafloor during sampling can result in sediment resuspension, which can temporarily increase turbidity and decrease the amount of light needed for photosynthetic organisms. However, the footprint of geotechnical sampling devices is typically relatively small, on the scale of centimeters to meters. Additionally, geotechnical

sampling for these purposes is usually low in concentration (e.g., one sample/km [0.6 mi] of cable corridor).

4.2.4 Coastal Land Use and/or Modification

Although BOEM-regulated activities take place on the OCS, coastal habitats and associated biological communities are affected through construction and operation of infrastructure (e.g., ports, construction support facilities, pipelines, cables, processing facilities, etc.), as well as vessel traffic, that support BOEM-regulated activities. Coastal land disturbance through infrastructure installation can be long-term and can lead to permanent alteration of coastal habitats.

4.2.4.1 Onshore Infrastructure

Various types of onshore infrastructure (e.g., ports, pipelines, cables) support offshore activities (e.g., oil and gas) for OCS development, and their construction and operation could result in loss of coastal ecosystem structure (direct removal or fragmentation of coastal habitat) and function, as well as loss of recreational opportunities and value. State and federal permitting agencies discourage the placement and expansion of facilities in wetlands and require mitigation of impacts (e.g., CWA, USACE's 404 permit, and state permitting programs; see **Section 4.1.2** and **Table 4-3** for more detail). The high cost of wetland mitigation typically discourages industry from causing damage to wetlands when building onshore facilities. Additionally, the Gulf has a well-established industrial infrastructure network, and future expansion is expected to be limited. However, any large construction project in the coastal zone is still likely to impact some wetland acreage.

The direct effects of coastal habitat infilling and alteration from infrastructure construction and operation would typically be long-term and could affect biological communities, such as resident and migrant coastal bird species, that rely on these habitats for nesting and feeding. Vegetation and less mobile species within the footprint of the facilities would undergo mortality, and mobile species would likely be displaced to surrounding habitat.

Coastal land disturbance can also lead to indirect effects such as sedimentation via runoff and local hydrodynamic changes due to shoreline alteration (e.g., installation of berths, seawalls). Altered hydrodynamics may also lead to further shoreline erosion. Though sedimentation and habitat loss would likely be localized, coastal habitats, particularly in Louisiana, are already impacted by sea-level rise and land loss.

Vehicular traffic is associated with onshore support activities, especially in the vicinity of facilities. Increases in traffic associated with facility construction and operation (e.g., commuting employees, deliveries) can result from BOEM-regulated activities. Construction of new access roads can modify coastal areas and remove or diminish habitat. Hydrologic alteration, wildlife disturbance (e.g., light, noise), habitat fragmentation, habitat degradation (e.g., runoff, introduction of exotics), and habitat loss can result (Ko and Day 2004a). Collisions

among animals and vehicles or construction equipment could also occur and cause injury or mortality. Further, road construction could serve as an obstacle to movement and migration of coastal species. Depending on the location of newly established infrastructure, protected coastal areas (i.e., national and state parks and wildlife refuges, national estuaries) could be at risk of spillover effects. The EPA, which has less onshore infrastructure to support offshore energy, may be more susceptible to onshore infrastructure emplacement. As discussed in **Section 3.2**, coastal habitats along the Gulf are already impacted by, and responding to, impacts from sea-level rise and land loss. Mitigation measures and habitat restoration following construction (e.g., in support of section 404 of the CWA see **Section 4.1.2** and **Table 4-3** for more detail) could reduce impacts.

4.2.4.2 Vessel Traffic

A diverse suite of vessels is used in support of BOEM-regulated activities, including barges, support vessels, supply vessels, survey vessels, drill ships, pipelay vessels, etc. These vessels have a wide range in length, draft, and speed. According to BOEM's estimate, vessels conducting BOEM-regulated oil and gas activities on the OCS conservatively account for approximately 20 to 25 percent of all vessel traffic on the OCS. During port visits, and, while transiting to and from the OCS, vessels create wakes that can result in an increase in wave erosion and coastal habitat loss or degradation (Robb 2014). Further, coastal organisms and vegetation may be impacted by increased turbidity from vessels depending on the water depth and vessel drafts. Vessel traffic could be especially harmful to unprotected shorelines, potentially accelerating erosion in areas already affected by natural erosion processes. Vessel-induced saltwater intrusion may also occur and negatively impact habitat suitability in otherwise brackish or freshwater bodies. Due to habitat erosion, nesting and foraging coastal animals, including some ESA-listed bird and sea turtle species, may experience negative impacts from vessel traffic.

Vessel traffic associated with BOEM-regulated activities is expected to use established ports and transit onto and off the OCS through existing, maintained navigational channels and waterways. Port Fourchon, Louisiana is a major hub for activity, and BOEM estimates that approximately 40–45 percent of all vessel traffic conducting BOEM-regulated oil and gas activities use the Port. Port Fourchon is heavily armored and designed to accommodate deep-draft vessels, minimizing the potential for erosion. Ports that have navigation channels deep enough to accommodate deeper-draft vessels may expand their infrastructure, as well as deepen access channels, for larger vessel accommodation. However, northern Gulf port expansions appear to be related mostly to accommodating large container ships and/or bulk carriers (e.g., Neopanamax ships) and very large crude carriers that can now access the Gulf region through the expanded Panama Canal. These are not vessel types supporting BOEM-regulated activities.

4.2.4.3 Sediment Borrow Areas

The dredging of sediment (e.g., sand for beach nourishment projects) alters existing habitat within the project footprint, at least temporarily. Recovery of an OCS borrow area (e.g., infilling) after a dredging event is influenced by the dredge type, dredge plan, and storm activity. During dredging operations, spillage typically occurs and can form rows or piles, leaving the dredged surface uneven (Michel et al. 2013). Generally, cutterhead dredges leave a lower rugosity footprint compared to hopper dredges (Gartelman et al. 2024). After dredging, pit wall slopes decrease over time because of wall collapse and/or sediment deposition predominantly during high-energy events (e.g., hurricane wind and wave energy) (Pickens et al. 2020). Until the borrow area undergoes infilling and returns to its pre-construction bathymetric contours, a topographic depression will remain on the seafloor. As noted above, the source of the infill material can be the collapse of pit walls, resuspension of ambient seabed sediment, and/or settling of river plume sediment (Xu et al. 2022). The volume and type of sediment that replaces excavated sand from borrow sites varies by location, season, and storm events. Infill sediment would generally be expected to be consistent with sediments from adjacent ridges and swales deposits but could possibly fill in with finer sediments (e.g., fluvial source) (Xu et al. 2024). Water circulation inside the topographic low could be sluggish resulting in water column stratification and hypoxic conditions. Recovery of benthic communities to pre-dredge conditions is generally estimated to take 2.5 to >7 years (Pickens et al. 2020). Several early successional species, particularly those in the surrounding areas, may recolonize the disturbed site rather quickly, and full restoration of species composition would generally take longer (Zarillo et al. 2008; Pickens et al. 2020).

4.2.5 Offshore Habitat Modification and/or Space Use

Effects to coastal communities 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, see Coastal Land Use and/or Modification (**Section 4.2.4**).

4.2.6 Air Emissions and Pollution

The combustion of fossil fuels in support of BOEM-regulated activities (e.g., equipment, vessels) releases nitrogen, sulfur, carbon, and other compounds into the atmosphere. The degree of sensitivity of coastal habitats to any direct effects from air emissions would depend on the amount and type of emissions, as well as duration of exposure. Several existing regulatory programs and requirements reduce or minimize impacts from air emissions, such as NAAQS in coastal states, the MARPOL Annex VI and the Act to Prevent Pollution from Ships, and standards under Section 328 of the CAA (for more detail, see **Section 4.1.2** and **Table 4-3** for more detail). Additionally, offshore emissions are likely to disperse before reaching coastal habitats.

Deposition of pollutants or absorption of carbon dioxide can lead to acidification and reduced total alkalinity, potentially affecting the chemistry of coastal soils and surface waters. Ocean acidification refers to long-term decline in seawater pH resulting from increased atmospheric and water column carbon dioxide concentrations. Acidified waters may hinder growth of calcifying organisms, such as shellfish (e.g., oysters) and corals, but can also have a positive impact on vegetative community productivity (e.g., salt marsh, seagrass, mangrove). In addition to increased atmospheric carbon dioxide levels, coastal acidification is also influenced by other factors (e.g., changes in freshwater and nutrient input, land use), making the determination of potential impacts challenging. The Gulf's large influx of freshwater and nutrients (e.g., eutrophication, algal blooms), circulation patterns, and seasonality (i.e., temperature fluctuation) lead to carbonate chemistry variability (e.g., changes in buffering capacity) (Osborne et al. 2022). In addition to contributing to alteration of local pH, atmospheric deposition of sulfur and nitrogen oxides can also enhance nutrient loads to coastal ecosystems, causing eutrophication and possible algal blooms (Paerl 1997). Atmospheric nitrogen deposition may account for up to 40 percent of new nitrogen inputs in coastal systems (Paerl et al. 2002) which could be compounded by nutrient pollution (e.g., coastal runoff) (see **Section 4.2.2** Discharges and Wastes).

4.2.7 Lighting and Visual Impacts

Infrastructure and vessel lighting are a source of artificial light above the water surface that can also create a light field within the water column. Potential effects of artificial lighting include species attraction, species avoidance, and/or changes in diurnal migration patterns and predator-prey interactions (Russell 2005; Marangoni et al. 2022). Structure lighting (e.g., ports, channel markers) within an area would be long-term but localized, while vessel lighting would also be localized but intermittent and temporary within any one area. Artificial light sources on the Gulf coastline are prevalent, and it is unlikely that the consequences of lighting resulting from BOEM-regulated activities (e.g., port use, vessel transits) can be isolated from the background levels of light pollution along the industrialized coastline. Lighting of onshore structures is outside of BOEM's authority. Artificial lighting on the OCS (e.g., platforms) is generally too distant from coastal habitat to result in any significant effects to coastal biota (e.g., sea turtle hatchling disorientation). Therefore, the threat to coastal habitats posed by lighting and visual impacts from BOEM-regulated activities is considered low.

Additional information on the potential effects of artificial lighting is provided in **Section 4.5** for fish and invertebrates (e.g., predator-prey interactions), **Section 4.6** for sea turtles (e.g., disorientation of hatchlings), and **Section 4.8** for aerial fauna (e.g., mortality from allisions with structures).

4.2.8 Seawater Use and/or Uptake

Seawater uptake by vessels occurs in coastal areas during port visits and vessel transits onto and off the OCS in the form of cooling water and possibly ballast water uptake. Water uptake can also occur if hydrostatic test-water is sourced in coastal areas. Seawater uptake in coastal

areas would be intermittent, and any potential impacts would likely be localized. During uptake, plankton, including ichthyoplankton, can be impinged and entrained, resulting in mortality. For more information on impacts to fishes and invertebrates, see **Section 4.5.8** Seawater Use and/or Uptake [Fishes and Invertebrates].

4.2.9 Accidental Events

4.2.9.1 Accidental Releases

Both coastal and offshore oil spills (e.g., heavy and light crude oils, fuel oils) can result from large tropical storm events, faulty equipment (e.g., pipeline rupture), or human error (e.g., vessel collisions). Operators are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements, such as the National Contingency Plan (see **Section 4.1.2** and **Table 4-3**), which would be expected to limit impacts from an accidental spill. Additionally, OCS production facilities are located at least 3 nmi (5.6 km; 3.5 mi) from shore, and much of the OCS oil- and gas-related activity occurs farther out to sea. This distance may allow for oil spilled offshore to undergo weathering and biodegradation, which often reduces or eliminates its toxicity before it reaches the shore (OSAT-2 2011). Nonetheless, accidental spills are still a foreseeable risk to coastal communities, particularly spills from nearshore vessel accidents or pipeline ruptures. Pipeline ruptures could lead to high concentrations of oil directly contacting localized areas of habitat (e.g., wetlands, oysters) (Fischel et al. 1989). Catastrophic spills are generally not considered reasonably foreseeable events resulting from BOEM-regulated activities; however, an analysis of impacts from a low-probability, catastrophic spill can be found in BOEM's *Gulf Catastrophic Spill Event Analysis* (BOEM 2021).

Accidental releases into the environment could result in loss of coastal habitat function and structure, as well as loss of recreational opportunities and value. Depending on the location of a spill, protected areas (i.e., national and state parks and wildlife refuges, and national estuaries) could be at risk as well. Generally, impacts to coastal habitats from accidental spills depend on factors including spill type and composition, volume, and conditions, as well as affected habitat characteristics (e.g., permeability of substrate, wave energy, and tidal influence). To assess the risk posed to coastal habitats in the event of a nearby oil spill, NOAA created the Environmental Sensitivity Index (ESI). 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. According to the ESI, marshes, mangroves, and swamps are the most sensitive habitats, as oil tends to persist in these areas and is difficult to remove (MMS 2010; NOAA 2019). Vulnerability is generally highest for vegetated wetlands and semi-permeable substrates with low wave energy and high tidal currents (Hayes et al. 1992; NOAA 2017). Barrier island loss due to hurricanes and anthropogenic factors has reduced the protection of wetlands from offshore oil spills; this increases the likelihood that coastal wetlands could be impacted by offshore oil spills during an accidental event.

Effects of oil on plants can range from reduction in transpiration and carbon fixation to plant mortality. Oil spills can cause vegetation die-off, reduced above-ground cover (e.g., reduced

stem density, plant height, biomass), and reduced below ground biomass (Zengel et al. 2022b). Due to differences in oil tolerance among plant species, changes in species composition may be evident as a secondary impact of a spill (Pezeshki et al. 2000). Habitat degradation (i.e., loss of ecosystem function, physical structure, and/or value) caused by a spill could persist, leading to long-term residual impacts on species' populations and community structure. Depletion of coastal vegetation (e.g., marsh, mangroves) after a spill may also increase and accelerate erosion, resulting in land loss (Alexander and Webb Jr. 1987; Fischel et al. 1989; Silliman et al. 2012; McClenachan et al. 2013; Turner et al. 2016). Such erosion could increase coastal vulnerability to storms and sea-level rise, potentially impacting tourism, recreation, and environmental value.

Impacts of oil on coastal marsh habitat depend on the type, amount, and duration of oil exposure, as well as the specific plant species involved (Halanych et al. 2021). For example, Pezeshki et al. (2000) found that Louisiana crude oil was less damaging and fatal to *Spartina alterniflora* marsh grass than heavier crudes. Lin and Mendelssohn (1996) found that Louisiana crude oil applied to three species of marsh plants resulted in no regrowth after one year for *S. alterniflora* and *S. patens* but resulted in increased regrowth with increased oil application for *Sagittaria lancifolia*. After the *Deepwater Horizon* oil spill, black needlerush (*Juncus roemerianus*) was found to be more sensitive and less resilient to oiling than smooth cordgrass (*S. alterniflora*) (Zengel et al. 2022b).

The persistence of oil in marsh sediments is influenced by such factors as sediment type, condition of the soils, and the energy level of the environment (Teal and Howarth 1984; Teal et al. 1992; Baker et al. 1993; Burns et al. 1993; Irvine 2000). These factors result in varying levels of oil persistence across different shorelines (Hayes et al. 1980; Irvine 2000). Also, the specific characteristics of oil vary and can influence its persistence in the environment (Michel 1992; Lee et al. 2015). Oil is more persistent in oxygen-deprived sediments and can cause lasting damage to both vegetation and associated benthic species. Batubara et al. (2014) found that PAH degradation is higher in intertidal than in subtidal wetland soils.

Recovery of vegetation varies and depends on several factors. Studies show that lightly oiled vegetation experiences plant dieback but can recover without the need for replanting. Most impacts from light oiling are considered 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 (12,600-gal) spill of Louisiana crude oil impacted 20 ha (49 ac) of wetlands, resulting in considerable short-term effects to the brackish marsh community. Although there was considerable die-off, the marsh fully recovered within five years, despite residual hydrocarbons present within the marsh sediment. For larger spills, recovery may take a longer time.

If thick oil accumulates, effects on vegetation can be severe, with recovery taking years to more than a decade (Baca et al. 1987; Baker et al. 1993; Michel 2021a; Zengel et al. 2022b), and erosion (i.e., reduced soil shear strength) also influences the recovery rate (Zengel et al. 2022a; Zengel et al. 2022b). Kokaly et al. (2011) found that, where the predominant marsh grass (*Phragmites australis*) is tall and less susceptible to being completely oiled, damage is

minimized. A seven-year observation of southern Louisiana salt marshes after *Deepwater Horizon*, concluded that the impacts on salt marshes were multiyear, and that full recovery would likely exceed a decade, particularly in heavily oiled marshes. Reductions in below-ground biomass, another concerning result of large oil spills, were found to be more prolonged than the recovery of the above-ground vegetation, which suggests long-lasting impacts, limited recovery, and impaired resilience (National Academies of Sciences 2024). Zengel et al. (2022b) found that *S. alterniflora* experienced multiyear *Deepwater Horizon* oil spill impacts with a maximum of 88 percent mean reduction in cover for marsh edges that were heavily oiled. Recovery time for marsh plants was generally found to range between five to six years post-spill for marsh edges and three years post-spill for the marsh interior.

In addition to marsh habitat, mangroves are also highly vulnerable to oil spills (Hinwood et al. 1994; Duke et al. 1999; Australian Petroleum Production and Exploration Association 2003; Hensel et al. 2014). Oil spill impacts can include toxicity to tissues, physical smothering and elimination of gas exchange, defoliation, and/or leaf yellowing. Oiling can also result in sublethal effects, such as reduced growth for surviving trees, poor seedling establishment (Duke et al. 1997; Lewis et al. 2011; Hensel et al. 2014; Michel 2021b), deformities and/or morphological changes (e.g., pneumatophore branching) (Duke et al. 2005), reduced lenticel numbers (Böer 1993), and genetic mutations, such as variegated leaves and chlorophyll-deficient propagules (Duke and Watkinson 2002). Different species exhibit varying sensitivities to oil: those with stronger salt excretion strategies (e.g., *Avicennia*) are more susceptible. Like other intertidal communities, the abundance of burrows made by crabs and other fauna within mangrove habitat can potentially enhance retention of oil at depth; similar to marsh habitat, erosion may also occur due to the loss of root systems from dead trees and soil binding (Duke 2016). These effects could result in loss of ecosystem function and structure and loss of recreational opportunities and value. Because mangrove trees are long lived, recovery of mangroves forests from heavy oiling mortality can take decades, and sublethal impacts may be followed by recovery in 1 to 10 years (Duke 2016; Michel 2021a).

Although submerged, oil spills can also coat SAV during low tide events and/or coat subtidal SAV leaf blades that extend to or above the water surface. Direct impacts to SAV range from mortality to leaf exfoliation and sublethal stress. Though SAV below the waterline may avoid direct contact with spills, persistent oil sheens could cause decreased water clarity and shading, resulting in reduced chlorophyll production and a decrease in vegetation. Recovery from spills can take one to two years, and longer timeframes are possible if sediments are contaminated and roots and rhizomes are exposed to heavy oiling (Michel 2021b).

Beach and tidal flat sediments impacted by oil thicken as volatile components are degraded, forming tar balls or aggregations that incorporate sand, shell, and other materials. Oil penetration, burial, and persistence within beach and tidal flat sediments depend on the amount of oiling, chemical properties (e.g., viscosity), sediment grain size (e.g., permeability), and sediment dynamics (e.g., deposition rates). For example, open-water spills of diesel-like oils tend to spread quickly into thin slicks without enough oil to saturate beach sediments. Recovery of the impacted infaunal community can take months to several years depending on

the amount of oiling, sediment grain size, and persistence of oil residues in the sediments (Michel 2021a).

4.2.9.2 Release Response

Response activities in coastal habitats can include placing booms to prevent sheens from reaching shorelines; constructing barrier berms; flushing marshes with water; cutting, raking, and grappling vegetation; raking and scraping heavy oil deposits from soil surfaces; and placing loose sorbent materials. The response to a spill (e.g., equipment, chemicals) may result in secondary impacts to coastal habitat associated with the cleanup process, such as removing vegetation, trampling vegetation, accelerating erosion, and burying or mixing oil into the sediments (Long and Vandermeulen 1983; Mendelssohn et al. 1993; Zengel et al. 2015; Michel 2021a). Foot and vehicular traffic associated with response efforts may drive oil deeper into the sediment than would occur if left undisturbed. Coastal fauna can also be directly impacted by crushing and desiccation (e.g., sediment shifting) or indirectly impacted due to changes in habitat suitability, changes in prey resources, and reproduction disruption (e.g., nesting) (Michel et al. 2017). However, regulations that address spill response, such as the National Contingency Plan (see **Section 4.1.2** and **Table 4-3**), could minimize impacts by establishing standardized protocols.

Although booms would be deployed adjacent to shorelines, they could be lifted onto coastal habitat (e.g., marsh vegetation) by wave action resulting in disturbance to vegetation and habitat under the displaced booms. Also, booms and barrier berms can alter hydrology, affecting salinity and/or water clarity. These changes could cause mortality or reduced productivity for species of SAV tolerant to specific salinities and light levels (Zieman et al. 1984; Kenworthy and Fonseca 1996; Frazer et al. 2006).

Depending on the spill, cleanup activities can require extensive and prolonged use of mechanical treatments, potentially resulting in delayed recovery (e.g., vegetation) and accelerated erosion rate. For example, cleanup operations on beaches often involve manual, rather than mechanical removal methods, to minimize the amount of sediment removed and damage from vehicular traffic. However, when large amounts of oiled sediments need to be removed quickly, responders evaluate trade-offs among the use of manual compared to mechanical methods (e.g., backhoes, bulldozers). Close monitoring and restrictions on response activities, including the use of specific response equipment, may help avoid or minimize direct and indirect impacts.

For smaller spills, it can be prudent to allow coastal areas to recover naturally (Zengel et al. 2014; Michel 2021a). For example, some dominant freshwater marsh species (*S. lancifolia*) are tolerant to oil fouling and may recover without being cleaned (Lin and Mendelssohn 1996). This is especially effective in marshes where tidal flushing can naturally reduce oil concentrations (Kiesling et al. 1988). Studies after the *Deepwater Horizon* spill indicated a high degree of marsh plant resilience to oiling, especially if the oil did not penetrate into the sediment (Beyer et al.

2016). However, in areas of thick oil deposits, active cleanup efforts may facilitate greater recovery (Baker et al. 1993).

In-water response activities could result in direct impacts to SAV from propeller scarring, propeller wash, anchoring (e.g., vessels, booms), and vessel grounding. Physical damage to seagrass can take years to decades to recover. Secondary effects to SAV may also occur from increased turbidity from vessel activity or shading due to the presence of moored equipment (e.g., booms) and response vessels (Michel 2021a).

The use of dispersants offshore can prevent or minimize the potential of a surface slick reaching the shoreline, including sensitive coastal wetland and beach areas. Dispersants are typically used for larger offshore spills (Quigg et al. 2021a). During the *Deepwater Horizon* spill dispersants were used to help reduce or prevent coastline oiling (Dannreuther et al. 2021). Though dispersants can break up surface slicks, they also increase the bioavailability of oil in the water column, potentially increasing the exposure of aquatic organisms and habitats (Techtmann et al. 2023). Information on the impacts of dispersants (e.g., toxicity) comes primarily from laboratory experiments and controlled mesocosms, and in the field they are not used in the absence of oil. This makes it challenging to estimate the impacts of dispersants (e.g., toxicity, sublethal effects) at the community or ecosystem level (Halanych et al. 2021; Quigg et al. 2021a). Alternative dispersant technologies (e.g., chemical formulations) continue to be explored to reduce their potential impacts (Dannreuther et al. 2021; Quigg et al. 2021a).

In-situ burning of oil offshore can rapidly remove large quantities of oil from the sea surface which, like dispersants, can reduce the amount of oil reaching coastal habitat. However, in-situ burning may result in residue balls that can move inshore and contaminate benthic habitats and shorelines. Burning can also affect air quality for coastal plants (Michel and Rutherford 2013).

4.2.9.3 Marine Trash and Debris

The introduction of trash and debris from offshore and onshore facilities and vessels can pollute coastal areas. Marine debris from both ocean- and land-based (e.g., riverine output, runoff) sources can result in effects to coastal fauna (e.g., birds and fish) through ingestion and entanglement. The severity of the impact of both ingestion and entanglement varies according to the type of debris and species impacted (e.g., ability to regurgitate debris) (Gall and Thompson 2015; Egbeocha et al. 2018). Ingestion can result in intestinal blockage, internal abrasions and ulcers, starvation, and pollutant exposure. The accumulation of plastic debris on the seafloor can also inhibit gas exchange between sediment pore waters and overlying waters (Moore 2008). Plastics can break down further into microplastics, carrying pollutants and heavy metals into coastal environments and negatively impacting the survival and development of filter feeders (e.g., oysters) (Moore 2008; Kumar et al. 2021; Craig et al. 2022).

All vessels performing work within U.S. jurisdictional waters are expected to comply with federal regulations and MARPOL (see **Section 4.1.2** and **Table 4-3**). MARPOL establishes regulations to protect the marine environment from ship-generated garbage and provides

guidance on reducing marine debris. Because operators must comply with the federal regulations and would be expected to follow the guidance provided by BOEM and BSEE, marine debris resulting from BOEM-regulated activities is generally expected to be minimal and accidental.

4.2.9.4 Strikes and Collisions

Vessels conducting BOEM-regulated activities are anticipated to use existing ports and navigational waterways. Strikes to habitat within shallow, coastal environments are expected to be extremely rare. Should they occur, they may result in bottom disturbance to coastal habitats (e.g., scarring of seagrass beds), the impacts of which are discussed in **Section 4.2.3**. Were a ship to run aground in a coastal environment, an accidental spill may occur, resulting in potential effects discussed in **Sections 4.2.9.1** and **4.2.9.2**.

4.2.9.5 Entanglement and Entrapment

The presence of flexible lines (e.g., buoy lines used to mark pipelines, diver down lines) could create an entanglement risk to mobile species in coastal waters. Mitigation can prevent or reduce impacts (for more details, see **Sections 4.1.2** and **4.1.3** and **Table 4-3**). Entanglement and entrapment risk can be minimized with the use of in-water lines (e.g., rope, chain, and cable, including lines to secure turbidity curtains) that are stiff, taut, and non-looping. Further, the risk from flexible lines, if used, is minimized if they are enclosed in plastic or rubber sleeves and/or tubes that add rigidity and prevent the line from looping and tangling. The potential for entrapment can also be reduced if turbidity curtains and in-water equipment are placed in a manner that does not enclose individuals within construction areas (e.g., borrow area dredging) or block access for navigation.

4.3 PELAGIC HABITATS AND COMMUNITIES

4.3.1 Noise

Many marine species that comprise pelagic communities are sensitive to underwater sound. For a description of the potential impacts on pelagic fishes and invertebrates in their adult forms, see **Section 4.5** Fish and Invertebrates. For impacts on marine mammals and sea turtles, see **Section 4.6** (Sea Turtles) and **Section 4.7** (Marine Mammals). This section focuses on potential impacts to planktonic organisms, i.e., egg and larval stages.

Planktonic eggs and larvae may experience physiological effects when exposed to high-intensity, impulsive sounds like seismic airguns or pile driving. Some work has shown seismic airguns can irreversibly damage internal anatomy and physiology if eggs and larvae are close enough to the sound source (Govoni et al. 2003; Govoni et al. 2008; Aguilar de Soto et al. 2013), or such noises could cause them to swim out of harm's way (Dalen and Knutsen 1987). Most of the research with seismic airguns focused on relatively small spatial scales (i.e., tens of meters) and has shown minimal effects even at these distances (Kostyuchenko 1973; Holliday et al.

1987; Pearson et al. 1994; Booman et al. 1996; Saetre and Ona 1996; Govoni et al. 2008; Bolle et al. 2012). However, a study by (McCauley et al. 2017) that observed zooplankton after seismic airgun exposure demonstrated elevated mortality rates at much greater distances than previous studies had shown (>1,000 m [3,280 ft]). This discrepancy between previous work and recent work underscores the need for additional research. Nevertheless, rates of mortality are already very high for plankton, so it is unlikely that this additional mortality would have population-level impacts.

A handful of studies have directly investigated the effects of pile driving noise on eggs and larvae of marine fishes. Laboratory work by Bolle et al. (2012; 2014)–using a device similar to Halvorsen et al. (2012a)–showed that larvae of sole, seabass, and herring were relatively resilient to mortality even at high received levels (exceeding SELs of 206 dB re 1 uPa2s, which the authors surmise is equivalent to the received level at approximately 100 m from a 4 m [13 ft] diameter pile). Together, the tested larvae represent the entire range of swim bladder shape types described by (Popper et al. 2014). This work suggests that fish larvae–regardless of differing hearing anatomy–may be relatively resilient to pile driving noise, which is generally consistent with the early literature on seismic airguns (e.g., Kostyuchenko 1973; Holliday et al. 1987; Booman et al. 1996; Saetre and Ona 1996).

Research on invertebrate larvae is even more limited and has yielded mixed results. Two studies found little effect of exposure to seismic airguns on the embryonic or larval stages of spiny lobster (received SEL: 185 dB re 1 μPa^2s (Day et al. 2016b) or crab (received SPL: 231 dB re 1 µPa (Pearson et al. 1994). Though Aguilar de Soto et al. (2013) did show that scallop larvae exposed to playback sounds of seismic airguns showed body abnormalities and developmental delays, the larvae were held 5–10 cm (2–4 in) away from the speaker for 90 hours of playbacks, which does not represent real-world conditions of exposure to airgun noise. Results from (Gigot et al. 2024) indicate that when adult scallops (*Pecten maximus*) are exposed to pile driving sounds in the lab, for 10 weeks during gametogenesis, their larvae have an increased growth rate and faster metamorphosis compared to larvae from non-exposed parents. The exposed parents did have a lower gonadic volume than control adults, supporting that increased growth rates at the larvae stage may be an adaptive strategy to stress exposure (i.e., animals transition through the mobile, water column phase faster and may avoid predation). Solé et al. (2022) examined hatching and survival of cuttlefish eggs and larvae after exposure to 16 hours of pile driving sound in the same chamber as in Bolle et al. (2012). The larvae and eggs were exposed to maximum of 170 and 167 dB re 1 μPa^2, for the pile driving or drilling sounds, respectively, and assessed for hatching and larval survival, behavioral, and structural effects. Hatching success decreased and larval mortality increased with increasing received level. A reduction in hatching success from 72 percent to 9 percent occurred in the most severe pile driving treatment, and 71 percent to 13 percent for the most severe drilling treatment, relative to a silent control group. Similarly for larvae, survival rate decreased with increasing received level: from 100 percent to 10–19 percent in the loudest treatment for pile driving, and from 100 percent to 20–37 percent for drilling. The research suggests invertebrate larvae may be more sensitive to physiological effects than fish larvae, but impacts would be limited to areas very

close to pile driving, and effects are likely to be species-specific. Given naturally high rates of mortality in marine larvae, it is unlikely to have significant population-level effects.

Beyond physical effects, the planktonic larvae of fishes and invertebrates may experience behavioral impacts or acoustic masking from continuous sound sources like vessels, drilling, or dredging. Several studies have shown that larvae are sensitive to acoustic cues and may use these signals to navigate towards suitable settlement habitat (Simpson et al. 2005; Montgomery et al. 2006), stimulate metamorphosis into their juvenile forms (Stanley et al. 2012), or even to maintain group cohesion during their pelagic journey (Staaterman et al. 2014). However, considering the short range of such biologically relevant signals for particle motion-sensitive animals (Kaplan and Mooney 2016), the spatial scale at which these cues are relevant is rather small.

4.3.2 Discharges and Wastes

Pelagic habitats and communities, including *Sargassum*, are exposed to operational discharges and wastes as a result of routine OCS activities in the Gulf. Routine activities can include production activities (e.g., drilling mud and cuttings, produced water, produced sand, and well treatment, workover, and completion fluids), exploratory and development activities (e.g., drilling fluids, drill cuttings, various waters, such as bilge, ballast, fire, and cooling), and additional discharges (e.g., desalination unit discharges, blowout preventer fluids, excess cement slurry and several fluids used in subsea production). Routine discharges and wastes may also occur from onshore facility point sources, such as a pipe outfall or nonpoint sources like runoff from paved surfaces during rainfall. Vessel discharges are a minor but consistent discharge generated by offshore development. Bilge, ballast, and fire water can be legally discharged into the ocean, provided vessels adhere to the federal regulations and agency guidance (e.g., from USEPA, USCG). Elevated turbidity from routine discharges and wastes can reduce light availability for photosynthesis by phytoplankton and may 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). However, the impacts from this increased turbidity would be localized and short-term due to dilution, and so not likely to cause a population-level impact on pelagic communities or habitat degradation to the Gulf pelagic zone. For more information on the effects of discharges and wastes, see **Section 4.5.2** (Fish and Invertebrates), **Section 4.6.2** (Sea Turtles), **Section 4.7.2** (Marine Mammals), and **Section 4.8.2** (Birds).

Impacts on pelagic communities and habitat are not expected to negatively affect the function or use of Gulf pelagic habitats by marine biota, as all operational discharges and wastes are regulated. The USEPA and USCG regulate the release of produced water, drilling muds, and cuttings to ensure contaminants remain below harmful levels (for more detail, see **Section 4.1.2** Regulatory Compliance and **Table 4-3**). These discharges, 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 reach harmful concentrations and affect only small areas of water (Neff et al. 2005). Most mud cuttings settle quickly to the seafloor and only

near the drill site, with the are impacted depending on drilling depth and mud line cellar size. As a result, impacts on water quality are localized and temporary, making lasting effects on pelagic habitats and associated communities unlikely. Also, it is assumed that operators on the OCS will comply with BSEE regulations, BOEM guidance, and the USEPA (through the NPDES permits) and USCG regulations (see **Sections 4.1.2** and **4.1.3** and **Table 4-3** for more detail).

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 **Section 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, see **Section 4.4.5**.

4.3.4 Coastal Land Use and/or Modification

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, see **Section 4.2.4**.

4.3.5 Offshore Habitat Modification and/or Space Use

The placement of platforms for BOEM-regulated activities in Gulf pelagic habitats have long-term impacts because 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 seafloor 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). See **Sections 4.5.5** (fish and invertebrates)**, 4.6.5** (sea turtles), **4.7.5** (marine mammals), and **4.8.5** (birds) for more information on offshore habitat modification impacts on these animals.

Fish and invertebrates are also attracted to structural habitats. The large-scale introduction of platforms in the pelagic Gulf 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). Vertical structures and artificial reefs in the Gulf have enhanced local fish populations, contributing to both ecological diversity and potential economic benefits for local

fisheries (Hicks et al. 2025). These organisms are likely attracted to the light field, or the structure provided by the platforms in an otherwise barren underwater landscape (for more information on visual and lighting impacts see **Section 4.5.7** and for more information on offshore habitat modification and space use for fish and invertebrates see **Section 4.4.5**).

Drill spudding, offshore infrastructure emplacement, structure or pipeline removal, and OCS sand borrowing activities individually create short-term turbidity plumes. Cumulatively these effects can be present long term in pelagic habitats. Sand from the OCS borrowing activities would create less 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 (0–200 m; 0–656 ft). 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 et al. 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 these effects, see **Sections 4.5** (fish and invertebrates), **4.6** (sea turtles), **4.7** (marine mammals), and **4.8** (birds).

