Draft Environmental Assessment for Marine Geophysical Surveys in the Northwestern Gulf of Mexico, Fall 2023

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

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Responsible Agency: United States Department of Energy

Title: Marine Geophysical Surveys by the University of Texas in the Northwestern Gulf of Mexico, Draft Environmental Assessment, DOE/EA-2191D

Location: The proposed survey area is located at ~28.9–29.1°N, ~94.9–95.2°W, within Texas state water; approximately 22 km northeast of Freeport, TX, and approximately 3 km from shore.

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Abstract: The U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) prepared this Draft Environmental Assessment (EA) to analyze the potential environmental, cultural, and social impacts of partially funding the University of Texas at Austin (UT) to conduct high-resolution 3-dimensional (HR3D) marine seismic surveys in the Gulf of Mexico (GoM). The proposed seismic surveys would be conducted from a research vessel on the shallow shelf in Texas state waters. The surveys would use up to 2 Generator-Injector (GI) airguns, with a total discharge volume of ~210 in^3, in water depths less than 20 meters. These surveys would be used to validate novel dynamic acoustic positioning technology for improving the accuracy in time and space of HR3D marine seismic technology. In particular, the seismic data would be used for field validation of monitoring, verification, and account technology for future offshore sub-seabed carbon storage. DOE's proposed action is to provide funding to UT; DOE would provide approximately $2.5 million of the project's $3.1 million total cost.

This Draft Environmental Assessment was prepared in compliance with the National Environmental Policy Act of 1969 (Title 42, Section 4321 et seq., United States Code) and DOE's NEPA implementing procedures (Chapter 10, Part 1021, Code of Federal Regulations) to evaluate the potential environmental impacts of DOE's proposed action to provide funding to UT, UT's proposed project, and the No Action alternative. Based on the expected environmental impacts for the proposed project, UT on behalf of itself and DOE, is requesting an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental (i.e., not intentional) harassment of small numbers of marine mammals should this occur during the seismic surveys. The analysis in this document supports the IHA application process and provides additional information on marine species that are not addressed by the IHA application, including sea turtles, seabirds, fish, and invertebrates listed under the U.S. Endangered Species Act (ESA), including candidate species. As analysis on endangered and threatened species was included, this document will also be used to support ESA Section 7 consultation with NMFS. Alternatives addressed in this EA consist of the Proposed Action with issuance of an associated IHA and the No Action alternative, with no IHA and no seismic surveys.

Potential impacts of the proposed seismic surveys on the environment would be primarily a result of the operation of the airgun(s). Impacts from the surveys would be associated with increased underwater anthropogenic sounds, which could result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned surveys is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed surveys, and to document, as much as possible, the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airgun(s). However, a precautionary approach would be taken, and the planned monitoring and mitigation measures would reduce the possibility of any effects.

Proposed protection measures designed to mitigate the potential environmental impacts to marine mammals and sea turtles include the following: ramp ups if 2 GI airguns are used; at least one dedicated observers maintaining a visual watch during all daytime airgun operations; two observers before and during start ups during the day; and shut downs when marine mammals or sea turtles are detected in or about to enter designated exclusion zones. With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal or sea turtle that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel.

Availability: This Draft EA is being released for public review and comment via newspaper announcements and online. Hard copies of the EA are being distributed to agencies and the library in Galveston, with electronic copies sent to others who request an electronic copy. The public is invited to provide written or e-mail comments to DOE on the Draft EA during the 30-day comment period, from March 17, 2023 to April 16, 2023. Comments should be provided to the National Energy Technology Laboratory, 3610 Collins Ferry Road, Morgantown, MW 26505, Attention: Mark Lusk or mark.lusk@netl.doe.gov. Comments received after April 16, 2023 will be considered to the extent possible.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

~	approximately
3-D	three-dimensional
AEP	Auditory Evoked Potential
AFTT	Atlantic Fleet Testing and Training
AMVER	Automated Mutual-Assistance Vessel Rescue
BIA	Biologically Important Areas
CFR	Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
CZMA	Coastal Zone Management Act
dB	decibel
DFO	Canadian Department of Fisheries and Oceans
DOE	Department of Energy
DoN	Department of the Navy
DPS	Distinct Population Segment
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	(U.S.) Endangered Species Act
EZ	Exclusion Zone
FAO	Food Agricultural Organization
FECM	Office of Fossil Energy and Carbon Management
FM	Frequency Modulated
FMP	Fishery Management Plan
FOA	Funding Opportunity Announcement
FONSI	Finding of No Significant Impact
G&G	geological and geophysical
GCCC	Gulf Coast Carbon Center
GI	Generator-Injector
GIS	Geographic Information System
GMFMC	The Gulf of Mexico Fishery Management Council
h	hour
HAPC	Habitat Area of Particular Concern
hp	horsepower
HR3D	high-resolution 3-dimensional
Hz	Hertz
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
IODP	International Ocean Discovery Program
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometer
kt	knot
L-DEO	Lamont-Doherty Earth Observatory
LFA	Low-frequency Active (sonar)
m	meter
MFA	Mid-frequency Active (sonar)
min	minute

MMPA	(U.S.) Marine Mammal Protection Act
MPA	Marine Protected Area
ms	millisecond
MVA	monitoring, verification, and accounting
NEPA	National Environmental Policy Act
NEFSC	Northeast Fisheries Science Center
NETL	National Energy Technology Laboratory
NMFS	(U.S.) National Marine Fisheries Service
nmi	nautical mile
NMS	National Marine Sanctuary
NOAA	National Oceanic and Atmospheric Administration
NRC	(U.S.) National Research Council
NSF	National Science Foundation
OCS	Outer Continental Shelf
OEIS	Overseas Environmental Impact Statement
p or pk	peak
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
rms	root-mean-square
R/V	research vessel
s	second
SEA	Supplemental Environment Assessment
SEL	Sound Exposure Level (a measure of acoustic energy)
SMA	Seasonal Management Area
SOSUS	(U.S. Navy) Sound Surveillance System
SPL	Sound Pressure Level
SPUE	Sighting per unit effort
SubTER	Subsurface Technology and Engineering
SWFSC	Southwest Fisheries Science Center
SWOT	The State of the World's Sea Turtles
t	tonnes
TTS	Temporary Threshold Shift
U.K.	United Kingdom
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.S.	United States of America
USCG	United States Coast Guard
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
UT	University of Texas at Austin
μPa	microPascal
vs.	versus
WCMC	World Conservation Monitoring Centre

1.0 INTRODUCTION

The U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) proposes to fund the University of Texas at Austin (UT) to conduct high-resolution 3-dimensional (HR3D) marine seismic surveys from the research vessel (R/V) *Brooks McCall* (or a similar vessel operated by TDI-Brooks) in the Gulf of Mexico (GoM) in water <20 m deep, off the coast of Texas. UT proposed this project in response to a funding opportunity announcement (FOA) for "Development of Technologies for Sensing, Analyzing, and Utilizing Novel Subsurface Signals in Support of the Subsurface Technology and Engineering (SubTER) Crosscut Initiative" (DE-FOA-0001445), funded through DOE's Office of Fossil Energy and Carbon Management (FECM). DOE would provide approximately $2.5 million of the project's $3.1 million total cost.

This Draft Environmental Assessment (EA) was prepared pursuant to the National Environmental Policy Act (NEPA) and DOE's NEPA implementing procedures (Chapter 10, Part 1021, Code of Federal Regulations [CFR]) to evaluate the potential environmental impacts of DOE's proposed action to provide funding to UT, UT's proposed project, and the No Action alternative. The purpose of this Draft EA is to provide the information needed to assess the potential environmental impacts associated with the Proposed Action, including the use of airgun(s) during the proposed seismic surveys.

The Draft EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic surveys on marine mammals, sea turtles, seabirds, fish, and marine invertebrates. The Draft EA will also be used in support of other regulatory processes, including an application for an Incidental Harassment Authorization (IHA) and Section 7 consultation under the Endangered Species Act (ESA) with the National Marine Fisheries Service (NMFS). The IHA would allow the non-intentional, non-injurious "Level B harassment" of small numbers of marine mammals during the proposed seismic surveys. No Level A takes are requested because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds; Level A takes would be considered highly unlikely. No long-term or significant effects would be expected on individual marine mammals or sea turtles, the populations to which they belong, or their habitats.

1.1 Purpose of and Need for the Proposed Action

DOE NETL has a continuing need to fund research that meets the laboratory's vison to deliver integrated solutions to enable transformation to a sustainable energy future. The purpose of the proposed seismic surveys would be to validate novel dynamic acoustic positioning technology for improving the accuracy in time and space of high-resolution 3-dimensional (HR3D) marine seismic technology. In particular, the seismic data would be used for field validation of monitoring, verification, and accounting (MVA) technology of offshore, sub-seabed carbon storage.

1.2 Regulatory Setting

The regulatory setting of this EA includes:

- National Environmental Protection Act (NEPA);
- Marine Mammal Protection Act (MMPA);
- Endangered Species Act (ESA);
- Coastal Zone Management Act (CZMA); and
- Magnuson-Stevens Fishery Conservation and Management Act – Essential Fish Habitat (EFH).

This Draft Environmental Assessment was prepared in compliance with the National Environmental Policy Act of 1969 (Title 42, Section 4321 et seq., United States Code) and DOE's NEPA implementing procedures (10 CFR 1021) to evaluate the potential environmental impacts of DOE's proposed action to provide funding to UT, UT's proposed project, and the No Action alternative. This statute and the implementing regulations require that DOE, as a federal agency:

- assess the environmental impacts of its proposed action;
- identify any adverse environmental effects that cannot be avoided, should the proposed action be implemented;
- evaluate alternatives to the proposed action, including a no action alternative; and
- describe the cumulative impacts of the proposed action together with other past, present, and reasonably foreseeable future actions.

These provisions must be addressed before a final decision is made to proceed with any proposed federal action that has the potential to cause impacts to the natural or human environment, including providing federal funding to a project. This Draft EA is intended to meet DOE's regulatory requirements under NEPA and provide DOE with the information needed to make an informed decision about providing financial assistance. In accordance with the above regulations, this EA allows for public input into the federal decision-making process; provides federal decisionmakers with an understanding of potential environmental effects of their decisions before making these decisions; and documents the NEPA process.

Based on the expected environmental impacts for the proposed project, UT on behalf of itself and DOE, is requesting an IHA from NMFS to authorize the incidental (i.e., not intentional) harassment of small numbers of marine mammals should this occur during the seismic surveys. The analysis in this document supports the IHA application process and provides additional information on marine species that are not addressed by the IHA application, including sea turtles, seabirds, fish, and invertebrates listed under the ESA. Thus, this document will also be used to support ESA Section 7 consultation with NMFS. To be eligible for an IHA under the MMPA, the proposed "taking" (with mitigation measures in place) must not cause serious physical injury or death of marine mammals, must have negligible impacts on the species and stocks, must "take" no more than small numbers of those species or stocks, and must not have an unmitigable adverse impact on the availability of the species or stocks for legitimate subsistence uses. Alternatives addressed in this EA consist of the Proposed Action with issuance of an associated IHA and the No Action alternative, with no IHA and no seismic surveys. Ultimately, survey operations would be conducted in accordance with all applicable international, U.S. state and federal regulations, including IHA and Incidental Take Statement (ITS) requirements.

Numerous species of cetaceans occur in the GoM, including the ESA-listed sperm whale and Rice's whale. However, those two ***endangered*** cetaceans, along with the ***threatened*** West Indian manatee, are not likely to be encountered in the proposed shallow-water survey area in the northwestern GoM. Other ESA-listed species that could occur in the area that are listed as ***endangered*** include the leatherback, Kemp's ridley, and hawksbill sea turtles. ***Threatened*** species or Distinct Population Segments (DPSs) under the ESA that could occur in the proposed survey area include the Northwest Atlantic DPS of loggerhead sea turtle, North Atlantic DPS of green sea turtle, South Atlantic DPS of green sea turtle, giant manta ray, oceanic whitetip shark, and Nassau Grouper. The ***threatened*** piping plover could also occur in the survey area. The queen conch is proposed for listing as ***threatened*** under the ESA and could also occur in the survey area.

1.3 Public Involvement and Agency Coordination

As this Draft EA assesses potential impacts on marine mammals, endangered species, and critical habitat, it will be used to support the ESA Section 7 and EFH consultation processes with NMFS. A letter was sent to NMFS advising that the Draft EA was being prepared. DOE sent a letter to U.S. Fish and Wildlife Service (USFWS) requesting its concurrence with DOE's determination that the proposed activities would have no effect on ESA-listed species and critical habitat under USFWS jurisdiction pursuant to Section 7 of the ESA of 1973 (16 U.S.C. 1531-1544), as amended, and that no further consultation is required. The Draft EA will also be used as supporting documentation for an IHA application submitted by UT, on behalf of itself and DOE, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic surveys. A CZMA Consistenty Determination will be submitted to the Texas General Land Office who administers the Texas Coastal Management Program. DOE will also notify non-governmental organizations and the pubic of the availability of the Draft EA. The public will be informed/involved through newspaper announcements, a 30-day comment period, and document availability in libraries and online.