4.3.6 Air Emissions and Pollution

Air emissions from BOEM-regulated activity occur above the sea surface but could indirectly impact pelagic waters through the absorption of carbon dioxide or deposition of pollutants. Emissions resulting from routine OCS oil- and gas-related activities are not anticipated to reach a level that would affect Gulf pelagic habitat function or use by marine biota because these emissions are 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 light (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. Light emitting diode (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 because 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; Hays 2003; Cohen and Forward Jr. 2009); artificial lighting can disturb this activity (Moore et al. 2006; 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 (Hays 2003; Cohen and Forward Jr. 2009) is a major carbon cycle pathway in marine environments (Davies et al. 2014). Lighting can also impact larger pelagic organisms. For more information on these effects, see **Sections 4.5.8** (fish and invertebrates), **4.6.8** (sea turtles), **4.7.8** (marine mammals), **and 4.8.8** (birds).

4.3.8 Seawater Use and/or Uptake

Vessels uptake seawater in pelagic areas while transiting onto, within, and off the OCS. Water is commonly used for cooling or as ballast water. When a hydrostatic test is conducted in pelagic waters, plankton may be impinged and entrained during water uptake, potentially leading to mortality. However, the impacts of seawater uptake are generally temporary and localized. Because plankton have a naturally high mortality rate, they are expected to recover quickly from these short-term effects. Offshore oil and gas platforms typically use large intake pipes and pumps to draw seawater onto the platform for cooling systems and drilling operations. Seawater may also be injected into wells to improve oil recovery by stabilizing pressure difference between oil zones. As with vessel water uptake, plankton may be impinged and entrained during this process, but the impacts are expected to be temporary and not result in population-level effects.

4.3.9 Accidental Events

Several accidental events can occur on the Gulf 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, see **Sections 4.5.10** (fish and invertebrates), **4.6.10** (sea turtles), **4.7.10** (marine mammals)**,** and **4.8.10** (birds).

4.3.9.1 Accidental Releases

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). The Gulf is dynamic in nature with interactions from the Loop Current, Mississippi River plume, fronts, and eddies, that act to retain and aggregate surface oil, particles, and zooplankton, which can ultimately increase the opportunities for oil exposure in the event of a spill. After the *Deepwater Horizon* oil spill in 2010, Sutton et al. (2022) identified phytoplankton and mesozooplankton as having high vulnerability to toxins released during the spill, but an equally high resilience. Mesozooplankton in the Gulf after the *Deepwater Horizon* spill have been observed showing little to no difference in assemblages pre- and post- spill (Patterson III et al. 2023). Patterson III et al. (2023) attributed this resilience to their high environmental variability and patchy distribution of oil across the northern Gulf. Sutton et al. (2022) mentions that some zooplankton, like dinoflagellates, copepods, and doliolids, have been observed ingesting oil droplets and excreting them in fecal pellets, that could be re-ingested by other particle feeders further increasing the impacts of an oil spill through bioaccumulation in upper-trophic levels animals and marine snow on the seafloor. The ingestion of oil components was found to persist throughout large chain diatom blooms during the summer of 2010, which could have indirect impacts on fish and invertebrates, marine mammals, sea turtles, and birds (Quigg et al. 2021b; Sutton et al. 2022). The *Deepwater Horizon* spill caused significant degradation of pelagic habitats in the Gulf, resulting in changes to water quality due to elevated PAHs (Marques et al. 2023). The pelagic habitat is vulnerable to oil spills, particularly due to the significant presence of plankton (Marques et al. 2023). Exposure to oil components has been shown to be toxic to phytoplankton, leading to reduced photosynthesis, growth rates, and reproductive success (Maurya and Gupta 2024). This toxicity can result in shifts in community composition, often favoring more resilient species. Maurya and Gupta (2024) also identified changes in phytoplankton abundance to negatively affect zooplankton populations. The decreased reproductive rates of phytoplankton may lead to increased mortality in zooplankton because of a lack in their primary food source. Both disruptions to these plankton populations may cascade through the marine food web and lead to reduced food availability for higher trophic levels. The recovery of plankton communities varies depending on factors including spill magnitude, environmental conditions, and the resilience of the specific species impacted (Maurya and Gupta 2024). Catastrophic spills are generally not considered as reasonably foreseeable events, but what is learned about the resulting impacts on marine biota improves the body of knowledge of impacts of oil in the marine environment. More information about very large, catastrophic events like the *Deepwater Horizon* oil spill and the impacts of an event this size can be found in BOEM's *Gulf of Mexico Catastrophic Spill Event Analysis* (BOEM 2021).

Spilled oil on the surface is highly likely to interact with *Sargassum* due to both substance's tendency to float, presence at the surface, and accumulation in convergence zones. *Sargassum* and oil share similar factors that influence their aggregation, such as location and timing, making it probable that recoverable oil will also contain *Sargassum* (Zengel et al. 2024). On-water response activities like aerial dispersant application, in-situ burning, and mechanical recovery can also impact *Sargassum* and associated species. Sea turtles, other wildlife, and an abundance of fish are likely to be present in *Sargassum*, resulting in injury and a high possibility

of mortality for these associated species during the accidental release of oil. For more information on these effects, see **Sections 4.5.10.1** (fish and invertebrates), **4.6.10.1** (sea turtles), **4.7.10.1** (marine mammals), and **4.8.10.1** (birds).

4.3.9.2 Release 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 of oiled *Sargassum* can result in mortality to the *Sargassum* and associated species. This response to accidental releases may result in overall oil reduction impacts because of the speed of which surface oil is removed, yet burning could pose a severe threat to pelagic biota in the activity area (Zengel et al. 2024). Mechanical removal, such as skimming or booming, is most commonly used compared to other on-water response methods. Skimming could remove pelagic biota from the activity area or trap them in oiled water (BOEM 2011). Zengel et al. (2024) identifies challenges associated with mechanical removal processes, such as the clogging or overwhelming of equipment parts due to the high volume and water content oiled *Sargassum* takes up. Mechanical removal processes have a high potential of trapping and killing, or injuring smaller, slower animals that are unable to avoid this process (i.e., juvenile sea turtles). These cleanup processes could also trap and destroy patches of *Sargassum*; however, these patches would likely already be 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. Though dispersants can break up surface slicks, they also increase the bioavailability of oil in the water column, potentially increasing the exposure of aquatic organisms such as plankton (Techtmann et al. 2023). Chemicals used during an oil-spill response are toxic, though less toxic than spilled oil (National Research Council 2005b; Hemmer et al. 2011), and their toxicity varies by dispersant type as well as varying levels of toxicity among species (CDC 2010; Fingas 2017). (Powers et al. 2013) identified that chemical dispersants increase the water column's oil exposure for *Sargassum*, ultimately causing it to sink more rapidly. (Zengel et al. 2024) call for the consideration of *Sargassum* in oil spill response when accidental releases occur and state that the use of chemical dispersants may be beneficial to *Sargassum* and its associated species by reducing the amount of oil exposure. When not applied directly on or near *Sargassum*, effects of dispersant would likely be limited to a few hours post application. The use of dispersants may increase the bioavailability of petroleum hydrocarbons to *Sargassum* and other organisms. Studies are mixed as to whether chemically dispersed oil is more toxic than mechanically dispersed oil (National Research Council 2005b; Kolak 2011; Fingas 2017). After *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 (National Research Council 2005b), 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 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, see **Sections 4.5.10.2** (fish), **4.6.10.2** (sea turtles), **4.7.10.2** (marine mammals), and **4.8.10** (birds).

4.3.9.3 Marine Trash and Debris

MARPOL and other regulations regulate marine trash and debris (for more detail, see **Sections 4.1.2** and **4.1.3** and **Table 4-3**). 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*. Lestrade and Hernandez (2023) collected *Sargassum* in the northern Gulf to quantify microdebris concentration and assess the extent to which juvenile fish associated with *Sargassum* ingest microdebris. This study found that *Sargassum* accumulated microdebris concentrations 180 times higher than those found in open water habitats, concluding that microdebris concentrations increased with *Sargassum* biomass (Lestrade and Hernandez 2023). Due to its complex structure, *Sargassum* provides habitat and refuge for juvenile fishes and acts as an accumulator, capturing and concentrating microdebris in surface waters. This overlap may have little impact on the plants themselves but can impact the associated organisms. Because of the lack of stationary Gulf 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.

4.3.9.4 Strikes and Collisions

Vessel strikes could occur with *Sargassum* mats and associated communities. *Sargassum* would encounter either 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 occur only if the strike happened while the vessel was traveling at high speeds. It is expected that if individual plants are broken into moderately sized pieces, 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.

4.3.9.5 Entanglement and Entrapment

The presence of flexible lines in the water column (e.g., buoy lines used to mark pipelines, diver down lines) may create an entanglement risk to mobile species, such as marine mammals and sea turtles, in pelagic waters. Entanglement and entrapment risk can be minimized with the use of stiff in-water lines such as rope, chain, and cable. The risk from flexible lines can be further minimized by enclosing the lines with plastic or rubber sleeve and/or tubes to add rigidity and prevent tangling (for more details, see **Sections 4.1.2** and **4.1.3** and **Table 4-3**). For more

information on entanglement and entrapment to species that occur in pelagic waters see **Section 4.5.9** (fish), **Section 4.6.9** (sea turtles), and **Section 4.7.9** (marine mammals).

4.4 Benthic Habitats and Communities

4.4.1 Noise

Many of the marine species that make up the benthic epifauna and infauna communities are likely to be sensitive to underwater sound. For a description of hearing capabilities and an overview of potential impacts, see **Section 4.5** (Fishes and Invertebrates). In particular, sources that are coupled with seabed (e.g., pile driving, drilling, dredging) or directed towards the seabed (e.g., seismic surveys) can also excite substrate and introduce substrate-borne vibrations. Because the seafloor is not strictly a fluid medium, it also supports the propagation of shear waves, in addition to compressional waves in the water column. In addition, a recent study has also confirmed that Scholte waves are introduced from impact pile driving activities (Giordano et al. 2025); this is an interface wave between the water column and seafloor that is expected to propagate to greater distances. As with exposure to water-borne noise, exposure to substrate-borne vibration can cause various adverse effects on benthic organisms ranging from behavioral disturbance, physiological stress, to communication masking (Hawkins et al. 2021; Roberts et al. 2022). However, more research is needed to understand the extent and degree of such impacts.

4.4.2 Discharges and Wastes

Discharges from oil and gas industry activities are managed through federal law and regulation, such as the NPDES permitting process and MARPOL Annex V Treaty. Vessel discharges can also be legally discharged into the ocean, provided they comply with federal regulations and agency guidance (e.g., the 2013 Vessel General Permit requirements and the newly developing national standards under VIDA). Enforcement of the relevant laws and regulations is conducted by several federal agencies, including the USEPA, BSEE, and USCG (for more information on regulatory compliance, see **Section 4.1.2** and **Table 4-3**). For the purpose of this analysis, compliance with these laws and regulations is assumed, as described in **Section 4.1.2** (Regulatory Compliance).

4.4.2.1 Drilling Discharges

Drilling operations have the capacity to deposit up to 2,000 metric tons (4.4 million lbs) of combined muds and cuttings and drilling fluid onto the seafloor (Neff et al. 2005). Any releases to the OCS from oil and gas operations must meet the conditions of the EPA's NPDES permit for that region (see **Section 4.1.2** and **Table 4-3**, for more detail). The spatial footprint of discharge varies with discharge volume, water depth, local hydrography, sediment particle size distribution, settlement rate, floc formation, and time (Neff et al. 2005; Niu et al. 2009). Cuttings discharged at the sea surface tend to disperse in the water column and be distributed at low concentrations (Continental Shelf Associates Inc. 2004a). In deep water, most cuttings

discharged at the sea surface are likely to be deposited within 250 m (820 ft) of the well (Continental Shelf Associates Inc. 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 et al. 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' abilities 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). BOEM stipulations and mitigations, which distance bottom-disturbing activities from sensitive benthic communities, can reduce potential injury to sensitive benthic communities (for more detail, see **Sections 4.1.2** and **4.1.3** and **Table 4-3**).

The chemical content of drilling muds and cuttings, and to a lesser extent produced waters, may contain hydrocarbons, trace metals including heavy metals, elemental sulfur, 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 (Continental Shelf Associates Inc. 2004b). 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 (Hart et al. 1989; Chapman et al. 1991; Carr et al. 1996; Kennicutt II et al. 1996; Montagna and Harper Jr. 1996; Continental Shelf Associates Inc. 2004b). See **Section 4.5.2** and also Sections 2.2, 4.2.2, and 5.11 of the SID (BOEM 2023) for a discussion of what may and may not be discharged and the conditions that must be met for USEPA Regions 4 and 6.

Produced waters dilute rapidly with distance from the source; impacts are generally only observed very close to the source (Gittings et al. 1992; Neff et al. 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 Freiwald et al. 2004).

4.4.2.2 Dredge Spoil

Typically, dredge spoil materials are disposed of at established dredge material disposal areas permitted by the USACE, 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 (Desprez 2000). Benthic communities associated with unconsolidated soft sediments will recover more quickly than those associated with hard bottom habitat (Rogers and Garrison 2001; Dernie et al. 2003; Brooks et al. 2006; Wilber and Clarke 2007; Tamsett et al. 2010). Soft-bottom habitats are inherently dynamic due to the mobility of their substrate (i.e., sands, silts, muds and clays). Recovery of soft-bottom habitat is facilitated largely by the recolonization of mobile organisms within the community (see **Sections 3.4.1.2** and **3.4.2.1** for more details on soft-bottom communities) and the physical process of sediment resettlement and redistribution (Desprez 2000; de Marignac et al. 2009). Soft-bottom habitats are continuously influenced by natural phenomena, such as storms, wave action, and tidal currents. The physical dynamics of waves and currents can promote the recovery of soft-bottom communities by gradually restoring the structure and composition of the sediment (Desprez 2000; de Marignac et al. 2009). 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) (Ulfsnes et al. 2013; Cordes et al. 2016). 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), 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 Morgan et al. 2006).

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, but 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 on filter feeders following 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). BOEM stipulations and mitigations, which distance bottom-disturbing activities from sensitive benthic communities, can reduce potential injury to sensitive benthic communities for more detail, see **Section 4.1.2** and **4.1.3** and **Table 4-3** for more detail).

4.4.4 Coastal Land Use and/or Modification

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, are discussed in **Section 4.2.4**.

4.4.5 Offshore Habitat Modification and/or Space Use

4.4.5.1 Sediment Borrow Areas

Sand shoals represent significant sources of sand on the OCS for potential coastal beach nourishment and coastal stabilization projects. Dubois et al. (2009) predict that sand extraction from significant sand shoals (e.g., Ship Shoal) in the northern Gulf 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. BOEM is currently funding a study on the ecological function of Ship Shoal biological communities subject to sand dredging. Six years post-dredging, the Caminada Dredge Pit has lower biological diversity and evenness than the reference

community. The differences are likely due to the accumulation of mud in the dredged pit (Johnson et al. 2025). Sediment dredging also results in direct bottom disturbance and sediment suspension (see **Section 4.4.3 and 4.4.4**).

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. 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 that species. Evidence of these types of changes has been documented for some shallow-water hermatypic species (Sammarco et al. 2012), but parallel research in deep water is lacking.

At the end of their use-life, operators are legally required to remove platforms. A typical four-leg platform jacket for oil and gas operations 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 well-known vector for the movement of nonnative and invasive species (Bax et al. 2003; Simons et al. 2016). In the Gulf, 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). Orange cup coral 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 and prefers artificial to natural substrates; at this time, it does not appear to threaten natural coral communities (Kolian et al. 2017).

4.4.6 Air Emissions and Pollution

Benthic habitats on the OCS are not expected to be vulnerable to air emissions from BOEM-permitted activities 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), but direct effects to benthic organisms in the Gulf 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 Seawater Use and/or Uptake

For an analysis of the potential effects of seawater use and/or uptake to the larvae of benthic invertebrates, see **Section 4.5.8**.

4.4.9 Accidental Events

4.4.9.1 Accidental Releases

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. Operators are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements, such as the National Contingency Plans (40 CFR 300), which provide effective control and containment, and would be expected to limit the volume and area of exposure (**Section 4.1.2** and **Table 4-3**).

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 parts per million (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 Gulf 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). Were this plume 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 oil composition (characteristics of the initial oil and its chemical characteristics as it weathers) location of the oil, and the hydrographic characteristics of the area (Bright et al. 1978; McGrail 1982; Rezak et al. 1983; Le Hénaff 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 (Cook and Knap 1983; Dodge et al. 1984; Wyers et al. 1986; 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 deep-sea gorgonian, 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 (partitioning through sorption process and physical entrapment during flocculation) 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 oil particles associated with solid 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).

4.4.9.2 Release Response

Benthic organisms are also vulnerable to spill cleanup and/or response activities. Though oil spill dispersants can break up surface slicks, they also increase the bioavailability of oil in the water column, potentially increasing the exposure of aquatic organisms such as corals and other benthic species (Techtmann et al. 2023). The potential impacts of chemical dispersants and dispersant-treated oil are discussed in the previous section.

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. Spill response activities are subject to regulations and mitigating measures that reduce potential injury to benthic habitat and communities such as the National Contingency Plans (40 CFR 300; see **Section 4.1.2** and **Table 4-3**).

4.4.9.3 Marine Trash and Debris

Trash and debris from BOEM-regulated activities are subject to regulations that prohibit intentional discharge into the marine environment (see **Sections 4.1.2** and **4.1.3** and **Table 4-3** for more detail). However, accidental loss of equipment or materials can still occur despite these requirements, typically during transfers between vessels and platforms, vessel transit, severe storms, or operational mishaps such as misplacement of anchors or structures. When such incidents occur, hardbottom habitats may be affected in ways similar to how they are affected by bottom disturbance (**Section 4.4.3**), including crushing, breaking, compaction, or smothering of benthic communities.

4.4.9.4 Strikes and 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 vessel strikes are expected to be infrequent and highly localized. For an analysis of vulnerabilities to coastal and estuarine benthic habitats and organisms from accidental vessel collisions and strikes, see **Section 4.2.8**.

4.4.9.5 Entanglement and Entrapment

Benthic habitats on the OCS are not expected to be vulnerable to entanglement and entrapment. If streamers or lines in the water were to impact the seafloor, it would result in bottom disturbance. For an analysis of the vulnerability of benthic habitats to bottom disturbance, see **Section 4.4.3**.

4.5 FISHES AND INVERTEBRATES

4.5.1 Noise

4.5.1.1 Seismic Surveys (Airguns)

If very close to an impulsive sound source (e.g., seismic airgun), a fish could experience barotrauma or TTS. McCauley et al. (2003) found damage to hearing structures in fish held in cages while an airgun passed overhead (5–800 m; 16–2,625 ft distance from the cages), although they did not measure hearing thresholds. In Popper et al. (2005), two species with hearing specializations experienced TTS when held 13–17 m (43–26 ft) from an airgun, but they recovered within 18 hours, and the species with least-sensitive hearing showed no evidence of TTS. Several additional studies in subsequent years (Hastings et al. 2008; McCauley et al. 2008; McCauley and Kent 2012) found mixed results depending on the species, proximity to the airgun, and received levels. Taken together, this body of work has shown that TTS and damage to hearing structures is possible from high-intensity sources. However, these types of effects are generally observed in animals very close to the source (<10 m; 33 ft). Species without gas-filled cavities are less likely to sustain effects, and even those can recover within several days of exposure. There is potential for secondary effects. For example, after exposure, a fish with decreased fitness (due to decreased hearing sensitivity) may be more vulnerable to predation, less likely to find a mate, or unable to find food while their hearing is recovering. High-intensity sources may also cause stress responses, including increased cortisol and oxidative stress, which have been demonstrated in freshwater species exposed to airgun noise (Réalis-Doyelle et al. 2025).

Studies that have examined potential behavioral impacts to fishes have generally found that most species exhibit subtle, short-term changes when exposed to seismic airguns (Slabbekoorn et al. 2019). The research has covered a range of species, each with different hearing capabilities, and has employed a variety of methods. For example, some studies have used echosounders to observe potential changes in schooling behaviors of wild fish in the vicinity of impulsive sound sources (e.g., Dalen and Knutsen 1987; Jorgenson and Gyselman 2009; Peña et al. 2013; Hawkins et al. 2014; Réalis-Doyelle et al. 2025). In some cases, fish swim lower in the water column and schooling behaviors are disrupted, but only temporarily (Slotte et al. 2004; Hawkins et al. 2014). Other work has held animals in cages or used video cameras to observe potential startle responses or changes in heart rate (Wardle et al. 2001; McCauley et al. 2003; Hassel et al. 2004; Boeger et al. 2006; Thomsen 2008), which also tend to be temporary.

The most revealing studies have tagged or counted wild fish and observed their behavior in response to real airgun arrays. For example, van der Knaap et al. (2021) examined the response of free-ranging, tagged Atlantic cod during multiple passes of a full-scale (2,950 in^3) seismic survey and found subtle changes in behavior, with no evidence that cod left the area during the survey. In 2022, McQueen et al. (2022) found similar results with spawning Atlantic cod when exposed to seismic airgun noise over two 1-week periods, with received SELs up to 145 dB re 1 μPa^2s, which was comparable to a full-scale industrial survey 5–40 km (3–25 mi) away. By comparing the residency and departure rates of tagged cod at both control and test sites over three years, the authors concluded that free-ranging cod were not displaced from spawning grounds and speculated that strong affinity to selected spawning sites overcame any behavioral effects of noise exposure. Finally, in the most comprehensive study to date, Meekan et al. (2021) used a Before-After-Control-Impact design to examine the movements and behavior of fish assemblages (via both tagging and video surveys) during seismic surveys (2,600 in^3 arrays). All of the fishes sampled had swim bladders, but it was not known whether they were all hearing specialists. The team found no overall change in fish assemblages from the underwater videos, no significant changes in fish behavior (e.g., time to approach bait on the video), and no significant change in the movements of red snapper between the high exposure and control areas; most fish stayed within 150 m^2 (1,615 ft^2) of the place where they were first detected. Because the team collected data several months prior to and after exposure to seismic airguns, used a full-scale seismic array, and had a high sample size, the results of this study do provide helpful insights into the overall effects of seismic airguns on fish behavior.

The studies described above cover a range of methods and have focused on different species, each with their own hearing capabilities. Yet a common trend that emerges is that fish often show an initial response (either a startle response or a change in schooling behavior), but this response decreases with repeated exposure or ramp-up of the sound source. There is not compelling evidence suggesting that fishes abandon their habitat, cease feeding, or show a prolonged disruption in normal diel patterns when a seismic survey passes nearby.

Studies on the effects of seismic surveys on marine invertebrates have yielded mixed results; several reviews point out that the varying experimental conditions make it difficult to draw meaningful conclusions across such a wide taxonomic group (Morley et al. 2014; Edmonds et al. 2016; Carroll et al. 2017). Several studies have examined impacts of high-intensity sounds on benthic invertebrates. Day et al. (2017) found that airgun exposure changed blood chemistry and altered normal behaviors in burrowing scallops within several hundred meters of the source. Although no mass mortality occurred, rock lobsters exposed to seismic airguns also exhibited reflex impairment and changes in blood chemistry (Day et al. 2016a). Follow-up work by Day et al. (2019; 2022) showed that rock lobsters had impaired righting reflexes and significant damage to sensory hairs of the statocyst, and these effects persisted up to 365 days post-exposure and did not improve following molting. These results indicate that exposure to airgun signals at close ranges caused morphological damage to the statocyst of juvenile and adult rock lobsters, which can, in turn, impair complex reflexes (Day et al. 2019; 2022). In contrast, Christian et al. (2003) observed no significant impacts on the behavior or health of

adult snow crabs that were exposed to seismic airguns. Payne et al. (2007) also showed no obvious mortality or physiological changes in American lobster exposed to airguns, but sublethal effects to blood biochemistry were observed. Alarm and startle responses have been observed in squid (Fewtrell and McCauley 2012) and cuttlefish (Samson et al. 2014). As a result of these mixed results, there is not a clear consensus within the scientific community about the scale and nature of acoustic impacts from seismic surveys on marine invertebrates.

4.5.1.2 High-Resolution Geophysical Surveys

Only a handful of high-resolution geophysical sources (e.g., boomers, sparkers, bubble guns, and some sub-bottom profilers [SBPs]) emit sounds at frequencies that are within the hearing range of most fishes and invertebrates (see **Appendix B** for more detail on these sources). This means that side-scan sonars, multibeam echosounders, and some SBPs would not be audible to, and thus would not affect, those taxa. For the sources that are audible, it is important to consider other factors such as source level, beamwidth, and duty cycle (Ruppel et al. 2022). Boomers, sparkers, hull-mounted SBPs, and bubble guns have source levels close to the threshold for injury for pressure-sensitive fishes, so unless a fish would be within a few meters of the source, injury would be highly unlikely (Popper et al. 2014; Crocker and Fratantonio 2016). Behavioral impacts could occur over slightly larger spatial scales. For example, if one assumes an SPL threshold of 150 dB re 1 µPa for behavioral disturbance (Greater Atlantic Regional Fisheries Office 2020), sounds with source levels of 190 dB re µPa·m would fall below this threshold several hundred meters from the source (assuming 15*log(range) propagation loss). This means that the lowest-powered sparkers, boomers, and bubble guns would not result in behavioral disturbance beyond this distance, and this range would be even smaller for quieter sources like towed SBPs (Crocker and Fratantonio 2016). It should be noted that these numbers are reported in terms of acoustic pressure because there are currently no behavioral disturbance thresholds for particle motion. It is expected that behavioral impact ranges would be even smaller for particle motion-sensitive species, including invertebrates. Because most high-resolution geophysical sources are typically “on” for short periods with silence in between, only a few “pings” emitted from an active acoustic source towed from a moving vessel would reach fish or invertebrates below, so behavioral effects would be intermittent and temporary.

4.5.1.3 Geotechnical Surveys

Considering the relatively low source levels from geotechnical surveys (see **Appendix B**), they are unlikely to have impacts on fishes or invertebrates. Animals would have to be very close to geotechnical equipment to even experience behavioral disturbance, based on the current SPL threshold of 150 dB re 1 µPa for behavioral disturbance (Greater Atlantic Regional Fisheries Office 2020).

4.5.1.4 Dredging

Mechanical and/or hydraulic dredging may be required to prepare areas for construction, to widen or deepen ports, or to collect offshore sediments for shoreline restoration activities. Because of the physical qualities of dredging noise (see **Appendix B**), injury and auditory impairment are unlikely, but fishes and invertebrates could experience behavioral disturbance or masking close to these activities. Impacts are likely to be similar but less intense than those observed from vessel noise, although these activities are not as widespread or frequent as vessel transits.

4.5.1.5 Drilling and Production

Very few studies have explicitly examined the effects of drilling noise on fishes. Spiga et al. (2017) conducted playback experiments of European seabass in tanks, and their responses to a mock predator after exposure to drilling noise were observed. Control fish became immobile when the predator was present, and fish exposed to drilling noise spent more time sheltering in the safety zone. Opercular beat rate (OBR) which generally tracks with metabolic rate, was elevated during playbacks of drilling noise compared to control periods (Spiga et al. 2017). Kusku et al. (2020) examined OBR on a regular basis over a four-month period with Nile tilapia that were kept in tanks and exposed to either drilling or pile driving noise on a daily basis. Similar to Spiga et al. (2017), they found that OBR was elevated in the presence of both sound types. They also found reduced growth rates in noise-exposed fish for the first four weeks, but growth rates eventually "caught up" to those of control fish. These studies suggest that chronic exposure to drilling noise could affect metabolic rates in fishes.

4.5.1.6 Vessels and Dynamic Positioning Systems

Several types of vessels are used to support BOEM activities in the Gulf. For a description of the potential impacts of vessel noise (low-level, continuous noise) on fish, see **Sections 3.5.5** and **3.5.6**. Only one study has explicitly examined the impacts of vessel DP noise on fish (Peña et al. 2013); it found reactions similar to other vessel noise (e.g., some changes in schooling behavior and vertical displacement). Received levels were not measured in this study, so it is difficult to predict the distance at which such reactions may occur, but generally speaking, effects are expected to occur over a relatively small area, especially for particle motion-sensitive species. Some species may become habituated to persistent vessel noise.

4.5.1.7 Trenching and Pipeline Laying

Because of the physical qualities of noise associated with trenching and pipeline laying (see **Appendix B**), impacts to fishes and invertebrates are expected to be relatively minor, occurring over small spatial scales around the activity.

4.5.1.8 Pile Driving

The installation of the relatively small pin piles typically used for oil and gas structures in the Gulf are unlikely to cause injury or mortality to fish and invertebrates, because noise levels are relatively low. However, there is now a suite of literature looking at effects of larger monopile installation and impacts to fishes. Most of the literature cited below consequently refers to potential impacts from driving larger piles.

Much of the literature on behavioral and physiological effects of pile driving noise on fish has focused on commercially important species like the European seabass, which lacks hearing specializations and has a closed swim bladder. Adult seabass generally dive deeper and increase swimming speed and group cohesion when exposed to intermittent and impulsive sounds like pile driving (Neo et al. 2014; 2018), but juveniles become less cohesive (Herbert-Read et al. 2017) and generally seem to be more sensitive to pile driving noise than adults (Kastelein et al. 2017). There is also some evidence that respiration rates may be affected by pile driving noise (Spiga et al. 2017). Importantly, a number of studies have shown that European seabass are likely to habituate to pile driving sounds over repeated exposure (Bruintjes et al. 2016; Neo et al. 2016; Radford et al. 2016). This is consistent with the findings from Stanley et al. (2023) and Jarriel et al. (2025) , who found that black seabass generally show short-term behavioral reactions, with no lasting impacts on spawning behavior. Field studies on other species indicate that fish may be startled, temporarily displaced, or change their schooling behaviors during exposure to pile driving or other impulsive sources, but that when the sound is over, they are likely to resume normal behaviors relatively quickly (Hawkins et al. 2014; Iafrate et al. 2016; Krebs et al. 2016). Overall, the research thus far indicates that fishes may exhibit short-term behavioral or physiological responses to impulsive sounds like impact pile driving. Species with more sensitive hearing would be more susceptible to TTS and behavioral disturbance–and at greater distances–than those with less sensitive hearing. These impacts are only likely for larger pile driving operations rather than the smaller piles required for oil and gas infrastructure.

Sessile marine invertebrates like bivalves are sensitive to substrate-borne vibrations and may be affected by noise from driving large piles (Roberts et al. 2015; Spiga et al. 2016; Day et al. 2017). Jézéquel et al. (2022) observed behavior of scallops in response to a real pile driving event at distances of 8 and 50 m (26–164 ft) from the pile (pile diameter 0.3 m; 1 ft). None of the scallops exhibited swimming behavior, an energetically expensive escape response. At the close site only, scallops increased valve closures during pile driving noise but returned to their pre-exposure behaviors within 15 minutes. A follow-up study revealed that reduced valve opening and rapid valve adduction resulted in a decrease in oxygen levels and an increase in metabolic rates, respectively, over baseline conditions (Cones et al. 2024). In addition, they found that exposure to pile driving resulted in a weakened anti-predatory response, including fewer swimming events and a shorter time to exhaustion in comparison to unexposed scallops. Increased time spent with closed valves could reduce feeding opportunities and thus have energetic consequences, though the biological consequences of this effect have not been studied.

The potential impacts of impulsive noise on marine crustaceans are difficult to predict because of the mixed results from studies on seismic airguns (see **Section 4.5.1.1** Seismic Surveys [airguns]) and the relative dearth of research on pile driving noise. Though the sound sources are somewhat similar, the key difference is that acoustic energy from pile driving travels through the substrate and it is not well understood how substrate-borne vibrations may affect animals that live in direct contact with the substrate. Pile driving sounds have been shown to affect certain behaviors in crustaceans, such as reducing locomotor activity in Norway lobster (Solan et al. 2016), decreasing feeding activity in crabs (Corbett 2018), and inhibiting attraction to chemical cues in hermit crabs (Roberts and Laidre 2019). The research thus far indicates that marine crustaceans may alter their natural behaviors in response to pile driving sounds, but further work is required to understand the biological significance of these changes and the degree to which high levels of substrate-borne particle motion may affect their behavior (Hawkins et al. 2021; Wale et al. 2021; Popper et al. 2022; Solé et al. 2023). This is critical for understanding the spatial scale at which they may be affected by pile driving noise.

Cephalopods can detect low-frequency sounds by sensing particle motion with their statocysts (Mooney et al. 2010), which, similar to the fish ear, act like three-dimensional accelerometers and could be injured from high sound exposures. Indeed, damage to cephalopod statocysts has been observed in several tank-based studies (André et al. 2011; Solé et al. 2022), and Jones et al. (2020) observed inking and jetting behaviors in longfin squid when exposed to pile driving noise in a tank. A follow-up field study found that alarm behaviors occurred with the first acoustic stimulus but diminished quickly. Responses were only observed in squid at the near site, suggesting that at greater distances from pile driving there is unlikely to be any alarm response (Cones et al. 2022). A similar field study, conducted by Jézéquel et al. (2023), focused on behavioral responses of both squid individuals and shoals (groups of squid) to repeated pile driving sound exposure. Pile driving induced short-term alarm responses and rapid habituation of squid, but using the same field-based design, Jézéquel and Mooney (2024) found no statistical evidence of TTS in any squid exposed to impulsive pile driving sound. When exposed to particle acceleration equivalent to 500 m (1,640 ft) from installation of a 1.3 m (4.3 ft) diameter steel pile, longfin squid showed a reduction in feeding success, and squid abandoned predation attempts when noise was introduced (Jones et al. 2021). Interestingly, additional work showed that interactions between males, as well as reproductive behaviors between males and females, were unaffected by pile driving noise, suggesting that the motivation to mate exceeds the potential stress that noise may introduce (Stanley et al. 2023). Lab studies of other cephalopods, such as cuttlefish, also did not detect impacts of impulsive sounds on mating or egg laying (Solé et al. 2022). This work suggests that squid (and likely all cephalopods) are sensitive to low-frequency sound but may habituate to repeated exposures and/or recover quickly. When pile driving noise co-occurs with feeding periods, it could negatively affect feeding but is unlikely to affect mating behaviors.

4.5.1.9 Decommissioning

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. 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. When a fish is close to a detonation, there can be a rapid contraction and overextension of the swim bladder, resulting in damage to internal tissues (barotrauma). The distance at which barotrauma may occur is generally expected to be smaller than that at which hearing effects could occur.

The explosions related to decommissioning of oil and gas infrastructure would happen below the mudline, but most of the research has focused on open-water explosions (more relevant for U.S. Navy purposes). For example, Jenkins et al. (2022) and Smith et al. (2022) exposed Pacific mackerel to a 6.2 kg (13.7 lbs) midwater explosive in-situ at distances ranging 21–807 m (69–2,647 ft) and found that there were increases in mortality observed at distances up to 157 m (515 ft) from the explosion, and other non-auditory injuries (e.g., damage to swim bladder and kidneys) occurred up to 333 m from the source at received peak pressures (Lpk¬) of 226 dB re 1 µPa (Jenkins et al. 2022). At greater distances and lower received levels (400 m [1,312 ft]; 220 dB re 1 µPa), there was evidence of hair cell damage, suggesting that hearing would likely be impaired at this distance, although no hearing tests were conducted (Smith et al. 2022). Interestingly, a similarly-designed study with sardines (Dahl et al. 2020) showed the greatest physical effects (burst capillaries, swim bladder rupture, and kidney rupture) occurred at the closest distances (<50 m; 164 ft), but then a secondary peak at 125–150 m (410–492 ft); the secondary peak was likely explained by propagation pathways–reflections off the seafloor and sea surface may have converged at this distance and created a particularly rapid decrease in acoustic pressure. A follow on study assessing Pacific mackerel to a 4.5 kg (9.9 lbs) midwater explosive using a similar set up found swim bladder bruising to the injury most indicative of exposure to an underwater explosion, and the greatest hair cell loss occurred in fish at the closest distance, 150 m (492 ft) from the explosion (Bowman et al. 2024).

Fishes and invertebrates that lack swim bladders are more resistant to underwater blasts than those with swim bladders (Goertner et al. 1994). Modeling work by Goertner (1978a) predicted that the range at which effects could occur in a non-swim bladder fish was 100 times smaller than that of a fish with a swim bladder. Keevin and Hempen (1997) reported on several studies in which various invertebrate species were exposed to charges of different sizes. Overall, despite some studies lacking adequate controls and sample sizes, they concluded that invertebrates are resilient to pressure-related damage from underwater explosions.

Together these studies show that acoustic injury to fish as a result of explosive detonation is possible, but the degree of effect will depend on whether the species has a swim bladder (and whether it is open or closed), as well as orientation of the fish at the time of detonation (Jenkins et al. 2023). 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 only a small portion of the total stocks in the Gulf (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.

4.5.1.10 Aircraft

Offshore projects may require use of aircraft for crew transport during construction and maintenance. The penetration of noise from aircraft into the water is limited because much of the noise is reflected off of the water's surface (see **Appendix B**); due to the air-water interface, an animal needs to be close to the sea surface to be affected. Because most fish and invertebrates do not spend significant time near the sea surface, impacts to finfish and invertebrates from aircraft use are expected to be insignificant.

4.5.2 Discharges and Wastes

Routine discharges and wastes associated with BOEM-authorized activities in the Gulf include sanitary waste, gray water, cooling water, drilling muds and cuttings, and other operational discharges such as bilge, ballast, fire water, and deck drainage. These originate from coastal infrastructure (see **Sections 4.2.2** and **4.2.4**), vessels (support, service/construction, seismic, and drilling), and platforms. Not all vessels generate drilling-related wastes; these are specific to drilling operations. The USEPA and USCG administer regulations and permits designed to prevent environmental degradation by limiting contaminants in allowable discharges and reducing the risk of introducing nonindigenous species. Discharges that are permitted must meet requirements to ensure they remain below harmful levels. For additional information on discharge and waste regulations, see **Section 4.1.2** Regulatory Compliance and **Table 4-3**.

Releases of authorized discharges and wastes into the water column can result in altered water chemistry, salinity, turbidity, and temperature surrounding the point source. These alterations would impact habitat quality and suitability for various fishes and invertebrates, potentially resulting in biodiversity loss and community structure shifts. However, discharges and wastes in the Gulf, particularly in offshore waters, generally disperse and dilute due to the volume of water they are expelled into and the influence of currents, wind, and wave action. Rates of dispersal and dilution of discharges and wastes depend on several factors including the discharge composition, discharge rate, and oceanographic conditions. Stationary sources of discharges and wastes (e.g., coastal infrastructure, platforms) may accrue longer-term localized impacts surrounding the point source due to their persistence in one location, whereas mobile sources of discharges and wastes (e.g., vessels) would likely not result in any sustained effects to localized fish and invertebrate communities or their habitats.

Compounds toxic to marine life may be found in produced waters, drilling muds and cuttings, and their additives (e.g., radioisotopes, heavy metals, petroleum hydrocarbons, other organics, chrome or ferrochrome lignosulfonate, sodium hydroxide, chromate salts, surfactants, paraformaldehyde, and other biocides and chemicals) (Neff et al. 2011; USEPA 2022). Effluent waters and deck drainage may also contain biocides, detergents, solvents, metals, coagulants, corrosion inhibitors, and dispersants, among other chemicals (USEPA 2022). Exposure to these

compounds may cause impacts to mobility, development, physiology, behavior, development, and reproductive success among fishes and invertebrates (Neff et al. 2011; Folkerts et al. 2020; Gissi et al. 2021). The USEPA prohibits the discharge of some wastes including oil-based drilling muds and cuttings, produced sands, synthetic-based muds, waste oil, chemical products, and trash and debris. However, some wastes (e.g., water-based drilling muds) are authorized to be discharged if they meet permitting requirements; such wastes may be dispersed and diluted in the offshore environment (see **Section 4.1.2** and **Table 4-3** for more detail).

Impacts to water quality have been shown to remain within 1,000 m (3,280 ft) of the source for drilling fluids and cuttings and within several hundred meters for produced waters (Beyer et al. 2020; USEPA 2022). Drilling an exploratory well can result in the discharge of approximately 2,000 metric tons (2,205 tons) of water-based muds and cuttings, and may be less for development wells (Neff et al. 2005). Though cuttings discharged at the surface tend to disperse in the water column and are distributed at low concentrations (Continental Shelf Associates Inc. 2004b), 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). Suspended materials may clog invertebrate feeding structures, resulting in injury or mortality (Lissner et al. 1991; Abdul Wahab et al. 2017). Increased turbidity can alter predation dynamics for fishes and invertebrates by either enhancing or decreasing predator feeding efficiency, potentially leading to changes in community structure or growth and condition of larvae (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; 2020). Fish eggs and larvae are unable to avoid sediment plumes because they cannot swim against a current, which may result in reduced oxygen uptake in eggs and hatching success (Gray et al. 2012), and physical or visual impairment of larvae during feeding (Axler et al. 2020).

Coastal fishes and invertebrates 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. For example, organisms living in shallow sand shoals are adapted to high-energy, turbid environments and can recolonize relatively quickly after coastal dredging (Dernie et al. 2003). Sedimentation resulting from discharges and wastes can smother benthic species with little to no mobility, resulting in injury or mortality.

Overall, mobile fishes and invertebrates are expected to be able to avoid discharge plumes and thus avoid potential negative impacts. Localized communities of non-mobile fishes and invertebrates would have the highest potential for negative impacts from discharges and wastes, particularly from drill muds and cuttings shunted to the seafloor or other activities that result in seafloor sedimentation. Additionally, early life stages of fishes and invertebrates that cannot swim against a current cannot avoid sediment plumes and may experience injury or mortality. However, the regulation of discharges and wastes combined with oceanographic current, wind, and wave action makes it unlikely that most fishes and invertebrates would

experience significant injury or mortality from authorized discharges and wastes. No population-level impacts are reasonably expected.

4.5.3 Bottom Disturbance

Bottom disturbance results from a variety of BOEM-regulated activities. Anchoring, drilling, trenching, jetting, pipe and cable laying, dredging (e.g., for canals and harbors, and for shoreline restoration projects), structure emplacement, pile driving, and geological/geophysical investigations (e.g., sediment coring, ocean bottom node placement) are all examples of bottom-disturbing actions that are associated with BOEM-regulated activities.

Bottom-disturbing actions can directly impact fishes and invertebrates by crushing individuals with limited or no mobility and exposing infauna, making them more vulnerable to predation. Physical impacts to sensitive habitats (e.g., natural hardbottoms) can also indirectly affect fishes and invertebrates by degrading habitats used to support a variety of life history stages. Soft-bottom communities generally recover from disturbance relatively quickly (3 months to 2.5 years) in comparison to hard bottom communities (8–10 or more years) (Rogers and Garrison 2001; Brooks et al. 2006; Wilber and Clarke 2007; Tamsett et al. 2010). In regards to offshore sediment borrow for shoreline restoration projects, the recovery of benthic communities to pre-dredge conditions is generally estimated to take 2.5 to >7 years (Pickens et al. 2020). Several early successional species, particularly those in the surrounding areas, may recolonize the disturbed site rather quickly, while full restoration of species composition would generally take longer (Zarillo et al. 2008; Pickens et al. 2020). In the Gulf, soft-bottom habitat is far more ubiquitous than hard bottom habitat. Accordingly, BOEM/BSEE place distancing mitigations on bottom-disturbing activities to protect those sensitive, slow-to-recover hard bottom habitats (see **Section 4.1.3** Mitigation Strategies and **Table 4-3**). Fishes and invertebrates associated with hardbottom habitats are therefore more likely to benefit from those mitigations. Bottom disturbance is generally not mitigated for soft bottoms, and damage to those habitats and associated fishes and invertebrates may still occur.

Bottom-disturbing actions can also impact fishes and invertebrates by suspending sediments into the water column, increasing turbidity and causing sedimentation. This results in potential effects to fishes and invertebrates as described earlier in **Section 4.5.2** Discharges and Wastes. Due to a combination of the spatiotemporally limited nature of suspended sediments, avoidance behaviors, and a range of tolerances for various environmental conditions, fishes and invertebrates would in most cases be unlikely to be significantly impacted by turbidity resulting from BOEM-regulated activities. Overall, bottom disturbance may result in localized mortality, particularly to immobile and benthic species, but no population-level impacts are reasonably expected.

4.5.4 Coastal Land Use and/or Modification

Coastal land disturbance from BOEM-regulated activities may include navigation canal dredging, the construction of new onshore facilities (including decommissioning refurbishment

or disposal sites) and pipeline landfalls, and vessel traffic. These activities could impact fishes and invertebrates in similar ways as described earlier for discharges and wastes (e.g., reduced water quality), bottom disturbance (e.g., crushing and increased turbidity), and noise (e.g., masking from vessel traffic). These can have important environmental implications as shallow, coastal waters house important habitats that serve as important feeding grounds for adult fish and invertebrates, as well as nursery grounds for juveniles. The amount of coastal construction or dredging associated with new OCS activities is expected to be relatively low as infrastructure is already largely in place. However, maintenance dredging of channels still occurs and may result in changes to habitat availability and quality, as well as injury and mortality to fishes and invertebrates in the area of impact. The USACE, state, county, commercial, and private interests maintain federal channels and canals. Coastal construction and vessel traffic can contribute to shoreline erosion and operational discharges and wastes, leading to localized habitat degradation and increases in turbidity and sedimentation. Nonpoint sources of pollution from onshore facilities, particularly as runoff from paved surfaces during heavy rain events, may degrade water quality for fishes and invertebrates; however, the contribution would be localized and miniscule compared to the cumulative runoff received from other sources (e.g., river outflows and coastal developments). For more information on impacts from BOEM-regulated activities in coastal areas, see **Section 4.2** Coastal Habitats and Communities.

4.5.5 Offshore Habitat Modification and/or Space Use

Fishes and invertebrates 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), dredging for marine minerals (e.g., sand), and vessel presence. Although offshore energy 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). Any installation or decommissioning activities that disturb the seafloor would result in impacts similar to those described in **Section 4.5.3** Bottom Disturbance. 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; 2020; Shipp and Bortone 2009). The resulting assemblages frequently include commercially and recreationally valuable coastal and oceanic fishes. Gulf fishes have generally been found to interact with platforms over a wide range of environmental conditions and platform characteristics, prioritizing distribution around platforms rather than specific environmental conditions or specific platform characteristics (Bolser et al. 2020). However, the distribution of some species around offshore structures may be dependent on factors such as water quality, water depth, and distance to shore (Bolser et al. 2020). Offshore structures can influence the settlement, abundance, and biodiversity patterns of fish communities (Bolser et al. 2020).

A study on offshore platforms in the Gulf showed the potential role of platforms as nursery habitat for larvae or refugia for post-larval 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 Jr. et al. (2001) and Shaw et al. (2002) found highest taxonomic richness and diversity at midshelf 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. The well-known association of fishes 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).

Removal of offshore structures and equipment as part of the decommissioning process may negatively impact associated fishes and invertebrates. Soft-bottom habitat is ubiquitous in the Gulf, while hard bottom habitats and seafloor features with significant vertical relief are less common. As such, BOEM typically places mitigations on proposed activities to distance bottom-disturbing activities from hard bottom habitats to avoid impacts (see **Section 4.1.3** and **Table 4-3**), thus causing most offshore infrastructure to be placed in soft-bottom locations. While removal of offshore structures is necessary to restore the seafloor to its original composition, removal can result in an altered community as the restored site is recolonized. Removal of offshore structures and equipment may reduce areas favorable for refuge and feeding, and lessen the connectivity (i.e., remove the “stepping stones”) of hard substrate on the OCS (Shams et al. 2023). The removal of structures and equipment may result in community-level changes, such as an overall reduction in species diversity of epifaunal organisms, fishes, and invertebrates (Schroeder and Love 2004).

Some structures may be converted to artificial reefs when they are decommissioned. If portions of a platform are permitted to be reefed in place, the hard substrate and encrusting communities would remain part of the benthic habitat. Changes to associated fish and invertebrate communities may occur if the size and structural complexity of a structure is altered for reefing. Structures redeployed at another location may also support substantially different communities, depending on the environmental characteristics of the reef site (e.g., different water depth, hydrology) and other factors. Regardless, reefed structures would be expected to continue supporting a variety of fishes and invertebrates.

4.5.6 Air Emissions and Pollution

Due to steady vertical and horizontal air motion throughout the Gulf region (Wang and Angell 1999) that rapidly disperses any pollutants from routine BOEM-regulated activities, fish and invertebrate populations are not expected to receive direct impacts from air emissions and pollution associated with BOEM-regulated activities. However, emissions and pollution may indirectly contribute to increased carbon dioxide uptake in the Gulf, which may have downstream effects to fish and invertebrates as described in **Section 3.5.6.6** Climate-Related Factors.

4.5.7 Visual and Lighting Impacts

Onshore facilities, vessels, and offshore structures (e.g., standing platforms, drillships, tension-leg platforms, etc.) associated with BOEM-regulated activities may emit artificial light at night. Sources of artificial light on offshore structures can include floodlights, aid-to-navigation lights, and flare stacks (Keenan et al. 2007). The amount of light input experienced by fishes and invertebrates can vary depending on the optical properties of the water column and the type of light. High-turbidity waters can restrict light penetration into the water column. Similarly, light penetration is greater in calmer waters than in rougher seas (Keenan et al. 2007). The color of light also determines its attenuation in the water column. Blue and green wavelengths, which may be emitted through the broader spectrum of light emitting diodes (LEDs), for example, attenuate at deeper water depths (Bolton et al. 2017).

Impacts to fishes and invertebrates from artificial light at night are difficult to generalize. Some studies suggest that the attraction of smaller zooplankton and ichthyoplankton to artificial light at night subsequently attracts higher trophic levels of fishes due to increased predation opportunities (Keenan et al. 2007). Artificial light can concentrate prey, while also optimizing feeding conditions for predatory fishes that rely on visual cues for prey capture (Bolton et al. 2017). This can lead to altered predator-prey interactions and potentially create unnatural top-down regulation of fishes (Becker et al. 2013). To the contrary, other evidence suggests that while fish are attracted to lit offshore structures, they may avoid the reach of artificial light at the surface either to escape nocturnal predation or to forage away from platforms (Barker and Cowan Jr. 2018). Additionally, a study testing the effects of short-term artificial light exposure to seagrass bed communities identified no clear patterns (Martin et al. 2021). Responses of fishes to artificial light at night are likely species- and community-specific and may be difficult to isolate from other factors.

Artificial light at night may 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 on fishes and invertebrates are still largely unknown. When evaluating impacts of artificial light in coastal areas, it is difficult to parse out impacts specific to BOEM-regulated activities, since the light input into the marine environment would additionally come from other sources including coastal housing developments, restaurants, marinas, and jetties.

4.5.8 Seawater Use and/or Uptake

Impingement and entrainment are known effects of seawater use and/or uptake for some BOEM-regulated offshore activities. Cooling water is used for contact or noncontact cooling for equipment or dilution of effluent heat content. For oil and gas activities, drill ships have been recorded intaking 16–20 million gal/day (61–76 million L/day), while submersibles have been documented taking in 2 to over 10 million gal/day (7.5–38 L/day) from a water depth 122 m (>400 ft) from the water's surface (USEPA 2006). All cooling water requires seawater uptake, but not all seawater uptake is used as cooling water. Some water may be used for ballast water, cleaning, firewater, or testing. This routine activity can result in injury or mortality for fishes, invertebrates, and their eggs and larvae. These organisms can become trapped against the entrance screen to a cooling water system through the force of water being drawn through the intake structure, known as impingement. Entrainment, wherein organisms are completely sucked up through the intake structure and eventually discharged from the facility or structure may also occur. Both effects are likely to result in injury or mortality of fishes and invertebrates. Smaller individuals, eggs, and larvae are the most vulnerable to these impacts, since they are less likely to be able to swim against the current of intake water. Impacts likely affect fishes and invertebrates in the water column, where intake entrances are usually located. Benthic fishes and invertebrates would be less likely to undergo impingement and entrainment because they would be further distanced from water intake. Overall, localized injury and mortality of smaller fishes, invertebrates, and their eggs and larvae are expected to occur. No population-level impacts are reasonably expected from this activity.

4.5.9 Accidental Events

4.5.9.1 Accidental Releases

Though regulations are in place to prevent unauthorized discharges into the marine environment (e.g., the CWA; see **Section 4.1.2** Regulatory Compliance and **Table 4-3**), unintended releases of oil, or other chemicals may still occur as a result of faulty equipment, human error, or extreme weather events. These accidental releases may adversely affect fishes and invertebrates, although the impact of a spill depends on many factors including the mobility of the organism, the organism's ability to metabolize toxins, the chemicals or compounds spilled, the spill concentration, spill volume, and surrounding hydrology. Regulations such as the National Contingency Plan may also help contain accidental spills, limiting their volume and area of exposure (see **Section 4.1.2** and **Table 4-3**). Fish and invertebrates inhabiting shallow-water habitats (e.g., estuaries) are at increased risk because they can receive higher oil loading per unit volume of seawater than in the deeper offshore environment (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 may allow for the toxicity of spilled oil to be reduced or eliminated by weathering and biodegradation before it reaches coastal habitats (OSAT-2 2011). Though catastrophic oil spills are generally not considered reasonably foreseeable events (see **Section 1.1**), what is learned about the resulting impacts on marine biota improves the body of

knowledge of impacts of oil in the marine environment. References in this section to catastrophic spills (such as *Deepwater Horizon*) are not meant to imply that they are reasonably foreseeable activities but are instead meant to illustrate the types of negative impacts to fishes and invertebrates that can result from oil exposure. For an assessment of potential impacts resulting from and characterized as low-probability catastrophic spills in the Gulf similar in nature to the *Deepwater Horizon* explosion, oil spill, and subsequent response, see the Gulf of Mexico Catastrophic Spill Event Analysis: High-Volume, Extended-Duration Oil Spill Resulting from Loss of Well Control on the Gulf of Mexico Outer Continental Shelf; 2nd Revision (*Gulf Catastrophic Spill Event Analysis* [BOEM 2021]).

For most reasonably foreseeable oil spills, impacts to mobile, adult fish would likely be sublethal as they 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). Lasting sublethal effects from oil exposure can include sensory system impairment, constrained development, reduced reproductive success, decreased energy budgets, and reduced survival (Schlenker et al. 2022). Schlenker et al. (2022) observed short-term exposure of mahi-mahi to crude oil in the Gulf, finding profound effects on survival and reproduction through an increase in predation risk and lower reproductive potential on individuals that survived the initial spill. This study found that even a brief and low exposure to crude oil can impair fitness significantly in adult mahi-mahi. Patterson III et al. (2023) found reef fish populations in the Gulf had clear population declines after a catastrophic sized oil spill (*Deepwater Horizon*) due to petroleum compounds that persisted in the food web for years after the spill. Romo-Curiel et al. (2022) described the exposure risk of large bony fishes and elasmobranchs to oil spills, noting that while the intensity of the impact depends on species and ecological vulnerability, a range of vulnerability can still be determined. This study found that elasmobranchs are highly vulnerable, with a medium to high exposure risk due to their low reproductive potential. In contrast, large bony fish would have a low to medium exposure risk and vulnerability to oil exposure (Romo-Curiel et al. 2022). For some species, such as elasmobranchs and bluefin tuna, low productivity can result in high vulnerability to oil exposure. This vulnerability could be attributed to long life spans and slow growth rates (Romo-Curiel et al. 2022).

Fishes and invertebrates with more limited mobility, including many benthic species, may be even more greatly impacted by oil spills. Sutton et al. (2022) examined the impact of diel vertical migration of deep-pelagic fishes, and showed species that were exposed to oil near the surface can expand the footprint of oil spills in those communities as they migrated deeper. For example, the total distribution of *Deepwater Horizon* toxins throughout the water column was significantly larger than the surface footprint, suggesting that a substantial portion of fish assemblages may have been impacted. This study also highlighted that the avoidance behavior of deep-pelagic marine fauna towards oil spills is primarily vertical instead of horizontal. It has

additionally been found that oil-derived residues persist longer in the pelagic deep-sea environment (Romero et al. 2020). PAHs are the most toxic component of oil and are associated with a wide range of deleterious health effects in fish. Pulster et al. (2021) analyzed red snapper in the Gulf for hepatic PAHs, biliary fluorescent aromatic compounds and microscopic hepatobiliary changes (MHC) from 2011 to 2017. Out of 566 red snapper collected for this study, 99 percent of samples contained between one and nine microscopic hepatic changes with an average 5 in an individual fish. The MHCs observed in red snapper were characterized as inflammatory responses, metabolic responses, degenerative responses, and lesions that could be a signal of disease progression (Pulster et al. 2021). Deep-pelagic cephalopods are of particular concern when exposed to these toxic compounds. PAHs are highly lipid-soluble and can cross lipid membranes and bioaccumulate in marine invertebrates such as cephalopods and mollusks (Romero et al. 2020). The PAHs detected in cephalopods in the northern Gulf before and after the *Deepwater Horizon* oil spill suggest episodic exposure to petrogenic PAHs.

Oil floating on the surface can directly contact and coat the eggs and larvae of fish and invertebrates found at or near the surface. 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). The physical processes that move oil and dispersants are also responsible for transporting epipelagic fish larvae, increasing the risk of contact and exposure to the toxins released from an oil spill. Eggs and larvae are largely 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). Additional effects include changes to cardiac development and function, buoyancy control, and swimming performance (Sutton et al. 2022). Following catastrophic spills like *Deepwater Horizon*, a reduction in the abundance of pelagic fish larvae may be observed, likely due to the impacts of PAHs and other toxic components from the oil spill. 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. Overall, impacts to early life stages of fishes and invertebrates would largely depend on the spill concentration, surrounding hydrology, and duration of exposure.

Although an unlikely occurrence, a subsea loss of well control could suspend large amounts of sediment. Effects of suspended sediments on fishes and invertebrates are described in **Section 4.5.3** Bottom Disturbance.

4.5.9.2 Release Response

Regulations, such as the National Contingency Plan (see **Section 4.1.2** and **Table 4-3**), standardize protocols for response to accidental oil spills to minimize damage to the environment. However, negative impacts from spill response itself may occur to fishes and invertebrates. Chemical dispersants may be used in response to oil spills 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; Johann et al. 2021). For example, Laramore et al. (2016) found that larval pink shrimp exposed to oil treated with dispersants experienced greater negative impacts than those exposed to oil alone. Additionally, the impacts differed between larval stages, with zoea being the most sensitive. Similarly, eastern oysters exposed to dispersants may experience negative impacts 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, when the effects of chemical dispersants were laboratory tested on the larvae of blue crabs, only the larvae exposed to the highest treatment levels experienced significant increases in mortality (Anderson Lively 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.

Burning is an alternative to using chemical dispersants that may result in less harmful overall effects to fishes and invertebrates due to its combustion of a large volume of oil (Johann et al. 2021). However, the toxicity of compounds resulting from in-situ burning may either remain the same as an unweathered slick or be altered and depends on factors such as oil type, burn efficiency, and susceptibility of particular organisms (Fritt-Rasmussen et al. 2015; Johann et al. 2021). Fishes and invertebrates beneath the surface are expected to have little to no effects from this response method. However, sunken residue, like submerged oil mats, may have negative impacts on benthic organisms (Buist et al. 1999).

Mechanical spill response techniques may also be employed, depending on the characteristics of a spill. Booms are a common example of mechanical spill response, and are floating barriers used to contain a spill. This method could trap surface-dwelling organisms, such as pelagic eggs and larvae, as well as juvenile and adult fishes and invertebrates that inhabit *Sargassum* mats or floating debris, leading to injury or mortality either through physical crushing and/or increased oil contact. However, most fishes and invertebrates would generally be expected to be able to avoid such equipment.

4.5.9.3 Marine Trash and Debris

Routine BOEM-authorized activities, such as vessel operations, are subject to requirements (e.g., from BOEM, BSEE, USEPA, USCG) 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 (for more detail, see **Section 4.1.2** and **4.1.3** and **Table 4-3**). 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 19 km (12 mi)

from shore, which are passed through a comminutor (a machine that breaks up solids) and 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 for trash and debris to be accidentally released into the marine environment.

Marine trash and debris can degrade in the environment and become microdebris (i.e., small synthetic, semisynthetic, or naturally derived particles), later being ingested by fishes and invertebrates which can result in pseudo-satiation or physical blockage (Lestrade and Hernandez 2023). Ingestion of microdebris can occur not only in the pelagic environment but also through bioaccumulation in seafloor sediments and *Sargassum*. This can result in benthic, benthopelagic, and *Sargassum*-associated fishes (e.g., jacks and triggerfish) being particularly vulnerable to exposure and ingestion (Lestrade and Hernandez 2023).

Microplastics, a type of microdebris, are of particular concern for fishes and invertebrates. Several studies have identified microplastics in both lower trophic levels such as zooplankton and in higher levels of invertebrates and vertebrates (Enyoh et al. 2020). Many larval fish have been found with microplastics in their systems (Gove et al. 2019). Waddell et al. (2020), in assessing the frequency of microplastics in blue crab stomachs, determined that 36 percent of blue crabs collected in Corpus Christi Bay, Texas contained an average of 0.87 items of microplastics (fully synthetic and semisynthetic fragments and fibers) per crab. They theorized that microplastics can accumulate and settle in areas of low water turbulence conditions, where blue crabs feed (Waddell et al. 2020). Similarly, Gad and Midway (2022) observed the quantity of microplastics in southern flounder and hardhead catfish, two recreationally and commercially important fish species in the Gulf. They found 25 percent of southern flounder and 15 percent of hardhead catfish sampled had ingested microplastics. The researchers noted that high concentrations of microplastics have been reported in the Gulf, with a significant portion believed to originate from the Mississippi River (Gad and Midway 2022). The presence of microplastics at various levels of the marine food web poses a great threat to the health of marine ecosystems due to physical impacts to biota as well as the absorption of toxic chemicals including heavy metals and pollutants.

Foley et al. (2018) conducted a meta-analysis of scientific literature investigating the effects of microplastic exposure on consumption, growth, reproduction, and survival of fish and aquatic invertebrates. Many of the studies showed neutral effects and interspecies variation, and that the most consistent effect was a reduction in consumption of natural prey when microplastics were present. However, there were also examples of within-taxa negative effects to growth, reproduction, and survival (Foley et al. 2018). Negative effects of microplastics to copepod feeding, fecundity, and survival, for example, have been documented in previous laboratory-based toxicological studies (Cole et al. 2016).

4.5.9.4 Strikes and Collisions

Accidental strikes to marine biota by vessels supporting BOEM-regulated activities would likely not affect most fishes and invertebrates because many can actively avoid oncoming ships, and only few may occupy the shallowest depths of the water column at a given moment. Larval fish and invertebrates with limited mobility may experience highly localized and minimal mortalities, but most would only be temporarily displaced. However, there remains the potential for OCS-associated vessels to strike large, surface-feeding fish such as whale sharks (Ramírez-Macías et al. 2012; Schoeman et al. 2020).

During the spring and summer, some whale sharks travel to the north-central Gulf where they have been observed feeding at the surface in aggregations of 16–100 individuals (Hoffmayer et al. 2007; Chen 2017; McKinney et al. 2017; **Figure 4-2**). These aggregations occur near existing oil and gas infrastructure on the OCS, which potentially makes them vulnerable to ship strikes. On a global scale, whale shark presence has been found to spatially overlap with cargo vessel routes by more than 80 percent on a monthly average (Womersley et al. 2022). Due to their frequent occupancy of shallow waters and swimming speeds that are 10 times slower than those of large vessels, whale sharks are at significant risk of collision with oncoming ships, as their slow and limited movement makes it difficult for them to avoid vessels (Womersley et al. 2022). No data currently exist indicating that vessel strikes to whale sharks have occurred in the north-central Gulf; however, whale sharks are negatively buoyant and may sink quickly if a mortality were to occur 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 Gulf 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 Gulf by OCS-related vessel activity.

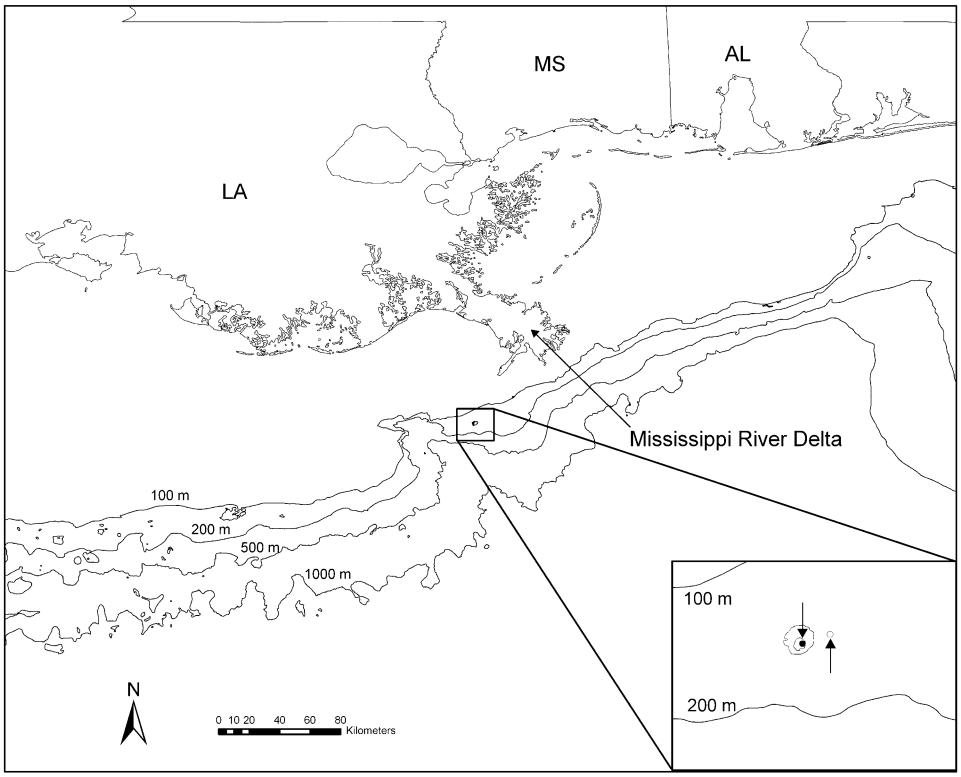


Figure 4-2. Map of the location of a whale shark feeding aggregation, as reported in Hoffmayer et al. (2007) during June 2006 in the north-central Gulf.

Note: The inset map depicts the location where the aggregation was sighted (closed circle) and control sites (open circle) show where zooplankton samples were taken for this particular study. The study site was located in surface waters 78 m (256 ft) above the eastern edge of the crest of a topographic high, the base of which is located at 100-m (328-ft) water depth.
Credit: Reprinted by permission of Dr. Mark Peterson on May 5, 2020, whose permission is required for further use.

4.5.9.5 Entanglement and Entrapment

Entanglement or entrapment of fishes and invertebrates may occur from BOEM-regulated OCS activities. Lines in the water (e.g., diver lines, anchor lines, ROV and crane cables) may result in entanglement of larger fishes such as whale sharks. However, the interaction between a whale shark or other large fish with lines in the water would be highly unlikely, and mitigations placed by BOEM on OCS activities to prevent slack in lines to protect larger marine mammals from entanglement would also consequently reduce the risk to larger marine fishes and invertebrates (for more detail, see **Sections 4.1.2** and **4.1.3** and **Table 4-3**). It is highly unlikely entanglement would result in any significant impacts to fish and invertebrate populations.

Entrapment of fishes and invertebrates may occur from BOEM-regulated activities, such as offshore sediment dredging for shoreline restoration and site-clearance trawling after offshore oil and gas platform removal. Entrapment of fishes and invertebrates would likely result in mortality to those captured but would likely not result in population-level impacts.

4.6 SEA TURTLES

4.6.1 Noise

Noise sources that sea turtles could be vulnerable to include 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 Gulf planning areas, though minimally in the EPA (Nelms et al. 2016). For more information about sea turtle bioacoustics, see **Section 3.6.6** and see **Figure 4-1** for approximate hearing ranges of sea turtles and frequency ranges of various common anthropogenic sources. As applicable, discussion of turtles outside of the Gulf OCS is included as a proxy for Gulf sea turtles, representing the best available information at this time.

4.6.1.1 Seismic Surveys (Airguns)

Although little is known about the effects of anthropogenic noise on sea turtles, potential effects of seismic surveys may include auditory effects (TTS or AUD INJ) and/or behavioral disturbance. Research on responses to seismic airguns have shown a range of behavioral effects in sea turtles, including startle responses, rapid swimming (McCauley et al. 2000), and swimming toward the surface at the onset of the sound (O'Hara and Wilcox 1990; Moein et al. 1994; Bowles et al. 1999; McCauley et al. 2000; Lenhardt 2002; Weir 2007; Southwood et al. 2008; DeRuiter and Doukara 2010). Moein et al. (1994) found that caged loggerheads exposed to airguns at received levels of 175–179 dB re 1 µPa SPL initially avoided the sound source, but appeared to habituate with repeat exposures, even when the exposures were separated by several days. McCauley et al. (2000) approached one green and one loggerhead turtle in cages with a single airgun and observed startle responses starting at received SPLs of 166 dB re 1 uPa. O'Hara and Wilcox (1990) observed nine turtles in a large enclosure within a canal, and saw that turtles spent more time in the areas further from the airgun when the firing pressure was at 140 kg/cm^2 (309 lbs/in^2), but not at 70 kg/cm^2 (154 lbs/in^2) (received sound levels not reported).

Field studies with free-swimming animals are generally more appropriate for drawing conclusions, but the work thus far has observed variable behavioral responses. DeRuiter and Doukara (2012) observed that 57 percent of loggerhead sea turtles in the vicinity of a seismic survey exhibited a diving response after exposure to received levels between 175 and 191 dB re 1 µPa. Observations of multiple species during a 10-month seismic survey off Africa showed that the majority of turtles continued to bask at the surface as the vessel moved by (regardless of whether the airguns were actively shooting) (Weir 2007). Out of the 180 turtles that the authors were able to observe both before and after exposure, only 20 initiated response dives, with no clear difference in whether the airguns were on or off; however, data were too limited to draw firm conclusions and it was unclear if responses were to the airgun sound or vessel presence (Weir 2007).

Subadult and adult turtles are presumably more susceptible to seismic airgun noise compared to post-hatchlings, because they spend more time submerged and at depth. In contrast, post-hatchlings typically reside at or near the surface and may be less likely to experience injury from the sound field produced by an airgun array below the surface. Seismic airgun surveys conducted in shallower areas are anticipated to affect a greater number of turtles than deepwater surveys, but deepwater surveys are more likely to impact leatherbacks, particularly in upwelling zones where these turtles may gather to feed. Additionally, surveys conducted during summer nesting periods may affect more adult turtles, particularly loggerhead, green, and leatherback turtles, compared to nonnesting periods (Popper et al. 2014).

In addition to changing behavior, exposure to anthropogenic noise may result in the displacement of individuals from important habitats used for foraging, resting, and reproducing (Reese et al. 2023). Such disruptions are expected to be temporary, however, and should not affect the overall survival and reproduction of individual turtles. Based on the current understanding of sea turtle hearing capabilities, it remains uncertain whether sea turtles rely completely on sound for communication and navigation, and therefore they may additionally be affected by auditory masking (Popper et al. 2014). Taken together, the results of studies with sea turtles suggest that they exhibit short-term responses to airgun noise when relatively close to the source, and while they may experience physiological stress during avoidance, this is expected to dissipate once they are outside the affected area. Mitigation measures (e.g., ramp-up procedure, the use of observers, shutdown zones) could prevent or minimize potential effects from seismic survey noise on sea turtles (**Section 4.1.2** and **4.1.3** and **Table 4-3**).