1.4 Organization of EA

The DOE prepared this EA in compliance with NEPA and other relevant federal and state laws and regulations. This EA disclosed the direct, indirect, and cumulative environmental effects that would result from the proposed action and alternatives. The document is organized into four parts:

- Chapter 1: Introduction – This chapter includes information on the purpose of and need for the project, the agency's proposal for achieving that purpose and need, applicable laws and regulations, and other permits that may be required.
- Chapter 2: Proposed Action and Alternatives – This chapter provides a more detailed description of the agency's proposed action and evaluates the no action alternative. Alternatives considered by the applicant are also discussed in this chapter.
- Chapter 3: Affected Environment – This chapter contains a description of current resource conditions in the project area.
- Chapter 4: Environment Consequences – This chapter provides and assessment of the environmental effects of the proposed action.
- Chapter 4: List of Preparers – The chapter also includes a list of preparers for the EA.
- Chapter 5: Acronyms and Abbreviations – This chapter includes a listing of all acronyms and abbreviations used in the EA.
- Chapter 6: References – This chapter provides references for literature and data cited throughout the document.
- Appendices – The appendices provide information on consultation efforts and other information to support the analyses presented in the EA.

2.0 PROPOSED ACTION AND ALTERNATIVES

In this Draft EA, two alternatives are evaluated: (1) the Proposed Action – DOE provides funding to conduct the proposed research, including seismic surveys and associated issuance of an IHA and (2) the No Action alternative – DOE provides no funding. Two additional alternatives were considered (alternate location and technology) but were eliminated from further analysis. A summary of the Proposed Action, the alternative, and alternatives eliminated from further analysis is provided at the end of this section.

2.1 Proposed Action

The Proposed Action, including project objectives and context, activities, and monitoring/mitigation measures for the seismic surveys, is described in the following subsections.

2.1.1 Project Objectives and Context

DOE proposes to provide funding to UT to conduct HR3D seismic surveys using the TDI-Brooks owned R/V *Brooks McCall* (or similar vessel operated by the same company) in the northwestern GoM, off the coast of Texas (Fig. 1). The main goal of the seismic surveys proposed by the Principal Investigator Dr. T. Meckle is to collect data using HR3D marine seismic technology which would allow interpretation of the upper ~1 km of the geologic subsurface. In particular, the seismic data would be used for field validation of monitoring, verification, and accounting technology of sub-seabed carbon storage.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed surveys would occur within the 222 km^2 survey area located at approximately 28.9–29.1°N, 94.9–95.2°W, within Texas state waters and within the U.S. Exclusive Economic Zone (EEZ) (Fig. 1). The area of interest is located offshore San Luis Pass, which defines the southern tip of Galveston Island, Texas, and is situated approximately 22 km northeast of Freeport, TX, and approximately 3 km from shore (Fig. 1). The water depth at the site in some parts is as shallow as 10–12 m and no deeper than 20 m. The proposed survey area is shown in Figure 1. The seismic surveys could occur anywhere within the survey area and the coordinates noted above. The closest approach to shore would 3.2 km.

2.1.2.2 Description of Activities

The research project would be focused on validating novel dynamic acoustic positioning technology for improving the accuracy in time and space of HR3D seismic datasets, in particular as it pertains to field technology of offshore CCS. UT Gulf Coast Carbon Center (GCCC) designed and built GPS receivers that can be used to accurately position the streamer receivers and the acoustic source via tail buoys. Otherwise, the survey would use conventional seismic methodology, requiring third-party positioning technology and services at additional project expense.

The source vessel would tow one or two 105 in^3 Generator-Injector (GI) airguns, with a total possible discharge volume of ~210 in^3, at a depth of 3 m. The receiving system would consist of four 25-m solid-state (solid flexible polymer – not gel or oil filled) hydrophone streamers, spaced 10-m apart (i.e., 30-m spread), towed at a 2-m depth. The airguns would fire at a shot interval of 12.5 m (~5–10 s). As the airgun(s) are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system. Approximately 1704 km of seismic acquisition are proposed. All survey effort would occur in water <20 m deep.

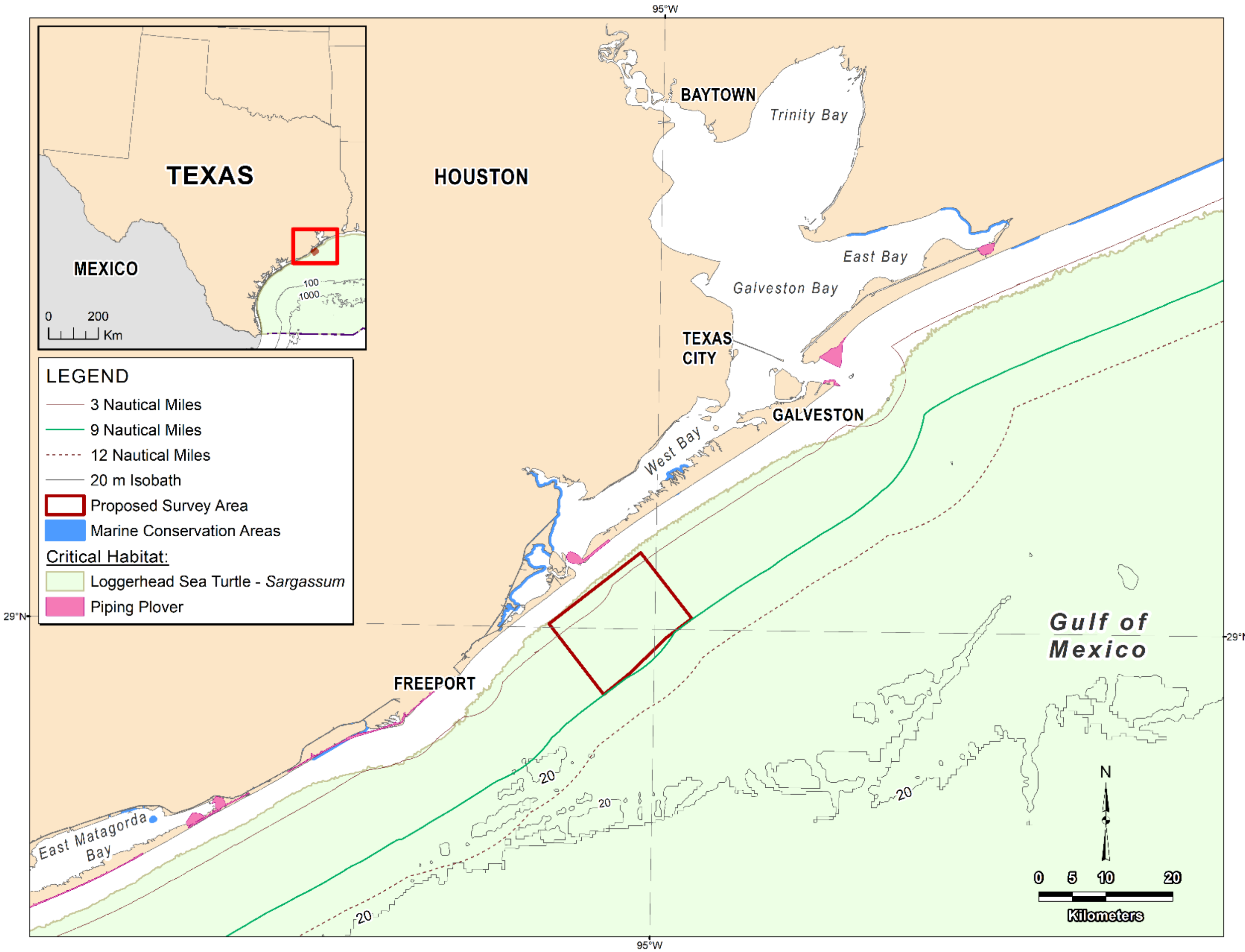

FIGURE 1. Location of the area of interest for the proposed seismic surveys at the offshore portion of Galveston Island at San Luis Pass. Also shown are marine conservation areas, and marine critical habitat in the Gulf of Mexico. The seismic tracklines could occur anywhere within the proposed survey area. Texas state waters extend 9 nautical miles from shore.

All planned marine-based geophysical data acquisition activities would be conducted by UT with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

2.1.2.3 Schedule

The proposed seismic survey would take place during fall 2023 for a period of approximately 10 days. R/V *Brooks McCall* (or similar) would likely leave out of and return to port in Freeport or Galveston, Texas. Because of the nature of the DOE NETL merit review process and the long timeline associated with the ESA Section 7 consultation and IHA processes, not all vessel logistics are identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations.

2.1.2.4 Vessel Specifications

R/V *Brooks McCall* has an overall length of 48.5 m, a beam of 12.2 m, and a draft of 3.0 m. The vessel speed during seismic operations would be ~4–5 kts (7.4–9.3 km/h); it has a maximum speed of 11 kts (~20.4 km/h). When R/V *Brooks McCall* tows the airgun(s) and hydrophone streamers, the turning rate of the vessel would be limited.

Vessel Specifications

Owner/Operator:	OMA McCall/TDI Brooks International
Port/Flag:	United States of America /Cameron LA
Date Built:	March 2000
Gross Tonnage:	805 GT
Accommodation Capacity:	32

2.1.2.5 Airgun Description

During the seismic surveys, R/V *Brooks McCall* (or similar) would tow one or 2 GI airguns (with a volume of up to 105 in^3 each) and a total discharge volume of ~210 in^3, ~2 m apart, at a depth of ~3 m. The receiving system would consist of four 25-m solid-state (solid flexible polymer – not gel or oil filled) hydrophone streamers, spaced 10-m apart (i.e., 30-m spread), and towed at a 2-m depth. The airguns would fire at a shot interval of ~12.5 m (~5–10 s). The firing pressure of the airguns would be ~2000 psi. During firing, a brief pulse of sound with duration of ~0.1 s would be emitted. The airguns would be silent during the intervening periods. During operations, airgun(s) would be operated 24/7 for multiple days to meet science objectives unless maintenance or mitigation measures warranted.

2-GI Airgun Source Specifications

Energy Source	Two Sercel GI airguns of 105 in^3
Gun Position	Two in-line, ~2 m apart
Tow Depth	3–4 m
Source output (downward)	0-peak: 233.8 dB re 1 μPa·m peak-peak: 239.6 dB re 1 μPa·m
Air discharge volume	~210 in^3
Dominant frequency components	0–188 Hz
Firing pressure:	2000 psi
Pulse duration:	~0.113 s

2.1.3 Monitoring and Mitigation Measures

Numerous papers have been published with recommendations on how to reduce anthropogenic sound in the ocean (e.g., Simmonds et al. 2014; Wright 2014; Dolman and Jasny 2015), some of which have been taken into account here. Typical monitoring and mitigation measures for seismic surveys would occur in two phases: pre-cruise planning and operations. The following sections describe the efforts during both stages for the proposed activities.

2.1.3.1 Planning Phase

Mitigation of potential impacts from the proposed activities begins during the planning phase. Several factors were considered during the planning phase of the proposed activities, including:

***Energy Source*.—**Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. Two GI airguns were determined to be the lowest practical source to meet the scientific objectives and to image the upper ~1 km of the geologic subsurface; if possible, a single GI airgun would be used. Although the proposed area of interest has been previously surveyed, the existence of the previous surveys would provide a good test of the novel positioning technology because those surveys were acquired using standard positioning technology.

***Survey Location and Timing*.—**The PI and DOE NETL considered potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, and equipment. Most marine mammal and sea turtle species are expected to occur in the proposed survey area throughout the year. Fall was determined to be the most practical timing for the proposed surveys based on the occurrence of sea turtles, weather conditions, other operational requirements, and availability of researchers.

***Mitigation Zones*.—**Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the two GI airguns, based on previous modeling by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University (see Appendix A). The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. Table 1 also shows the distances at which the 175-dB re $1\mu Pa_{rms}$ sound level is expected to be received for the two GI airguns; this level is used by NMFS, based on U.S. DoN (2017), to determine behavioral disturbance for sea turtles. Although Level A takes are not requested and will likely not be issued, the predicted distances to the Level A threshold distances for two GI airguns were previously determined by L-DEO for a seismic survey in the Ross Sea (LGL Ltd 2022).

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). Although Level A takes would not be anticipated, for other recent low-energy seismic surveys, NMFS required protected species observers (PSOs) to establish and monitor a 100-m exclusion zone (EZ) and an additional 100-m buffer zone beyond the EZ. Enforcement of mitigation zones via shut downs would be implemented as described below.

TABLE 1. Predicted distances to behavioral disturbance sound levels ≥160-dB re 1 μPa$_{rms}$ and 175-dB re 1 μPa$_{rms}$ that could be received from two 105-in^3 GI guns (separated by ~2 m, at a tow depth of up to 4 m) that would be used during the proposed surveys in the Northwestern Gulf of Mexico. The 160-dB criterion applies to all hearing groups of marine mammals (Level B harassment), and the 175-dB criterion applies to sea turtles.

Source and Volume	Max. Tow Depth[1] (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Two 105 in^3 GI airguns, 210 in^3 total discharge	4 m	<100 m	1,750[2]	284[2]

[1]Maximum tow depth was used for conservative distances. [2] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.