4.6.1.2 High-Resolution Geophysical Surveys

Only a subset of high-resolution geophysical (HRG) sources (e.g., boomers, sparkers) are likely to be audible by sea turtles given the frequency range of the sounds and the hearing range of turtles (**Section 3.6.6**), but that subset may have some effects. PTS is highly unlikely given the intensity and short duration of signals generated by this equipment (Crocker and Fratantonio 2016). BOEM and USGS characterized the acoustic qualities of HRG sources and their potential to result in behavioral disturbance of marine species, including sea turtles (Ruppel et al. 2022). In addition to frequency range, other characteristics of the sources like the source level, duty cycle, and beamwidth make it very unlikely that these sources would result in behavioral disturbance of sea turtles, even without mitigation (Ruppel et al. 2022). In coastal Massachusetts, a field study exposing thirteen tagged leatherback sea turtles to high-intensity (221 dB re 1µPa) impulsive sounds from a sparker found significant changes in movement patterns, dive behavior, and an approximately 64 percent reduction in foraging (Patel et al. 2026).

The small reduction in foraging rate that may occur is unlikely to be biologically significant since the actual duration of exposure at these received levels would be very short, since both the sound source and turtle are moving during a survey. Therefore, although temporary displacement or behavioral responses may occur, these disruptions would be limited in extent, and short-term in duration.

4.6.1.3 Geotechnical Surveys

There is a lack of studies specifically examining the effects of noise from geotechnical operations on sea turtles. Most existing research focuses on broader categories of underwater noise, leaving a critical gap in understanding how geotechnical activities uniquely effect sea turtles. Continuous noise produced by geotechnical surveys has the potential to disrupt normal sea turtle activities such as foraging, nesting, and migration. Prolonged exposure to the sounds associated with geotechnical surveys may also increase stress, resulting in changes to swimming patterns and increased energy expenditure, and avoidance of areas with heightened noise levels. Low-frequency continuous noise can mask natural sounds that sea turtles depend on for communication and navigation, potentially impairing their ability to interact with their environment.

4.6.1.4 Dredging

As with many other sound sources, the response of sea turtles to dredging noise is not well researched and is poorly understood relative to marine mammals. A description of the physical qualities of dredging noise can be found in **Appendix B**. Even right at the source, SELs from dredging are not expected to exceed the recommended sea turtle cumulative sound exposure threshold for TTS or PTS. Behavioral responses are possible close to the source; for example, suction dredging may produce sounds up to an SPL of 190 dB re 1 µPa (Robinson et al. 2011; Todd et al. 2015), which exceeds the behavioral response threshold of 175 dB re 1 µPa.

There is currently no information on the effects of dredging noise on sea turtles (Popper et al. 2014). There is evidence, however, of potentially positive impacts of dredging to breeding flatback sea turtles, which increased their use of a dredging area and made longer and deeper resting dives during dredging operations (Whittock et al. 2017). The most likely driver for the observed behavioral response was speculated to be the absence of predators which were displaced by the noise from dredging operations. Despite the presence of active dredge vessels (which can often pose a risk to turtles), no events of injury or mortality were recorded.

4.6.1.5 Drilling and Production

There is very little information on the impacts of drilling and production noise on sea turtles. However, sea turtle hearing sensitivity is within the frequency range (100–1000 Hz) of sound produced by low-frequency sources such as marine drilling (Popper et al. 2014). It is unlikely that sounds from drilling would reach injury thresholds, unless the sea turtle is within very close proximity to the drilling activity (McCauley et al. 2000; Piniak et al. 2012a; Finneran et al. 2017), but it may cause temporary avoidance or displacement of sea turtles. Drilling-related noise is continuous, and source levels for drillships have been reported to be as high as 191 dB re 1 µPa during drilling, which exceeds the behavioral disturbance threshold of SPL of 175 dB re 1 µPa. Studies of sea turtles in the proximity of platforms are not conclusive regarding whether or not the turtles may habituate to the continuous sound source. Further research is required, but based on current data, the risk of substantial effects is expected to be low.

4.6.1.6 Vessels and Dynamic Positioning Systems

Vessel noise may affect sea turtle behavior, leading to temporary startle responses, altered submergence patterns, masking of biologically relevant sounds, and physiological stress (Samuel et al. 2005; National Science Foundation 2011). Sea turtles may exhibit a startle reaction, such as diving or swimming away, and temporary stress responses by increasing submergence time, extending dive durations, or surfacing (O'Hara and Wilcox 1990; Lenhardt 1994; Samuel 2004; Samuel et al. 2005). Hazel et al. (2007) found that sea turtles typically respond behaviorally to vessels at a distance of approximately 10 m (33 ft) or closer, suggesting their detection of approaching vessels relies more on visual than on acoustic cues. Díaz et al. (2024) found that traveling green sea turtles increased vigilance with increasing vessel noise. However, those resting on the seabed did not exhibit increased vigilance, suggesting sea turtles may also respond differently when in different behavioral states.

Current evidence indicates that sea turtles respond to vessel noise at very close ranges, making population-level effects unlikely. Though behavioral responses do occur, attributing them specifically to noise rather than visual or other cues remains challenging. Reactions such as avoidance behavior may disrupt essential activities like feeding. Therefore, it is prudent to consider that noise from vessels could elicit behavioral changes, such as evasive maneuvers, potentially leading to short-term behavioral changes and auditory masking.

4.6.1.7 Trenching and Pipeline Laying

Preparing an area for pipeline laying may require jetting, plowing, or removal of soft sediments, as well as the excavation of rock and other material through various dredging methods. Pipeline and cable-laying installation vessels are likely to use DP systems while laying the cables. The sound associated with DP generally dominates over other sound sources present, especially compared to the sounds produced by the dredging, trenching, and cable or pipeline laying activities themselves. A description of the physical qualities of these sound sources can be found in **Appendix B**. Because of the estimated source levels and transitory nature of these sources, exceedance of PTS and TTS sound levels are not likely for sea turtles (Heinis et al. 2013), and behavioral disturbances would likely be low intensity and localized.

4.6.1.8 Pile Driving

Noise from impact pile driving is generally low frequency, which means it overlaps with the hearing range of sea turtles. It is characterized as impulsive because of its high peak pressure, short duration, and rapid onset time. High levels of exposure can adversely affect sea turtles through auditory injury, impairment, and behavioral disturbance. Underwater sound levels generated during pile driving depend on many factors including the pile material and size, characteristics of the substrate, penetration of the pile in the seabed, hammer energy and size, and water depth. Generally, with increasing pile diameter, greater hammer energy is used. For oil and gas development, typical impact pile driving generates a high-energy acoustic pulse with

each hammer strike, which operates at a rate of 15 to 60 blows per minute and requires 500 to 5,000 strikes to drive the pile into the seabed (Jiménez-Arranz et al. 2020).

Vibratory pile driving may be used in addition to or instead of impact pile driving in some cases. A physical description of vibratory pile driving noise can be found in **Appendix B**. Vibratory pile driving is expected to create nearly continuous, non-impulsive, low-frequency noise. This means that the most damaging elements of sound exposure (the rapid rise time) that are possible with impact pile driving do not pose a risk. To date, no studies have examined the impact of vibratory pile driving on sea turtles, but if animals remain within an area where vibratory piling is occurring for long enough, they may experience auditory fatigue and acoustic masking due to the continuous nature of this sound source. Reduced hearing sensitivity because of pile driving could limit the ability to detect predators, prey, or potential mates, and reduce the survival and fitness of affected individuals. However, the role and importance of sound in these biological functions for sea turtles remains poorly understood (Lavender et al. 2014). Mitigation measures (e.g., use of observers, soft-start procedure, and shutdown procedure) could prevent or minimize potential impacts of pile driving noise on sea turtles (**Section 4.1.2** and **4.1.3** and **Table 4-3**).

4.6.1.9 Decommissioning

Decommissioning and removal of OCS structures can be performed using either explosive or nonexplosive severance methods. A physical description of underwater explosives and mechanical cutting, that are typically used for decommissioning, can be found in **Appendix B**. The shock and pressure waves associated with explosions may cause a number of effects to sea turtles, including behavioral disturbances, hearing impacts, injury, and death (MMS 2005). 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). Injuries have also been documented. For example, Duronslet et al. (1986) examined the physiological response of submerged and caged turtles placed at 228 m (750 ft), 365.7 m (1,200 ft), 548.6 m (1,800 ft), and 914 m (3,000 ft) to a detonation of 23 kg (50 lbs). of nitromethane. The animals closest to the blast had the most severe physiological responses including dilated blood vessels (loggerhead) and an everted cloaca (Kemp's ridley), while all animals showed some degree of lost control of their vaso-constrictor control centers (sustained pink coloration on throat and flippers).

As is the case with effects seen in mammals, the physical range at which injury or mortality could occur will vary based on the amount of explosive material, the size of the turtle, and the location of the turtle relative to the explosive. Injuries may include hemorrhage or damage to the lungs, liver, brain, or ears, as well as auditory impairment such as AUD INJ and TTS (Ketten et al. 2005; Finneran et al. 2017). Turtles that are recovering after exposure may be more vulnerable to infection and predation, so there also could be indirect increases in mortality (Popper et al. 2014). For the use of explosives in structure decommissioning, mitigation measures (e.g., designed to identify the presence of sea turtles and marine mammals nearby a

structure prior to the detonation of explosive) could avoid or reduce exposure of sea turtles to the shock and pressure waves (**Section 4.1.2** and **4.1.3** and **Table 4-3**).

4.6.1.10 Aircraft

Noises generated by aircraft that are directly relevant to sea turtles include both airborne sounds for turtles nesting or on the sea surface, and underwater sounds from air-to-water transmission from passing aircraft. The dominant tones for both types of aircraft are generally below 500 Hz (Richardson et al. 1995) and are within the auditory range of all sea turtles. A description of the physical qualities of these sound sources can be found in **Appendix B**. Because of the frequency range and sound levels produced, when aircraft travel at relatively low altitude, aircraft noise has the potential to elicit stress or behavioral responses in turtles (e.g., diving or swimming away or altered dive patterns) (Samuel et al. 2005; National Science Foundation 2011; BOEM 2016). Sea turtle sensitivity to airborne noise is not well understood, and existing studies have yielded mixed results. For example, Balazs and Ross (1974) exposed postnatal green sea turtles in a transplanted nest to short duration high-intensity noise from aircraft engine testing. On numerous occasions, a sudden burst of activity was noted within the nest at the onset of engine noise and continued until the noise subsided (Balazs and Ross 1974). On the other hand, Bevan et al. (2018) observed no evidence of behavioral responses from three species of sea turtles (green, flatback, and hawksbill turtles) exposed to drones flown directly overhead at altitudes ranging from 18 to 31 m (50 to 102 ft). Aircraft would likely operate throughout the Gulf at altitudes below 457 m (1,500 ft), except when landing or departing from service vessels. Therefore, potential disturbance effects on sea turtles are likely to be minimal given the planned altitude and generally low frequency of flights.

4.6.2 Discharges and Wastes

The USEPA- and USCG-administered regulations prevent impacts from produced water, drilling muds, and cuttings; because these regulations are designed to keep contaminants below harmful levels for public health and welfare, it is assumed potential sea turtle effects from produced water, drilling muds, and cuttings would be prevented (**Section 4.1.2** and **Table 4-3**). These discharges are not expected to persist in the water column. Because of 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 seafloor habitats and 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. Turtles forage on a variety of benthic species including crabs, shellfish, and seagrass. Green sea turtles in the northwest Gulf have an omnivore diet that is composed primarily of seagrasses in shore waters and supplemented by benthic

macroalgae as they transition into offshore waters (Howell and Shaver 2021). Generally, loggerhead sea turtles are carnivores that feed on benthic invertebrates; however, there is considerable regional variability in the diet of loggerheads (Donaton et al. 2019). Hawksbill turtles feed in coral and hard bottom areas, which would be avoided due to mitigations (e.g., separation distances between bottom-disturbing activities and hard bottom habitats) (**Sections 4.1.2** and **4.1.3** and **Table 4-3**). Such mitigations would protect hard bottom patches where sea turtles, like hawksbill turtles, may forage.

Sessile prey for sea turtles, including macroalgae, sea pens, and sea sponges, are less likely to be able to relocate during or after a bottom-disturbing activity. Mobile prey species, such as crabs, may temporarily relocate because of bottom disturbance, depending on the swiftness and severity of the disturbance. Although mobile prey species may be able to avert potential effects of bottom disturbance or relocate, sea turtles may be affected due to site fidelity for foraging. Adult loggerheads tend to remain in one foraging area when they are not in breeding season (Evans et al. 2019). Although loggerheads tend to remain in one foraging area, they have also showed plasticity in their foraging areas (Evans et al. 2019). Similar patterns have been observed in green sea turtles that return to foraging areas after migration (Broderick et al. 2007). This indicates that although sea turtles may prefer to stay in one foraging area if food is abundant, they are able to change foraging areas if necessary. Prey species may move after a bottom disturbance or repopulate the area. However, the speed of repopulation will vary depending on the species. For example, sea turtles that forage on sea pens are more likely to be affected by bottom-disturbing activities due to the slow nature of sea pens' regrowth. Individuals that forage on mobile benthic invertebrates and/or macroalgae are likely to experience less effects due to the abundance and mobility of their prey species.

Dredging operations can affect turtles through incidental interactions with equipment. In addition to direct interactions, dredging can degrade foraging and migratory habitat through spoil dumping, degraded water quality and clarity, and altered current flow (National Research Council 1990) and/or disrupt the prey base of turtles. The majority of documented interactions with sea turtles during dredging operations is related to hopper dredges. Dredging or sand mining from borrow areas has documented interactions with sea turtles (NMFS 2012). Hopper dredges move relatively rapidly in comparison to sea turtle swimming speeds and can entrain sea turtles as the drag arm of the moving dredge overtakes the slower moving sea turtle. NMFS-approved protected species observers are placed aboard hopper dredges during operations to monitor the hopper bin, screening, and dragheads for sea turtles (**Table 4-3**).

Additionally, if turtles are present when bottom-disturbing activities occur, suspended sediment could pose a potential risk. The resulting sediment deposition and increased turbidity may temporarily displace turtles from the area as it may impair their vision and potentially cause respiratory issues through inhalation. 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 effects are not expected to occur outside of the immediate area, nor is habitat loss expected (Neff et al. 2005). In addition, infrastructure emplacement, pipeline

trenching, and structure removal would be localized and temporary, and habitat loss is not expected.

4.6.4 Coastal Land Use and/or Modification

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 (though pipelines making landfall are not considered reasonably foreseeable) 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 land loss. Because 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. 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 the Federal Energy Regulatory Commission).

4.6.5 Offshore Habitat Modification and/or Space Use

Several activities, including drilling, coastal and offshore infrastructure emplacement, decommissioning, and OCS sand and gravel borrowing, could alter coastal and/or estuarine habitats (**Section 4.2**). Vessel traffic (e.g., from 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 from vessels, though speed restrictions are required (**Section 4.1.3** and **Table 4-3**) that can help reduce habitat loss and degradation. 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.

Construction, operation, and decommissioning activities on the OCS may be temporary or long-term. The placement or removal of infrastructure (e.g., pipelines) can create long-term alterations to the existing seascapes (i.e., the physical habitat) including seabed, water column, and/or sea surface habitats (Shams et al. 2023). However, these modifications, from activities such as decommissioning via structure removal, infrastructure and/or pipeline emplacement, G&G surveys, pile driving, and drilling, would likely be localized. Infrastructure and/or pipeline emplacement, including pipeline trenching and construction activities, are expected to create temporary effects (e.g., bottom disturbance, vessel traffic, noise) within the localized area of construction. Once structures have been constructed, long-term effects may include the presence of the structures during operations as well as any activities required for maintenance. The effects from construction, operation, and maintenance of infrastructure, including

pipelines, include air emissions and pollution; operational discharges and wastes; bottom disturbance; and noise.

Over time, decommissioning allows for the return of pre-construction conditions, providing a beneficial effect. Delayed decommissioning of structures and wells, and pipeline decommissioning-in-place, would provide no net positive or negative effect on sea turtles, though could provide a beneficial localized foraging source for some sea turtles. Considering operators are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements (**Section 4.1.2** and **Table 4-3**), the effects of these activities are expected to be localized and temporary, and long-term habitat modification or habitat loss is not expected.

4.6.6 Air Emissions and Pollution

Routine activities result in air emissions above the air-water interface, some of which are regulated by the OCSLA (**Section 4.1.2** and **Table 4-3**). 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 is scarce, measurements near Panama City, Florida (Hsu et al. 1980), show that the mixing height can vary between 400 and 1,300 m (1,312 and 4,265 ft), with a mean of 900 m (2,953 ft). 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. There is uncertainty about complex processes, such as pollutant transport and dispersion throughout the OCS, and the interactions between the land, air, and water surface are highly dynamic (Sullivan et al. 2023). However, though there are challenges in fully understanding complex coastal systems (Sullivan et al. 2023), available information indicates exposure to air pollutants would be minimal for sea turtles.

Due to stack height, exit gas velocity from the stack, distance of sea turtles from the sources, the temporary nature of vessel activity, and the atmospheric processes that transport regulated air pollutants upward, sea turtles are not generally vulnerable to OCS activity-related air emissions (Hsu et al. 1980; Barber et al. 1988; Han and Park 1988). Generally, air pollution would be expected to disperse quickly into the atmosphere. Further, due to diffusion and transport of air emissions well above the air-water interface (900-m [2,953-ft] mixing height), no detectable effects to sea turtles from air emissions (e.g., from vessel transits and operations, support helicopter use, pipelaying operations, flaring and venting, and decommissioning of facilities and pipelines) are expected.

4.6.7 Lighting and Visual Impacts

Ports, support facilities, construction facilities, transportation infrastructure, and processing facilities emit light onshore, which can affect sea turtles. Sea turtles in the Gulf may be affected 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. After they hatch, 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 (Witherington and Martin 2003; Silva et al. 2017). This is particularly important for the loggerhead sea turtle, which has critical reproductive habitat along the Gulf Coast (79 FR 73706; NMFS and FWS 2008), and the Kemp's ridley turtle, which also might use this coastal habitat for nesting (Valverde and Holzwart 2017).

OCS activities produce infrastructure presence and light emissions that can (1) create annoyance or interfere with activities; (2) contrast with, or detract from, the visual resources and/or the visual character of the existing environment; and (3) provide for human safety and security by illuminating dark areas. OCS structures typically have lights located 20 and 40 m (66 and 131 ft) above the water surface to illuminate the structure and the surrounding water to a depth of at least 100 to 200 m (328 to 656 ft), and can often be observed several miles away from the platform (Keenan et al. 2007). Artificial lighting from vessels conducting BOEM-regulated oil and gas activities will be localized, intermittent, and temporary within any one area. Several factors can affect light transmission in water, such as turbidity levels and waves, and the type of light can affect transmission distance and intensity. OCS lighting is not expected to affect free-swimming juveniles or adults and would be located too far away to disorient hatchlings. Due to OCS structures' (e.g., platforms) distances from nesting beaches, lighted structures are expected to be located too far way to disorient sea turtle hatchlings.

4.6.8 Seawater Use and/or Uptake

Any sea turtle could be exposed to seawater use and/or uptake activities during offshore development, oil production, and/or vessel and platform maintenance. Some sea turtles would be too large to be impinged or entrained by such activities and may be able to swim against the current of intake water. Coarse mesh may be used around the perimeter of an intake structure to prevent larger marine life, including sea turtles, from being trapped (USEPA 2006).

Sea turtles in the water column, where intake entrances are usually located, would likely be most vulnerable. Sea turtles near the seafloor would likely be less vulnerable, because they would be further distanced from water intake. Potential interactions between sea turtles and seawater use and/or uptake activities are expected to be highly localized and ephemeral; therefore, sea turtles are expected to experience no quantifiable effect or temporary effects from seawater use and/or uptake activities.

4.6.9 Accidental Events

4.6.9.1 Accidental Releases

Water quality contaminants could accidentally be released into the ocean as a result of human activity associated with the development of oil and gas structures, though they are subject to laws and regulations (**Section 4.1.2** and **Table 4-3**). Historical trends in the Gulf show that the frequency of oil spills has decreased substantially over the last two decades, and most spills are categorized as small in size (i.e., less than 1,000 bbl; Anderson and LaBelle 1990; Anderson et al. 2012; ABS Consulting Inc. 2016). Improvements in technology, industry practice, and regulations (**Section 4.1.2** and **Table 4-3**) have contributed in part to decreased spill risk. Catastrophic oil spills include high volume, high impact events, and are considered low probability. Though catastrophic oil spills are generally not considered reasonably foreseeable events, what is learned about the resulting effects on marine biota improves the body of knowledge of effects of oil in the marine environment. 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 Catastrophic Spill Event Analysis* (BOEM 2021).

The potential effects of an oil spill could vary depending on the spill magnitude, frequency, timing, location, and the meteorological and oceanographic conditions at the time (National Research Council 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. 2010; Shigenaka et al. 2010), and affinity to the *Sargassum* community for food and cover (Witherington et al. 2012). In general, an oil spill <1,000 bbl (42,000 gal) 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 spill of this size 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 larger 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 affected by contact with spilled oil (NPS 2010). During nesting, a female turtle might crawl through tar before 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 effects to embryos would depend on the type of oil and degree of weathering, type of beach substrate, and especially on 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 effects. Fritts and McGehee (1982) concluded that oil contamination of nesting

beaches would have its greatest effect 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 affected. 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 coming in contact with 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 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 may pursue and swallow tarballs; 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 effect 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; 1995). Kemp's ridley sea turtles were studied to characterize the adrenocortical and thyroid status of those affected by the *Deepwater Horizon* oil spill (Innis et al. 2024). The study results indicated elevated plasma concentrations, confirming that aldosterone can serve as a reliable marker in sea turtle plasma samples (Innis et al. 2024). Aldosterone concentrations have been found to correlate positively with glucocorticoid concentrations and increase in response to stressors. 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 are not fully understood; 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 effects, such as salt gland disruption or liver impairment (Vargo et al. 1986; Lutz and Lutcavage 1989; Camacho et al. 2012). 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, effects would occur as a result of contact with the spilled oil, regardless of the source. Oil could affect sea turtles through various pathways, including direct contact, inhalation of 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. Operators are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements, such as the National Contingency Plans (40 CFR part 300) (**Section 4.1.2** and **Table 4-3**), which provide effective control and containment, and would be expected to limit the volume and area of exposure.

4.6.9.2 Release Response

Ultimately, and only when deemed necessary, the removal methods used during any spill will be determined by the USCG's Federal On-Scene Coordinator (FOSC) and representatives of the Regional Response Team (RRT) or National Response Team (NRT); therefore, accidental event response activities would be conducted on a case-by-case basis, and not by BOEM or BSEE. Response efforts are unlikely for spills <1,000 bbl (42,000 gal) given that they dissipate, evaporate, weather, and biodegrade rapidly. Depending on the size, spills >1,000 bbl (42,000 gal) may dissipate, weather, and degrade before response efforts are necessary. Response efforts are more likely for spills >10,000 bbl (420,000 gal).

Aspects of spill response 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 (**Section 4.1.2** and **Table 4-3**).

Spill-response activities could adversely affect sea turtle habitat and cause temporary displacement from suitable habitat. Potential effects to sea turtles or their habitats are likely to increase with spill size (i.e., volume). 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 cause an increase in vessel traffic, and thus, an increased possibility for vessel strikes.

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, short-term behavioral effects, such as altered diving patterns and abnormal basking, may occur in the immediate affected area. Spill-response effects 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 (Shigenaka et al. 2010). 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.

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 or oil mixture 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 effects are likely similar to the empirically demonstrated effects of oil alone (Hoff and Shigenaka 2003). The effects to sea turtles from chemical dispersants could include nonlethal injury (e.g., tissue irritation, chemical burns, and respiratory effects), long-term exposure through bioaccumulation, infection, and potential shifts in distribution from some habitat (NOAA 2010; Shigenaka et al. 2010).

Larger neritic sea turtles are not expected to have the same probability of exposure to dispersants as turtles found in offshore habitats (Ylitalo et al. 2017). Laboratory studies have demonstrated increased rates of dispersant degradation in surface water conditions with more light and increased temperatures compared to those in deep water conditions with reduced temperature and light (Ylitalo et al. 2017). Effects of dispersants on sea turtles largely depends on the location of the spill, location of turtles, and the environmental conditions in those areas. Surface-pelagic juvenile turtles exposed to dispersants are expected to have minimal to no detectable effects due to dispersant degradation, depending on the timing of the dispersant application and occurrence of turtles in the region (Ylitalo et al. 2017).

4.6.9.3 Marine Trash and Debris

The oil and gas industry makes up only a small part of marine trash and debris sources. Marine trash and debris could accidentally be released into the ocean as a result of human activity associated with the development of oil and gas structures. Possible marine debris from OCS oil and gas-related facilities include gloves, various plastics (from packaging, etc.), light bulbs, oil and gas containers, pipe thread protectors, rope, and floats and buoys. Accidental releases of marine trash and debris into the environment could result in localized effects that are not expected to occur outside of the immediate area.

Marine debris affects habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking) (Gall and Thompson 2015; Senko et al. 2020). Entanglement in marine debris could lead to injury, infection, reduced mobility, increased susceptibility to predation, decreased feeding ability, fitness consequences, and/or mortality (e.g., drowning) of sea turtles (Gall and Thompson 2015; Senko et al. 2020). Ingestion of marine debris could lead to intestinal blockage, which can affect feeding ability and lead to injury or death (Gall and Thompson 2015; Senko et al. 2020). Adherence to regulatory requirements and mitigative measures designed to prevent or substantially reduce accidental marine trash and debris, would prevent or minimize sea turtle interactions with marine trash and debris (**Sections 4.1.2** and **4.1.3** and **Table 4-3**). For additional information on general sea turtle vulnerability to marine trash and debris, see **Section 3.6.8.7**.

4.6.9.4 Strikes and Collisions

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). 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/h (2.5 mph), which is common in open water (Hazel et al. 2007; Work et al. 2010). For instance, though 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 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.

Little data is available about potential sea turtle effects 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 Gulf (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 Gulf 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 no apparent effects, serious injury, and/or minor, nonlethal 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 Gulf; however, collisions with small or submerged sea turtles

may go undetected. Mitigative measures (e.g., use of observers, separation distances) could prevent or minimize sea turtle interactions with transiting vessels. (**Sections 4.1.2** and **4.1.3** and **Table 4-3**). For more information about general sea turtle vulnerability to vessel strikes, see **Section 3.6.8.4**.

4.6.9.5 Entanglement and Entrapment

While oil- and gas-related construction, operations, and decommissioning activities are being conducted, sea turtles can be exposed to entanglement and entrapment risks from diving activities, site-clearance trawling activities, or when moon pools are used during diving activities or drilling operations. Sea turtles can become incidentally entrapped in moon pools or entangled in lines during operations. Depending on the type of biological survey activities, sea turtles could be injured or drowned. If entanglement occurs, effects to sea turtles can occur, potentially causing stress, physical injury, or death. Mitigation measures (e.g., requiring lines to remain taut, maintaining line tenders on duty throughout operations, using tensioning tools to reduce line looping) could prevent or minimize sea turtle interactions with entanglement and entrapment risks (**Sections 4.1.2** and **4.1.3** and **Table 4-3**). For more information on general sea turtle vulnerability to entanglement and entrapment, see **Section 3.6.8**.

4.7 Marine Mammals

4.7.1 Noise

For information on marine mammal bioacoustics, see **Section 3.7.5**, and **Figure 4-1** for approximate hearing ranges of marine mammals and frequency ranges of various common anthropogenic sources. As applicable, discussion of marine mammals outside of the Gulf is included as a proxy for Gulf marine mammals, representing the best available information at this time.

4.7.1.1 Seismic Surveys (Airguns)

Seismic surveys can cover large swaths of the ocean and represent a mobile sound source that regularly emits high-energy pulses into the marine environment. This can be particularly impactful for populations with high fidelity in a given area, especially during ecologically important times, such as feeding, mating, or calving. It may also come at a high energetic cost to animals migrating through an area.

The potential effects of airgun noise on marine mammals include physical injury, physiological effects, behavioral disruption, and acoustic masking. Depending on the specifics of the survey, behavioral effects and acoustic masking may occur on the scale of tens of kilometers from the survey vessel. Because auditory injury thresholds vary with hearing group, the scale at which auditory injury could occur ranges from several kilometers (miles) for low-frequency cetaceans (LFC), to <50 m (164 ft) for high-frequency cetaceans (HFC) and very-high frequency cetaceans (VHFC). Airgun noise may also harm marine mammals indirectly if there are changes to the

distribution and abundance of their prey within key foraging grounds. For information about effects on prey species, see **Section 4.5.1** (fish and invertebrates). Decades of research have been conducted since the 1980s on the potential effects of airgun noise on marine mammals (Richardson et al. 1986; Ljungblad et al. 1988; McCauley et al. 1998; Gordon et al. 2003; Johnson et al. 2007; Affatati and Camerlenghi 2023). Though much of that is summarized here as it relates to species or similar species as those found in the Gulf, the reader is encouraged to read the many review papers on the subject for further details.

Though injury is possible, an animal must be very close to a seismic airgun survey to be exposed to injurious sound levels. Because marine mammals are mobile, they are likely to move away from a sound before sufficient duration has passed to cause auditory injury or TTS. Mitigations (e.g., ramp-up procedure, use of observers, shutdown zones) could prevent or minimize these effects (**Section 4.1.2** and **4.1.3** and **Table 4-3**).

Physiological responses are also possible and more likely than auditory injury, although difficult to study in the wild. Williams et al. (2022) monitored the cardiovascular, respiratory, and locomotor responses of narwhals (n=2), toothed whales, during seismic survey activities. The animals' heart rates switched between bradycardia (excessively slow heart rate) and tachycardia (excessively fast heart rate) during exposure, while simultaneously reducing their glide duration and increasing their stroke frequency, all of which was represented in a more than doubling in the energetic cost of a dive. Prolonged exposure can lead to more serious consequences, such as physiological instability and potentially some of the injuries previously described.

The most likely and well-studied effects to marine mammals from seismic surveys are behavioral. Many studies have been conducted over the last 40 years, provide insight about the effects of airgun surveys on marine mammals, and are organized here by the behavioral state under study. Based on the evidence available, which is summarized below, there is a wide range of behavioral responses by marine mammals to seismic surveys.

Gross movement

Many early studies focused on assessing the potential for a gross change in behavior of marine mammals in response to seismic surveys. Baleen whales were documented initiating avoidance behaviors to full-scale seismic surveys at distances of less than 10 km (6.2 mi) (Richardson et al. 1986; Ljungblad et al. 1988; McCauley et al. 1998; Johnson et al. 2007) and as far away as 20 km (12.4 mi) (Richardson et al. 1999). Yazvenko et al. (2007a) found limited redistribution of gray whales during a full seismic survey (i.e., 2–4 fewer observed whales) when sound energy was highest. However, the total animals observed in the area remained stable throughout the survey period, with no sudden flight reaction from the animals to the seismic survey. In a different study, fin whales moved away from a seismic survey during the first 72 hours of a 10-day seismic survey, the displacement persisting well beyond the seismic survey (Castellote et al. 2012).

Another study found that sperm whales in the Gulf previously observed in an area being surveyed were found only on the periphery of the survey area after two days of survey, and only observed at a range of 60 km (37 mi) after 5 days of activity in the area (Mate et al. 1994). In an assessment of Gulf protected species observer data, Barkaszi and Kelly (2019) found evidence that, for whales (with sperm whales driving much of the data) and dolphins, the closest point of approach to airguns were significantly farther during full-power operations than during silence, indicating that there may be some avoidance response to the full-power operations. Many of the previously mentioned studies were opportunistic as opposed to experimentally controlled; therefore, confounding factors such as the presence or noise of the survey vessel, or movement of prey were not necessarily observed or accounted for but may have a substantial role in the variability of response by the animals.

Migration

In a comprehensive series of behavioral response studies built upon one another, Dunlop et al. (2016) evaluated a range of airgun arrays on the behavior of migrating humpback whales in order to develop a dose response curve for humpback whale to seismic survey noise. In one study, the researchers found that when the seismic vessel towing a 20 in^3 airgun was in the migratory path of the humpback whales, the animals decreased their dive time and speed of southward movement (Dunlop et al. 2015). Dunlop et al. (2016) found that ramping up the airgun made no difference in comparison to the full power source and that, regardless, animals avoided the survey vessel at greater distances than the mitigation zone. During seismic surveys with a 3,130 in^3 array, Dunlop et al. (2017a) found changes in respiration rate and southward migration speed when animals were within 4 km (2.5 mi) of the survey vessel or a received SEL of 135 dB re 1 mPa^2 s. The team conducted a series of dose-response assessments (Dunlop et al. 2017b; 2018) and found that when including single airguns, small array, and commercial array data, there was a 50 percent probability of response at received levels of 150 dB re 1 mPa^2 s when an animal was within 2.5 km (1.6 mi) of the airgun source (Dunlop et al. 2018). The overall conclusion from these studies was that changes in movement were small and temporary, and likely in part attributed to vessel presence.

However, there may be differences in vulnerability to underwater sound based on life stage. For example, a lactating female may suffer greater energy deficits from such disturbances during migration than other demographics. Kavanagh et al. (2016) remarked that observed behavioral responses were not always attributed to the exposure to the seismic surveys, and that the water depth and other environmental conditions played a role in their responses. McCauley et al. (2000) also found that migrating humpback whales avoided a seismic survey vessel at 4 km (2.5 mi), while resting humpbacks avoided the vessel at a distance of 7–12 km (4.3–7.5 mi).

Social behavior and acoustic behavior

Though effects on humpback whale movement were observed within 4 km (2.5 mi) of a survey, Dunlop et al. (2020) also found changes in social behavior beyond 4 km (2.5 mi), mainly, a 50 percent reduction in joining behavior (i.e., joining in breeding vocalizations) at approximately

7.5 km (4.7 mi) and a reduction to 0–20 percent at 2 km (1.2 mi) from the vessel. They found that there was not a relationship between the magnitude of response and airgun size or received level, and ramping up the airgun was not useful in mitigating the disruption to social behavior. Dunlop et al. (2020) speculated that the longer than expected range of airgun noise effects on social behavior in humpback whales was likely attributed in part to masking of communication signals. In another study of humpback whales, Cerchio et al. (2014) found there was a significant decrease in the number of humpback whales singing (a breeding display) due to increasing received levels associated with a seismic survey.

Similar changes in vocalizations have been seen across other baleen whale species. McDonald et al. (1995) observed that blue whales stopped singing within a 10 km (6.2 mi) radius of a seismic survey. In another set of studies, the call rates of bowhead whales during autumn migration were compared before, during, and after airgun use at sites near (45 km; 30 mi) and distant (>104 km; 65 mi) to the activities. Call rates dropped at the nearby sites when received levels were between 116–129 dB re 1 µPa (10–450 Hz) but not at distant sites where received levels were 99–108 dB re 1 µPa (Blackwell et al. 2013).

In a subsequent study to investigate whether the calls decreased due to a cessation of calling or the animals moved away, vocalizations were recorded at five sites at varying distances from a seismic survey with a 3,147 in^3 24-gun array (Blackwell et al. 2015). Bowhead whales increased their calling rates as the cumulative SEL increased up to around 94 dB re 1 μPa^2s when call rates leveled off, decreased when cumulative SEL exceeded 127 dB re 1 μPa^2s, and calling ceased altogether when sound levels were above 160 dB re 1 μPa^2s. Thode et al. (2020) reported similar findings of cessation when sound levels were excessive. Blackwell et al. (2015) also found that calling rates were 5–6 times higher at the farthest recording site than at sites closer to the survey, indicating that the animals decreased their call rates when in proximity to seismic operations. Notably, there was no significant change in calling rate for shallow hazard surveys using an airgun with volumes up to 880 in^3 (Blackwell et al. 2015). The risk for complete masking is low relative to continuous sounds (e.g., ship noise) due to the duty cycle of the airgun signal (approximately 6–10 percent, or a 1-second signal every 10–15 seconds). However, as evidenced here, it may cause animals to change their call or song characteristics to compensate for the partial loss of communication space.

Fine-scale movement behavior

From 2002 to 2005, the Sperm Whale Seismic Study was a multiyear controlled exposure experiment seeking to understand the potential effects of seismic airgun survey noise on the behavior of eight sperm whales by monitoring their diving, swimming, and vocalization behaviors using D-tags (Jochens et al. 2008). While emphasizing limited statistical power due to low sample size, the study revealed that sperm whales do not avoid airgun arrays during ramp ups at a distance of 7.3–12.5 km (4.5–7.8 mi) or full power operations at a distance of 1–12 km (0.6–7.5 mi) and received sound levels up to 167 dB re 1 µPa peak-to-peak or SPL of 147 dB re 1 µPa (Madsen et al. 2006; Jiménez-Arranz et al. 2020). Only one of eight tagged animals exhibited a change in their dive pattern behavior, resting at the surface for four hours during

the survey (Miller et al. 2009). This discrepancy highlights the need to have a robust sample size to capture the inherent variability in marine mammal behavior. Swimming pitch during foraging dives was 6 percent lower during exposure, though not statistically significant (Miller et al. 2009). Jochens et al. (2008) concludes that there were no biologically significant effects of seismic activities on sperm whales, but due to the limited sample size and exposure sound levels this cannot be viewed as conclusive.

Comprehensive visual and acoustic monitoring was conducted during a seismic survey with three vessels each towing two 2,400 in^3 airgun arrays to minimize exposure of gray whales to sound levels exceeding the behavioral impact threshold (Aerts et al. 2022; Rutenko et al. 2022). Mitigation was imposed based on comprehensive real-time monitoring; however, behavioral and respiratory responses were not entirely eliminated (Gailey et al. 2022). As cumulative SEL increased, respiration intervals decreased, dive times decreased, and animals spent less time at the surface. The movement of whales also changed with increasing cumulative SEL, with whales appearing to avoid the survey vessel by moving closer to shore, moving perpendicularly to the vessel, and changing their speed. It is worth noting that the primary factors that predicted the whales' behaviors and respiration responses were their current behavioral state and the water depth, rather than the anthropogenic activity.

Baleen whales are not the only species observed moving closer to shore in response to a seismic survey. Heide-Jørgensen et al. (2021) observed narwhals moving toward the shore as sound levels increased at a range of 10–15 km (6.2–9.3 mi). They also found that narwhals increased their horizontal speed by 30 percent up to 2 hours before the survey vessel was in sight, changing their swimming speed and direction at distances between 5 and 24 km (3.1 and 15 mi). Avoidance reactions to the airgun were detected at a range of >5 and >11 km (>3.1 and >6.8 mi) from the seismic vessel for a 207 in^3 airgun and 1,040 in^3 airgun array, respectively.

Feeding

Researchers have observed the responses of feeding gray whales to a 100 in^3 airgun, and found that there was a 50 percent probability that the whales would stop feeding and move away from the area when the received levels reached 173 dB re 1 µPa SPL (Malme et al. 1986). However, Yazvenko et al. (2007b) found no change in feeding activity of western gray whales off Sakhalin Island, Russia (<50 m; 164 ft water depth) during a 3-D seismic survey overlapping their foraging grounds. In a study of the effects of airgun noise on narwhals, Tervo et al. (2021) found a 50 percent reduction in narwhal buzz rates when an operational airgun vessel was 12 km (7.5 mi) from the whales, and foraging ceased altogether when animals were 7–8 km (4.3–5 mi) from the vessel. Miller et al. (2009) found sperm whale buzz rates—a proxy for capturing prey—were 19 percent lower during airgun surveys, though not statistically significant.

Overall conclusions regarding airgun effects on marine mammal behavior

It is worth reiterating the opportunistic nature of many of these studies, which present many confounding factors (e.g., presence of the survey vessel, the movement of prey) that cannot necessarily be ruled out as the potential cause, or at least a contributing factor, to the

responses observed. In addition, there are environmental factors that appear to have a significant and potentially greater role in the variable behavior observed in individuals than the seismic activity. Also, there are many interacting contextual and animal-specific factors that play a role in the possible response of a marine mammal to airgun noise.

What these studies reveal is that there is a lot of variability in marine mammal responses and it is highly dependent on the species, context, environmental conditions, and exposure scenario. Though there is not a clear correlation with received level, behavioral effects are consistently seen at much longer ranges than those predicted based on the NMFS behavioral threshold alone. Although certain species groups appear to be more susceptible to low-frequency noise (i.e., LFC), based on the significant overlap in the frequency of the sound source and the frequency range of best hearing, the decades of studies on the subject suggest that at least some species in all hearing groups appear vulnerable to behavioral disturbance from airgun noise. It is not always evident whether these effects will have biologically meaningful effects on the individual or population.

In addition, the response strategy may vary across taxa, with some species leaving a disturbed area, where others stay. In these cases, it is important to note that not all effects may be visible or audible, because an animal constantly exposed to noise may appear to behave normally but could be experiencing chronic stress. This potential phenomenon is not well understood because stress physiology studies are difficult to perform in the wild and may also be affected by sampling bias (i.e., the mere sampling of biomarkers may induce stress in an animal).

All other things equal, disturbance may be more costly to an animal that is resident or resting in an area with a longer window of exposure compared to an animal traveling through an area. Disruption to certain behaviors may come with a greater energetic cost such as when an animal is migrating or foraging. Disturbances to certain demographics may be more energetically costly, such as to a lactating or pregnant female.

4.7.1.2 High-Resolution Geophysical Surveys

Smaller-scale, higher-resolution geophysical surveys are not typically used to identify oil and gas resources, but rather to identify shallow-water hazards and/or to image the immediate subsurface for the purposes of offshore construction and marine minerals exploration. A description of the physical qualities of geophysical sound sources can be found in **Appendix B** and BOEM's Sound Source List (Center for Marine Acoustics 2023). BOEM and USGS characterized underwater sounds produced by HRG sources and their potential to result in incidental take of marine mammals (i.e., behavioral effects) (Ruppel et al. 2022).

Because of several key physical characteristics of the sound sources—including source level, frequency range, duty cycle, and beamwidth—Ruppel et al. (2022) concluded that most HRG sources, even without mitigation, are unlikely to result in substantial behavioral disturbances, which is generally consistent with field observations. For example, Vires (2011) found no change in Blainville's beaked whale click durations before, during, and after a scientific survey

with a 38 kHz EK-60 scientific echosounder; Quick et al. (2017) found that short-finned pilot whales did not change foraging behavior but did increase their heading variance during use of an EK-60; and Cholewiak et al. (2017) found a decrease in beaked whale echolocation clicks during use of an EK 60. Kates Varghese et al. (2020) found no change in three of four beaked whale foraging behavior metrics (i.e., number of foraging clicks, foraging event duration, click rate) during two deepwater mapping surveys using a 12 kHz multibeam echosounder. There was an increase in the number of foraging events during one of the mapping surveys, but this trend continued after the survey ended, suggesting that the change was more likely in response to another factor, such as prey availability, than to the mapping survey. During both multibeam mapping surveys, foraging continued in the survey area and the animals did not leave the area (Kates Varghese et al. 2020; Kates Varghese et al. 2021). For some of the higher-amplitude sources, such as bubble guns, some boomers, and the highest-power sparkers, Ruppel et al. (2022) concluded that behavioral disturbance is possible, but would be unlikely if mitigation measures (**Section 4.1.2** and **4.1.3** and **Table 4-3**), such as pre-start clearance and shutdowns, are applied (Ruppel et al. 2022).

4.7.1.3 Geotechnical Surveys

Geotechnical surveys may introduce low-level (i.e., <160 dB re 1 µPa·m source level), intermittent, broadband noise into the marine environment. These sounds could result in acoustic masking in LFC or HFC, but are unlikely to result in behavioral disturbance given their low source levels and intermittent use. Behavioral disturbance or masking may occur in more sensitive species such as beaked whales and species with a hearing range that directly overlaps the sound sources, specifically HFC and VHFC.

4.7.1.4 Dredging

Because of the low source levels and transitory nature of dredging sources, exceedance of auditory injury thresholds is unlikely, but TTS and behavioral thresholds could be exceeded (Todd et al. 2015). For example, using measurements of the highest source level from multiple dredging vessel operations, Heinis et al. (2013) modeled harbor porpoise and seal exposure to a dredging operation. They found that TTS levels would not be exceeded for harbor porpoise at any distance and would be exceeded only for seals at distances within 90 m (295 ft) of the dredging vessel.

Empirical studies suggest that some HFC may avoid dredging activities. Pirotta et al. (2013) found that, despite a documented tolerance of high vessel presence, as well as high availability of food, bottlenose dolphins spent less time in the area during periods of dredging. The study also showed that with increasing intensity in the activity, bottlenose dolphins avoided the area for longer durations, with one instance being as long as 5 weeks (Pirotta et al. 2013).

Todd et al. (2015) provide an extensive review of the effects of dredging on marine mammals. Several studies showed temporary to long-term avoidance behavior for bowhead, gray, humpback, and minke whales (Richardson et al. 1990; Borggaard et al. 1999; Tyack 2008;

Anderwald et al. 2013; Todd et al. 2015). For example, gray and humpback whales seem to avoid certain areas, even key breeding habitats, when dredging is occurring (Borggaard et al. 1999; Tyack 2008). These studies suggest that dredging does not produce sounds sufficient enough to cause permanent hearing injuries, but at close ranges the sounds are at levels that have the potential to cause behavioral disturbance or temporary hearing impairment to marine mammals.

Though behavioral responses may occur from site preparation activities, they are expected to be short-term and of low intensity. Masking and behavioral reactions from dredging may be more likely for baleen whales because of the low-frequency spectrum over which the sounds occur and the overlap with their hearing sensitivity.

4.7.1.5 Drilling and Production

See **Appendix B** for a description of drilling-related noise. Research suggests that the sensitivity of marine mammals to drilling noise varies among and within species and is likely context dependent (Richardson et al. 1990). Early studies on small odontocetes indicate relatively high tolerance under many conditions. During operations in the Scotian Basin, baleen whales, odontocetes, and porpoises continued to be detected at 2–20 km from a mobile offshore drilling unit (MODU) with no evidence of displacement, though masking of low-frequency baleen whale calls occurred intermittently near the rig (Martin et al. 2019).

Most studies on baleen whale behavioral responses to drilling noise have been conducted on Arctic species in the context of oil and gas extraction; these studies are currently the best available proxies. Baleen whale responses, particularly among bowhead whales in Arctic regions, tend to be stronger and more variable, influenced by migration context, ice cover, and received sound levels. Bowhead whales have been observed diverting migration paths by approximately 10 km (6.2 mi) around an operating drillship, with some individuals maintaining distances of 15–30 km (9.3–18.6 mi) away (Richardson et al. 1995). Richardson et al. (1990) performed playback experiments of drilling and dredging noises and observed bowhead whale responses. Behavioral reactions were observed for most of the animals, such as reorientation, temporary cessation of feeding, and altered surfacing and diving patterns (Richardson et al. 1990). Roughly half of the bowhead whales responded to the drilling noise playback at a received level of 115 dB re 1 µPa (20–1000 Hz band) (Richardson et al. 1990). However, substantial variability exists. During spring migration in heavy ice, some bowheads passed within 100–500 m of drilling noise without interruption, while others, particularly mothers with calves, showed avoidance at lower levels (Richardson et al. 1990). Blackwell et al. (2017) reported that bowhead whale calling rates were correlated with increasing levels of drilling noise, where calling rates initially increased, peaked, and then decreased. Though such behavioral responses may result from offshore drilling, they are expected to be short-term.

More recent monitoring in other regions has revealed mixed responses. During exploratory drilling in Flemish Pass, detections of blue whales, fin whales, harbor porpoises, and pilot whales declined within 2–5 km of a MODU using DP (interpreted as short range avoidance or

reduced calling) and sound levels intermittently exceeded TTS thresholds for animals remaining within approximately 2 km (Delarue et al. 2021). However, detections at ≥ 32 km remained unchanged (Delarue et al. 2021). The authors concluded that drilling noise can cause localized avoidance, temporary hearing effects, and significant masking of low-frequency communication space within a few kilometers of the MODU, but did not find evidence for population-level displacement or long-term distribution changes at larger spatial scales (Delarue et al. 2021).

Acoustic modeling of exploratory drilling in East Asia similarly indicates low risk of hearing impairment beyond approximately 40 m but potential behavioral disturbance out to approximately 1.9 km, with reduced cetacean and pinniped communication space (Huang et al. 2023). Conversely, monitoring during 2012 exploratory drilling in the Chukchi and Beaufort Seas reported largely neutral or mild reactions from cetaceans and pinnipeds, with limited avoidance and no evidence of large-scale displacement despite persistent drilling and support vessel noise (Bisson et al. 2013). Overall, these studies show that baleen whales can exhibit avoidance, reduced calling, or altered behavior within a few to tens of kilometers of drilling, particularly in quiet environments or during sensitive migratory periods, while broader-scale displacement has rarely been documented. Many individuals appear to tolerate or habituate to drilling noise when migration routes or foraging needs constrain movement. Behavioral responses to drilling are therefore best characterized as highly context dependent, typically localized, and generally of short duration relative to the activity.

4.7.1.6 Vessels and Dynamic Positioning (DP) Systems

For a description of the physical qualities of vessel noise and DP systems, see **Appendix B**. Underwater radiated noise from small vessels (e.g., for crew transport) and larger vessels (e.g., oil tankers) may have effects on marine mammals in the area. These mobile sound sources would temporarily ensonify an area as the vessel passes through. A summary of the general effects of vessel noise on marine mammals can be found in **Section 3.7.6.1**.

DP systems may be used to keep large vessels in place during construction, drilling, or production. This is considered a fixed sound source that would ensonify an area during the entire duration of the activity. Note that the specific effects of DP noise on marine mammals have not been studied. Behavioral reactions are expected to occur over a wide spectrum of responses, some of which may be discountable; other behavioral responses can possibly result in disturbance.

4.7.1.7 Trenching and Pipeline Laying

Preparing an area for pipeline laying or cable laying may require jetting, plowing, or removal of soft sediments. Installation vessels are likely to use DP systems while laying the cables or pipeline. The sound associated with DP generally dominates other sound sources present especially in the situation of cable laying or pipeline laying. A description of the physical qualities of these sound sources can be found in **Appendix B**. Though no research has explicitly

examined the effects of pipeline- and cable-laying noise on marine mammals, effects are expected to be relatively low due to the low intensity and localized nature of the sound source.

4.7.1.8 Pile Driving

Impact pile driving is used to install ocean infrastructure. For a description of the physical qualities of pile driving noise, see **Appendix B**. Pile driving noise has the potential to affect all marine mammal functional hearing groups in the area. For marine mammals, and, depending on several factors, pile driving could result in auditory injury, TTS, behavioral disturbance, and masking (Würsig et al. 2000a; Graham et al. 2017). Based on the size of the piles typically associated with oil and gas infrastructure, it is unlikely that noise would cause auditory injury or TTS, but there could be some behavioral effects or acoustic masking. The majority of research on pile driving noise has focused on large piles (e.g., several meters (feet) in diameter) and HFC (Carstensen et al. 2006; Dähne et al. 2013; Haelters et al. 2015; Kastelein et al. 2018; Graham et al. 2019).

The most commonly observed behavioral effect of pile driving activity on marine mammals has been short-term avoidance or displacement from the pile driving site, such as with Indo-Pacific humpback dolphins (Würsig et al. 2000b). In addition to displaying avoidance behaviors, dolphin foraging success during pile driving was shown to be related to prey density, and an interaction between prey density and received level (Branstetter et al. 2018). There is currently no data on the potential effects from pile driving noise on baleen whales but, considering the overlap in frequency content with their vocalizations (mostly below 1 kHz), they would be most susceptible to acoustic masking. In addition, low-frequency sound can propagate greater distances than higher frequencies, meaning masking may occur over larger distances than masking related to higher-frequency noise. When masking cannot be avoided, increasing noise could interfere with locating and communicating with other individuals.

Overall, it is reasonable to assume that there would be greater effects to LFC (i.e., baleen whales) than other species groups, even though direct research on pile driving noise on baleen whales is limited. LFC are more likely to experience acoustic masking of communication signals from pile driving than other species due to the overlapping frequency content of their vocalizations with the acoustic energy from pile driving, which is mostly below 1 kHz. Because that pile driving occurs intermittently, with some quiet periods between pile-strikes, it is unlikely that complete masking would occur with impact pile driving. Based on the evidence in the literature, HFC and VHFC are likely to avoid areas where pile driving is taking place. In addition, mitigative measures (e.g., visual monitoring, and pre-clearance, soft start, and shutdown procedures) could prevent or minimize potential effects to marine mammals from pile driving noise (**Section 4.1.2** and **4.1.3** and **Table 4-3**).

4.7.1.9 Decommissioning

For a physical description of underwater explosives and mechanical cutting, which are two potential methods that could be used for decommissioning, see **Appendix B**. Underwater

explosions create shock waves characterized by extreme changes in pressure, which can cause injury and mortality to animals, depending on how close it is to the blast. To predict the potential effects of underwater explosives on marine species, several models have been developed. Goertner (1982) developed a model for physical injuries to cetaceans at a range of depths; a modified version of this model is recommended by NMFS for predicting injury impacts to marine mammals (NMFS 2024a). The physical range at which injury or mortality could occur will vary based on the amount of explosive material used, size of the animal, and the location of the animal relative to the explosive. Injuries may include hemorrhage or damage to the lungs, liver, brain, or ears, as well as auditory impairment such as PTS and TTS (Ketten 2004). Smaller animals are generally at a higher risk of blast injuries.

Behavioral effects are possible out to further ranges, but because an explosion is ephemeral, behavioral effects are expected to be short term, challenging to observe, and of less concern compared to potential injury and mortality effects. Todd et al. (1996) observed humpback whales near underwater explosions and did not note any overt behavioral changes (e.g., changing course, abrupt dive behavior, etc.) within 1.83 km (1.1 mi) from the blast, at received peak pressures of 123 dB re 1 µPa. They saw no overall trend in humpback whale movements during the month when intermittent blasting was taking place.

Mitigative measures could prevent or decrease marine mammal exposure to potential risks from explosive severance (**Section 4.1.2** and **4.1.3** and **Table 4-3**). For example, visual and passive acoustic monitoring of impact zones can be used to ensure the detonation does not occur until there are no animals detected.

4.7.1.10 Aircraft

Offshore activities may employ helicopters and fixed-wing aircraft for transporting construction and/or maintenance crew. A description of the physical qualities of aircraft noise can be found in **Appendix B**. In general, marine mammal behavioral responses to aircraft have most commonly been observed at altitudes of less than 150 m (492 ft) from the aircraft (Patenaude et al. 2002; Smultea et al. 2008). Aircraft operations have resulted in temporary behavioral responses, including short surface durations (bowhead and beluga whales - Patenaude et al. 2002; transient sperm whales - Richter et al. 2006), abrupt dives (sperm whales - Smultea et al. 2008), and percussive behaviors (i.e., breaching and tail slapping, Patenaude et al. 2002). Responses appear to be heavily dependent on the behavioral state of the animal, with the strongest reactions seen in resting individuals (Würsig et al. 1998). In addition, based on the physics of sound propagation across different media (e.g., air and water), only a small portion of the acoustic energy from aircraft operations couples into the water.

The FAA regulates helicopter flight patterns. Guidelines and regulations issued by NMFS under the authority of the MMPA include provisions specifying helicopter pilots to maintain an altitude of 305 m (1,000 ft) within 91 m (299 ft) of marine mammals (**Section 4.1.2** and **Table 4-3**). The FAA's Advisory Circular 91 36D (2004) encourages pilots to maintain higher than minimum altitudes (i.e., higher than 610 m [2,000 ft]) over noise-sensitive areas. Corporate

helicopter policy states that helicopters should maintain a minimum altitude of 229 m (750 ft) while in transit offshore and 152 m (500 ft) while working between platforms and drilling rigs (Helicopter Safety Advisory Conference 2010).

4.7.2 Discharges and Wastes

Pollutants discharged into navigable waters of the U.S. are regulated by the USEPA under the CWA 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 CWA of 1972 (45 FR 65942). 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 marine mammals from being affected by produced water, drilling muds, and cuttings (**Section 4.1.2** and **Table 4-3**). These discharges are not expected to persist in the water column. Due to the localized and transient nature of the water quality effects, 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 so are not expected to directly or indirectly affect (Kennicutt II 1995) or have any detectable effect on marine mammals.

BSEE, USCG, and USEPA regulations, and BOEM guidance would be followed by oil and gas operators. For example, 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 operational discharges and wastes will be released into the marine environment, and negative effects are expected to be avoided. See **Section 4.1.2** and **Table 4-3** for more information about regulatory requirements pertaining to operational discharges and wastes.

4.7.3 Bottom Disturbance

The majority of the benthos in the Gulf is soft-bottom sediments. Rarer hard bottom and live bottom habitats, which may provide habitat and/or prey for some marine mammals, have a more limited distribution and are expected to be protected through routinely applied mitigations (**Section 4.1.2** and **4.1.3** and **Table 4-3**). Distancing of bottom-disturbing activity from sensitive benthos is expected through mitigations. Bottom disturbance is expected to be limited to ubiquitous, soft sediment habitat type, and any affected seabed would not constitute unique or unusual habitat (**Section 4.4.3**). Bottom-disturbing activities could destroy benthic habitat (e.g., hard bottom and/or SAV) (Neff 2005; Continental Shelf Associates Inc. 2006) that some marine mammals, such as Rice's whales or sperm whales, may depend on for feeding. However, the likelihood for any substantial portion of any marine mammal population to forage repeatedly around structures while disturbances are occurring would be very low given species distribution. Further, the benthic habitats used by the Florida manatee are in coastal, inland waters, which would not be within typical locations for BOEM-regulated activities.

The removal of infrastructure can create disturbances similar to those created by infrastructure installation. It can result in bottom disturbance creating turbidity in the water column, which may affect prey availability and foraging efforts for some marine mammals if the water conditions persist. Where practicable, mechanical removal and severance avoids the potential harm caused by the use of explosives to marine mammals (Bull and Love 2019). Routine structure-removal activities—such as support vessel and barge anchoring, pre-severing operations (e.g., jetting around legs of the structure), severing operations (e.g., explosive and nonexplosive severing of the structure), post-severing operations (e.g., standard or sectioned lift and load of structure), site-clearance activities (e.g., trawling), and reefing of portions of the removed structure—could all contribute to localized bottom disturbance. In addition, bottom disturbance from activities such as dredging, G&G surveys, infrastructure and anchor emplacement, drilling, and seafloor sampling could all contribute to localized bottom disturbance. Any associated turbidity effects would be localized and temporary. Permanent habitat loss or long-term modification other than under the footprint of emplaced structures would not be expected. Sediment disturbance would occur on a limited area of seafloor over a time period of less than a week to about a month for the most extensive removal projects (MMS 2005). Drilling would be localized and effects are not expected to occur outside of the immediate area. In addition, bottom disturbance from dredging, infrastructure emplacement, pipeline trenching, and structure removal would be localized and temporary, and loss of live or hard bottom habitat is not expected. Most marine mammal species are not expected to be within the immediate vicinity of any dredging operations, since these operations are short-term and typically conducted in shallow waters. Marine mammals in the vicinity of dredging operations should be able to avoid these operations, and mitigations are expected to be applied to minimize or prevent potential effects.

4.7.4 Coastal Land Use and/or Modification

Coastal land disturbance would not affect most cetaceans because they are strictly marine inhabitants. The Florida manatee is located primarily in the EPA, where BOEM has no expected oil and gas activity. Also, marine mammals are not expected to be affected by pipeline landfall due to the unlikely potential for it to occur in the WPA and CPA, and because most cetaceans use strictly 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 and/or Space Use

Construction, operation, and decommissioning activities on the OCS may be temporary or long-term. The placement or removal of infrastructure (e.g., pipelines) can create long-term alterations to the existing seascapes (i.e., the physical habitat) including seabed, water column, and/or sea surface habitats (Shams et al. 2023). However, these modifications from activities—such as decommissioning via structure removal, infrastructure and/or pipeline emplacement, G&G surveys, pile driving, and drilling—would likely be localized. Infrastructure and/or pipeline emplacement, including pipeline trenching and construction activities, are expected to create

temporary effects (e.g., bottom disturbance, vessel traffic, noise) within the localized area of construction. Once structures are constructed, long-term effects may include the presence of the structures during operations, as well as any activities required for maintenance. The effects from construction, operation, and maintenance of infrastructure, including pipelines, include air emissions and pollution, operational discharges and wastes, bottom disturbance, and noise.

Over time, decommissioning will allow for the return of pre-construction conditions, providing a beneficial effect. Delayed decommissioning of structures and wells, and pipeline decommissioning-in-place, would provide no net positive or negative effect on marine mammals, though could provide a beneficial localized foraging source for some marine mammals. Considering operators are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements (**Section 4.1.2** and **Table 4-3**), the effects of these activities are expected to be localized and temporary, and long-term habitat modification or habitat loss is not expected.

4.7.6 Air Emissions and Pollution

There is uncertainty about complex processes, such as pollutant transport and dispersion throughout the OCS, and the interactions among the land, air, and water surface are highly dynamic (Sullivan et al. 2023). Due to stack height, exit gas velocity from the stack, distance of marine mammals from the sources, the temporary nature of vessel activity, and the atmospheric processes that transport regulated air pollutants upward, marine mammals are not generally vulnerable to OCS activity-related air emissions (Hsu et al. 1980; Barber et al. 1988; Han and Park 1988). Generally, air pollution would be expected to disperse quickly into the atmosphere. While there are challenges in fully understanding complex coastal systems (Sullivan et al. 2023), available information indicates exposure to air pollutants would be mitigated through the regulations (see **Section 4.1.2** and **Table 4-3**) and physical processes described above, and marine mammals' exposure would be minimal. Further, due to diffusion and transport of air emissions well above the air-water interface (900-m [2,953-ft] mixing height), no detectable effects to marine mammals from air emissions (e.g., from vessel transits and operations, support helicopter use, pipelaying operations, flaring and venting, and decommissioning of facilities and pipelines) are expected.

4.7.7 Lighting and Visual Impacts

Migratory, feeding, and breeding behaviors of cetaceans are not generally affected by artificial light because they depend on acoustic rather than visual cues. Lighting and visual effects on marine mammals are not expected to occur because 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 Seawater Use and/or Uptake

Any marine mammal could be exposed to seawater use and/or uptake activities during offshore development, oil production, and/or vessel and platform maintenance. Most marine mammals

in the Gulf would be too large to be impinged or entrained by such activities and may be able to swim against the current of intake water. Coarse mesh may be used around the perimeter of an intake structure to prevent larger marine life, including marine mammals, from being trapped (USEPA 2006). Marine mammals in the water column, where intake entrances are usually located, would likely be most vulnerable. Marine mammals near the seafloor would likely be less vulnerable, because they would be further distanced from water intake. Potential interactions between marine mammals and seawater use and/or uptake activities are expected to be highly localized and short-term; therefore, marine mammals are expected to experience no quantifiable effect or temporary effects from seawater use and/or uptake activities.

4.7.9 Accidental Events

4.7.9.1 Accidental Releases

Water quality contaminants could accidentally be released into the ocean as a result of human activity associated with the development of oil and gas structures, though they are subject to laws and regulations (**Section 4.1.2** and **Table 4-3**). Historical trends in the Gulf show that the frequency of oil spills has decreased substantially over the last two decades, and most spills are categorized as small in size (i.e., less than 1,000 bbl; Anderson and LaBelle 1990; Anderson et al. 2012; ABS Consulting Inc. 2016). Improvements in technology, industry practice, and regulations (**Section 4.1.2** and **Table 4-3**) have contributed, in part, to decreased spill risk. Catastrophic oil spills include high volume, high impact events, and are considered low probability. Though catastrophic oil spills are generally not considered reasonably foreseeable events, what is learned about the resulting effects on marine biota improves the body of knowledge of effects of oil in the marine environment. For more information about very large, catastrophic events like the *Deepwater Horizon* oil spill, and the effects of an events of this size, see BOEM's *Gulf Catastrophic Spill Event Analysis* (BOEM 2021).

In the event of an accidental oil spill, the eruption of gases and fluids may generate significant pressure waves and noise that may stress, injure, or kill marine mammals, depending on their distance from 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.

Potential effects of an oil spill depend on a variety of factors, such as the type of oil, spill magnitude, frequency, timing, location, and the meteorological and oceanographic conditions at the time (National Research Council 2003b). The fate of an oil spill must be considered relative to the region and period of exposure. The effects of an oil spill on marine mammals could depend on many external variables, such as oil characteristics; time of year; response efforts (e.g., burning, dispersant use); and types of habitats, as well as the behavior and physiology of the marine mammals themselves (Johnson and Ziccardi 2006; Ziccardi et al. 2015; Sullivan et al. 2019). Further, timing and location would also contribute to determining which species may be affected and the scale of the effect. It is impossible to know precisely which

cetacean species, population, or individuals would be most affected, to what magnitude, or in what numbers because each species has unique distribution patterns in the Gulf and because of difficulties attributed to predicting when and where oil spills would occur.

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 decreased health, reproductive fitness, and longevity; increased vulnerability to disease; and possibly mortality. The oil from a spill can adversely affect marine mammals by causing soft-tissue irritation, fouling of baleen plates, 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.

There is evidence that some species of marine mammals can metabolize hydrocarbons (Engelhardt 1983; Lee and Anderson 2005). However, the extent to which species metabolize and eliminate hydrocarbons, and the specific gene biomarker pathways used, are unclear (Ruberg et al. 2021). 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. Oil spills may also affect feeding behavior, especially in the case of baleen whales (e.g., Rice's whales) with fouled baleen plates (Geraci 1990), though whale baleen has not been shown to be altered structurally or functionally by oil adsorption (Werth et al. 2019).

Results from studies on the toxicity oil have been ambiguous, due partly to inconsistent study methods (Michel 2021a), and considering oil is a mixture of various components and does not have a single makeup. 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 (Werth et al. 2019). Studies by Geraci and St. Aubin (1982) 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 1990; Geraci and St. Aubin 1990).

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 and St. Aubin 1982; Geraci 1990). 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, before evaporation and

dispersion of volatile aromatic hydrocarbons and other light components (Geraci and St. Aubin 1982).

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 affect 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 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 effects of even brief exposure to oil (St. Aubin and Lounsbury 1990).

Marine mammals may actively avoid poor environmental conditions. However, though cetaceans can detect oil, they may not always avoid it (Gubbay and Earll 2000; Schwacke et al. 2014; Frasier et al. 2024a). For example, reactions of free-ranging dolphins to spilled oil have appeared varied, ranging from avoidance to apparent indifference (Geraci 1990). It is unknown whether animals in some cases are not affected by the presence of oil or perhaps are drawn to the area in search of prey attracted to the oil's protective surface shadow (Geraci 1990).

Potential effects to marine mammals from an oil spill are expected to increase with spill size (i.e., volume). A high-volume spill could potentially contribute to more significant and longer-lasting effects that could include mortality and chronic or sublethal effects. In most cases, the majority of oil is found at the water's surface during a spill. The effects to cetaceans swimming through an area of oil would depend on several 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). Due to the animal's relatively short time spent at the water's surface overall, depending on species and time of day, it is unlikely that marine mammals would spend prolonged periods of time close to the majority of the oil in a spill.

Most oil spills <50 bbl; 2,100 gal are expected to disperse quickly in the open ocean. In general, a 10–49 bbl (420–2,058 gal) spill 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. In general, spills <1,000 bbl; 42,000 gal, although more numerous than larger spills, dissipate quickly and would likely not contact any individual marine mammals. Prolonged exposure would be unlikely for any individuals in the open ocean given the spill's size, rapid dissipation, short duration, and weathering. A spill of this size would be highly unlikely to result in mortality, decreased fitness, or life-threatening injury of individual marine mammals or the long-term displacement of marine mammals from preferred feeding, breeding, or calving areas.

Brief dermal exposure that may potentially occur with a spill of this size, however, would not be expected to result in long-term effects to an individual or species.

Spills of <10,000 bbl; 420,000 gal may spread at the sea surface or may disperse underwater from the seafloor and never broach the sea surface. Regardless, a slick is an expanding but aggregated mass of oil that, with time, would degrade into smaller units as it evaporates (if at the sea surface) and weathers. As the slick breaks up and some of the oil components weather, tarballs may remain in 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 dissipate, some marine mammal species may be exposed via the waters that they inhabit, as well as the prey they consume. The probability of an individual marine mammal encountering an oil slick from a single spill is extremely low.

Cetaceans could experience long-lasting effects, including reduced reproduction, increased disease, and death, from larger oil spills (Michel 2021a). These effects were documented in cetaceans that were resident in semi-enclosed, heavily oiled (i.e., >20,000 bbl [840,000 gal]; not considered reasonably foreseeable to occur) waterbodies. The difficulty in determining effects to marine mammals is partially due to the lack of accurate stock assessments to establish a baseline with influences from other long-standing anthropogenic continuous sources to stocks while incorporating into proper modeling techniques (Michel 2021a).

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 effects 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).

Because of the distribution of potential leases and pipelines, and the distribution of marine mammals in the northern Gulf, the fate of an oil or chemical 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 can 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.

Unintended releases of chemicals or oil into the marine environment may result in negative effects to marine mammals in the immediate area from exposures at harmful concentrations before the spill is contained and/or dissipates. If the spill contained persistent and bioaccumulating pollutants, longer-term effects are possible over a broader area through dietary exposure and bioaccumulation. Operators are required to conduct OCS oil- and gas-related activities in accordance with regulatory requirements, such as the National Contingency

Plans (40 CFR 300), which provide effective control and containment, and would be expected to limit the volume and area of exposure (**Section 4.1.2** and **Table 4-3**).

4.7.9.2 Release Response

Ultimately and only when deemed necessary, the removal methods used during any spill will be determined by the USCG's FOSC and representatives of the RRT or NRT; therefore, accidental event response activities would be conducted on a case-by-case basis, and not by BOEM or BSEE. Response efforts are unlikely for spills <1,000 bbl; 42,000 gal given that they dissipate, evaporate, weather, and biodegrade rapidly. Depending on the size, spills >1,000 bbl; 42,000 gal may dissipate, weather, and degrade before response efforts are necessary. Response efforts are more likely for spills >10,000 bbl; 420,000 gal.

Spill-response activities that may affect marine mammals directly or indirectly include increased vessel traffic, the use of dispersants, and remediation activities (e.g., controlled burns, skimmers, boom, etc.) (Sullivan et al. 2019). 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 affected marine mammals further and possibly making them more vulnerable to various physiologic and toxic effects of spilled oil. Response vessels could increase risk of vessel strike. Vessel noise would also increase as a result of increased vessel activity and could result in behavioral changes in some individuals.