2.1.3.2 Operational Phase

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities would be expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with past IHA and incidental take statement (ITS) requirements, include: (1) monitoring by PSOs for marine mammals, ESA-listed sea turtles and seabirds (diving/foraging) near the vessel, and observing for potential impacts of acoustic sources on fish; (2) PSO data and documentation; and (3) mitigation during operations (shut down and ramp up procedures).

It would be unlikely that concentrations of large whales would be encountered within the 160-dB isopleth, but if they were, they would be avoided.

During daytime, the PSO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.

Mitigation measures that would be adopted during the proposed surveys include (1) shut down procedures and (2) ramp up procedures.

***Shut down Procedures*.—**The operating airgun(s) would be shut down if a toothed whale, sea turtle, or ESA-listed seabird (diving/foraging) were observed within or approaching the 100-m EZ. In the unlikely event that baleen, sperm, or beaked whales would be encountered, shut downs would occur at any distance. Following a shut down, airgun activity would not resume until the marine mammal, sea turtle, or ESA-listed seabird has cleared the EZ. The animal would be considered to have cleared the EZ if

- it was visually observed to have left the EZ, or
- it was not seen within the zone for 15 min in the case of small odontocetes, ESA-listed seabirds, and sea turtles, or
- it was not seen within the zone for 30 min in the case of mysticetes and large odontocetes.

***Ramp up Procedures*.—**A ramp up procedure would be followed when the 2 GI airgun cluster begins operating after a specified period without airgun operations. It is proposed that this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal, sea turtle, or ESA-listed seabird has not cleared the EZ as described earlier. Ramp up would begin by activating a single GI airgun and adding the second GI airgun 5 minutes later. During ramp up, the PSOs would monitor the EZ, and if marine mammals or ESA-listed sea turtles/seabirds (diving/foraging) are sighted, a shut down would be implemented.

The proposed operational mitigation measures are standard for seismic cruises. Three independently contracted PSOs would be on board the survey vessel with rotating shifts to allow at least one observer to monitor for marine species during daylight hours. A monitoring report would be provided to NMFS, both the Permits and Conservation Division and the ESA Interagency Cooperation Division.

With the proposed monitoring and mitigation provisions, potential effects on most, if not all, individual marine mammals and sea turtles would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individuals and on the associated species and stocks. Ultimately, survey operations would be conducted in accordance with all applicable international and U.S. federal regulations, including IHA and ITS requirements.

2.2 Alternative 1: No Action Alternative

An alternative to conducting the Proposed Action is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations. Under the "No Action" alternative, DOE NETL would not provide funding to UT to conduct the proposed research operations. Under the No Action Alternative, the proposed research activities would likely not occur. From NMFS' perspective, pursuant to its obligation to grant or deny permit applications under the MMPA, the "No Action" alternative entails NMFS denying the application for an IHA. If NMFS were to deny the application, UT would not be authorized to incidentally take marine mammals. If the research was not conducted, the "No Action" alternative would result in no disturbance to marine mammals attributable to the Proposed Action. Although the No-Action Alternative is not considered a reasonable alternative because it does not meet the purpose and need for the Proposed Action, it is included and carried forward for analysis in Section 4.3.

2.3 Alternatives Considered but Eliminated from Further Evaluation

During preparation of its proposal to DOE, UT considered other alternatives for this research, as follows.

2.3.1 Alternative E1: Alternative Location

The area of interest is an ideal location for this study, as data were previously collected there in 2012 and 2013 using standard positioning technology; thus, a comparison can be made. In addition, the site has potential for carbon storage. The proposed science underwent the DOE NETL merit review process, and the science, including the site location, was determined to be meritorious.

2.3.2 Alternative E2: Use of Alternative Technologies

Under this alternative, UT would use alternative survey techniques, such as marine vibroseis or sparker source technology, that could potentially reduce impacts on the marine environment. At this time, however, alternative technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. More specifically, acoustic sources like sparkers do not allow reflected energy from the required dpeths to be recorded.

3.0 AFFECTED ENVIRONMENT

The description of the affected environment focuses only on those resources potentially subject to impacts. Accordingly, the discussion of the affected environment (and associated analyses) focuses mainly on those related to marine biological resources, as the proposed short-term marine activity has the potential to impact marine biological resources within the project area. These resources are identified in Section 3, and the potential impacts to these resources are discussed in Section 4. Initial review and analysis of the proposed project activity determined that the following resource areas did not require further analysis in this EA:

- *Air Quality/Greenhouse Gases*—Project vessel emissions would result from the proposed activity; however, these short-term emissions would not result in any exceedance of Federal Clean Air standards. Emissions would be expected to have a negligible impact on the air quality within the proposed survey area. Greenhouse gas emissions would similarly be negligible for this short duration project.
- *Land Use*—All activities are proposed to occur in the marine environment. Thus, no changes to current land uses or activities in the proposed survey area would result from the proposed project.
- *Safety and Hazardous Materials and Management*—No hazardous materials would be generated or used during the proposed activities. All project-related wastes would be disposed of in accordance with international, U.S. state, and federal requirements.
- *Geological Resources (Topography, Geology and Soil)* —The proposed project would result in minor, if any, disturbances to seafloor sediments from the release of pressurized air. Thus, the proposed activities would not significantly impact geologic resources;
- *Water Resources*—No discharges to the marine environment that would adversely affect marine water quality are expected in the project area. Therefore, there would be no impacts to water resources resulting from the proposed project activity.
- *Terrestrial Biological Resources*—All proposed project activities would occur in the marine environment and would not impact terrestrial biological resources;
- *Visual Resources*—No visual resources would be expected to be negatively impacted as the proposed activities would be short-term and more than 3 km from shore.
- *Socioeconomics and Environmental Justice*—Implementation of the proposed project would not affect, beneficially or adversely, socioeconomic resources, environmental justice, or the protection of children. No changes in the population or additional need for housing or schools would occur. Airgun sounds would have no effects on solid structures; no significant impacts on shipwrecks would be expected. Other human activities in the area around the survey vessel would include fishing and vessel traffic. Fishing and potential impacts to fishing are described in further detail in Sections 3.7 and 4.1.2, respectively. No other socioeconomic impacts would be anticipated as result of the proposed activities.

3.1 Oceanography

The GoM Large Marine Ecosystem (LME) is a semi-enclosed sea bordered by Cuba, Mexico, and the U.S. The continental shelf is extensive, covering ~30% of the LME (Heileman and Rabalais 2005). Ocean circulation in the eastern GoM is dominated by the Loop Current, which flows into the GoM through the Yucatán Channel, between Mexico and Cuba, and flows out through the Straits of Florida, between

Florida and Cuba, where it forms the Florida Current and then the Gulf Stream. Upwelling along the edge of the Loop Current is a major source of nutrients to this LME (Spies et al. 2016). In the central and western GoM, an anticyclonic eddy is the primary circulation feature (Davis et al. 2002). Oceanic fronts also form over the Louisiana-Texas shelf from December through March (Heileman and Rabalais 2015), indicated a gradient in water properties (e.g., temperature, salinity, nutrients) between the shelf waters and the deeper waters of the Gulf. The average sea surface water temperature in the GoM is approximately 26°Celsius (Heileman and Rabalais 2005).

The GoM is considered a moderately high productive ecosystem, with eutrophic (high-nutrient) conditions in shallow coastal areas and oligotrophic (low-nutrient) in deeper offshore waters (Heileman and Rabalais 2005); the primary productivity in the northern GoM is 712.6 mgC/m^2 per day (SeaAroundUs 2016). The GoM is also heavily influenced by freshwater input, especially from the Mississippi River, which drives the productivity (increase of nutrients) and conditions (increased turbidity) in the northern GoM (Spies et al. 2016). The increased productivity and variable habitat within the GoM supports high biodiversity and increased biomass of fish, birds, and marine mammals in this region (Heileman and Rabalais 2005).

The continental shelf is particularly wide in the GoM, including the Louisiana-Texas shelf; shelf waters <200 m cover approximately 35 percent of the GoM, with slope waters (200–3000 m) making up another 40 percent; only a small proportion of the GoM is deeper than 3000 m (Würsig 2000). The geology of the GoM is influenced by the movement of salt deposits, which were deposited there 200 million years ago (Kramer and Shedd 2017). These deposits shift, compact, or expand, changing the bathymetry of the ocean floor (Kramer and Shedd 2017).

3.2 Protected Areas

There are no marine protected areas within the proposed survey area in the northwestern GoM. Flower Garden Banks National Marine Sanctuary (NMS) is located >100 km to the southeast – Stetson Bank, one of the banks in the NMS, is located the closest to the survey area at 110 km away. There are also several nearshore conservation areas along the coast of Texas, but these are located at least 3 km from the proposed survey area. The survey area is located within critical habitat for loggerhead turtles – this is described below in Section 3.4.2. Critical habitat has also been designated for piping plover along the coast of Texas (USFWS 2009), but this is located at least 3 km from the survey area.

3.3 Marine Mammals

Twenty-eight species of cetaceans and one species of manatee are known to occur in the GoM (Jefferson and Schiro 1997; Würsig et al. 2000). Most of these species occur in oceanic waters (>200 m deep), whereas the continental shelf waters (<200 m) are primarily inhabited by bottlenose and Atlantic spotted dolphins (Mullin and Fulling 2004; Mullin 2007). As the proposed survey area in the northwestern GoM occurs in water <20 m deep, species that only occur in deep water of the GoM are unlikely to be encountered and are not discussed further. These include beaked whales, such as Cuvier's beaked whale (*Ziphius cavirostris*), Blainville's beaked whale (*Mesoplodon densirostris*) and Gervais' beaked whales (*M. europaeus*), as well as the ***endangered*** sperm whale (*Physeter macrocephalus*), and *Kogia* spp. It is also unlikely that the ***endangered*** Rice's whale (*Balaneoptera ricei*), fin whale (*B. physalus*), blue whale (*B. musculus*), sei whale (*B. borealis*), or North Atlantic right whale (*Eubalaena glacialis*) would be encountered in the survey area. Most baleen whales are considered rare in the GoM, except for Rice's whale which typically occurs only in the northeastern Gulf; however, one sighting has been reported in water >200 m deep off Texas (Hayes et al. 2021). In addition, non-ESA listed baleen whales, such as humpbacks (*Megaptera novaeangliae*) and minke whales (*B. acutorostrata*) are also unlikely to be encountered during the surveys. Thus, baleen whales are not included in the species descriptions below. In addition, the ***endangered*** Florida stock of the West Indian manatee (*Trichechus manatus*) is also unlikely to occur in the proposed survey area, and pinniped occurrence in the GoM is extralimital; therefore, manatees and pinnipeds are not discussed further. Thus, 14 marine mammals species (all odontocetes) could potentially be encountered in the proposed survey area, although only two species (bottlenose and Atlantic spotted dolphins) are likely to be seen (Table 2).

3.3.1 Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin occurs in tropical, subtropical, and temperate waters throughout the world (Wells and Scott 2018). Although it is more commonly found in coastal and shelf waters, it can also occur in deep offshore waters (Jefferson et al. 2015; Mannocci et al. 2015). In the Northwest Atlantic, these dolphins occur from Nova Scotia to Florida, the GoM, and the Caribbean and southward to Brazil (Würsig et al. 2000). There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal

waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998, 2002). Klatsky (2004) noted that offshore dolphins show a preference for water <2186 m deep. As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995).

Both types of bottlenose dolphins are known to occur in the GoM (Walker et al. 1999). The inshore type inhabits shallow lagoons, bays, inlets, and nearshore waters and is the most likely type to be seen in the proposed survey area; the oceanic population occurs in deeper, offshore waters over the continental shelf (Würsig et al. 2000). Vollmer and Rosel (2017) suggested that there may be as many as seven stocks in coastal, shelf, and oceanic waters of the GoM, but NMFS currently recognized only five, including the Northern GoM Continental Shelf, GoM Eastern Coastal, GoM Western Coastal, GoM Northern Coastal, and the Northern GoM Oceanic stocks (Hayes et al. 2022). The Western Coastal stock occurs in water <20 m deep, and numerous sightings have been made within and near the proposed survey area (Hayes et al. 2022). The Northern GoM Continental Shelf stock occurs in water 20–200 m deep off the coast of Texas (Hayes et al. 2022); it mainly consists of coastal type dolphins, but could also include offshore types (Vollmer 2011 *in* Hayes et al. 2022). There are also 31 bay and estuary stocks in the northern GoM (Hayes et al. 2022). The West Bay stock occurs within ~20 km of the survey area, but individuals from this stock are only likely to occur up to 1 km from shore off San Luis Pass (Hayes et al. 2022). The Galveston Bay, East Bay, Trinity Bay stock occurs >20 km away, with most individuals staying within 2 km from shore and up to 5 km out from the Galveston jetties/ship channel (Hayes et al. 2022). These areas in and near West Bay and Galveston Bay, along with numerous other ones along the coast of Texas, have been identified as year-round Biologically Important Areas (BIAs) for resident bottlenose dolphins (LeBresque et al. 2015).

TABLE 2. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed survey area in the Northwestern Gulf of Mexico.