Some oil will naturally disperse, whether dispersants are added or not. Dispersants may be applied to the affected area or point of release (e.g., injection at the wellhead) on a case-by-case basis, typically depending on the spill size and location. Removing oil from the surface would reduce the risk of oil 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 Gulf because there is no known accurate method to measure the amount of whale exposure to dispersants (Wise et al. 2014). It is assumed that any effects potentially resulting from exposure to dispersants or accentuated by dispersion of oil would increase in likelihood or magnitude with increased use of dispersants.

Results from studies on the toxicity of dispersants and dispersed oil have been ambiguous, due partly to inconsistent study methods (Michel 2021a). Laboratory experiments have found that dispersant components degrade rapidly, within hours to days (Michel 2021a), and field studies have found that dispersant concentrations typically decrease to less than 1 ppm within minutes to hours (National Academies of Sciences 2020). The acute toxicity of most oil dispersant chemicals is 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; 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). Dispersants may be irritants to tissues and sensitive membranes (National Research Council 2005a) and could cause nonlethal effects, such as behavioral changes, tissue irritation, respiratory effects, long-term exposure through bioaccumulation, and

shifts in distribution from some habitats. The extent of marine mammal exposure to and health effects from aerosolized oil droplets resulting from dispersant use are not completely understood (National Academies of Sciences 2020). One assumption concerning the use of dispersants is that the chemical dispersion of oil would considerably reduce effects to marine mammals, primarily by reducing their exposure to petroleum hydrocarbons (French-McCay 2004; National Research Council 2005a).

Some remediation activities likely to be used for spills <10,000 bbl; 420,000 gal that could affect marine mammals include the use of skimmers, booms, and in-situ burns. Skimmers could capture or entrain individuals (Sullivan et al. 2019). Booming operations could potentially affect certain species, particularly manatees, because 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 affect manatees by entanglement. In addition, booming and other response operations could cause habitat exclusion (Sullivan et al. 2019). In-situ burns could affect some individuals if they were in the burning oil or via smoke inhalation; however, it is expected that animals would avoid the area once it is ignited. In spill response operations (e.g., dispersant application, skimming and controlled burning activities), the use of trained observers is common. Some marine mammals, such as manatees, spend a significant amount of time at the surface or near the surface but may avoid contaminated areas and areas experiencing increased vessel traffic due to response efforts.

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 distributions and behaviors reduces the likelihood of effects on marine mammals. Further, due to the relatively short time spent at the water's surface overall, depending on species and time of day, it is unlikely that marine mammals would spend prolonged periods of time close to any associated response activities if deployed. Through the National Contingency Plan (40 CFR 300) and the federal laws that underpin this regulation, there are mitigations and plans in place at the federal, state, and local levels (e.g., from USCG, BSEE, states, NMFS, USFWS, and NPS) that decrease or avoid effects to marine mammals during response activities (**Section 4.1.2** and **Table 4-3**). These plans increase surveillance and the detection of animals, thus reducing potential effects through avoidance measures.

4.7.9.3 Marine Trash and Debris

Marine debris affects marine habitats and marine life worldwide, primarily through entanglement or ingestion (e.g., choking or intestinal blockage) (Gall and Thompson 2015; Senko et al. 2020). 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 (Gall and Thompson 2015; Senko et al. 2020). Marine debris ingestion can lead to intestinal blockage, which can affect feeding ability and lead to injury or death (Gall and Thompson 2015; Senko et al. 2020). There are few data on marine debris specifically from OCS oil- and gas-related activities in the Gulf; therefore, it is difficult to determine the extent of the problem and its effects on marine mammal populations.

Operators are required to follow BSEE, USCG, and USEPA regulations pertaining to marine trash and debris prevention and handling (**Section 4.1.2** and **Table 4-3**). 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. In addition, mitigations designed to prevent or substantially reduce accidental marine trash and debris could prevent or minimize potential marine debris effects to marine mammals (**Section 4.1.2** and **4.1.3** and **Table 4-3**). For more information on general marine mammal vulnerability to marine trash and debris, refer to **Section 3.7.6**.

4.7.9.4 Strikes and Collisions

All marine mammals are vulnerable to accidental vessel strike; however, some marine mammal species may be more vulnerable than others, including primarily slow-moving species or those that spend extended periods of time at the surface, and deep-diving species while on the surface (Vanderlaan and Taggart 2007). Accidental vessel strike could result in marine mammal injury or mortality, or no apparent effects (Laist et al. 2001; Van Waerebeek et al. 2007; Vanderlaan and Taggart 2007; Pace 2011). The potential for vessel strikes on marine mammals and potential effects to marine mammals depend on many factors, with vessel speed and vessel size of note when assessing strike risk (Stevens et al. 2024; Garrison et al. 2025). Larger vessels at higher speeds pose the most risk for strikes on marine mammals (Stevens et al. 2024; Garrison et al. 2025). Higher speeds limit the ability of marine mammals to actively avoid a vessel strike and the ability of vessel operators (especially of larger vessels) to detect and react in time.

Reports of vessel strikes by OCS oil- and gas-related vessels are rare. All of the larger OCS oil- and gas-related vessel types (i.e., ≥80 m; 262 ft) are expected to be typically operating either below or at the lower range of speeds noted to result in the majority of large whale ship strikes. Also, seismic operations with towed gear generally are conducted at relatively slow speeds of 4–6 kn (4.6–7 mph), with a maximum speed of less than 8 kn (9 mph). Service and support vessels traveling through coastal areas to and from the OCS have the potential to affect manatees via vessel strike. Mitigation measures (e.g., speed reductions and separation distances for certain situations; use of observers) could prevent or minimize marine mammal interactions with transiting vessels (**Section 4.1.2** and **4.1.3** and **Table 4-3**). For more information on general marine mammal vulnerability to vessel strike, see **Section 3.7.6**.

4.7.9.5 Entanglement and Entrapment

While construction, operations, and decommissioning activities are being conducted, marine mammals may be exposed to entanglement and entrapment risks from equipment used. For example, marine mammals can become entangled in lines in the water (e.g., diver lines) during operations, potentially leading to stress, injury, or mortality. Mitigation measures (e.g., in-water line precautions requiring lines in the water to remain taut; using tensioning tools) could prevent or minimize entanglement and entrapment risks to marine mammals (**Section 4.1.2**

and **4.1.3** and **Table 4-3**). Vessel moon pools would generally be too small to entrap a marine mammal in the Gulf. For more information on general marine mammal vulnerability to entanglement and entrapment, see **Section 3.7.6**.

4.8 BIRDS

4.8.1 Noise

For information on bird bioacoustics (air and underwater), see **Section 3.8.4** and see **Figure 4-1** for frequency ranges of various anthropogenic sources (e.g., seismic surveys, vessels, and equipment). The severity of impact depends partly on the frequency range and sound intensity and on the hearing abilities of the species of interest. Approximate hearing ranges of birds are 1-4 kHz. Previous work indicated that densities over the open ocean are typically less than 10 birds/km^2 (0.4 mi^2) (Davis et al. 2000b). In contrast to mammals, avian species exhibit the exceptional biological ability to achieve complete regeneration of inner ear sensory hair cells following acoustic trauma or age-related decline. This restorative process facilitates a return to pre-auditory thresholds within approximately four to five weeks and functions effectively across both terrestrial and aquatic environments (Sato et al. 2024; Miranda Portillo et al. 2025). As applicable, discussion of birds outside of the Gulf is included as a proxy for Gulf birds, representing the best available information at this time.

4.8.1.1 Seismic Surveys (Airguns)

The degree of underwater noise exposure varies by species and foraging behavior. For most birds, such as surface feeders, plunge-divers, or those that briefly dip below the surface, exposure is likely minimal due to their short duration underwater. In contrast, pursuit-diving bird species may remain underwater from seconds to minutes, possibly increasing the chance of sound exposure. Researchers have documented a range of bird behavioral responses to noise, including no reaction, head turns, alert postures, startle responses, flying away, and increased call amplitude (e.g., Black et al. 1984; Ellis et al. 1991; Stalmaster and Kaiser 1997; Brown et al. 1999; Pytte et al. 2003; Rojek et al. 2007). These responses are influenced by several factors, including the noise characteristics, distance from the source, and whether they resemble biologically relevant sounds, such as predator cues or alarm calls from other birds.

Seismic surveys produce intense underwater sound primarily through the firing of airguns, which may impact diving seabirds that forage underwater. Exposure depends on species-specific foraging behaviors, with pursuit-diving birds being most susceptible due to their extended underwater durations. 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. Seismic noise can cause temporary disturbance or displacement from seabird foraging habitats, resulting in lost foraging opportunities and increased energetic effort spent foraging (Pichegru et al. 2017). It should be noted that studies by Stemp (1985) and Lacroix et al. (2003) did not observe any difference in distribution or abundance of seabirds because of seismic survey activity, nor did they observe

increased mortality to the several species of seabirds studied. Behavioral effects are expected to be temporary. Masking of acoustic cues or disruption of foraging patterns may occur but are not expected to result in long-term harm. Airgun array pulses are directional, so only diving foraging birds would encounter active sources.

4.8.1.2 High-Resolution Geophysical Surveys

Smaller-scale, higher-resolution geophysical surveys are not typically used to identify oil and gas resources, but rather to identify shallow-water hazards and/or to image the immediate subsurface for the purposes of offshore construction and marine minerals exploration. A description of the physical qualities of geophysical sound sources can be found in **Appendix B** and BOEM's Sound Source List (Center for Marine Acoustics 2023). Generally speaking, sources that emit sound in narrow beams directed at the seafloor are less likely to affect marine species because they ensonify a smaller portion of the water column (Ruppel et al. 2022) and are considered de minimis. Most HRG sources emit short pulses of sound, with periods of silence in between. Based on several key physical characteristics of the sound sources—including source level, frequency range, duty cycle, and beamwidth—Ruppel et al. (2022) concluded that most HRG sources, even without mitigation, are unlikely to cause substantial behavioral disturbances to underwater species, as birds are not underwater-dwelling organisms.

Despite birds' generally low hearing sensitivity at low frequencies (1–4 kHz), it may be possible that they could detect some OCS-related underwater noise. Underwater noise from some of the higher-amplitude sources such as bubble guns, some boomers, and the highest-power sparkers could affect seabirds and waterfowl that dive below the water surface to forage at the specific activity site. The degree of underwater noise exposure varies by species and foraging behavior. For most birds, such as surface feeders, plunge-divers, or those that briefly dip below the surface, exposure is likely minimal due to their short duration underwater. In contrast, pursuit-diving bird species may remain underwater from seconds to minutes, possibly increasing the chance of sound exposure. Researchers have documented a range of bird behavioral responses to noise that included no reaction, head turns, alert postures, startle responses, flying away, and increased call amplitude (e.g., Black et al. 1984; Ellis et al. 1991; Stalmaster and Kaiser 1997; Brown et al. 1999; Pytte et al. 2003; Rojek et al. 2007). These responses are influenced by several factors that include the noise characteristics, distance from the source, and whether they resemble biologically relevant sounds such as predator cues or alarm calls from other birds.

4.8.1.3 Geotechnical Surveys

Geotechnical surveys are performed in offshore and coastal waters to assess the sediment type and characteristics that will be encountered during various OCS activities (e.g., for pipeline and cable installation, sediment borrow for shoreline restoration). Geotechnical surveys use shallow-bottom coring and surface sediment sampling devices such as CPTs, piston/gravity cores, vibracores, rotary borings, sediment profile imagers, and grab samplers. Generally, the noise produced is low level and low frequency (<2 kHz). Underwater bird behavioral foraging

effects directly around surveys are expected to be temporary. Masking of any acoustic cues or disruption of foraging patterns may occur but are not expected to result in long-term harm.

4.8.1.4 Dredging

Dredging activities as a whole generally produce low-frequency sounds; most energy is below 1 kHz, with peaks typically occurring between 150–300 Hz (McQueen et al. 2018). Diving birds with their generally low hearing underwater sensitivity at low frequencies (1–4 kHz) will not likely be vulnerable to dredging produced noise.

4.8.1.5 Drilling and Production

Sounds from drilling and production are generally considered to be non-impulsive and are nearly continuous in nature, though they may be highly variable depending on the type of substrate that is encountered (Richardson et al. 1995). There could be tonal sound generated by the drill bit, mechanical noise transferred through the ship's hull, and noise from the vessels and dynamic positioning systems. Drilling noise is also expected to be low-frequency in nature. For example, Greene Jr. (1987) measured noise from several drillships and found that the dominant energy was typically below 600 Hz, with the prominent tones coming from the diesel-electric generators.

Noise generated from offshore platforms during drilling and production includes both in-air and underwater components, though much of the related acoustic energy is below the hearing range for most seabirds (e.g., Crowell et al. 2015). Some seabirds are attracted to offshore structures as they use the platforms for resting or foraging (Tasker et al. 1986; Baird 1990; Montevecchi et al. 1999; Russell 2005; Ronconi et al. 2015). Therefore, species that are in the close proximity of platforms might experience disturbance or possible temporary displacement from airborne sounds around the platforms (Tasker et al. 1986; Russell 2005). Overall, while seabirds that are attracted to platforms may be more exposed to noise, the associated impacts are anticipated to be short-term and localized. Diving birds with their generally low hearing underwater sensitivity at low frequencies (1–4 kHz) will not likely be vulnerable to drilling and production noise.

4.8.1.6 Vessels and Dynamic Positioning Systems

Vessel and equipment noise make up most of the sounds produced by BOEM-regulated activities, including vessel (installation, support, and decommissioning) and aircraft traffic, surveys, drilling, and offshore and onshore construction. The severity of impact depends partly on the frequency range and sound intensity, as well as the hearing abilities of the species of interest. In general, vessel noise increases with ship size, power, speed, propeller blade size, number of blades, and rotations per minute. Small vessels, like those used for crew transport, typically produce higher-frequency sound than large container ships, with most energy concentrated in the 1–5 kHz range. During seismic or HRG surveys, vessels typically travel at slower speeds (typically 5 kn; 5.8 mph) which reduces underwater radiated noise. DP systems

typically do not have a high peak sound pressure and rapid rise time compared to impulsive sounds but can still produce significant acoustic energy, most of which is below 1 kHz, with tones related to engine and propeller size and type (American National Standards Institute 1995; National Institute for Occupational Safety and Health 1998). The sound can also vary directionally, and this directionality is much more pronounced at higher frequencies.

Seabirds may be exposed to both in-air and underwater noise generated by vessels associated with OCS activities. Though many seabirds show minimal reactions to vessels and vessel noise, behavioral responses, such as alertness, flushing, avoidance, and temporary displacement, have been observed (e.g., Stalmaster and Kaiser 1997; Burger et al. 2010; Schwemmer et al. 2011). Birds foraging or resting in areas with heavy vessel traffic may be disturbed or displaced from the activity. Some species, such as albatrosses, are attracted to vessels (Hyrenbach 2001), while others, including diving birds, tend to avoid them (Burger et al. 2010; Schwemmer et al. 2011). The physical presence of vessels may also contribute to disturbance independent of noise. Underwater vessel noise generally contains low-frequency energy that is often below the hearing sensitivity of diving seabirds (e.g., McGrew et al. 2022), so this makes significant impacts unlikely unless birds are in close proximity. However, continuous noise from vessels may mask biologically important sounds, particularly in areas like ports where vessel activity is concentrated. Diving birds may show higher sensitivity to marine traffic noise and may avoid high-activity areas, and that could lead to reduced foraging efficiency and increased energetic costs (Marine Management Organisation 2018).

From these activities, anticipated impacts on birds exposed to only vessel traffic sound sources could include localized disturbance, temporary displacement, and masking of bird vocalization and communication. Vessels could cause disturbance to breeding birds and possibly decrease nesting success if the traffic occurs too close to a breeding colony. If disturbance were to occur, birds have shown the ability to return to pre-disturbance behavior within 5 minutes (Komenda-Zehnder et al. 2003). Overall, vessel-related impacts on seabirds are typically short-term and species-specific.

4.8.1.7 Trenching, Cable Laying, and Pipeline Laying

Trenching sleds dig the trenches for laying pipeline or cable by displacing the sediment with a water jet. Pipelines are installed by lay barges that are either anchored or dynamically positioned while the pipeline is laid. Noise is also introduced into the water from the DP systems, the movement of supply ships and tugs, and anchoring. Nedwell and Edwards (2004) measured sounds from a 130 m- (227 ft-) long trenching vessel and found that sound levels were similar to those produced during pipeline laying in the same area, with the exception of a 20 kHz tonal sound, which they attributed to the vessel's DP thrusters. In shallower areas, they found increased sound levels at distances up to 2.3 km (1.4 mi) at frequencies <1 kHz; at 7.4 km (4.6 mi) from the source, so sounds from pipeline laying faded into ambient noise. Diving birds with their generally low hearing underwater sensitivity at low frequencies (1–4 kHz) will not likely be vulnerable to trenching, cable-laying, and pipeline laying noise.

Onshore construction activities related to OCS projects can generate airborne noise that may affect nearby coastal and marine bird species. Noise can cause localized disturbance and temporary displacement, particularly when construction occurs near nesting colonies or roosting sites. Onshore construction noise may also mask bird vocalizations and interfere with essential communication, potentially disrupting important biological activities, including mating, parental care, or territory defense (Dooling and Popper 2007). However, seabirds are generally less vulnerable when construction activities are located away from nesting aggregations or scheduled outside the breeding season. Site-specific planning, such as locating pipeline corridors in low-sensitivity areas, can help minimize impacts.

4.8.1.8 Pile Driving

Underwater sound levels generated during pile driving depend on many factors, including the pile material and size, characteristics of the substrate, penetration of the pile in the seabed, hammer energy and size, and water depth. The dominant frequencies from down-the-hole (DTH) pile driving are below 2 kHz, similar to conventional impact pile driving and vibratory hammer. Some seabirds are attracted to offshore structures as they use the platforms for resting or foraging (Tasker et al. 1986; Baird 1990; Montevecchi et al. 1999; Russell 2005; Ronconi et al. 2015). Therefore, species that are close to platforms might experience disturbance or possible temporary displacement from airborne sounds around the platforms (Tasker et al. 1986; Russell 2005). Overall, though seabirds that are attracted to platforms may be more exposed to noise, the associated impacts are anticipated to be short-term and localized. Diving birds with their generally low hearing underwater sensitivity at low frequencies (1-4 kHz) will not likely be vulnerable to pile driving noise.

4.8.1.9 Decommissioning

During platform decommissioning, underwater explosives used to dismantle structures pose a higher risk to diving seabirds. The likelihood of birds being near during detonation is low. Birds are expected to vacate areas during the dismantling process because prey is limited, further reducing risk. Although individuals are attracted to platforms for foraging, the likelihood of their presence during platform decommissioning and removal activities is low. Decommissioning involves dismantling the above platform structures, sometimes with the use of underwater explosives, typically 15 m (49 ft) below the mudline, 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. Most of the birds using the platform would have likely left the area during the dismantling process before the explosives are used. Platform removal may cause short-term and localized disturbance and displacement of foraging and resting marine birds if present and with low vulnerability.

4.8.1.10 Aircraft

The research suggests that birds have a relatively restricted hearing range for airborne noise. Jiménez-Arranz et al. (2020) and Richardson et al. (1995) reviewed sound measurements recorded below passing aircraft of various models. These SPL measurements included 124 dB re 1 µPa (dominant frequencies between 56–80 Hz) from a maritime patrol aircraft with an altitude of 76 m (249 ft), 109 dB re 1 µPa (dominant frequency content below 22 Hz) from a utility helicopter with an altitude of 152 m (499 ft), and 107 dB re 1 µPa (tonal, 82 Hz) from a turbo propeller with an altitude of 457 m (1,499 ft). Generally, aerial hearing sensitivity in non-nocturnal terrestrial birds occurs at frequencies between about 1 and 5 kHz, with absolute (best) sensitivity often approaching 0–10 dB re 20 µPa SPL at the most sensitive frequency, which is usually in the region of 2–4 kHz (Dooling 1980; 1982; 1992; Dooling et al. 2000).

Birds exposed to aircraft noise may exhibit short-term behavioral responses, such as head-turning, increased vigilance, or flushing from nesting or foraging areas (e.g., Efroymson et al. 2000). These effects are generally transient and do not appear to significantly affect reproductive success, although it has been speculated that flushes from nests may be a good predictor of eventual reproductive loss (Awbrey and Bowles 1990). For example, several raptor species exposed to frequent, low-level military jet aircraft overflights and simulated mid- to high-altitude sonic booms have shown aircraft and detonation noise elicit some short-term behavioral responses but have little effect on reproductive success (Ellis et al. 1991). Studies of simulated aircraft noise at crested tern colonies indicated that increased exposure resulted in more head-turning and alert responses, and animals did not take flight unless sounds exceeded 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). Low-level (<152 m [500 ft] above ground level) military training flights have been shown to have no effects on the establishment, size, or reproductive success of wading bird colonies in Florida (Black et al. 1984). Also, if disturbance were to occur, birds have shown the ability to return to pre-disturbance behavior within five minutes (Komenda-Zehnder et al. 2003). Required FAA flight routing (FAA: AC No: 91-36D) and avoiding low-altitude flights near known colonies can reduce potential impacts (Kaulia 2004). Aircraft noise is expected to have only short-term, localized effects on seabird behavior and habitat use.

4.8.2 Discharges and Wastes

Birds in the Gulf can be exposed to operational discharges and wastes that include produced waters, drilling muds and cuttings, and vessel discharges. Oil sheens from produced waters may result in mortality if sheen contacts the birds' feathers, where it can compromise the structure, leading to starvation and hypothermia (Wiese and Ryan 2003; Fraser et al. 2006). Discharges of drilling muds rapidly settle to the seafloor around the drill site, where there is potential to lead to temporary loss of benthic foraging habitat for deep-diving birds (Neff 2005). The release of routine OCS oil- and gas-related discharges and wastes are localized and temporary, and discharges are expected to disperse quickly. These routine OCS oil- and gas-related releases may result in small and temporary disturbances, which are unlikely to have the potential to

affect individuals or small groups of birds, if present directly near the source. Routine OCS oil- and gas-related discharges and wastes are regulated by BSEE, USEPA, and USCG, who are tasked with protecting against degradation of the marine environment. Lessees are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements that minimize or avoid impacts to foraging habitat from discharges (e.g., ballast), trash, and other waste (e.g., NPDES, 30 CFR 250.300, and MARPOL 73/78) (for more detail see **Section 4.1.2** and **4.1.3** and **Table 4-3**).

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 impact diving seabirds, considering the limited footprint of disturbance, limited offshore bird densities, and widespread availability of similar feeding grounds (i.e., offshore pelagic waters). Overall, bottom disturbance is not expected to pose vulnerability to marine and coastal birds because they do not inhabit the seafloor or water column beyond quick, infrequent foraging trips (seconds to minutes) that are mostly in inshore or coastal waters.

4.8.4 Coastal Land Use and/or Modification

Coastal land disturbance could temporarily or permanently reduce the availability of bird nesting and feeding habitats. New construction or expansion of onshore facilities, temporary or permanent roads, and pipeline landfalls can alter coastal and estuarine habitats. These activities could potentially impact bird species that rely on these habitats for nesting and feeding, leading to displacement. Construction-related disturbance could increase the temporary suspension of sediments in the coastal water column, temporally decreasing the local water quality. Decreased water quality and increased turbidity could compromise the quality of the prey and the birds' ability to locate prey within the construction area. Additionally, vessel traffic could contribute to shoreline erosion, leading to possible habitat degradation and localized, increased temporary turbidity. The removal of infrastructure can create disturbances similar to infrastructure installation; it can result in bottom disturbance creating turbidity in the water column that may impact prey availability if the water conditions persist. The effects of these activities would be localized and temporary, and habitat loss is not expected. State and federal permitting agencies discourage the placement and expansion of facilities in wetlands and mitigate impacts (e.g., CWA, USACE's 404 permit, CZMA, and state permitting programs), and lessees are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements that minimize or avoid impacts (for more detail see **Section 4.1.2** and **4.1.3** and **Table 4-3**).

4.8.5 Offshore Habitat Modification and/or Space Use

The placement of oil and gas structures and associated offshore equipment has the potential to affect birds found in the Gulf. Offshore oil and gas structures create a structural presence in the Gulf that otherwise would not exist that could function as habitats for birds, resulting in potentially complex direct and indirect effects on birds (Nemes et al. 2023). Infrastructure emplacement could cause temporary and long-term disturbance via avoidance or attraction (Tasker et al. 1986; Baird 1990; Russell 2005; Montevecchi 2006). Structures can serve as artificial reefs supporting biodiverse communities, including bird prey. Many species opportunistically use these spaces for roosting and resting sites (Burke et al. 2012). Delayed decommissioning of structures and wells, and pipeline decommissioning-in-place would provide no net positive or negative effect on birds, though could provide a beneficial localized foraging source for some birds.

Within this geographic area, impacts from offshore habitat modification and/or space use could affect birds close to the structures on the OCS (e.g., platforms). Many species opportunistically use 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, stopover behavior may be detrimental as birds will still expend energy reserves while at the platforms (Hope Jones 1980). Further, migratory birds using platforms for stopover sites could be increasing their exposure to predators (e.g., falcons) (Russell 2005). Traditional landbirds have also been sighted at Gulf platforms. For example, North American peregrine falcon juveniles use platforms to rest and hunt during migration. A multiyear, standardized survey on Gulf 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). Offshore habitat modification and/or space use has the potential to create habitat that would otherwise not exist and possibly alter normal migration patterns and predator/prey interactions.

4.8.6 Air Emissions and Pollution

There is uncertainty about complex processes, such as pollutant transport and dispersion throughout the OCS, and the interactions among the land, air, and water surface that are highly dynamic (Sullivan et al. 2023). Though there are challenges in fully understanding complex coastal systems (Sullivan et al. 2023), available information indicates exposure to air pollutants would be mitigated through the regulations and physical processes described previously (see **Section 4.1.2** and **Table 4-3**) as well as below. There is little information about the toxicity of offshore oil and gas air emissions, especially with regard to marine species. Adverse effects can include cancer risk, cardiorespiratory, or pulmonary exposures and disease (Amoatey et al. 2019). Similar to expectations about on-land facilities, it is expected that the highest concentrations of chemicals near the water surface or area of potential effects to species would be located within a few kilometers (miles) downwind of a facility (Smargiassi et al. 2014;

Olaguer et al. 2016). Close to the facility, the pollutant plume would still be higher in the atmosphere, while farther away from the facility, the pollutant would disperse.

Dispersion depends on emission height, atmospheric stability, mixing height, exhaust gas temperature and velocity, and wind speed. For emissions within the atmospheric boundary layer, the vertical heat flux that includes effects from wind speed and atmospheric stability (via air-sea temperature differences) is a good indicator of turbulence available for dispersion (Lyons and Scott 1990). 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. The mixing height is important because it dictates the vertical space available for spreading the pollutants. The mixing height is the height above the surface through which vigorous vertical mixing occurs. Vertical mixing is most vigorous during unstable conditions and is suppressed during stable conditions, so the worst periods of air quality occur during stable conditions. Although mixing height information throughout the Gulf is scarce, measurements near Panama City, Florida (Hsu et al. 1980), show that the mixing height can vary between 400 and 1,300 m (1,312 and 4,265 ft), with a mean of 900 m (2,953 ft). The mixing height tends to be lower in winter, with daily changes smaller than in summer.

Due to the atmospheric processes on air pollutant transport, stack height, exit gas velocity from the stack, distance of the bird species from the potential 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. Many of the BOEM-authorized activities within the OCS are transitory, as are most marine and coastal Gulf birds, which may reduce interaction opportunities. Further, due to diffusion and transport of air emissions well above the air-water interface (900-m [2,953-ft] mixing height), no measurable effects to bird populations from air emissions (e.g., from vessel transits and operations, support helicopter use, pipelaying operations, flaring and venting, and decommissioning of facilities and pipelines) are expected.

4.8.7 Lighting and Visual Impacts

Artificial lighting (e.g., structure lighting) is required on offshore oil and gas structures and other infrastructure for safety and operations. Potential effects of artificial lighting include species attraction, avoidance, changes in migration patterns, and/or changes in predator and/or prey interactions (Marangoni et al. 2022). Structures proposed for decommissioning would have very limited lighting and delayed decommissioning of these structures would provide no net positive or negative effect to birds. Due to the distance from shore, artificial lighting on OCS platforms and infrastructure is expected to have no effect on any species whose habitat includes inland and nearshore coastal waters, beaches, barrier islands, and/or marsh. This includes species with inland and/or coastal migration routes (e.g., piping plovers, monarchs).

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 (Longcore and Rich 2004). Alternatively, artificial lighting can create foraging opportunities for birds. For example, gulls

rest and forage at night on the sea surface under the structure lights, which are thought to attract their prey to the surface (Burke et al. 2012). Although there is evidence that some rufa red knots (an ESA-listed species) cross Gulf open waters while migrating (Russell 2005; Perkins 2023), the response of rufa red knots to artificial lighting is not known (FWS 2014b). Documented Gulf crossing locations for the rufa red knot have minimal overlap with BOEM-regulated oil- and gas-related activity on the OCS (Russell 2005; Perkins 2023); therefore, it is anticipated that oil and gas structure lighting has no impact on the rufa red knot population.

The only ESA-listed species under FWS authority that would be expected to use the OCS and could be affected by OCS lighting and flaring is the black-capped petrel (88 FR 89611). Bright light sources are known to attract petrels, especially on nights with inclement weather (e.g., fog, rain). Inclement weather can obscure other light sources (e.g., stars, moon) which may hamper avian orientation and navigation (Russell 2005; Poot et al. 2008; Coleman et al. 2022). Some have postulated that the loss of visual cues to the horizon may result in birds being reluctant to leave and to circulate within the cone of light surrounding structures (Russell 2005). Inexperienced black-capped petrel fledglings and juveniles are especially sensitive to artificial lighting, likely due their high dependence on visual cues for nocturnal navigation (88 FR 89611), but the closest known nesting area is in southern Haiti (Jodice et al. 2021), which is distant from BOEM and BSEE-regulated oil- and gas-related activity. Adult black-capped petrels do forage and migrate offshore and are known to occur on the OCS, feeding mostly at the surface at night (88 FR 89611). OCS lighting could result in petrel disorientation, collisions with wires and structures, and/or wasting of energy (e.g., circling a structure) (Van De Laar 2007; Simons et al. 2013). Alternatively, the presence of lighted structures could provide foraging opportunities with attraction of prey (Ronconi et al. 2015; Marangoni et al. 2022). Based on offshore observations, migrating or foraging adult petrels are most likely to occur in the eastern region of the Gulf (east of approximately 88° west longitude), predominantly outside of the area of Bureau-regulated oil- and gas-related activity (Jodice et al. 2021). For example, none were observed on structures or flying above structures during a three-year BOEM observational study (Russell 2005).

Oil- and gas-related vessels transiting onto and off the OCS create transient lighting within coastal habitat. Vessel lights are a source of artificial lighting above water and could also create a light field within the upper water column. Any effects to ESA-listed species (e.g., disorientation, avoidance) would be localized and temporary within any one area. Oil- and gas-related vessels transit into and out of established port areas using lighting that is similar in nature to other vessel types in the area (e.g., barges, fishing boats), so no impacts are expected.

Birds can be attracted to flares used on offshore structures (Russell 2005; Montevecchi 2006; Poot et al. 2008; Ronconi et al. 2015). Attraction has been documented during a nocturnal gas flaring event that had an installed anti-collision lighting system (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).

There are several papers with conflicting accounts of the impacts of flaring in the OCS. 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). Bourne (1979) estimated that annual mortality rates from interactions with gas flares are a few hundred birds per structure. However, one study suggests that incinerations from colliding with gas flares may be killing more birds than previously thought (Bjorge 1987).

4.8.8 Seawater Use and/or Uptake

Diving seabirds (e.g., grebes, loons, cormorants, and sea ducks) could be exposed to seawater use and/or uptake activities during offshore development, oil production, and/or vessel and platform maintenance. Seabirds' diving methods (e.g., surface feeding, pursuit diving, and plunge diving) can influence their possibility of being impacted by the use and uptake methods of seawater; though birds are diving for ease of prey. Birds in the water column, where intake entrances are usually located, would likely be most vulnerable. Potential interactions between birds and seawater use and/or uptake activities are expected to be highly localized and short-term; therefore, birds are expected to experience no quantifiable effect or temporary effects from seawater use and/or uptake activities.

4.8.9 Accidental Events

4.8.9.1 Accidental Releases

The effects of unintended releases (e.g., oil or chemicals) on birds depend on many variables, including spill location, spill size, spill composition, weather events, oceanographic conditions, time of year, and the behavior and physiology of the birds (Wiese and Jones 2001; Castege et al. 2007). Repeated exposure to spills could also be a factor in determining the level of impact on birds. Direct impacts to birds that encounter accidentally spilled oil could include tissue and organ damage from ingested or inhaled oil, interference with food detection, predator avoidance, homing of migratory species, disease resistance, growth rates, reproduction, and respiration. Birds could 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 could cause bird mortality. Through the National Contingency Plan (40 CFR 300) and the federal laws that underpin this regulation, mitigations and plans are in place at the federal, state, and local levels (e.g., from USCG, BSEE, states, NMFS, FWS, and NPS) that could decrease impacts to birds, including ESA-listed and migratory birds, if present from oil spills. Lessees are required to perform OCS oil- and gas-related activities in accordance with regulatory requirements (see **Section 4.1.2** and **4.1.3** and **Table 4-3** for more detail).

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, 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 where 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 (Selman et al. 2016). 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) (Miller et al. 1978; Peakall et al. 1989; Albers 2006; Xu et al. 2016; 2017; Bursian et al. 2017; Dean et al. 2017; Harr et al. 2017a; 2017b; Fallon et al. 2018; Dorr et al. 2019; Bonisoli-Alquati et al. 2020).

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 Gulf and residents of the Gulf 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. Seabirds are vulnerable to chronic and acute oil exposure from offshore energy development, with an index showing that even limited spatial overlap between high-quality habitat and oil and gas infrastructure can disproportionately affect high-risk species (e.g., Northern gannet) (Michael et al. 2022). The effectiveness of the containment and cleanup activities also influences the degree of impact that oil or chemical spills have on birds.

4.8.9.2 Release Response

The effectiveness of the response, containment, and cleanup activities (offshore and shoreline) could influence the degree of impact that post-oil or chemical spills have on birds. 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. Oil-spill response and cleanup activities could affect birds' prey, their coastal habitats, and their reproductive abilities. Birds may experience fewer foraging opportunities and lower quality food availability. Birds could also face habitat loss of foraging, nesting, breeding, wintering, and roosting grounds. Chemical dispersants have been shown to be toxic to birds and, if used, may lead to decreases in hatching success (Finch et al. 2012; Wooten et al. 2012).

Though dispersants are used in spill responses to encourage microbial degradation, they can also be toxic to biota. 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. (2012) 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. Nonnesting 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 Catastrophic Spill Event Analysis* (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 (**Section 4.5.10**). Birds could also face habitat loss of foraging, breeding, wintering, and roosting grounds (**Section 4.2.10**). 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.

4.8.9.3 Marine Trash and Debris

Coastal and marine birds are susceptible to entanglement in floating, submerged, and beached marine debris, specifically plastics discarded from both offshore sources and land-derived litter and waste disposal. This discussion applies to both federally listed Threatened or Endangered avian species and non-listed species. It is believed that coastal and marine birds are less likely to become entangled in or ingest OCS-related trash and debris due to BSEE regulations that prohibit the disposal of equipment, containers, and other materials into offshore waters by lessees (30 CFR 250.300) (see **Section 4.1.2** and **4.1.3** and **Table 4-3** for more detail).