			Abundance			**Conservation Status**		
Species	**Habitat**	**Occurrence in North-western GoM study area[1]**	**GoM[2]**	**GoM[3]**	**GoM[3]**	**US ESA[4]**	**IUCN[5]**	**CITES[6]**
Bottlenose dolphin	Shelf, coastal and offshore	Common	138,602	63,280[7] 16,407[8] 11,543[9] 20,759[10]	155,453[11]	NL	LC	II
Atlantic spotted dolphin	Mainly coastal	Common	47,488	21,506	6,187[11]	NL	LC	II
Pantropical spotted dolphin	Mainly pelagic	Rare	84,014	37,195	67,225	NL	LC	II
Spinner dolphin	Coastal, pelagic	Rare	13,485	2,991	5,548	NL	LC	II
Striped dolphin	Off the shelf	Rare	4,914	1,817	5,634	NL	LC	II
Clymene dolphin	Pelagic	Rare	11,000	513	4,619	NL	LC	II
Fraser's dolphin	Water >1000 m	Rare	1,665	213	1,665	NL	LC	II
Rough-toothed dolphin	Mostly pelagic	Rare	4,853	unk	4,853	NL	LC	II
Risso's dolphin	Outer shelf, slope, oceanic	Rare	3,137	1,974	1,501	NL	LC	II
Melon-headed whale	Oceanic	Rare	6,733	1,749	6,113	NL	LC	II
Pygmy killer whale	Oceanic	Rare	2,126	613	N.A.	NL	LC	II
False killer whale	Pelagic	Rare	3,204	494	N.A.	NL	NT	II
Killer whale	Widely distributed	Rare	185	267	N.A.	NL	DD	II
Short-finned pilot whale	Mostly pelagic	Rare	1,981[13]	1,321[13]	2,741	NL	LC	II

N.A. = not applicable. unk = unknown.

1 Occurrence in area at the time of the survey; based on professional opinion and available data.
2 Roberts et al. (2016a).
3 From NMFS (2023), based on data from Garrison et al. (2022), except abundance estimates for Fraser's and rough-toothed dolphins, which are from Roberts et al. (2016a)..
4 U.S. Endangered Species Act: NL = not listed.
5 International Union for the Conservation of Nature Red List of Threatened Species version 2022-2: NT = near threatened; LC = least concern; DD = data deficient.
6 Convention on International Trade in Endangered Species of Wild Fauna and Flora: Appendix II = not necessarily threatened with extinction but may become so unless trade is closely controlled.
7 Continental shelf stock.
8 Eastern coastal stock.
9 Northern coastal stock.
10 Western coastal stock.
11 Shelf population.
12 Estimate for North Atlantic (Iceland and Faroese Islands; Reyes 1991).
13 Estimate includes all *Globicephala* sp., although only short-finned pilot whales are present in the GoM.

The bottlenose dolphin is the most widespread and common cetacean in coastal waters of the GoM (Würsig et al. 2000; Würsig 2017). Based on Würsig (2017), fall sightings have been made throughout the northern GoM, but primarily on the shelf, whereas during spring and summer surveys, sightings were typically made between the 100- and 1000-m isobaths. During surveys of the eastern GoM by Griffin and Griffin (2003), the bottlenose dolphin was the most common species in water <20 m deep. Baumgartner et al. (2001) reported bottlenose dolphins in the northern GoM on the shallow continental shelf <150 m deep during spring surveys. Fulling et al. (2003) reported a fall density of 10.3 dolphins/100 km^2 for water 20–200 m deep in the northern GoM. For oceanic waters (>200 m) of the northern GoM, Mullin and Fulling (2004) reported a spring density of 0.59 dolphins/100 km^2. Although bottlenose dolphins occur in the GoM year-round, seasonal variation in abundance has been reported for this species (e.g., Hubard et al. 2004).

There are several records within and near the proposed survey area in the OBIS database; the records within the survey area are for August and September (OBIS 2022).

3.3.2 Atlantic Spotted Dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is distributed in tropical and warm temperate waters of the North Atlantic from Brazil to New England and to the coast of Africa (Jefferson et al. 2015). In the western Atlantic, the distribution extends from southern New England, south to the GoM, and the Caribbean to Venezuela (Leatherwood et al. 1976; Perrin et al. 1994a; Rice 1998). There are two forms of Atlantic spotted dolphin—a large, heavily spotted coastal form that is usually found in shelf waters, and a smaller and less-spotted offshore form that occurs in pelagic offshore waters and around oceanic islands (Jefferson et al. 2015).

Atlantic spotted dolphins are common in the GoM (Würsig et al. 2000). They do not typically occur in deep water of the northern GoM, but mainly inhabit shallow waters on the continental shelf inshore of the 250-m isobath (Davis et al. 1998, 2002; Fulling et al. 2003; Würsig 2017; Hayes et al. 2022). Mannocci et al. (2015) also showed occurrence of Atlantic spotted dolphins in deeper waters of the GoM. Numerous sightings have been reported in water <100 m deep off the coast of Texas (Würsig 2017; Hayes et al. 2022). Although Atlantic spotted dolphins prefer shallow-water habitats, they are not common in nearshore waters (Davis et al. 1996).

In the eastern GoM, Atlantic spotted dolphin is the predominant species in water 20–180 m deep (Griffin and Griffin 2003). Similarly, Fulling et al. (2003) noted that the Atlantic spotted dolphin was the most abundant species sighted during a fall survey in water 20–200 m deep, with densities ~8x higher in the northeast (20.1 dolphins/100 km^2) than in the northwestern (2.6 dolphins/100 km^2) GoM. Mullin and Fulling (2004) reported a density of 0.05 dolphins/100 km^2 in water >200 m deep for the northern GoM. Although spotted dolphins occur in the GoM year-round, Griffin and Griffin (2004) noted significant seasonal variations in densities of spotted dolphins on the continental shelf. Griffin and Griffin (2004) noted that abundance was lower in nearshore waters during the summer, and that densities were higher during the winter. Würsig et al. (2000) noted these dolphins move inshore in the spring and summer, perhaps associated with the arrival of carangid fishes. In the OBIS database, there are numerous records in the northern GoM in water >20 m deep; the closest record to the proposed survey area is located ~70 km to the southeast in water <100 m deep (OBIS 2022).

3.3.3 Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). It is one of the most abundant cetaceans and is found in coastal, shelf, slope, and deep waters (Perrin 2018a). In the Northwest Atlantic, it occurs from North Carolina to the West Indies and down to the Equator (Würsig et al. 2000). In the GoM, it is the most common species of cetacean in deeper water (Davis and Fargion 1996; Würsig et al. 2000), but only rarely occurs over the continental shelf or continental shelf edge (Davis et al. 1998). Sightings have been made throughout the northern GoM, mainly in water >200 m, during systematic surveys during 1996–2018; one sighting was made in water 100–200 m deep off Florida (Würsig 2017; Hayes et al. 2021). It was the most abundant species during spring surveys in oceanic waters (>200 m) in the northern GoM, with a density of 24 dolphins/100 km^2 (Mullin and Fulling 2004). It occurs in the GoM year-round (Mullin et al. 2004). The closest record in the OBIS database is ~75 km to the south, in water <100 m deep (OBIS 2022).

3.3.4 Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, occurring in tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2015). In the western North Atlantic, it occurs from South Carolina to Florida, the Caribbean, the GoM, and southward to Venezuela (Würsig et al. 2000). It is generally considered a pelagic species (Perrin 2018b), but can also be found in coastal waters and around oceanic islands (Rice 1998). During systematic surveys of the northern GoM during 1996–2018, sightings were widespread in water deeper than 200 m (Würsig 2017; Hayes et al. 2021). Almost all sightings in the GoM have been made east and southeast of the Mississippi Delta, in areas deeper than 100 m (Würsig et al. 2000; Würsig 2017). Mullin and Fulling (2004) reported a density of 3.15 dolphins/100 km^2 in oceanic waters of the northern GoM. There are several sightings in the OBIS database to the south of the proposed survey area, in water >200 m deep (OBIS 2022).

3.3.5 Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994b; Jefferson et al. 2015). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015; Mannocci et al. 2015). In the Northwest Atlantic, it occurs from Nova Scotia to the GoM and south to Brazil (Würsig et al. 2000). A concentration of striped dolphins is thought to exist in the eastern part of the northern GoM, near the DeSoto Canyon just east of the Mississippi Delta (Würsig et al. 2000). Nonetheless, sightings have been made throughout the northern GoM in water >200 m during systematic surveys during 1996–2018 (Würsig 2017). Mullin and Fulling (2004) reported a mean density of 1.71 dolphins/100 km^2 for oceanic waters of the northern GoM. In the OBIS database, there is one record south of the survey area in water >1000 m deep (OBIS 2022).

3.3.6 Clymene Dolphin (*Stenella clymene*)

The Clymene dolphin only occurs in tropical and subtropical waters of the Atlantic Ocean (Jefferson et al. 2015). It inhabits areas where water depths are 700–4500 m or deeper (Fertl et al. 2003). However, there are a few records in water as shallow as 44 m (Fertl et al. 2003). In the western Atlantic, it occurs from New Jersey to Florida, the Caribbean Sea, the GoM, and south to Venezuela and Brazil (Würsig et al. 2000; Fertl et al. 2003). During systematic surveys of the northern GoM during 1996–2018, sightings were made throughout the northwestern GoM, primarily in deep water beyond the 1000-m isobath; no sightings were made in water <100 m deep (Würsig 2017; Hayes et al. 2021). It is widely distributed in the western GoM during spring and the northeast during summer and winter (Würsig et al. 2000). Mullin and Fulling (2004) also noted that this dolphin is primarily sighted in the western GoM in the spring, with an estimated density of 4.56 dolphins/100 km^2 for oceanic waters of the northern GoM. In the OBIS database, there are several records south of the survey area in water >1000 m deep (OBIS 2022).

3.3.7 Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999). although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014; Hartman 2018). In the western Atlantic, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999). Sightings have been made throughout the northern GoM during systematic surveys during 1996–2018 (Würsig 2017; Hayes et al. 2021). It has mainly been sighted off Florida and in the western GoM off the coast of Texas, and stranding records also exist for Texas and

Florida (Würsig 2017; Würsig et al. 2000). Several sightings have been reported for water <200 m deep off the coast of Texas (Würsig 2017; Hayes et al. 2021). Mullin et al. (2004) reported sightings for this species during all seasons in the northern GoM; spring density was reported as 0.57 dolphins/100 km^2 in oceanic waters (>200 m) of the GoM (Mullin and Fulling 2004). In the OBIS database, there are several records south of the survey area in water >200 m deep (OBIS 2022).

3.3.8 Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical and subtropical waters (Jefferson et al. 2015). In the western Atlantic, this species occurs between the southeastern U.S. and southern Brazil, including the GoM (Jefferson et al. 2015). Although it is generally seen in deep, oceanic water (Davis et al. 1998; Jefferson et al. 2015), it also occurs in continental shelf waters of the GoM (Ortega-Ortiz 2002; Fulling et al. 2003). Sightings have been made throughout the northern GoM in water >100 m during systematic surveys of the northern GoM during 1996–2018 (Würsig 2017; Hayes et al. 2021). The fall density for the outer continental shelf waters (20–200 m deep) of the northern GoM was estimated at 0.5 dolphins/100 km^2 (Fulling et al. 2003), whereas that for oceanic waters in spring was estimated at 0.26 dolphins/100 km^2 (Mullin and Fulling 2004). Rough-toothed dolphins are thought to occur year-round in the GoM (Würsig et al. 2000; Mullin et al. 2004). Strandings are known for Texas and Florida (Würsig et al. 2000). In the OBIS database, there are several records south of the survey area in water >100 m deep (OBIS 2021).

3.3.9 Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical oceanic species generally distributed between 30°N and 30°S that generally inhabits deeper, offshore water (Dolar 2018). It ranges from the GoM to Uruguay in the western Atlantic (Rice 1998). Fraser's dolphin has been sighted on occasion in the northern GoM (Jefferson and Schiro 1997), including in water deeper than 100 m during systematic surveys (Würsig 2017; Hayes et al. 2021). A density of 0.19 dolphins/100 km^2 was estimated for oceanic waters of the northern GoM (Mullin and Fulling 2004). In the OBIS database, there are no records in shelf waters off Texas (OBIS 2022).

3.3.10 Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters but also occurs in tropical waters (Heyning and Dahlheim 1988). High densities of this species occur at high latitudes, especially in areas where prey is abundant. The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975). In the Northwest Atlantic, killer whales occur from the polar pack ice to Florida and the GoM (Würsig et al. 2000). It is unknown whether killer whales in the GoM are a separate stock or from the North Atlantic population (Würsig 2017).

Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). In the GoM, killer whales are occasionally seen, with most sightings occurring in waters 200–2000 m deep southwest of the Mississippi Delta (Würsig 2017; Würsig et al. 2000; Hayes et al. 2021). No sightings were reported for water <100 m deep (Würsig 2017). Mullin and Fulling (2004) reported five sightings in the northwestern GoM during the spring and a density of 0.03 animals/100 km^2 for oceanic waters of the northern GoM. There have also been summer reports of killer whales off Texas near the 200-m isobath (Würsig et al. 2000). In the OBIS database, there are no records in shelf waters off Texas (OBIS 2022).

3.3.11 Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical and warm temperate waters, and the long-finned pilot whale (*G. melas*) is distributed antitropically in cold temperate waters (Olson 2018). Short-finned pilot whale distribution does not generally range south of 40°S (Jefferson et al. 2015). In the western North Atlantic, short-finned pilot whales occur from Virginia to northern South America, including the Caribbean and GoM (Würsig et al. 2000). The ranges of the two species show little overlap, and only the short-finned pilot whale is expected to occur in the GoM (Olson 2018). The short-finned pilot whale typically occurs in deep water at the edge of the continental shelf and over deep submarine canyons (Davis et al. 1998; Mannocci et al. 2015).

Short-finned pilot whales are known to strand frequently in the GoM and are likely to occur there year-round (Würsig et al. 2000). In the northern GoM, it is most commonly seen in the central and western areas in waters 200–1000 m deep, i.e., along the continental slope (Würsig 2017; Würsig et al. 2000; Hayes et al. 2021). No sightings were reported for waters <100 m deep (Würsig 2017). Mullin and Fulling (2004) noted that during a spring survey in the northern GoM, short-finned pilot whales were primarily seen west of Mobile Bay, AL (~88ºW); they reported a mean density of 0.63 *Globicephala* spp./100 km^2 for oceanic waters >200 m deep. In the OBIS database, there are several records south of the survey area in water >200 m deep (OBIS 2022).

3.3.12 False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but is not abundant anywhere (Carwardine 1995). It generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2015; Baird 2018). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018). In the Northwest Atlantic, it occurs from Maryland to the GoM and the Caribbean (Würsig et al. 2000).

In the GoM, most false killer whales have been seen in the northeastern region (Mullin and Hoggard 2000; Würsig 2017) in water 200–2000 m deep (Würsig 2017; Würsig et al. 2000; Hayes et al. 2021). During systematic surveys of the northern GoM during 1996–2001 and 2003–2004, sightings were primarily beyond the 1000-m isobath (Würsig 2017). Mullin and Fulling (2004) reported a spring density of 0.27 whales/100 km^2 in the oceanic waters of the northern GoM. Strandings have also been reported for the GoM, with records for Texas, Florida, Louisiana (Würsig et al. 2000). In the OBIS database, there is one record southwest of the survey area in water >200 m deep (OBIS 2022).

3.3.13 Pgymy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical and subtropical waters, generally not ranging south of 35°S (Jefferson et al. 2015). It is known to inhabit the warm waters of the Indian, Pacific, and Atlantic oceans (Jefferson et al. 2015). In the Northwest Atlantic, it occurs from the Carolinas to Texas and the West Indies, and the GoM (Würsig et al. 2000). It is found in nearshore areas where the water is deep and in offshore waters (Jefferson et al. 2015). Pygmy killer whales are thought to occur in the GoM year-round (Würsig et al. 2000). Sightings have been made throughout the northern region of the GoM, in water >200 m during systematic surveys during 1996–2018 (Würsig 2017; Hayes et al. 2021). A spring density of 0.11 whales/100 km^2 has was reported for oceanic waters (>200 m) of the northern GoM (Mullin and Fulling 2004). Strandings have been reported from Florida to Texas, with most strandings occurring in the winter (Würsig et al. 2000). In the OBIS database, there are several records south of the survey area in water >200 m deep (OBIS 2022).

3.3.14 Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is an oceanic species found worldwide in tropical and subtropical waters from ~40°N to 35°S (Jefferson et al. 2015). It occurs most often in deep offshore waters and occasionally in nearshore areas where the water is deep (Jefferson et al. 2015). In the western Atlantic, its range extends from the GoM to southern Brazil (Rice 1998). In the GoM, melon-headed whales have been sighted in the northwest from Texas to Mississippi (Würsig et al. 2000; Würsig 2017), typically in waters >200 m deep and away from the continental shelf (Mullin et al. 1994; Würsig 2017; Würsig et al. 2000; Hayes et al. 2021). No sightings were reported for waters <100 m deep (Würsig 2017). Mullin and Fulling (2004) reported three sightings primarily west of Mobile Bay, AL, during spring surveys, and a density of 0.91 whales/100 km^2 for the northern GoM. Strandings have been reported for Texas and Louisiana (Würsig et al. 2000). In the OBIS database, there are several records southwest of the survey area in water >1000 m deep (OBIS 2022).

3.4 Sea Turtles

Five species of sea turtle could occur in the proposed survey area off the coast of Texas in the northwestern GoM, including the leatherback, loggerhead, green, hawksbill, and Kemp's ridley sea turtles (Valverde and Holzwart 2017). The leatherback, hawksbill, and Kemp's ridley sea turtles are listed as ***endangered*** throughout their range, while the Northwest Atlantic DPS of loggerhead sea turtle, North Atlantic DPS and South Atlantic DPS of green sea turtle are listed as ***threatened*** (Table 3). These sea turtle species are also protected under the InterAmerican Convention (IAC) for the Protection and Conservation of Marine Turtles, of which the U.S. is a signatory. The IAC complies with CITES and prohibits the deliberate take or harvesting of sea turtles or their eggs (NOAA 2021a).

All five sea turtle species nest in the GoM, and all nest along the coast of Texas (Eckert and Eckert 2019). Except for Kemp's ridley turtle, these turtle species also nest in the Wider Caribbean Region (WCR; Piniak and Eckert 2011). The vast majority of Kemp's ridley sea turtle nesting occurs in the western GoM, particularly in the Rancho Nuevo area in Tamaulipas, Mexico (NMFS and USFWS 2015; Valverde and Holzwart 2017).

3.4.1 Leatherback Sea Turtle (*Dermochelys coriacea*)

The leatherback is the most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). During the non-breeding season, it undertakes long-distance migrations between its tropical and subtropical nesting grounds, located between 38°N and 34°S, and high-latitude foraging grounds in continental shelf and pelagic waters (Eckert et al. 2012). This migration is the longest of any reptile, up to 5000 km; the species is known to traverse entire ocean basins, and is mostly oceanic (Valverde and Holzwart 2017). In the western Atlantic Ocean, leatherbacks are known to range from Greenland to Argentina, including the GoM. Juveniles, like adults, are oceanic and likely spend their early years in tropical waters until they reach a length of ~100 cm, when they can be found in more temperate waters (Eckert et al. 2012). The North Atlantic population is estimated to range from 34,000 to 94,000 adults (Turtle Expert Working Group 2007).

TABLE 3. The habitat, occurrence, and conservation status of sea turtles that could occur in or near the proposed project area in the Northwestern Gulf of Mexico.

Species	Habitat	Occurrence in Survey Area	US ESA[1]	IUCN[2]	CITES[3]
Leatherback sea turtle	Beaches (nesting females); oceanic (juveniles and foraging adults)	Uncommon	E	VU	I
Loggerhead sea turtle Northwest Atlantic DPS	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults); oceanic (migration)	Common	T	VU	I
Green sea turtle North Atlantic DPS	Beaches (nesting females); oceanic (juveniles and migrating adults); coastal (foraging adults)	Uncommon	T	E	I
Green sea turtle South Atlantic DPS	Beaches (nesting females); oceanic (juveniles and migrating adults); coastal (foraging adults)	Rare	T	E	I
Hawksbill sea turtle	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults)	Rare	E	CR	I
Kemp's ridley sea turtle	Beaches (nesting females); coastal/oceanic (juveniles); coastal (adults)	Common	E	CR	I

[1] U.S. Endangered Species Act: E = Endangered, T = Threatened.
[2] International Union for the Conservation of Nature Red List of Threatened Species, version 2022-2: CR = critically endangered, E = endangered, VU = vulnerable.
[3] Convention on International Trade in Endangered Species: Appendix I, species that are the most endangered and are considered threatened with extinction.

Nesting by leatherbacks in the GoM is generally less frequent than that of other sea turtle species (Piniak and Eckert 2011), but some nests occur along the coasts of Alabama, Florida, and Mexico, with occasional nesting in southern Texas (Valverde and Holzwart 2017; Eckert and Eckert 2019; SWOT 2022). The nesting season for the leatherback sea turtle on southeastern Florida coast is March through June (Stewart and Johnson 2006 *in* Valverde and Holzwart 2017). Leatherback sea turtles satellite tagged at Panama nesting beaches traveled through the Yucatán Channel into the GoM where they spent most of their time foraging primarily at three locations—the northeastern GoM from Louisiana to Florida, off southwestern Florida, and the eastern side of Campeche Bay, Mexico; there were no foraging hotspots identified within the proposed survey area (Aleksa et al. 2018). Leatherbacks in that study were tracked in the GoM during all months of the year; one turtle traveled near the proposed survey area in the coastal waters of Texas (Aleksa et al. 2018). Based on telemetry data compiled by State of the World Sea Turtles (SWOT 2022), leatherback turtle records were reported for waters off Louisiana, but not Texas. In the OBIS database, there is one record near the 20-m isobath southeast of the proposed project area for August, and another record in shallow water <20 m deep off southern Texas (OBIS 2022). Most other records are for deep offshore waters in depths >1000 m (OBIS 2022).

3.4.2 Loggerhead Sea Turtle (*Caretta caretta*)

The loggerhead sea turtle is widely distributed, occurring in tropical, subtropical, and temperate waters of the Atlantic, Pacific, and Indian oceans (Valverde and Holzwart 2017). Adults generally forage in coastal and shelf waters but can pass through oceanic waters during migrations. In 2011, the species was divided into nine DPSs globally for ESA-listing purposes (NMFS 2011), with the Northwest Atlantic Ocean DPS occurring in the proposed survey area. Loggerhead sea turtles are the most abundant sea turtle species in the GoM (Valverde and Holzwart 2017). The Northwest Atlantic Ocean DPS was estimated to consist of a minimum of 30,096 adult females, with most of these off peninsular Florida and perhaps a few thousand in the rest of the GoM and WCR (Richards et al. 2011).

In contrast to other sea turtle species, the loggerhead nests not only in tropical waters but also in temperate waters. Loggerhead nests have been recorded in the Atlantic as far north as New Jersey and as far south as southern Brazil (Witherington et al. 2019). Florida has the largest number of nesting loggerheads in the western Atlantic, with other major nesting areas on the eastern Yucatán Peninsula, Mexico, and in Brazil (Valverde and Holzwart 2017). Additional nesting occurs throughout the remainder of the southeastern U.S. from Georgia to North Carolina, the GoM, and WCR (Piniak and Eckert 2011; Valverde and Holzwart 2017; SWOT 2022). In the GoM, nesting occurs along the coasts of Texas (including near the proposed survey area), Louisiana, Mississippi, Alabama, and Florida, as well as Mexico (Eckert and Eckert 2019; SWOT 2022). The nesting season for the Northwest Atlantic loggerhead DPS is from April through September (NMFS and USFWS 2008).

Post-nesting adult female loggerheads satellite-tagged in the GoM were found to forage near the proposed survey area off the coast of Texas, but most foraging occurred east of Texas (Hart et al. 2014, 2018). Post-nesting movements by loggerheads that were tagged on beaches of western Florida started by mid-August, and the turtles reached their foraging grounds in the northern and southern GoM by mid-October; none of those turtles were recorded in Texas, but records were made off Louisiana, Mississippi, and Alabama (Girard et al. 2009). Based on telemetry data compiled by SWOT (2022), loggerhead records were reported for waters off Texas, as well as in the rest of the northern GoM. Dispersal modeling by Putman et al. (2019) indicates that hatchlings could also occur in the proposed survey area, but the greatest concentrations are expected to occur in the eastern GoM. There are numerous loggerhead sea turtle records in the OBIS database for water <20 m deep in the northern GoM, including near but not within the proposed survey area; two of those records are for September and October (OBIS 2022).

3.4.3 Green Sea Turtle (*Chelonia mydas*)

The green sea turtle is the largest of the hard-shelled turtles, exceeded in size only by the leatherback (Valverde and Holzwart 2017). Green sea turtles are widely distributed in tropical and subtropical waters, spending most of their lives in coastal foraging areas (Seminoff et al. 2015). Nesting occurs in more than 80 countries worldwide (Valverde and Holzwart 2017). Oceanic waters are used by juveniles and migrating adults, and sometimes for foraging by adults (see Putman et al. 2019). In 2016, the species was divided into 11 DPSs globally for ESA-listing purposes (NMFS 2016a). Most green sea turtles near the proposed study area belong to the North Atlantic DPS, although some individuals could be from the South Atlantic DPS. For example, Foley et al. (2007) found that 4% of green turtles in the GoM were not from U.S., Mexican, or Costa Rican rookies; thus, it is likely that these turtles originated from the South Atlantic DPS. It is estimated that 108,761 to 150,521 females nest annually worldwide (NMFS and USFWS 2007).

Green sea turtles nest throughout the GoM and WCR from May through September (Valverde and Holzwart 2017). The largest nesting colony is on Tortuguero Beach in Costa Rica, with >100,000 nests annually (Piniak and Eckert 2011). Other major nesting beaches in the Atlantic with >500 nesting attempts annually are broadly distributed elsewhere in Costa Rica and in French Guiana, Mexico, Suriname, and the U.S. (mainly Florida), as well as islands off Venezuela and Cuba. In the GoM, major nesting beaches are located in Mexico, but nesting has also been reported along the coasts of southern Texas, Alabama, and Florida (Valverde and Holzwart 2017; Eckert and Eckert 2019; SWOT 2022). Cuevas et al. (2012)

identified the Florida Keys as an important foraging habitat for this species, with 22% of turtles tagged off the Yucatán Peninsula migrating there. Based on telemetry data compiled by SWOT (2022), green turtles were reported for waters off Texas, as well as in the rest of the northern GoM. Dispersal modeling by Putman et al. (2019) indicates that hatchlings could occur throughout the GoM, including the proposed survey area. There is one OBIS record in the northern GoM which is located near the 20-m isobath more than 50 km southeast of the proposed survey area; this record is for February (OBIS 2022).