Much of the floating material discarded from vessels and structures offshore presumably drifts ashore, remains within coastal waters, or eventually sinks. These materials may include lost or discarded fishing gear, such as gill nets and monofilament lines, which cause the greatest overall damage to birds (Tasker et al. 2000; Dau et al. 2009; Ryan et al. 2009). Coastal and marine birds are commonly entangled in discarded trash and debris (Robards et al. 1995). Many species will readily ingest small plastic debris, either intentionally or incidental to consuming prey. Interaction with plastic materials may lead to debilitating injuries or even death (Pierce et al. 2004).

Birds could be impacted by plastic by mistakenly ingesting pieces when foraging or by trophic transfer (Moore 2008; Grace et al. 2022; Carrillo et al. 2023). Once ingested, these plastics are largely non-digestible and can cause blockages, internal damage, and a false sense of satiety (Wright et al. 2013b; Grace et al. 2022). Additionally, chemicals can leach from plastics following ingestion, which creates an ecotoxicological concern (Tanaka et al. 2013; 2019). Plastic has been found to leak contaminants, potentially threatening seabirds who use plastic debris as nesting materials. Seabirds that nest on top of plastic materials may be at risk for reproductive difficulties and cancers due to chemical absorption through their skin (Senko et al. 2020). Sea birds often can mistake marine trash and plastic debris as material to be used for nest building, often resulting in tangling their legs, feet, bill, and wings (Senko et al. 2020). Wilcox et al. (2015) estimates that by 2050, 99 percent of all seabird species and 95 percent of individuals within these species will have plastic in their digestive tracks, as a result of global distribution of marine trash and debris. High levels of plastic ingestion may result in slower growth rates and earlier mortality in seabirds due to severe internal impaction and blockage. To date, there is a lack of data on distribution of plastic, accumulation in biota, and potential vulnerable species in the Gulf. Therefore, it is difficult to draw conclusions about the extent of the problem and its impacts on bird populations.

Vessel operators per routine OCS oil- and gas-related activities 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. However, it is still possible to have accidental release of trash and debris into the marine environment, which has documented impacts to birds. Birds could be impacted by plastic by mistakenly ingesting pieces when foraging or by trophic transfer (Moore 2008; Grace et al. 2022; Carrillo et al. 2023). Once ingested, these plastics are largely non-digestible and can cause blockages, internal damage, and a false sense of satiety (Wright et al. 2013b; Grace et al. 2022). Also, chemicals can leach from plastics following ingestion, which creates an ecotoxicological concern (Tanaka et al. 2013; 2019). To date, there is a lack of data on distribution of plastic, accumulation in biota, and potential vulnerable species in the Gulf. Therefore, it is difficult to draw conclusions about the extent of the problem and its impacts on bird populations. Mitigating measures can reduce the potential for trash and debris in the marine environment. BSEE's, USCG's, and USEPA's regulations, and BOEM's guidance, minimize unintended releases of trash and debris by oil and gas operators. The prohibition of discharging materials into the marine environment is outlined in the Marine Plastic Pollution Research and Control Act, MARPOL Annex V, and the Marine Debris Research, Prevention and Reduction Act. Lessees are required to perform OCS oil- and gas-related activities, including decommissioning activities, in accordance with regulatory requirements (see **Section 4.1.2** and **4.1.3** and **Table 4-3** for more detail).

4.8.9.4 Strikes and Collisions

Some birds follow ships as a foraging strategy, though this is more common with commercial and recreational fishing vessels. In the open ocean, vessel transits and operations for routine OCS oil- and gas-related activities, including decommissioning activities, can attract birds from long distances. 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. These instances could increase the chance of a subsequent vessel strike, most particularly light-induced attraction to vessels at night (Black 2005). 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 1–3.5 m (3–11.5 ft) below the surface. 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 Gulf, which may increase the potential for vessel strikes. An analysis of North American bird banding data (1930–2023) identified at least 407 seabird collisions with buildings and similar structures, primarily affecting gulls, terns, and pelicans in coastal and urban areas (Lawson et al. 2025).

Low-flying aircraft (e.g., helicopters) for OCS oil- and gas-related activities, including decommissioning activities, could 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 could result in accidental strikes. However, the potential for bird collisions with aircraft decreases at speeds

greater than 80 kn (93 mph) (Rotocraft Bird Strike Working Group 2019). Most helicopters fly at an average speed of 140 kn (161 mph). The FAA recommends that aircraft fly at least 610 m (2,000 ft) above the ground when passing over noise-sensitive areas (i.e., national parks, national wildlife refuges, waterfowl protection areas, wilderness areas), which decreases the chances of behavioral responses and subsequent collisions from the higher density of birds in those areas (Kaulia 2004). Lessees are required to perform OCS oil- and gas-related activities, including decommissioning activities, in accordance with regulatory requirements (see **Section 4.1.2** and **4.1.3** and **Table 4-3** for more detail).

4.8.9.5 Entanglement and Entrapment

Seabirds in the Gulf are not likely to be impacted by entanglement and entrapment from BOEM-regulated activities. Diving seabirds generally do not dive deep enough or long enough to be vulnerable to lines in the water. Vessel moon pools could be opened or closed depending on the activity and would not be an entrapment vulnerability for birds in the Gulf. Further, no empirical evidence suggests that marine and coastal birds could become entangled in seismic survey gear.

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APPENDICES

A COMMON AND SCIENTIFIC NAMES

Common and scientific names of organisms that may appear in the document are listed below and not considered an all-inclusive list. The protective status of relevant species is indicated, though Distinct Population Segments of some species may have different listings under the ESA. All marine mammals are protected under the MMPA.

Table A-1. Marine mammals: dolphins

Common Name	Scientific Name
Atlantic spotted dolphin	*Stenella frontalis*
Bottlenose dolphin	*Tursiops truncatus*
Sei whale[1]	*Balaenoptera borealis*
False killer whale[1]	*Pseudorca crassidens*
Fraser's dolphin	*Lagenodelphis hosei*
Indo-Pacific humpback dolphin	*Sousa chinensis*
Sowerby's beaked whale	*Mesoplodon bidens*
Melon-headed whale	*Peponocephala electra*
Pantropical spotted dolphin	*Stenella attenuata*
Pygmy killer whale	*Feresa attenuata*
Risso's dolphin	*Grampus griseus*
Rough-toothed dolphin	*Steno bredanensis*
Short-finned pilot whale	*Globicephala macrorhynchus*
Spinner dolphin	*Stenella longirostris*
Striped dolphin	*Stenella coeruleoalba*

[1] This species or subspecies is listed under the ESA as Endangered.

Table A-2. Marine mammals: whales

Common Name	Scientific Name
Beluga whale[2]	*Delphinapterus lecus*
Blainville's beaked whale	*Mesoplodon densirostris*
Blue whale[2]	*Balaenoptera musculus*
Bowhead whale[2]	*Balaena mysticetus*
Bryde's whale	*Balaenoptera brydei*
Cuvier's beaked whale	*Ziphius cavirostris*
Dwarf sperm whale	*Kogia sima*
Fin whale[2]	*Balaenoptera physalus*
Gervais' beaked whale	*Mesoplodon europaeus*
Gray whale[2]	*Eschrichtius robustus*
Humpback whale[1 2]	*Megaptera novaeangliae*
Killer (orca) whale[2]	*Orcinus orca*
Minke whale	*Balaenoptera acuorostrata*

Common Name	Scientific Name
Narwhal	*Monodon monoceros*
North Atlantic right whale[2]	*Eubalaena glacialis*
Pygmy sperm whale	*Kogia breviceps*
Rice's whale[2]	*Balaenoptera ricei*
Sperm whale[2]	*Physeter macrocephalus*

[1] This species or subspecies is listed under the ESA as Threatened.

[2] This species or subspecies is listed under the ESA as Endangered.

Table A-3. Marine mammals: porpoises

Common Name	Scientific Name
Harbor porpoise	*Phocoena phocoena*

Table A-4. Marine mammals: manatees

Common Name	Scientific Name
West Indian manatee[1]	*Trichechus manatus*
Florida manatee	*Trichechus manatus latirostris*
Antillean manatee	*Trichechus manatus manatus*

[1] This species or subspecies is listed under the ESA as Threatened.

Table A-5. Other mammals

Common Name	Scientific Name
Alabama beach mouse[1]	*Peromyscus polionotus*
Choctawhatchee beach mouse[1]	*Peromyscus polionotus allophrys*
Nutria	*Myocastor coypus*
Perdido Key beach mouse[1]	*Peromyscus polionotus trissyllepsis*
Santa Rosa beach mouse	*Peromyscus polionotus leucocephalus,* *not listed under ESA
St Andrew beach mouse[1]	*Peromyscus polionotus peninsularis*

[1] This species or subspecies is listed under the ESA as Endangered.

Table A-6. Reptiles

Common Name	Scientific Name
American crocodile	*Crocodylus acutus*

Table A-7. Turtles

Common Name	Scientific Name
Eastern painted turtle	*Chrysemys picta picta*
Flatback sea turtle	*Natator depressus*
North Atlantic DPS green sea turtle[1]	*Chelonia mydas*
Hawksbill sea turtle[2]	*Eretmochelys imbricata*
Kemp's ridley sea turtle[2]	*Lepidochelys kempii*
Leatherback sea turtle[2]	*Dermochelys coriacea*
Northwest Atlantic ocean DPS loggerhead sea turtle[1]	*Caretta caretta*
Red-eared slider	*Trachemys scripta elegans*

[1] This species or subspecies is listed under the ESA as Threatened.

[2] This species or subspecies is listed under the ESA as Endangered.

Table A-8. Birds: shorebirds (i.e., Charadriiformes)

Common Name	Scientific Name
American oystercatcher	*Haematopus palliatus*
Black-necked stilt	*Himantopus mexicanus*
Bridled tern	*Onychoprion anaethetus*
Great black-backed gull	*Larus marinus*
Greater crested tern	*Thalasseus bergii*
Herring gull	*Larus argentatus*
Laughing gull	*Leucophaeus atricilla*
Least tern	*Sternula antillarum*
Roseate tern[1]	*Sterna dougallii*
Royal tern	*Thalasseus maximus*
Rufa red knot[1]	*Calidris canutus rufa*
Sandwich tern	*Thalasseus sandvicensis*
Sooty tern	*Onychoprion fuscatus*
Willet	*Tringa semipalmata*

[1] This species or subspecies is listed under the ESA.

Table A-9. Birds: passerines (i.e., Passeriformes)

Common Name	Scientific Name
Cape Sable seaside sparrow[1]	*Ammospiza maritima mirabilis*

[1] This species or subspecies is listed under the ESA.

Table A-10. Birds: raptors (i.e., Falconiformes, Accipitriformes)

Common Name	Scientific Name
Bald eagle	*Haliaeetus leucocephalus*
Everglade snail kite[1]	*Rostrhamus sociabilis plumbeus*
Osprey	*Pandion haliaetus*
Peregrine Falcon	*Falco peregrinus*

[1] This species or subspecies is listed under the ESA.

Table A-11. Birds: seabirds (e.g., Charadriiformes, Pelecaniformes, Procellariiformes, Gaviiformes, Podicipediformes)

Common Name	Scientific Name
African penguin	*Spheniscus demersus*
Atlantic puffin	*Fratercula arctica*
Black-capped petrel[1]	*Pterodroma hasitata*
Brown pelican	*Pelecanus occidentalis*
Black scoter	*Melanitta americana*
Bufflehead	*Bucephala albeola*
Canvasback	*Aythya valisineria*
Common eider	*Somateria mollissima*
Common goldeneye	*Bucephala clangula*
Common loon	*Gavia immer*
Common murre	*Uria aalge*
Gentoo penguin	*Pygoscelis papua*
Great cormorant	*Phalacrocorax carbo*
Greater scaup	*Aythya marila*
Harlequin duck	*Histrionicus histrionicus*
Hooded merganser	*Lophodytes cucullatus*
King penguin	*Aptenodytes patagonicus*
Lesser scaup	*Aythya affinis*
Long-tailed duck	*Clangula hyemalis*
Macaroni penguin	*Eudyptes chrysolophus*
Magnificent frigatebird	*Fregata magnificens*
Mallard	*Anas platyrhynchos*
Marbled murrelet	*Brachyramphus marmoratus*
Northern gannet	*Morus bassanus*
Red-throated loon	*Gavia stellata*

Common Name	Scientific Name
Ring-necked duck	*Aythya collaris*
Ruddy duck	*Oxyura jamaicensis*
Surf scoter	*Melanitta perspicillata*
White-winged scoter	*Melanitta deglandi*

[1] This species or subspecies is listed under the ESA.

Table A-12. Birds: wading and marsh birds (e.g., Ciconiiformes, Gruiformes)

Common Name	Scientific Name
Black rail	*Laterallus jamaicensis*
Eastern black rail[1]	*Laterallus jamaicensis jamaicensis*
Killdeer	*Charadrius vociferus*
Mississippi sandhill crane[1]	*Antigone canadensis pulla*
Piping plover[1]	*Charadrius melodus*
Snowy plover	*Charadrius nivosus*
Western grebe	*Aechmophorus occidentalis*
Whooping crane[1]	*Grus americana*
Wilson's plover	*Charadrius wilsonia*
Wood stork	*Mycteria americana*

[1] This species or subspecies is listed under the ESA.

Table A-13. Plants

Common Name	Scientific Name
Black mangrove	*Avicennia germinans*
Buttonwood	*Conocarpus erectus*
Cattail	*Typha domingensis*
Coastal dropseed	*Sporobolus virginicus*
Coontail	*Ceratophyllum demersum*
Cordgrass	*Spartina spp.*
Eurasian watermilfoil	*Myriophyllum spicatum*
Keygrass	*Monanthochloe littoralis*
Manatee grass	*Syringodium filiforme*
Perrenial glasswort	*Salicornia virginica*
Pondweed	*Potamogeton spp*
Red mangrove	*Rhizophora mangle*
Saltgrass	*Distichlis spicata*
Saltwort	*Batis maritima*
Sargassum	*Sargassum natans and Sargassum fluitans*
Sawgrass	*Cladium jamaicense*
Sea oxeye	*Borrichia frutescens*

Common Name	Scientific Name
Shoal grass	*Halodule wrightii*
Star grass	*Halophila engelmannii*
Turtle grass	*Thalassia testudinum*
Water celery	*Vallisneria americana*
Water nymph	*Najas guadalupensis*
White mangrove	*Laguncularia racemosa*
Wigeon grass	*Ruppia maritima*

Table A-14. Other terrestrial species

Common Name	Scientific Name
Bartram's hairstreak (or scrub-hairstreak) butterfly	*Strymon acis bartrami*
Eastern red bat	*Lasiurus borealis*
Florida bonneted bat	*Eumops floridanus*
Florida leafwing butterfly	*Anaea troglodyta floridalis*
Frosted flatwoods salamander	*Ambystoma cingulatum*
Hoary bat	*Lasiurus cinereus*
Northern long-eared bat	*Myotis septentrionalis*
Northern yellow bat	*Lasiurus intermedius*
Seminole bat	*Lasiurus seminolus*
Silver rice rat	*Oryzomys palustris natator*
Tricolored bat	*Perimyotis subflavus*

Table A-15. Marine invertebrates

Common Name	Scientific Name
American lobster	*Homarus americanus*
Amphipods	Amphipoda
Annelids	Annelida
N/A (Brisingid sea star)	*Midgardia xandaros*
Asian tiger shrimp	*Penaeus monodon*
Atlantic seabob	*Xiphopenaeus kroyeri*
Basket stars	*Euryalida* spp.
Bay scallop	*Argopecten irradians*
Black sea urchin	*Arbacia lixula*
Black spiny sea urchin	*Diadema antillarum*
Blue crab	*Callinectes sapidus*
Boulder star coral[1]	*Orbicella franksi*
Brittle stars	Ophiuroidea
Brown shrimp	*Farfantepenaeus aztecus*

Common Name	Scientific Name
Bryozoans	Bryozoa
Caribbean spiny lobster	*Panulirus argus*
Chaetognaths	Chaetognatha
Cnidarians	Cnidaria
Copepods	Copepoda
Ctenophores	Ctenophora
Decapod	Decapoda
Deepsea-gorgonian	*Callogorgia delta*
Eastern oyster	*Crassostrea viginica*
Echinoderms	Echinodermata
Elkhorn coral[1]	*Acropora palmata*
Fire coral	*Millepora alcicornis*
Fire worm	*Hermodice carunculata*
Foraminifera	Foraminifera
Ghost shrimp	*Palaemonetes paludosus*
Giant scallop	*Placopecten magellanicus*
Golden crab	*Chaceon fenneri*
Gulf stone crab	*Menippe adina*
Hermit crabs	*Pagurus* spp.
Heteropods	Pterotracheoidea
Horseshoe crab	*Limulus polyphemus*
Hummingbird bobtail squid	*Euprymna berryi*
Lesser blue crab	*Callinectes similis*
Lobed star coral[1]	*Orbicella annularis*
Longfin squid	*Doryteuthis pealeii*
Lophelia	*Lophelia pertusa / Desmophyllum pertusum*
Lophogastrid	Lophogastrida
Mantis shrimp	Stomatopoda
Mole crab	*Emerita* spp.
Mollusks	Mollusca
Mountainous star coral[1]	*Orbicella faveolata*
Mysid	Mysida
Norway lobster	*Nephrops norvegicus*
Orange cup coral	*Tubastraea coccinea*
Ostracods	Ostracoda
Pillar coral[2]	*Dendrogyra cylindricus*
Pink shrimp	*Farfantepenaeus duorarum*
Polychaete worms	Polychaeta
Protozoa	Protozoa
Pteropods	Pteropoda
Queen conch[1]	*Aliger gigas*

Common Name	Scientific Name
Rock lobster	*Jasus edwardsii*
Rock shrimp	Sicyoniidae
Rough cactus coral[1]	*Mycetophyllia ferox*
Royal red shrimp	*Pleoticus robustus*
Salps	Salpidae
Sargassum nudibranch	*Scyllaea pelagica*
Sargassum swimming crab	*Portunus sayi*
Siphonophores	Siphonophorae
Slender Sargassum shrimp	*Latreutes fucorum*
Smooth black coral	*Leiopathes glaberrima*
Squat lobster	*Eumunida picta*
Staghorn coral[1]	*Acropora cervicornis*
Stone crab	*Menippe* spp.
Sun cup coral	*Cladopsammia manuelensis*
Ten-ray star coral	*Madracis decactis*
Thorny oyster	*Spondylus americanus*
Tunicates	Tunicata
White shrimp	*Litopenaeus setiferus*
Wire coral	*Stichopathes lutkeni*
Zigzag coral	*Madrepora oculata*

[1] This species or subspecies is listed under the ESA as Threatened.

[2] This species or subspecies is listed under the ESA as Endangered.

Table A-16. Fishes

Common Name	Scientific Name
Albacore tuna	*Thunnus alalunga*
Almaco jack	*Seriola rivoliana*
Amberjacks	*Seriola* spp.
Anchovies	Engraulidae
Angelfishes	Pomacanthidae
Anglerfishes	Ceratioidei
Atlantic angel shark	*Squatina dumeril*
Atlantic cod	*Gadus morhua*
Atlantic croaker	*Micropogonias undulatus*
Atlantic herring	*Clupea harengus*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Banded rudderfish	*Seriola zonata*
Barracudinas	Paralepididae
Barrelfish	*Hyperoglyphe perciformis*
Basking shark	*Cetorhinus maximus*
Bigeye sand tiger	*Odontaspis noronhai*

Common Name	Scientific Name
Bigeye sixgill shark	*Hexanchus nakamurai*
Bigeye thresher shark	*Alopias superciliosus*
Bigeye tuna	*Thunnus obesus*
Bignose shark	*Carcharhinus altimus*
Billfish	Istiophoridae
Black drum	*Pogonias cromis*
Black grouper	*Mycteroperca bonaci*
Black seabass	*Centropristis striata*
Blackbelly rosefish	*Helicolenus dactylopterus*
Blackfin tuna	*Thunnus atlanticus*
Blacknose shark	*Carcharhinus acronotus*
Blacktip shark	*Carcharhinus limbatus*
Blue shark	*Prionace glauca*
Bluefin tuna	*Thunnus thynnus*
Bluefish	*Pomatomus saltatrix*
Bonnethead shark	*Sphyrna tiburo*
Bristlemouths	Gonostomatidae
Bull shark	*Carcharhinus leucas*
Caribbean reef shark	*Carcharhinus perezii*
Caribbean sharpnose shark	*Rhizoprionodon porosus*
Cobia	*Rachycentron canadum*
Cocoa damselfish	*Stegastes xanthurus*
Cookie cutter shark	*Isistius brasiliensis*
Crevalle jack	*Caranx hippos*
Cubera snapper	*Lutjanus cyanopterus*
Deep-sea pelagic eels	Saccopharyngiformes
Deep-sea smelts	Bathylagidae
Dog snapper	*Lutjanus jocu*
Dolphinfishes (mahi-mahi)	*Coryphaena* spp.
Dragonfishes	Stomiidae
Driftfishes	Nomeidae
Drums	Sciaenidae
Dusky shark	*Carcharhinus obscurus*
Dwarf sand perch	*Diplectrum bivittatum*
Escolar	*Lepidocybium flavobrunneum*
European eel	*Anguilla anguilla*
European seabass	*Dicentrarchus labrax*
Fangtooths	Anoplogastridae
Filefishes	Monacanthidae
Finescale menhaden	*Brevoortia gunteri*
Finetooth shark	*Carcharhinus isodon*
Flatfishes	Pleuronectiformes

Common Name	Scientific Name
Flying fish	Exocoetidae
Gag grouper	*Mycteroperca microlepis*
Galapagos shark	*Carcharhinus galapagensis*
Giant manta ray[1]	*Mobula birostris*
Goliath grouper	*Epinephelus itajara*
Gray snapper	*Lutjanus griseus*
Gray triggerfish	*Balistes capriscus*
Great hammerhead shark	*Sphyrna mokarran*
Great white shark	*Carcharodon carcharias*
Greater amberjack	*Seriola dumerili*
Groupers	Serranidae
Gulf menhaden	*Brevoortia patronus*
Gulf sturgeon[1]	*Acipenser oxyrhynchus desotoi*
Haddock	*Melanogrammus aeglefinus*
Halfbeaks	Hemirhamphidae
Hardhead catfish	*Ariopsis felis*
Hatchetfishes	Sternoptychinae
Hogfish	*Lachnolaimus maximus*
Jacks	Carangidae
King mackerel	*Scomberomorus cavalla*
Lake sturgeon	*Acipenser fulvescens*
Lane snapper	*Lutjanus synagris*
Lanternfish	Myctophidae
Lemon shark	*Negaprion brevirostris*
Lesser amberjack	*Seriola fasciata*
Little tunny	*Euthynnus alletteratus*
Longfin mako shark	*Isurus paucus*
Misty grouper	*Hyporthodus mystacinus*
Mutton snapper	*Lutjanus analis*
Narrowtooth shark	*Carcharhinus brachyurus*
Nassau grouper[1]	*Epinephelus striatus*
Night shark	*Carcharhinus signatus*
Nurse shark	*Ginglymostoma cirratum*
Oceanic whitetip shark[1]	*Carcharhinus longimanus*
Pacific mackerel	*Scomber japonicus*
Pinfish	*Lagodon rhomboides*
Porbeagle shark	*Lamna nasus*
Purple reeffish	*Chromis scotti*
Queen snapper	*Etelis oculatus*
Red drum	*Sciaenops ocellatus*
Red grouper	*Epinephelus morio*
Red hind	*Epinephelus guttatus*

Common Name	Scientific Name
Red lionfish	*Pterois volitans*
Red snapper	*Lutjanus campechanus*
Ridgeheads	Melamphaidae
Rock hind	*Epinephelus adscensionis*
Rock seabass	*Centropristis philadelphica*
Roughys	*Hoplostethus* spp.
Sand perch	Diplectrum formosum
Sand tiger shark	*Carcharias taurus*
Sandbar shark	*Carcharhinus plumbeus*
Sargassum frogfish	*Histrio histrio*
Scalloped hammerhead	*Sphyrna lewini*
Scamp	*Mycteroperca phenax*
Sevengill shark	*Heptranchias perlo*
Shortfin mako shark	*Isurus oxyrinchus*
Silky shark	*Carcharhinus falciformis*
Sixgill shark	*Hexanchus griseus*
Skipjack tuna	*Katsuwonus pelamis*
Sleeper shark	*Somniosus* sp.
Slippery dick	*Halichoeres bivittatus*
Smalltail shark	*Carcharhinus porosus*
Smalltooth sawfish[2]	*Pristis pectinata*
Smooth hammerhead	*Sphyrna zygaena*
Smooth-heads or slickheads	Alepocephalidae
Snappers	Lutjanidae
Snowy grouper	*Hyporthodus niveatus*
Southern flounder	*Paralichthys lethostigma*
Spanish mackerel	*Scomberomorus maculatus*
Speckled hind	*Epinephelus drummondhayi*
Spinner shark	*Carcharhinus brevipinna*
Spot	*Leiostomus xanthurus*
Spotted seatrout	*Cynoscion nebulosus*
Striped mullet	*Mugil cephalus*
Striped parrotfish	*Scarus iseri*
Swordfish	*Xiphias gladius*
Tarpon	*Megalops atlanticus*
Thornyheads	*Sebastolobus* spp.
Three-eye flounder	*Ancylopsetta dilecta*
Thresher shark	*Alopias vulpinus*
Tiger shark	*Galeocerdo cuvier*
Tilefish	Malacanthidae
Triggerfish	Balistidae
Tubeshoulders	Platyroctidae

Common Name	Scientific Name
Tunas	Scombridae
Vermilion snapper	*Rhomboplites aurorubens*
Wahoo	*Acanthocybium solandri*
Warsaw grouper	*Hyporthodus nigritus*
Whale shark	*Rhincodon typus*
Whalefishes	Cetomimidae
Wreckfish	*Polyprion americanus*
Yellowedge grouper	*Hyporthodus flavolimbatus*
Yellowfin grouper	*Mycteroperca venenosa*
Yellowfin menhaden	*Brevoortia smithi*
Yellowfin tuna	*Thunnus albacares*
Yellowmouth grouper	*Mycteroperca interstitialis*
Yellowtail reef fish	*Chromis enchrysurus*
Yellowtail snapper	*Ocyurus chrysurus*

[1] This species or subspecies is listed under the ESA as Threatened.

[2] This species or subspecies is listed under the ESA as Endangered.

B ACOUSTICS

B.1 SOURCES OF UNDERWATER SOUND

Ocean sounds originate from a variety of sources. Some come from non-biological sources such as wind and waves, while others come from the movements or vocalizations of marine life (Hildebrand 2009). Humans introduce sound into the marine environment through activities like oil and gas exploration, construction, military sonar, and vessel traffic (Hildebrand 2009). The acoustic environment or "soundscape" of a given ecosystem comprises all such sounds—biological, geophysical, and anthropogenic (Pijanowski et al. 2011). Soundscapes are highly variable across space, time, and water depth, among other factors, due to the properties of sound transmission and the types of sound sources present in each area. A soundscape is sometimes called the "acoustic habitat," because it can be a vital attribute of a given area where an animal may live (i.e., habitat) (Hatch et al. 2016).

B.2 PHYSICS OF UNDERWATER SOUND

Sounds are created by the vibration of an object within its medium (**Figure B-1**). When the object's vibration is coupled to the medium (e.g., water, in the case of underwater sound), that vibration travels as a propagating wave away from the sound source (**Figure B-1**). As this wave moves through the water, the water particles undergo tiny back-and-forth movements (i.e., particle motion), essentially oscillating in roughly the same location. When the particle motion results in more particles in one location (depicted as the area of compression in **Figure B-1**), that location has relatively higher pressure. Particles are then accelerated away from the higher-pressure region, causing the particles to transfer their energy to surrounding particles and propagating the wave. Acoustic pressure is a non-directional (scalar) quantity, whereas particle motion is an inherently directional quantity (a vector). The total energy of the sound wave includes the potential energy associated with the sound pressure as well as the kinetic energy from particle motion.

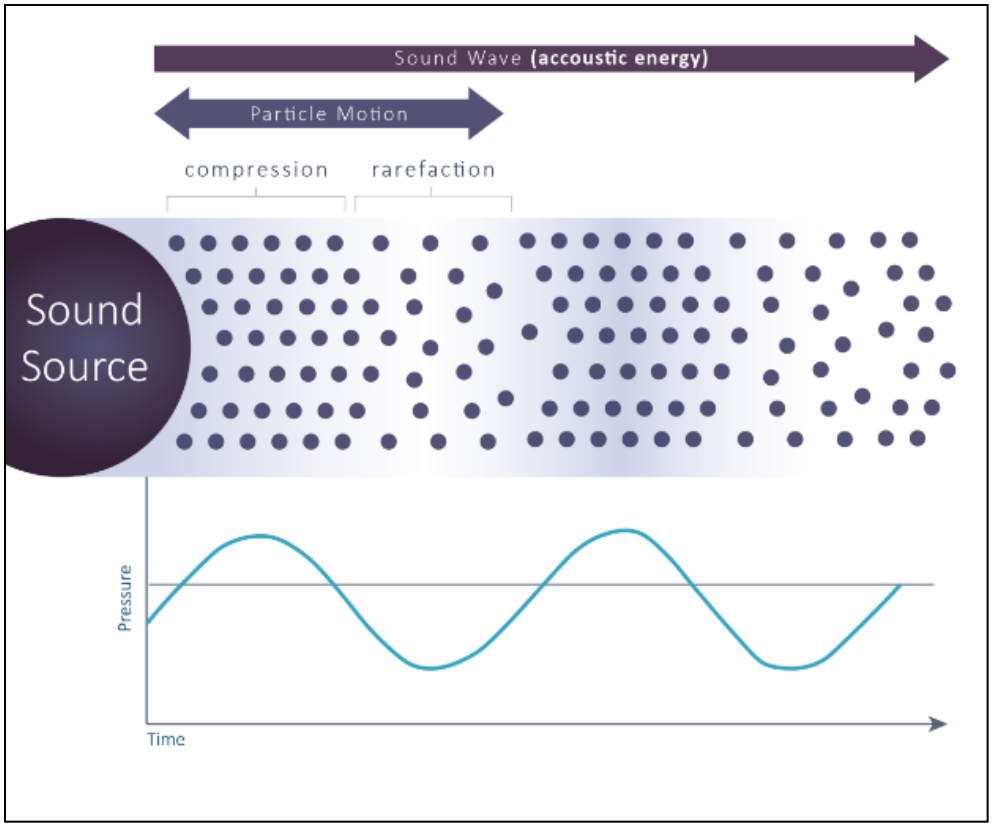


Figure B-1. Basic mechanics of a sound wave.
Credit: BOEM.

B.3 Units of Measurement

Sound can be quantified and characterized based on a number of physical parameters. A complete description of the units can be found in ISO 18405:2017 (International Organization for Standardization 2017). Some of the major parameters and their SI units (in parentheses) are below.

Acoustic pressure (pascal, Pa): The values used to describe the acoustic (or sound) pressure are peak pressure, peak-to-peak pressure and root-mean-square (rms) pressure deviation. The peak sound pressure is defined as the maximum absolute sound pressure deviation within a defined time period and is considered an instantaneous value. The peak-to-peak pressure is the range of pressure change from the most negative to the most positive-pressure amplitude of a signal (**Figure B-2**). The rms sound pressure represents a time-averaged pressure and is calculated as the square root of the mean (average) of the time-varying sound pressure squared over a given period (**Figure B-2**). The L_pk, Lpk-pk, and Lrms or SPL are computed by multiplying the logarithm of the ratio of the peak or rms pressures to a reference pressure (1 µPa in water) by a factor of 20 and are reported in dB.

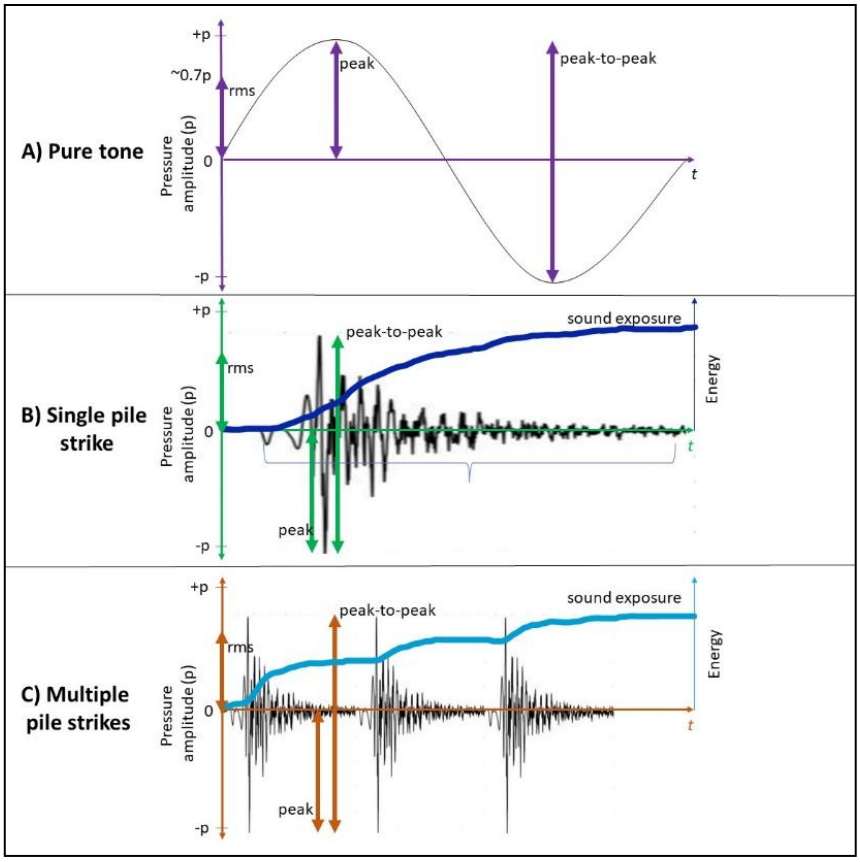


Figure B-2. Sound pressure wave representations of four metrics: root-mean-square (Lrms), peak (Lpk), peak-to-peak (Lpk-pk), and sound exposure (SEL).

A) A sine wave of a pure tonal signal with equal positive and negative peaks, so peak-to-peak is exactly twice the peak and rms is approximately 0.7 x peak.

B) A single pile driving strike with one large positive pulse and a large negative pulse that is not necessarily the same magnitude. In this example, the negative pulse is more extreme so is the reported peak value and peak-to-peak is less than double that. Sound exposure is shown as it accumulates across the time window. The final sound exposure would be considered the "single-shot" exposure and the rms value is that value divided by the duration of the pulse.

C) Three consecutive pile driving strikes with peak and peak-to-peak assessed the same way as in panel B). Sound exposure is shown accumulating across all three strikes and rms is the total sound exposure divided by the entire time window shown. The cumulative sound exposure for this series of signals would be considered the total energy from all 3 pile-strikes.

Credit: BOEM.

Particle velocity (meter per second, m/s): Particle velocity describes the rate of change in position of an oscillating particle about its origin with respect to time. Similar to sound pressure, particle velocity is dynamic and changes as the particles move back and forth. Therefore, peak particle velocity and root-mean-square particle velocity can be used to describe this physical quantity. One major difference between sound pressure and particle velocity is that the former is a scalar (i.e., without a directional component) and the latter is a vector (i.e., includes both magnitude and direction). Particle acceleration can also be used to describe particle motion, and is defined as the rate of change of velocity of a particle with respect to time. It is measured in units of meters per second squared, or m/s2.