Critical habitat for the Northwest Atlantic Ocean DPS of loggerhead sea turtle was finalized in 2014 (NMFS 2014). A total of 38 marine areas were designated as critical habitat for this loggerhead DPS. *Sargassum* critical habitat occurs throughout the proposed survey area (Fig. 1). *Sargassum* algae provides essential foraging and shelter habitat for loggerheads, particularly post-hatchlings and juveniles.

3.4.4 Hawksbill Sea Turtle (*Eretmochelys imbricata*)

Hawksbill sea turtles are the most tropical of all sea turtles, ranging throughout tropical and subtropical regions of Northwest Atlantic Ocean and WCR (Valverde and Holzwart 2017). Hawksbill sea turtles nest at low densities throughout the southern GoM and WCR (Piniak and Eckert 2011). It is estimated that 3626 to 6108 female turtles nest throughout the North Atlantic annually (NMFS and USFWS 2013). In the GoM, nesting occurs predominantly along the Yucatán Peninsula (the most important nesting area in the Atlantic), with fewer nests along other regions of the Mexican coast and Florida, with infrequent nesting also in southern Texas (Valverde and Holzwart 2017; Eckert and Eckert 2019). The hawksbill sea turtle nesting season in the Yucatán Peninsula is April–September (Cuevas et al. 2010). Stranding data from Texas and Florida in the GoM suggest that hatchlings from this area are transported by the current through the Yucatán Channel and throughout the GoM (Valverde and Holzwart 2017). Juveniles return to coastal waters when ~20 cm in length, and adults are often found foraging around coral reefs (Valverde and Holzwart 2017). Based on telemetry data compiled by SWOT (2022), hawksbill turtles were only reported for the southern GoM. There are no records near the proposed survey area, but sightings have been made in deep water off southern Texas (OBIS 2020).

3.4.5 Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)

Kemp's ridley sea turtle is the smallest and least abundant of the sea turtle species and has the most restricted distribution (Valverde and Holzwart 2017). It occurs only in the GoM and along the Atlantic coast of North America. Oceanic-phase juveniles can be carried by the current as far north as Nova Scotia, Canada, whereas adults are primarily found in coastal waters of the GoM (Valverde and Holzwart 2017; Putman et al. 2019). After the oceanic-phase, juveniles enter neritic habitats (Seney and Landry 2011). It is estimated that there are 7000 to 8000 breeding females in the population (Crowder and Heppell 2011).

The primary Kemp's ridley nesting beaches are in Mexico along the Tamaulipas coast; only three of these sites have >1000 nesting attempts per year, the largest of which is Rancho Nuevo (Piniak and Eckert 2011). In the northern GoM, there are some nests along the Florida coast, with fewer than 25 nesting attempts per year, and on the Texas coast, primarily at Padre Island National Seashore, with a few hundred nesting attempts annually (Piniak and Eckert 2011; Shaver and Caillouet 1998; NMFS, USFWS, and SEMARNAT 2011; Shaver et al. 2016; Eckert and Eckert 2019; SWOT 2022). Nesting has also been reported for the shoreline closest to the proposed survey area (Seney and Landry 2008; NMFS, USFWS, and SEMARNAT 2011; Shaver et al. 2016; Eckert and Eckert 2019), with fewer than 10 nests annually. The nesting season in the GoM is April–July (Valverde and Holzwart 2017).

Satellite-tagged adult female Kemp's ridley sea turtles from Padre Island National Seashore and Rancho Nuevo showed post-nesting movements to foraging sites along the coast of the northern GoM, with turtles spending most of their time foraging off Louisiana, but also in nearshore waters off Texas (Shaver et al. 2013). Foraging sites were found in water less than 26 m deep, averaging 33.2 km from shore (Shaver et al. 2013). Similarly, Seney and Landry (2008, 2011) noted that during the nesting season, adult female turtles tagged at Texas beaches typically stayed in nearshore waters of Texas, with core areas of activity located within and near the proposed survey area; post-nesting turtles also spent time within and near the proposed survey area during summer, but mainly foraged on the shelf off Louisiana. Tagged juveniles showed a preference for tidal passes, bays, coastal lakes, and waters nearshore, in water <5 m deep, particularly during the warmer months of May–October (Seney and Landry 2008; Valverde and Holzwart 2017); they typically did not occur in the proposed survey area. Several of the tracked adult turtles nested multiple times on the coast of Texas in one season (Seney and Landry 2008). Hart et al. (2018) also found that post-nesting adult females satellite-tagged in the GoM foraged near the proposed survey area off the coast of Texas, as well as most coastal waters along the northern and eastern GoM. Based on telemetry data compiled by SWOT (2022), Kemp's ridley turtle locations were reported along the entire northern coast of the GoM, including Texas. Dispersal modeling by Putman et al. (2019) indicates that hatchlings could also occur in the proposed survey areas. There are numerous records of Kemp's ridley turtles for the proposed survey area (OBIS 2022).

3.5 Marine-associated Birds

One ESA-listed seabird species could occur in or near the project area — the ***threatened*** piping plover occurs along the coast of the northern GoM (Table 4).

3.5.1 Piping Plover (*Charadrius melodus*)

The piping plover breeds on coastal beaches from Newfoundland to North Carolina during March–August and it winters along the Atlantic Coast from North Carolina south, along the Gulf Coast, and in the Caribbean (USFWS 1996). Its marine nesting habitat consists of sandy beaches, sandflats, and barrier islands (Birdlife International 2022). Wintering populations in the Gulf States were estimated at 2744 individuals in 2006, with 2090 of those wintering along the coast of Texas (Burger 2017). Feeding areas include intertidal portions of barrier beaches, mudflats, sandflats, and shorelines of coastal ponds, lagoons, or salt marshes (Birdlife International 2022). Revised critical habitat has been designated along the western and northern GoM, including along the coast of Texas in 2009; it includes intertidal sand beaches and sand flats or mud flats (between the mean lower low water line and annual high tide) with sparse emergent plants for feeding (USFWS 2009). The closest critical habitat is located along the shore of Galveston Island (TX-34; USFWS 2009).

TABLE 4. The habitat, occurrence, regional population sizes, and conservation status of protected marine-associated birds that could occur in or near the proposed project area off Texas, Northwestern Gulf of Mexico.

Species	Occurrence in Study Area[1]	U.S. ESA[2]	IUCN[3]	CITES[4]
Piping Plover	Nearshore	T	NT	NL

NL = Not Listed. [1] Occurrence based on available data and professional opinion. [2] U.S. Endangered Species Act; T = Threatened. [3] International Union for the Conservation of Nature Red List of Threatened Species, version 2022-2: NT = near threatened. [4] Convention on International Trade in Endangered Species.

3.6 Fish and Marine Invertebrates, Essential Fish Habitat, and Habitat Areas of Particular Concern

3.6.1 Fish Species of Conservation Concern

There are three fish species listed as ***threatened*** under the ESA that could potentially occur in the proposed survey area, including the giant manta ray, oceanic whitetip shark, and Nassau grouper (Table 5). The ***endangered*** smalltooth sawfish (*Pristis pectinate*) is only expected to occur in the eastern GoM and is not considered further. Although the scalloped hammerhead shark (*Sphyrna lewini*) also occurs within the survey area, the Northwest Atlantic and Gulf of Mexico DPS is not listed under the ESA (NOAA 2014). Thus, these two species are not discussed further. There are no ESA-listed invertebrates species that could occur within the survey area. However, the queen conch (*Strombus gigas*) is proposed for listing as threatened under the ESA, but it is unlikely to occur in the survey area. Off the coast of Texas, it is only known to occur in Flower Garden Banks National Marine Sanctuary (Horn et al. 2021).

3.6.1.1 Giant Manta Ray (*Manta birostris*)

The giant manta ray is a migratory species found in offshore, oceanic, and occasionally estuarine waters in tropical, subtropical, and temperate regions. It is a long-lived species with a low reproductive rate, generally producing a single pup every two to three years. The giant manta ray filter feeds on planktonic organisms, and often migrates to productive areas such as areas of upwelling or seamounts. While feeding, it is often found in the top 10 m of the water column, but tagging studies have recorded this species making dives of 200 to 450 m, and they are capable of diving to 1000 m (NOAA 2023a).

3.6.1.2 Oceanic Whitetip Shark (*Carcharhinus longimanus*)

The oceanic whitetip shark is a highly migratory species found in oceanic waters of tropical and subtropical regions. It can live for at least 25 years. Females reach maturity at six to nine years, and produce a litter of pups biennially. The oceanic whitetip shark is a top predator, and primarily feeds on fish and squid, although it will opportunistically feed on a wide variety of animals. Although it can occupy areas of deep open ocean, it primarily occurs in the top 200 m of the water column (NOAA 2023b).

3.6.1.3 Nassau Grouper (*Epinephelus striatus*)

The Nassau grouper's range includes Bermuda, Florida, the Bahamas, and the Caribbean. Although it has been document in the southern GoM, it is considered rare or transient off Texas (NOAA 2016). One sighting has also been made 180 km southeast of Galveston in the Flower Garden Banks National Marine Sanctuary (NOAA 2016). Nassau groupers are most common at depths less than 100 m but are occasionally found at deeper depths. Nassau grouper are usually found near high-relief coral reefs or rocky substrate. They are solitary fish except when they congregate to spawn in very large numbers (NOAA 2016).

TABLE 5. The habitat, occurrence, and conservation status of marine fish species of conservation concern that could occur in or near the proposed project area in the Northwestern Gulf of Mexico.

Species	Habitat[1]	Occurrence[2]	US ESA[3]	IUCN[4]	CITES[5]
Giant Manta Ray	Coastal, pelagic, migratory; deep-diving	Possible	T	EN	II
Oceanic Whitetip Shark	Pelagic, open ocean, migratory	Possible	T	CR	II
Nassau Grouper	Reef structures <130 m	Unlikely	T	CR	NL

NL = Not Listed. [1] Froese and Pauly (2022). [2] Occurrence in study area. [3] U.S. Endangered Species Act; T = Threatened. [4] International Union for the Conservation of Nature Red List of Threatened Species, version 2022-2: CR = critically endangered, EN = endangered. [5] Convention on International Trade in Endangered Species of Wild Fauna and Flora:Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

3.6.2 Essential Fish Habitat

Under the 1976 *Magnuson Fisheries Conservation and Management Act* (renamed *Magnuson Stevens Fisheries Conservation and Management Act* in 1996), Essential Fish Habitat (EFH) is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish. "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities (NOAA 2002). The *Magnuson Stevens Fishery Conservation and Management Act* (16 U.S.C.§1801–1882) established Regional Fishery Management Councils and mandated that Fishery Management Plans (FMPs) be developed to manage exploited fish and invertebrate species responsibly in federal waters of the U.S. When Congress reauthorized the act in 1996 as the *Sustainable Fisheries Act*, several reforms and changes were made. One change was to charge NMFS with designating and conserving EFH for species managed under existing FMPs.

The Gulf of Mexico fishery management council (GMFMC) is responsible for the management of fishery resources, including designation of EFH, in federal waters of the survey area. Highly migratory species (HMS) that occur in the proposed survey area, such as sharks, swordfish, billfish, and tunas, are managed by NOAA Fisheries under the Atlantic HMS FMP. FMPs for the GoM have been developed for Coastal Migratory Pelagics (such as mackerel and cobia), reef fish, coral, red drum, spiny lobster, stone crab, and shrimp (GMFMC 2022).

EFH has been designated in the GoM for several species, and overlaps with the survey area for Coastal Migratory Pelagics/Reef Fish/Shrimp (Fig. 2), as well as Atlantic Highly-Mobile Species. The species and life stages associated with the Atlantic Highly-Mobile Species are described in Table 6; those for Coastal Migratory Pelagics/Reef Fish/Shrimp are shown in Table 7.

TABLE 6. Marine species associated with the Atlantic Highly-Mobile Essential Fish Habitat.