Sound exposure (pascal-squared second, or Pa2-s): Sound exposure is proportional to the acoustic energy of a sound. It is the time-integrated squared sound pressure over a stated

period or acoustic event (see **Figure B-2**). Unlike sound pressure, which provides an instantaneous or time-averaged value of acoustic pressure, sound exposure is cumulative over a period of time.

Acoustic intensity (watts per square meter, or W/m2): Acoustic or sound intensity is the amount of acoustic energy that passes through a unit area normal to the direction of propagation per second. It is the product of the sound pressure and the sound velocity. With an idealized constant source, the pressure and particle velocity will vary in proportion to each other at a given location, but the intensity will remain constant.

Sound levels: There is an extremely wide dynamic range of values when measuring acoustic pressure in pascals, so it is customary to use a logarithmic scale to compress the range of values. Aside from the ease it creates for comparing a wide range of values, animals (including humans) perceive sound on a logarithmic scale. These logarithmic acoustic quantities are known as sound levels and are expressed in dB, which is the logarithm of the ratio of the measurement in question to a fixed reference value. Underwater acoustic sound pressure levels are referenced to a pressure of 1 µPa (equal to 10-6 pascals [Pa] or 10-11 bar). Note: airborne sound pressure levels have a different reference pressure: 20 µPa.

The metrics previously described (sound pressure, particle velocity, sound exposure, and intensity) can also be expressed as levels, and are commonly used in this way:

- root-mean-square sound pressure level (Lrms or SPL, in dB re 1 µPa)
- peak pressure level (Lpk, in dB re 1 µPa)
- peak-to-peak pressure level (L pk-pk, in dB re 1 µPa)
- sound exposure level (SEL, in dB re 1 $\mu Pa^2 s$)
- particle velocity level (SVL in dB re 1 nm/s)

Note: A few commonly used time periods are used for SEL, including a 24-hour period (used in the U.S. for the regulation of noise impacts to marine mammals [SEL24]), or the duration of a single event, such as a single pile driving strike or an airgun pulse, called the single-strike SEL (SELss). A sound exposure for some other period, such as the entire installation of a pile, may be written without a subscript (SEL), but to be meaningful, should always denote the duration of the event.

Source level: Another commonly discussed concept is source level. Source level is a representation of the amount of acoustic power radiated from the sound source being described. It describes how loud a particular source is in a way that can inform expected received levels at various ranges. It can be conceptualized as the product of the pressure at a particular location and the range from that location to a spherical (omnidirectional) source in an idealized infinite lossless medium. The source level is the sum of the received level and the propagation loss to that receiver. It is often discussed as what the received level would be 1 m from the source, but this can lead to confusion as an actual measurement at 1 m is likely to be

impossible for large and/or non-spherical sources. The most common type is an SPL source level in units of dB re 1 µPa·m, though in some circumstances an SEL source level (in dB re 1 $\mu Pa^2 s \cdot m^2$) may be expressed; peak source level (in units of dB re 1 µPa·m) may also be appropriate for some sources.

B.4 PROPAGATION OF SOUND IN THE OCEAN

Underwater sound can be described through a source-path-receiver model. An acoustic source emits sound energy that radiates outward and travels through the water and the seafloor. The sound level decreases with increasing distance from the acoustic source as the sound travels through the environment. The amount by which the sound levels decrease between the theoretical source level and a receiver is called propagation loss. Among other things, the amount of propagation loss that occurs depends on the source-receiver separation, the frequency of the sound, the properties of the water column, the water depth, and the properties of the seafloor and sea surface.

When sound waves travel through the ocean, they may encounter areas with different physical properties that will likely alter the propagation pathway of the sound, compared to a homogenous and boundary free environment. For example, near the ocean's surface, water temperature is usually higher, resulting in relatively fast sound speeds. As temperature decreases with increasing depth, the sound speed decreases. Sounds bend toward areas with lower speeds (Urick 1983). Ocean sound speeds are often slowest at mid-latitude depths of about 1,000 m, and because of sound's preference for lower speeds, sound waves above and below this "deep sound channel" often bend towards it. Sounds originating in this layer can travel great distances. Sounds can also be trapped in the mixed layer near the ocean's surface (Urick 1983). Latitude, weather, and local circulation patterns influence the depth of the mixed layer, and the propagation of sounds near the surface is highly variable and difficult to predict.

At the boundaries near the sea surface and the sea floor, acoustic energy can be scattered, reflected, or attenuated depending on the properties at the surface (e.g., roughness, presence of wave activity, or bubbles) or seafloor (e.g., bathymetric features, substrate heterogeneity) (Urick 1983). For example, fine-grain sediments tend to absorb sounds well, while hard bottom substrates reflect much of the acoustic energy back into the water column. The presence of ice on the ocean's surface can also affect sound propagation. For example, the presence of solid ice may dampen sound levels by scattering incident sounds. The effect will also depend on the thickness and roughness of the ice, among many other factors related to the ambient conditions. As a sound wave moves from a source to a receiver (i.e., an animal), it may travel on multiple pathways that may be direct, reflected, refracted, or a combination of these mechanisms, creating a complex pattern of transmission across range and depth. The patterns may become even more complicated in shallow waters due to repeated interactions with the surface and the bottom, frequency-specific propagation, and more heterogenous seafloor properties. All of these variables contribute to the difficulty in reliably predicting the sound field in a given marine environment at any particular time.

B.5 SOUND SOURCE CLASSIFICATION

In the current regulatory context, anthropogenic sound sources are categorized as either impulsive or non-impulsive, and either continuous or intermittent, based on their differing potential to affect marine species (NMFS 2018). Specifically, when it comes to potential damage to marine mammal hearing, sounds are classified as either impulsive or non-impulsive, and when considering the potential to affect behavior or acoustic masking, sounds are classified as either continuous or intermittent.

Impulsive noises are characterized as having (S1.13-2005 (R2010))

- broadband frequency content,
- fast rise-times and rapid decay times,
- short durations (i.e., <1 s),
- high peak sound pressures.

Whereas the characteristics of non-impulsive sound sources are less resolved but may be:

- variable in spectral composition, i.e., broadband, narrowband, or tonal;
- longer rise time/decay times, and longer total durations compared to an impulsive sound;
- continuous (e.g., vessel engine radiated noise), or intermittent (e.g., echosounder pulses).

For regulatory purposes, these classifications are based on properties of a sound at its source. However, the properties of a sound are likely to change as the sound propagates through the underwater environment. In addition, when there are multiple sound sources present in an environment simultaneously, this binary classification system may not accurately represent the complex characteristics of the sound to which an animal may be exposed.

The underwater bioacoustics community has proposed the use of kurtosis as a metric to more accurately classify the impulsivity of a sound transmitting through the environment for marine mammal exposures (e.g., Martin et al. 2020, Zeddies et al. 2023, Lucke et al. 2024). Kurtosis is a way to characterize the “peakiness” of a signal. A sound with high kurtosis is characterized as having sharp peaks in its waveform and produces more hearing damage than exposure to an equivalent-energy sound with low kurtosis, which has a more uniform waveform and very few if any peaks. For humans, a kurtosis value of 3 is considered Gaussian noise (flat waveform), while a kurtosis value of >40 is considered fully impulsive.

NMFS has also expressed the value of kurtosis and has indicated the potential use of this metric in the future to more accurately characterize real-life sounds (NMFS 2024). Kurtosis-corrected SEL has been recommended as a reliable way to predict the onset of auditory injury in humans (Goley et al. 2011; Zhao et al. 2010) and terrestrial mammals (Hamernik and Qiu 2001, Hamernik et al. 2003). However, at present the information needed to apply this

concept to marine mammals, fish, and turtles is lacking. For example, what kurtosis value correlates with hearing damage in each of these species groups? And over what duration should kurtosis be evaluated? Though research has begun to provide insight into these questions (Muller et al. 2020, von Benda Beckman et al. 2022), there are still information gaps preventing the practical application of kurtosis in marine life acoustic impact regulations.

Impulsive sounds associated with oil and gas development include seismic airguns, explosions, sparkers, and boomers; it is generally accepted that impulsive sources have a greater likelihood of causing hearing damage than non-impulsive sources (note: explosions are further considered for non-auditory injury, see Thresholds for Non-Auditory Injury sections, **3.6.6.3.3** and **3.7.5.4.3**). At close distances to impulsive sounds, physiological effects to an animal are likely, including TTS and AUD INJ, which includes but is not limited to PTS. These effects are also possible after exposure to non-impulsive sounds if the duration of exposure is long enough. This binary at-the-source classification of sound types, therefore, provides a conservative framework upon which to predict potential adverse hearing impacts to marine mammals.

For behavioral effects of anthropogenic sound on marine mammals, NMFS classifies sound sources as either intermittent or continuous (NMFS 2018). Continuous sounds, such as drilling or vibratory pile driving, remain “on”, i.e., producing sound, for a given period of time, though this is not well-defined. An intermittent sound typically consists of bursts or pulses of sound on a regular on-off pattern, also called the duty cycle. Examples of intermittent sounds are those from scientific echosounders, sub-bottom profilers, and impact pile driving. It is important to recognize that these delineations are not always practical in application, as a continuous yet moving sound source (such as a vessel passing over a fixed receiver) could be considered intermittent from the perspective of the receiver.

In their environments, animals will encounter many signals that may contain many or all of these sound types, which called complex sounds. And even for sounds that are impulsive at the source, as the signal propagates through the water, the degree of impulsiveness decreases (Martin et al. 2020). While there is evidence, at least in terrestrial mammals (Hamernik and Hsueh 1991), that complex sounds can be more damaging than continuous sounds of the same energy, there is not currently a regulatory category for this type of sound. One approach for assessing the impulsiveness of a sound that has gained attention is to compute the kurtosis of that signal. Kurtosis is a statistical measure that describes the prevalence of extreme values within a distribution of observations, in other words the “spikiness” of the data. By definition, a sound with a kurtosis value of 3 or less has very few extreme values and is generally considered Gaussian (i.e., normally distributed) noise. Martin et al. (2020) showed that a kurtosis value greater than 40 represents a distribution of observations with many extreme values and is very spiky. This generally describes an impulsive noise. A distribution of sound level observations from a time series with a kurtosis value somewhere in between these two values would be considered a complex sound.

B.6 Sound Sources Expected in the Gulf of America

B.6.1 Seismic Surveys (Airguns)

Seismic surveys are used to locate oil and gas resources below the seafloor. Seismic airguns are steel cylinders that are towed behind a source vessel and are connected to shipboard air compressors. The chamber is filled with compressed air (usually 2,000 psi) which is rapidly released to create an impulsive sound. Depending on the need of the survey, airguns can be deployed as single elements or as part of an airgun array comprising dozens of individual elements. Specific geophysical surveys may span a single day, weeks, or months.

Surveys that use single airguns (or small arrays of four or fewer airguns) are typically intended to image the uppermost kilometer or less of the seafloor with source frequencies primarily between 10–200 Hz (Jiménez-Arranz et al. 2020). The time interval between single airgun "shots" is usually less than 6 s, and the reflected signals are received by a single hydrophone streamer of several hundred meters in length to create two-dimensional (2D) reflection profiles. Typical industry surveys that use single airguns are likely to cover only one OCS lease block, which is usually 4.8 km on a side (this differs from deep-penetration surveys). Including vessel turns at the end of lines, the time required to survey one OCS lease block is approximately 36 hr.

Deep-penetration 2D and three-dimensional (3D) seismic surveys are conducted by the hydrocarbon exploration industry, typically covering areas off existing leases or covering multiple lease areas. For 2D seismic surveys, a single streamer is towed behind the survey vessel, together with a single source or airgun array. Seismic vessels generally follow a systematic pattern during a survey, typically a simple grid pattern for 2D work, with lines typically no closer than half a kilometer. In simplified terms, 3D surveys collect a very large number of 2D slices, with minimum line separations of only 25–30 meters. A 3D survey may take many months to complete (e.g., 3 to 18 months) and involves multiple passes to cover a given survey area, thus providing a substantial increase in resolution. A series of 3D surveys collected over time (commonly referred to as 4D surveying) is used for reservoir monitoring and management. Wide azimuth (WAZ) survey configurations involve multiple vessels operating concurrently in a variety of source vessel-to- acquisition vessel geometries. Several source vessels (usually two to four) are used in coordination with single or dual receiver vessels either in a parallel or rectangular arrangement with a typical 1200-meter vessel spacing to maximize the azimuthal quality of data acquired. Finally, vertical seismic profiles (VSPs) involve placing seismic sensors inside a well at varying depths, recording both direct-arriving and reflection energy from the acoustic source. Usually a smaller total airgun volume (and therefore lower acoustic energy) is required for VSPs than for towed-streamer surveys.

2D and 3D surveys use large arrays of as many as several dozen airguns and total airgun volumes can be several thousand cubic inches. The airguns are discharged at regular time intervals, typically every 10 s (International Association of Oil & Gas Producers 2011). Most of the energy produced by airgun arrays are below 250 Hz (with 90 percent of the energy between 70–140 Hz), but there may be additional energy up to 20 kHz (Jiménez-Arranz et al.

2020; Madsen et al. 2006). SPL source levels of single airguns (40–70 in^3) are typically between 200 and 230 dB re 1 µPa·m, while source levels of arrays (~400-3,000 in^3) range from 230 to 260 dB re 1 µPa·m (BOEM sound source list).

Airgun arrays have important advantages as a seismic source compared to single airguns. Large "tuned" arrays use airguns of varying chamber volumes to reduce the bubble pulse of the array source signature and increase the resolution of the source signal. A horizontally distributed array of airguns produces a downward-focused source signal. In addition, the number of airguns in an array is a much more important factor in determining the peak output level of the source than total airgun volume. Peak-to-peak amplitude of an airgun array increases linearly with the number of airguns but only increases by the cube root of total air volume (Caldwell and Dragoset 2000; Jiménez-Arranz et al. 2020).

Additional detail on seismic surveys can be found in Jiménez-Arranz et al. (2020) and BOEM's Sound Source List (Center for Marine Acoustics 2023).

B.6.2 Airgun Alternatives

Alternative seismic technologies are being developed and evaluated as potentially less impactful substitutes for conventional airgun arrays used in marine geophysical surveys. These include emerging low-frequency sources, such as the Tuned Pulse Source (TPS), Gemini, and Harmony, which are designed to produce more controlled and targeted acoustic signals with peak energy below 7 Hz. In addition, modified airgun systems like the eSource and Bluepulse control the acoustic signal to reduce high-frequency emissions by smoothing the waveform and minimizing the sharpness of the pressure pulse. This results in a less impulsive sound that is expected to be less disruptive to marine mammals. Marine vibroseis, another promising technology, emits a swept-frequency signal over several seconds, and reduces peak sound pressure levels, controls the signal output, and potentially minimizes disturbance to marine life. Collectively, these technologies reflect a shift toward more environmentally considerate seismic survey methods, aimed at minimizing behavioral or physiological disturbances to marine species. These technologies are expected to reduce both the intensity and spatial extent of underwater noise exposure, offering a more environmentally responsible approach to seismic exploration.

B.6.3 High-Resolution Geophysical Surveys (HRG)

High-resolution geophysical (HRG) surveys are conducted to characterize the bathymetry, sediment type, and benthic habitat characteristics of the marine environment and to identify archaeological resources or obstacles on the seafloor. These surveys differ from deep-penetration seismic surveys because they only intend to image the seafloor or shallow subsurface. The suite of sources that may be used in HRG surveys includes side-scan sonars (SSS), multibeam echosounders (MBES), magnetometers and gradiometers, parametric sub-bottom profilers, compressed high-intensity radiated pulses (CHIRP) sub-bottom profilers, boomers, and sparkers. These HRG sources may be towed behind a ship, mounted on a ship's hull, or deployed from ROVs or autonomous underwater vehicles (AUVs). In deepwater

environments, sources are usually deployed from AUVs about 5–10 m off the seafloor; this means the ensonified area is smaller than if a source was deployed on a ship at the surface.

Many HRG sources are active acoustic sources, meaning they produce sound deliberately in order to obtain information about the environment. With the exception of some MBES and SSS, they produce sounds below 180 kHz and thus may be audible to marine species. Source levels vary widely depending on source type and operational power level used, from ~145 dB re 1 µPa·m for towed sub-bottom profilers up to 245 dB re 1 µPa·m for some multibeam echosounders (Crocker and Fratantonio 2016). While sparkers are omnidirectional, most other HRG sources have narrower beamwidths (e.g., MBES: up to 6°, parametric SBPs: 30°, boomers: 30–90°) (Crocker and Fratantonio 2016). Generally speaking, sources that emit sound in narrow beams directed at the seafloor are less likely to affect marine species because they ensonify a smaller portion of the water column (Ruppel et al. 2022) and are considered de minimis. Most HRG sources emit short pulses of sound, with periods of silence in between. This means that only several "pings" emitted from a vessel towing an active acoustic source would reach an animal below, even if the animal was stationary (Ruppel et al. 2022). Further detail on HRG sources can be found in BOEM's Sound Source List and Crocker and Fratantonio (2016).

B.6.4 Geotechnical surveys

Geotechnical surveys are conducted to determine the physical and mechanical properties of sediments and the structure of the sediment layers. These surveys typically rely on either on-site measurements of physical properties or the acquisitions of actual specimens which can then be tested in the laboratory. Some systems generate and use acoustic signals to acquire this data (e.g., acoustic corers); however, with many of these methods, noise is produced as an unintended by-product of the mechanical process of acquiring the sample. Generally, the noise produced is low level and low frequency (<2,000 Hz). Special geotechnical drillships are required when conducting geotechnical surveys in water too deep for jack-up rigs or semi-submersibles. Modern drillships use DP systems to hold them in place, which often introduces more noise into the marine environment than the geotechnical sampling itself.

For example, shallow test wells, which are used to evaluate subsurface properties, are actively drilled using an engine from a drilling barge, jack-up rig, or semi-submersible. "Shallow test drilling" refers to drilling into the seabed at depths less than those in a deep stratigraphic test, i.e., less than 152 m (500 ft). Standard penetration testing is a method in which a sample tube is driven into the seabed at the bottom of a borehole; the number of blows required to penetrate the seabed provides an indication of the density of the substrate and is termed the "standard penetration resistance." Erbe and McPherson (2017) measured sounds from a jack-up rig during standard penetration testing, and back-calculated SPL source levels to be 160 dB re 1 µPa·m, with most of the energy below 3 kHz. Another type of geotechnical drilling is called standard rotary coring. Two or three tubes (core liner, holder, and drill bit) are used in conjunction to obtain cores longer than 30 m and up to several hundred meters into seafloor. They are typically powered by diesel or gas engines, using air or muds for cooling the drill bits.

Erbe and McPherson (2017) found that when using an 8.3 cm drillbit to penetrate 4-20 m into the seafloor, SPL source levels were around 145 dB re 1 µPa·m, with most of the energy in the 30–400 Hz range. Tetra Tech reported sound levels measured at 150-m distance while drilling 4.5-inch diameter bores into clay and mud (Tetra Tech Inc. 2014). The depth of the bore was not reported. SPLs varied from 95–108 dB re 1 µPa while drilling was taking place, but this is comparable to ambient noise measurements taken before drilling commenced (Tetra Tech Inc. 2014).

A deep stratigraphic test (DST, also known as COST well) is drilled not to encounter hydrocarbons, but to provide information about regional stratigraphy, to ground truth geophysical data, to estimate the age of sediments from collected microfossils, and to evaluate the potential quality of source rocks (BOEM 2017). A DST is defined in 30 CFR 251 as "drilling that involves the penetration into the sea bottom of more than 500 feet (152 meters)." Finally, CPTs provide a precise stratigraphy of the sampled core. A CPT is a pointed steel pipe that is forced into the seafloor; penetration is achieved through a hydraulic jacking mechanism. In waters less than 30 m, floating or jack-up barges typically are used; in deeper water (>30m), the CPT can be placed on seafloor. (Chorney et al. 2011) measured sound levels from a mini-CPT while DP thrusters were operational, and the measured 1/3 octave band levels while the mini-CPT was operational were virtually identical to periods when only the DP thrusters were in use. Therefore, the use of CPTs did not significantly increase underwater sound levels beyond contributions from the dynamic positioning thrusters and are therefore expected to be relatively quiet.

B.6.5 Dredging

Dredging is a process in which sediments are removed from the seafloor and transported to be deposited elsewhere. Dredging may be used to increase the width of shipping lanes, open new areas for construction, or to renourish beaches.

Dredging produces distinct sounds during each specific phase of operation: excavation, transport, and placement of dredged material (Central Dredging Association 2011; Jiménez-Arranz et al. 2020). Engines, pumps, and support vessels used throughout all phases may introduce low-level, continuous noise into the marine environment. The sounds produced during excavation vary depending on the sediment type—the denser and more consolidated the sediment is, the more force the dredger needs to impart, and the higher sound levels that are produced (Robinson et al. 2011). Hydraulic dredges (with cutterheads or drag arms in continuous contact with the seabed) produce nearly continuous sounds during the excavation process. On the other hand, sounds from mechanical dredges occur in intervals as the dredge lowers a bucket, digs, and raises the bucket with a winch. During the sediment transport phase, many factors—including the load capacity, draft, and speed of the vessel—influence the sound levels that are produced (Reine et al. 2014b). Sounds are also produced during pumpout operations when dredge plant pumps are operated (Central Dredging Association 2011). Dredging activities as a whole generally produce low-frequency sounds; most energy is below 1 kHz, with peaks typically occurring between 150–300 Hz (McQueen et al. 2018).

McQueen et al. (2018) summarized results from several studies that measured sounds during dredging operations. For cutterhead suction dredges, SPL source levels were 168–175 dB re 1 µPa·m (Greene Jr. 1987; Reine et al. 2012b; 2014a). Trailing suction hopper dredges were slightly louder, with SPL source levels ranging from 172–190 dB re 1 µPa·m (McQueen et al. 2018). Dickerson et al. (2001) recorded a maximum SPL of 124 dB re 1 µPa at 154 m during the moment when the grab hit the seabed; during other phases of operation (e.g., raising and lowering of grab dredge, dumping sediment on barge), the received SPL was closer to ~110–115 dB re 1 µPa at 154 m. Finally, SPL source levels during backhoe dredge operations ranged from 163–179 dB re 1 µPa·m (Nedwell et al. 2008; Reine et al. 2012a). Hydraulic dredges are generally louder than mechanical dredges, and dredging of coarser sediments usually produces more noise than softer sediments (Jiménez-Arranz et al. 2020). Additional detail and measurements of dredging sounds can be found in Jiménez-Arranz et al. (2020), McQueen et al. (2018), and Robinson et al. (2011).

B.6.6 Drilling and Production

A range of facilities may be used for offshore drilling and production, depending on water depth, duration of the planned activity, and other factors. Fixed platforms and jack-up rigs are limited to relatively shallow waters (up to 500 m), while MODUs are necessary in deeper waters. Drillships and semi-submersibles are two types of MODUs, both of which are held in place using dynamic positioning systems. The levels of noise generated during drilling and production generally depends on the platform type and degree of coupling between these mechanical sources and the structure. Generally speaking, drilling from fixed platforms is quieter than from MODUs because the machinery is above the water line, there is a relatively small contact area between the legs of the structure and the water, and no DP systems are used. For example, (Gales 1982) measured drilling noise at 30-ft distance from a fixed platform and found SPLs in the frequency range of 50–500 Hz were around 130 dB re 1 µPa, whereas Nedwell and Edwards (2004) measured underwater noise from a 250 m-long drillship and estimated SPL source levels to be 195 dB re 1 µPa·m. Sounds from drilling and production are generally considered to be non-impulsive and are nearly continuous in nature, though they may be highly variable depending on the type of substrate that is encountered (Richardson et al. 1995). There could be tonal sound generated by the drill bit, mechanical noise transferred through the ship's hull, and noise from the vessels and dynamic positioning systems. Drilling noise is also expected to be low-frequency in nature; for example, Greene Jr. (1987) measured noise from several drillships and found that the dominant energy was typically below 600 Hz, with the prominent tones coming from the diesel-electric generators.

B.6.7 Vessels and Dynamic Positioning Systems

Transiting vessels generate continuous sound from their engines, propeller cavitation, onboard machinery, and hydrodynamics of water flow (Ross 1976) and the noise that is generated is underneath the path of the vessel. The actual radiated sound usually has a combination of broadband and tonal sounds, and depends on several factors, including the type of machinery on the ship, the material conditions of the hull, how recently the hull has been cleaned,

interactions with the sea surface, and shielding from the hull, which reduces sound levels in front of the ship.

In general, vessel noise increases with ship size, power, speed, propeller blade size, number of blades, and rotations per minute. Small vessels, like those used for crew transport, typically produce higher-frequency sound than large container ships, with most energy concentrated in the 1–5 kHz range. Kipple and Gabriele (2003) measured underwater sound from vessels ranging from ~4.3 to 19.8 m (14 to 65 ft long) (25 to 420 horsepower) and back-calculated source levels to be 157–181 dB re 1 µPa·m. Large oil tankers tend to have source levels between 175–185 dB re 1 µPa·m (Jiménez-Arranz et al. 2020). During seismic or HRG surveys, vessels typically travel at slower speeds (typically 5 kn) which reduces underwater radiated noise. For example, recordings from a speed reduction program in the Port of Vancouver (210–250 m water depths) showed that reducing speeds to 11 kn reduced vessel source levels by 5.9–11.5 dB, depending on the vessel type (MacGillivray et al. 2019). Jiménez-Arranz et al. (2020) provide measurements of noise from support and crew vessels, tugs, inflatable RIHBs, icebreakers, cargo ships, oil tankers, and more.

DP systems also produce continuous noise, but unlike transiting vessels, this source is usually stationary. DP systems use propellers and thrusters for station-keeping (e.g., holding station over a specific seafloor location), docking, and other precise maneuvering during operations. DP uses input from gyrocompasses, motion sensors, GPS, active acoustic positioning systems, and wind sensors to determine relative movement and the environmental forces at work. Most of the noise generated by DP systems (low frequency and high amplitude) comes from the vessel thrusters. As with propulsion, source levels during the use of DP vary greatly based on size and type of vessel, type of thruster, and operational conditions including both weather and oceanographic conditions.

DP systems typically do not have a high peak sound pressure and rapid rise time compared to impulsive sounds but can still produce significant acoustic energy, most of which is below 1000 Hz, with tones related to engine and propeller size and type (ANSI S3.20-1995; NIOSH 1998). The sound can also vary directionally, and this directionality is much more pronounced at higher frequencies. Because this is a dynamic operation, the sound levels produced will vary based on the specific operation, the exact system used (e.g., jet or propeller rotation, versus a rudder or steering mechanism), and factors such as the blade rate, blade pitch and cavitation, and material condition of the system. Representative sound field measurements from the use of DP are difficult to obtain because the sound transmitted is often highly directional and context specific. The direction of sound propagation may change as different DP needs requiring different configurations are applied simultaneously.

There are few dedicated sound source characterizations of DP. Nedwell and Edwards (2004) reported that DP thrusters of the semi-submersible drill rig Jack Bates produced periodic noise (corresponding to the rate of the thruster blades) with most energy between 3 and 30 Hz. The received SPL measured at 100 m from the vessel was 188 dB re 1 µPa. Warner and McCrodan (2011) found that most DP related sounds from the self-propelled drill ship, R/V *Fugro Synergy*

were in the 110–140 Hz range, with an estimated source level of 169 dB re 1 µPa·m. Sounds in this frequency range varied by 12 dB during DP, while the broadband levels, which also included diesel generators and other equipment sounds, varied by only five dB over the same time period (Warner and McCrodan 2011). All the above sources report high variability in levels with time. This is due, in part, to the intermittent usage, and relatively slow rotation rates of thrusters used in DP. It is difficult to provide a realistic range of source levels from the data thus far because most reports do not identify the direction from which sound was measured relative to the vessel, and DP thrusters are highly directional systems.

The active acoustic positioning systems used in DP can be additional sources of high-frequency sound. These systems usually consist of a transducer mounted through the vessel's hull and one or more transponders affixed to the seabed. Kongsberg High Precision Acoustic Positioning (HiPAP) systems produce pings in the 10–32 kHz frequency range. The hull-mounted transducers have source levels of 188–206 dB re 1 µPa·m depending on adjustable power settings (Kongsberg Maritime AS 2013). The fixed transponders have maximum source levels of 186–206 dB re 1 µPa·m depending on model and beam width settings from 15 to 90° (Jiminez-Arranz et al. 2020). These systems have high source levels, but beyond two km, they are generally quieter than other components of the sound from DP vessels.

B.6.8 Trenching, Cable Laying, and Pipeline Laying

Trenching sleds dig the trenches for laying pipeline or cable by displacing the sediment with a water jet. Depending on the technique used, the cable may be laid directly into the trench as the trench is being cut, allowing the sediment to settle back into the trench and cover the cable, or a separate burying pass may be made after the cable is laid. Nedwell and Edwards (2004) measured sounds from a 130 m-long trenching vessel and found that sound levels were similar to those produced during pipeline laying in the same area (see below), with the exception of a 20 kHz tonal sound, which they attributed to the vessel's DP thrusters.

Pipelines are installed by lay barges that are either anchored or dynamically positioned while the pipeline is laid. Noise is also introduced into the water from the DP systems, the movement of supply ships and tugs, and anchoring. Up to 10 ships may be operating in the same area during pipeline laying; barges with very heavy anchors continually move along the pipeline route. Certain joints of the pipeline must be welded into place while offshore, so a conventional lay barge with a welding station is required. Nedwell and Edwards (2004) measured noise from a pipeline laying ship working in both shallow (<50 m) and deeper (50–100 m) waters near the Shetland Islands. In shallower areas, they found increased sound levels at distances up to 2.3 km at frequencies <1 kHz; by 7.4 km from the source, sounds from pipeline laying had faded into ambient noise. Johansson and Andersson (2012) measured sounds during pipe laying operations in 40 m water depth; at 1.5 km distance, the SPL was 130.5 dB re 1 µPa. DP thrusters were active when the measurements were taken, so it is difficult to know sound levels from pipeline laying alone.

B.6.9 Pile Driving

Pile driving is used to install infrastructure on the seafloor. Fixed structures can generally be installed in up to about 300 m water depths and are secured to the sea floor with steel piles. For hydrocarbon production, pile driving may be used to install fixed platforms, caissons, well protectors, casing, wellheads, and conductors.

Impact pile driving employs a hammer to strike the pile head and force the pile into the sediment with a typical hammer strike rate of approximately 30–50 strikes/minute. Typically, force is applied over a period of less than 20 ms, but the pile can generate sound for upwards of 0.5 s. Impact pile driving noise is characterized as impulsive because of its high peak pressure, short duration, and rapid onset time. Underwater sound levels generated during pile driving depend on many factors including the pile material and size, characteristics of the substrate, penetration of the pile in the seabed, hammer energy and size, and water depth.

Vibratory hammers may be used as an alternative to impact pile driving, and the noise produced is non-impulsive and nearly continuous. The vibratory hammer continuously exerts vertical vibrations into the pile, which causes the sediment surrounding the pile to liquefy, allowing the pile to penetrate the substrate. The vibratory hammer typically oscillates at a frequency of 20–40 Hz (Matuschek and Betke 2009) and produces most of its acoustic energy below 2 kHz. For small piles potentially used in jacket foundations, we would expect source levels to be similar to those measured by Buehler et al. (2015) who found measured received levels of 185 dB re 1 µPa at 10 m distance from a 72-in steel pile.

Techniques that are quickly gaining use for installation of infrastructure in hard rock substrates are DTH systems (pile driving and drilling), which use a combination of percussive and drilling mechanisms, with a hammer acting directly on the rock to advance a hole into the rock, and also advance the pile into that hole (Guan et al. 2022; NMFS 2022). Noise characteristics for DTH pile driving include both impulsive and non-impulsive components. The impulsive component of the DTH pile driving is the result of a percussive hammer striking the bedrock, while the non-impulsive component is from drilling and air-lifting of cuttings and debris from the pile. While only limited studies have been conducted on DTH pile driving noise, its characteristics strongly resemble those of impact pile driving, but with a higher hammer striking rate (approximately 10–15 Hz). The dominant frequencies from DTH pile driving are below 2 kHz, similar to conventional impact pile driving. Due to the high rate of hammer striking, along with the sounds of drilling and debris clearing out, sound levels in between the pulses are much higher than conventional impact pile driving (Guan et al. 2022). Guan et al. (2022) report measurements from DTH pile drilling during the installation of 0.84 m shafts within 1.22 m steel piles: the single-strike sound exposure levels were 138–142 dB re 1 $\mu Pa^2 s$ at 10 m.

B.6.10 Decommissioning

When oil and gas platforms become obsolete, they go through a decommissioning process, which may include partial or complete removal of the platform structure using an explosive

severance technique or mechanical cutting. There has generally been a shift to using nonexplosive methods, i.e., mechanical cutting, for removing oil and gas infrastructure, but due to safety and other considerations, these methods may not always be a viable option in the Gulf. When using explosives under water, the underwater pressure signature of a detonation is composed of an initial shock wave characterized by extreme changes in pressure, both positive and negative, followed by a succession of oscillating bubble pulses. This is generally true for explosive severance of platforms too, but the shock wave is modified by passage through the structure and the ocean sediment, while the oscillation bubble is mostly contained within the structure itself, often venting upward inside the structure's legs or conductors. This alters the acoustic energy that is ultimately released into the ocean.

Below-mud-line detonations are likely to produce lower pressure levels at the same propagation distances than open-water shock trial configurations due to absorption or expended to actual cut through the structure, attenuation of energy by sediments, and the confinement of the explosion within well casings and platform piles. Depending on the type and configuration of the explosives used, as well as the thickness, age, and type of steel used in the structure, as well as the type of sediment present at the site, the energy released to the ocean may be 30–70 percent of an explosion of equivalent weight in the open ocean. Data have shown that at 122 m (400 ft) from the detonation site, the shock wave parameters measured for below-mud-line detonations were less than 10 percent of the values expected for open water detonations (Barkaszi et al. 2016). Additionally, as the depth of below-mud-line detonations increases, the impact zones for marine species decreases (Barkaszi et al. 2016).

B.6.11 Aircraft

Piloted aircraft consist of propeller and jet engines, fixed-wing craft, as well as helicopters. Unmanned systems also exist. For jet engine aircraft, the engine is the primary source of sound. For propeller driven aircraft and helicopters, the propellors and rotors also produce noise. Though aircraft noise can be substantial in air, penetration of aircraft noise into the water is limited because much of the noise is reflected off the water's surface (Richardson et al. 1995). Noise that penetrates the water column does so via a critical incident angle or cone. With an idealized flat sea surface, the maximum critical incident angle is ~13 degrees (Urick 1983). Beyond this, sound is reflected off the surface. When the sea surface is not flat, there may be some additional penetration into the water column in areas outside of this 13° cone. Nonetheless, the extent of noise from passing aircraft is more localized in water than it is in air.

Jiménez-Arranz et al. (2020) and Richardson et al. (1995) reviewed sound measurements recorded below passing aircraft of various models. These SPL measurements included 124 dB re 1 µPa (dominant frequencies between 56 and 80 Hz) from a maritime patrol aircraft with an altitude of 76 m, 109 dB re 1 µPa (dominant frequency content below 22 Hz) from a utility helicopter with an altitude of 152 m, and 107 dB re 1 µPa (tonal, 82 Hz) from a turbo propeller with an altitude of 457 m. Recent published levels associated with unmanned aircraft

(Christiansen et al. 2016; Erbe et al. 2017) indicate source levels are around or below 100 dB re 1 µPa·m.

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