Species	**Life Stages**
Bull Shark	Juvenile/Adult
Spinner Shark	Juvenile/Adult, Neonate
Lemon Shark	Neonate
Scalloped Hammerhead Shark	Neonate
Blacktip Shark (Gulf of Mexico Stock)	Juvenile/Adult, Neonate
Blacknose Shark (Gulf of Mexico Stock)	Juvenile/Adult
Atlantic Sharpnose Shark (Gulf of Mexico Stock)	Juvenile/Adult, Neonate
Bonnethead Shark (Gulf of Mexico Stock)	Adult, Juvenile, Neonate
Finetooth Shark	All

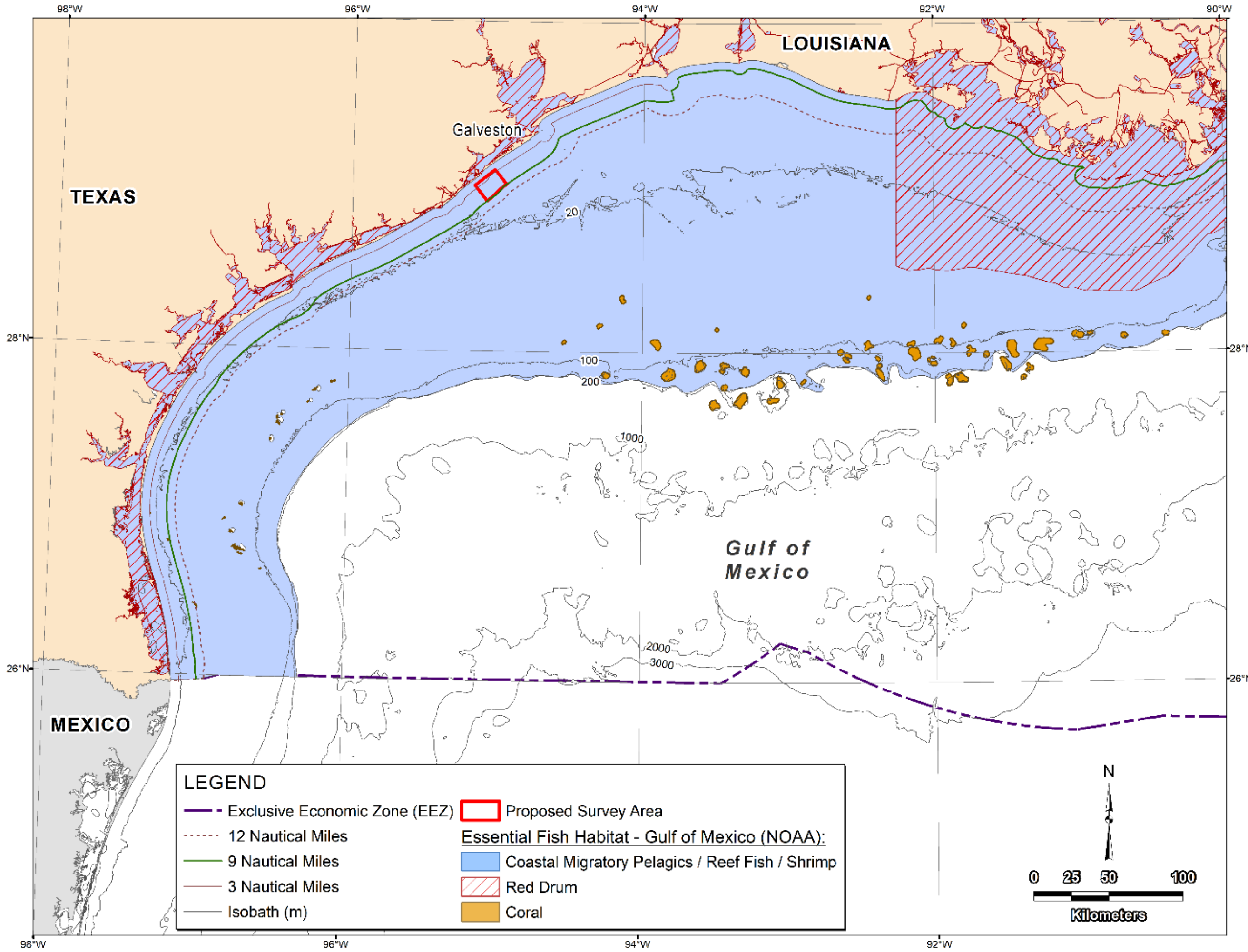

FIGURE 2. Essential Fish Habitat in the northern Gulf of Mexico (Data Source: NOAA 2021b). Not shown is EFH for Atlantic Highly-Mobile Species, as it overlaps with the Coastal Migratory Pelagics/Reef fish/Shrimp EFH.

3.6.3 Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPCs) are a subset of EFH that provide important ecological functions, are especially vulnerable to degradation, or include habitat that is rare (GMFMC 2020). HAPCs are designated by Fishery Management Councils. Although there are several HAPCs, including Coral HAPCs, in the northern GoM none are near the proposed survey area (NCEI 2022a; Fig. 3). The closest HAPC to the survey area is Stetson Bank (a Coral HAPC) which is located ~110 km southeast (Fig. 3).

3.7 Fisheries

Commercial and recreational fisheries data are collected by NMFS, including species, gear type and landings mass and value, all of which are reported by state of landing (NOAA 2022n).

TABLE 7. Marine species and life stages associated with the Coastal Migratory Pelagics/Reef Fish/Shrimp Essential Fish Habitat in Ecoregions 3,4, and 5 in the northern Gulf of Mexico.

		Depth Range (m) of Various Lifestages[2]						
Common Name[1]	**Species**	**Eggs**	**Larvae**	**Post-Larvae**	**Early Juveniles**	**Late Juveniles**	**Adults**	**Spawning Adults**
Almaco jack	*Seriola rivoliana*	✓	✓	✓	6.7-16.8	6.7-16.8	21-179	✓
Brown shrimp	*Penaeus aztecus*	18-110	0-82	<1	<1	1-18 (Sub-adults)	14-110	18-110
Cobia	*Rachycentron canadum*	<1	3-300	11-53	5-300	1-70	1-70	1-70
Gag	*Mycteroperca microlepis*						13-100	50-120
Goldface tilefish	*Caulolatilus chrysops*						237-345	
Goliath grouper	*Epinephelus itajara*	36-46	36-46		0.5	0-5	0-95	36-46
Gray snapper	*Lutjanus griseus*						0-180	0-180
Gray triggerfish	*Balistes capriscus*	10-100	✓	✓	✓	10-100	10-100	10-100
Greater amberjack	*Seriola dumerili*	✓	offshore	offshore	near&offshore	near&offshore	5-187	offshore
King mackerel	*Scomberomorus cavalla*	35-180	35-180		≤9	nearshore	0-200	35-180
Lane snapper	*Lutjanus synagris*	4-132	0-50	0-50	0-24	0-24	4-132	30-70
Lesser amberjack	*Seriola fasciata*	✓	✓	✓	55-348	55-348	55-348	55-348
Pink shrimp	*Penaeus duorarum*	9-48	1-50	1-50	0-3	1-65 (Sub-adults)	1-110	9-48
Red drum	*Sciaenops ocellatus*	20-30			0-3	0-5	1-70	40-70
Red snapper	*Lutjanus campechanus*	18-126	18-126	18-126	17-183	18-55	7-146	18-126
Royal red shrimp	*Pleoticus robustus*	250-550	250-550	250-550	250-550	250-550	140-730	250-550
Spanish mackerel	*Scomberomorus maculatus*	<50	9-84	9-84	2-9	2-50	3-75	<50
Spiny lobster	*Panulirus argus*		1-100					
Vermilion snapper	*Rhomboplites aurorubens*	18-100	30-40	30-40	18-100	18-100	18-100	18-100
Warsaw grouper	*Epinephelus nigritus*	40-525	40-525	40-525	20-30	20-30	40-525	40-525
Wenchman	*Pristopomoides aquilonaris*	80-200	80-200	80-200	19-481	19-481	19-481	80-200
White shrimp	*Penaeus setiferus*	9-34	0-82	<1	<1	1-30 (Sub-adults)	<27	9-34
Yellowedge grouper	*Hyporthodus flavolimbatus*	35-370	35-370	35-370	9-110	9-110	35-370	35-370
Yellowmouth grouper	*Mycteroperca interstitialis*	20-189	20-189	20-189			20-189	20-189

[1] Species in Ecoregions 3, 4, and 5 (includes waters off Texas, Louisiana, Mississippi, and western Alabama) for Nearshore and/or Offshore Habitat Zones.

[2] Lifestages of species expected to be encountered in the survey area in water <20 m deep are highlighted in gray. Depth ranges shown when available; ✓ indicates that the lifestage is present. Blanks mean that lifestage is not expected to occur in Ecoregions 3, 4, and 5.

Source: https://portal.gulfcouncil.org/EFHreview.html

3.7.1 Commercial Fisheries

Fisheries data from 2021 for the waters off Texas are shown in Table 8. In total, over 35,000 metric tons were landed with a worth >$237 million. The greatest proportion of commercial fishery catches consisted of northern brown and white shrimp, with a total of 80% of landings by weight and 75% of landings by worth; the next greatest landing was eastern oyster, followed by blue crab and red snapper. Numerous other fish and invertebrate species were also landed. Types of fishing gear used in the Northern GoM Marine Ecoregion mainly consists of purse seining, followed by bottom trawling; longlines and gillnets, and pelagic trawling also occurs (SeaAroundUs 2106).

3.7.2 Recreational Fisheries

In 2021, marine recreational fishers in the territorial waters of the U.S. GoM caught nearly 87 million fish; the greatest proportion were drums (20%), followed by snapper (12%), porgies (10%), and jacks (10%) (NOAA 2023d). The catches were taken during nearly 20 million trips; the majority of the trips (68%) in the territorial waters of the U.S. GoM occurred from shore, with the most trips (including charter and private/rental boats) occurring during May–June (~25% of trips), followed by July–August (20%), and September–October (12%) (NOAA 2023d).

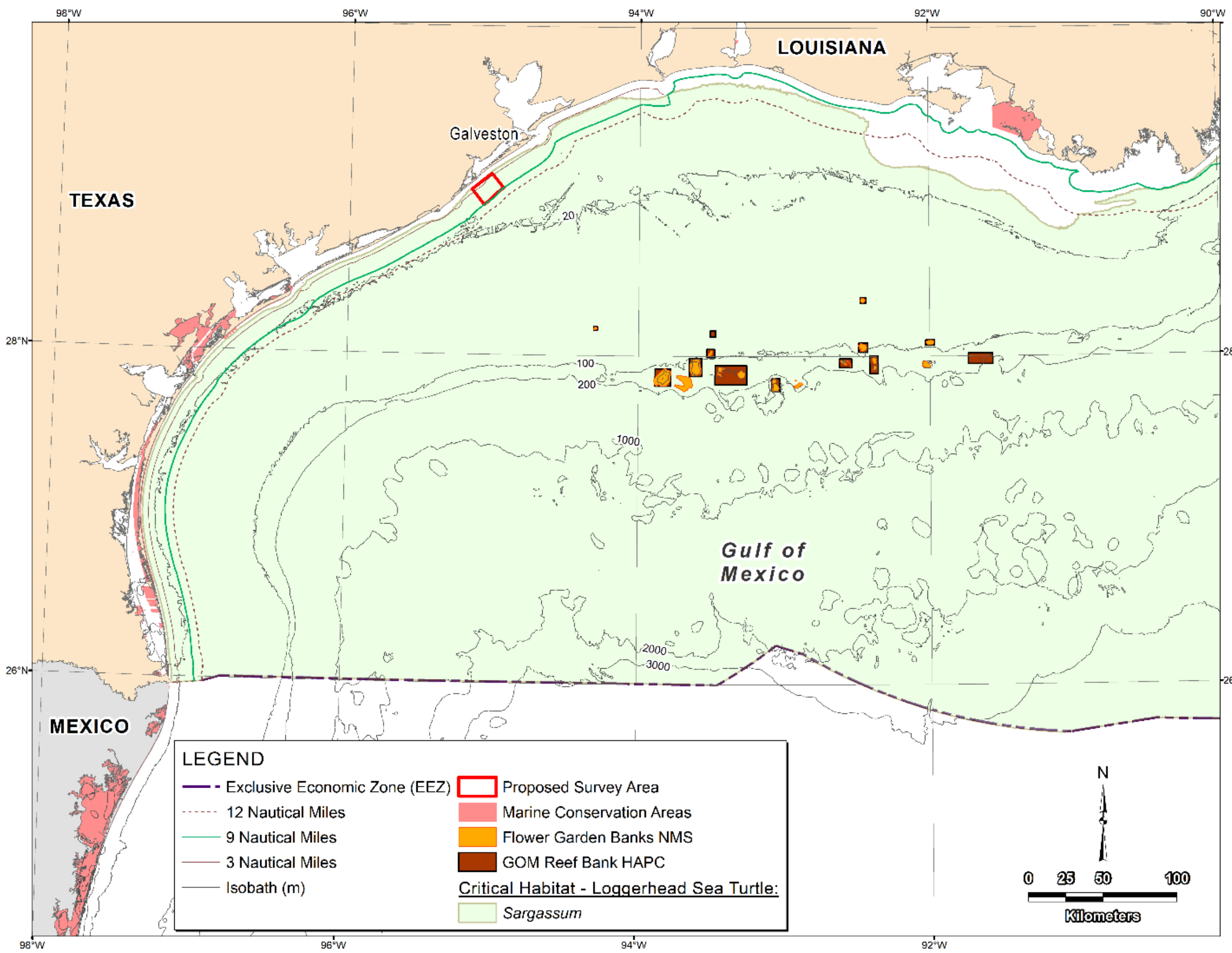

FIGURE 3. Habitat Areas of Particular Concern (HAPC) in the northwestern Gulf of Mexico (Data source: NOAA 2019a).

In 2015, there were more than 1 million recreational fishing trips in marine waters of Texas; most occurred in bays, but there were a total of 33,833 recreational trips in Texas territorial seas (BOEM 2017). Texas landings in 2015 totaled 1.7 million fish, including spotted seatrout (48%), red drum (14%), Atlantic croaker (13%), black drum (7%), sand seatrout (6%), southern flounder (5%), sheepshead (3%), red snapper (3%), and king mackerel (1%) (BOEM 2017).

TABLE 8. Commercial fishery catches for major marine species for Texas waters by weight and value for 2021 (NOAA 2023c).

Species Common Name	Species Scientific Name	Metric Tons	Dollar Amount
Shrimp, Northern Brown	*Farfantepenaeus aztecus*	17,314	102,611,794
Shrimp, Northern White	*Litopenaeus setiferus*	11,405	74,729,560
Oyster, Eastern	*Crassostrea virginica*	2,564	31,213,009
Crab, Blue	*Callinectes sapidus*	1,518	5,154,002
Snapper, Red	*Lutjanus campechanus*	1,225	12,646,666
Shrimp, Farfantepenaeus Spp.	*Farfantepenaeus*	557	5,429,160
Drum, Black	*Pogonias cromis*	476	1,621,538
Shrimp, Northern Pink	*Farfantepenaeus duorarum*	131	1,036,113
Mullets	*Mugilidae*	57	398,288
Catfish, Blue	*Ictalurus furcatus*	48	104,945
Croaker, Atlantic	*Micropogonias undulatus*	46	1,098,639
Grouper, Yellowedge	*Epinephelus flavolimbatus*	46	500,840
Snapper, Vermilion	*Rhomboplites aurorubens*	27	179,004
Herrings	*Clupeidae*	21	80,234
Menhadens	*Brevoortia*	14	69,488
Amberjack, Greater	*Seriola dumerili*	13	73,141
Mullet, White	*Mugil curema*	12	54,247
Mullet, Striped	*Mugil cephalus*	10	60,869
Stingrays, Dasyatidae (Family)	*Dasyatidae*	6	24,889
Flounders, Paralichthys	*Paralichthys*	4	39,043
Grouper, Warsaw	*Epinephelus nigritus*	4	33,295
Cutlassfish, Atlantic	*Trichiurus lepturus*	3	9,434
Flounder, Southern	*Paralichthys lethostigma*	3	28,682
Shrimps, Mantis	*Stomatopoda*	3	28,990
Ballyhoo	*Hemiramphus brasiliensis*	2	27,539
Grouper, Snowy	*Epinephelus niveatus*	2	14,601
Sheepshead	*Archosargus probatocephalus*	2	3,069
Catfish, Channel	*Ictalurus punctatus*	1	2,527
Catfish, Gafftopsail	*Bagre marinus*	1	1,532
Cobia	*Rachycentron canadum*	1	8,361
Crabs, Stone	*Menippe*	1	18,585
Gar, Alligator	*Lepisosteus spatula*	1	8,825
Killifishes	*Cyprinodontidae*	1	50,285
Mackerel, King	*Scomberomorus cavalla*	1	2,807
Pinfish	*Lagodon rhomboides*	1	9,005
Scamp	*Mycteroperca phenax*	1	12,957
Squid, Atlantic Brief	*Lolliguncula brevis*	1	7,683
Squids, Loliginidae	*Loliginidae*	1	5,736

3.8 Shipwrecks and other Cultural Sites

Locations for dive sites, shipwrecks, marine obstructions, and artificial reefs in and near the proposed survey area (Fig. 4) were obtained from NOAA's wreck and obstruction information system (NOAA 2023e), as well as from Shipwreck World (2022) and DiveBuddy (2022).

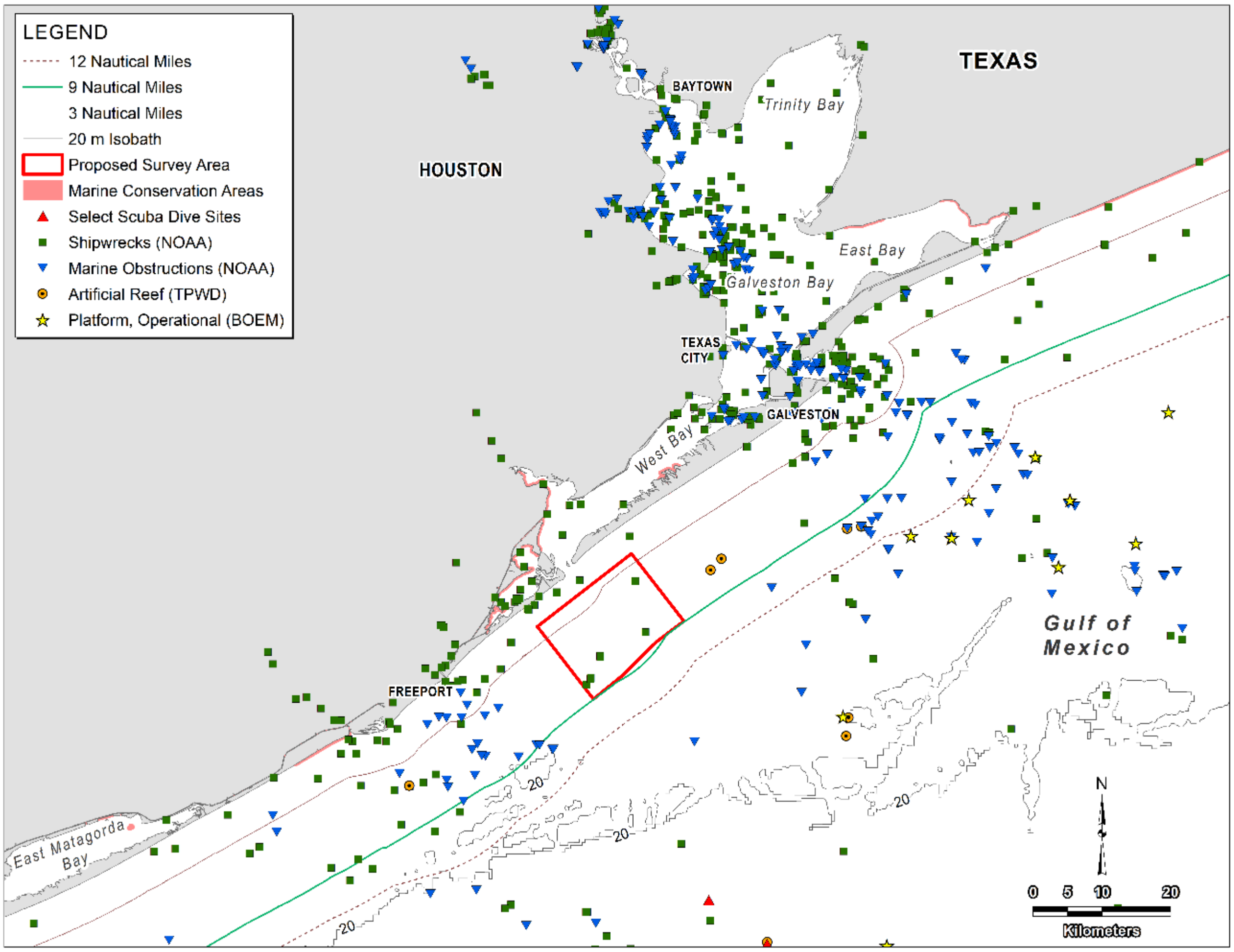

FIGURE 4. Shipwrecks, marine obstructions, artificial reefs, and dive sites off Texas. Sources: DiveBuddy (2022), Shipwreck World (2022), and NOAA (2023e).

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 Proposed Action

4.1.1 Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a summary of the expected potential effects of airgun sounds on marine mammals and sea turtles, including reference to recent literature. A comprehensive review of the relevant background information appears in the Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey, referred to herein as the NSF and USGS PEIS (NFS and USGS 2011); relevant background information on the hearing abilities of marine mammals and sea turtles can also be found in that PEIS. This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys. A description of the rationale for the estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 μPa_{rms} is also provided.

4.1.1.1 Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017a). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent (Hastie et al. 2019; Martin et al. 2020), and may become less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016; Houser 2021). Although the possibility cannot be entirely excluded, it would be unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals were encountered during an active survey, some behavioral disturbance could result, but this would be localized and short-term.

***Tolerance*.—**Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers (e.g., Nieukirk et al. 2012). Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen and toothed whales have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

***Masking*.—**Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Situations with prolonged strong reverberation are infrequent. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015; Thode et al. 2020; Fernandez-Betelu et al. 2021). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

***Disturbance Reactions*.—**Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001, p. 9293), National Research Council (NRC 2005), and Southall et al. (2007), we believe that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean, 'in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations'.

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Kastelein et al. (2019a) surmized that if disturbance by noise would displace harbor porpoises from a feeding area or otherwise impair foraging ability for a short period of time (e.g., 1 day), they would be able to compensate by increasing their food consumption following the disturbance. Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level; this has proven to be complicated by numerous factors including variability in responses between individuals (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017; Dunlop et al. 2021; Gallagher et al. 2021; McHuron et al. 2021; Mortensen et al. 2021).

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals could be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species; detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys; many data gaps remain where exposure criteria are concerned (Southall 2021).

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995). Kavanagh et al. (2019) analyzed more than 8000 hr of cetacean survey data in the northeastern Atlantic Ocean to determine the effects of the seismic surveys on cetaceans. They found that sighting rates of baleen whales were significantly lower during seismic surveys compared with control surveys.

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. Off Western Australia, avoidance reactions began at 5–8 km from the array, and those reactions kept most pods ~3–4 km from the operating seismic boat; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs (McCauley et al. 1998, 2000). However, some individual humpback whales, especially males, approached within distances of 100–400 m.

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b, 2020). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in^3) within 3 km and received levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000). Dunlop et al. (2020) found that humpback whales reduce their social interactions at greater distances and lower received levels than regulated by current mitigation practices.

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015; Stone et al. 2017). On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis (Malme et al. 1985). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007).

Matthews and Parks (2021) summarized the known responses of *right whales* to sounds; however, there are no data on reactions of right whales to seismic surveys. However, Rolland et al. (2012) suggested that ship noise causes increased stress in right whales; they showed that baseline levels of stress-related faecal hormone metabolites decreased in North Atlantic right whales with a 6-dB decrease in underwater noise from vessels. Wright et al. (2011), Atkinson et al. (2015), Houser et al. (2016), and Lyamin et al. (2016) also reported that sound could be a potential source of stress for marine mammals.

Bowhead whales show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999). Subtle but statistically significant changes in surfacing–respiration–dive cycles were shown by traveling and socializing bowheads exposed to airgun sounds in the Beaufort Sea, including shorter surfacings, shorter dives, and decreased number of blows per surfacing (Robertson et al. 2013). More recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are less responsive to seismic sources (e.g., Miller et al. 2005; Robertson et al. 2013).

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 μPa; at SPLs <108 dB re 1 μPa, calling rates were not affected. When data for

2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $CSEL_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 μPa$^2 \cdot$s, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 μPa$^2 \cdot$s, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 μPa$^2 \cdot$s. Thode et al. (2020) reported similar changes in bowhead whale vocalizations when data were analyzed for the period 2008–2014. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

A multivariate analysis of factors affecting the distribution of calling bowhead whales during their fall migration in 2009 noted that the southern edge of the distribution of calling whales was significantly closer to shore with increasing levels of airgun sound from a seismic survey a few hundred kilometers to the east of the study area (i.e., behind the westward-migrating whales; McDonald et al. 2010, 2011). It was not known whether this statistical effect represented a stronger tendency for quieting of the whales farther offshore in deeper water upon exposure to airgun sound, or an actual inshore displacement of whales.

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~170 dB re 1 μPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994–2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015; Stone et al. 2017). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015; Stone et al. 2017). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015; Stone et al. 2017). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015; Stone e al. 2017). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, fin whales were seen at significantly farther distances during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were seen significantly farther from the vessel during periods with than without seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010). However, Matos (2015) reported no change in sighting rates of minke whales in Vestfjorden, Norway, during ongoing seismic surveys outside of the fjord. Vilela et al. (2016) cautioned that environmental conditions should be taken into account when comparing sighting rates during seismic surveys, as spatial modeling showed that differences in sighting rates of rorquals (fin and minke whales) during seismic periods and non-seismic periods during a survey in the Gulf of Cadiz could be explained by environmental variables.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population continued to feed off Sakhalin Island every summer, despite seismic surveys in the region. In addition, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years. Pirotta et al. (2018) used a dynamic state model of behavior and physiology to assess the consequences of disturbance (e.g., seismic surveys) on whales (in this case, blue whales). They found that the impact of localized, acute disturbance (e.g., seismic surveys) depended on the whale's behavioral response, with whales that remained in the affected area having a greater risk of reduced reproductive success than whales that avoided the disturbance. Chronic, but weaker disturbance (e.g., vessel traffic) appeared to have less effect on reproductive success.

Toothed Whales

Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and

Myade 2014; Monaco et al. 2016; Stone et al. 2017). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994–2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015; Stone et al. 2017). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015; Stone et al. 2017). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther (>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015; Stone et al. 2017). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015; Stone et al. 2017).

During seismic surveys in the northwest Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly farther (by ~200 m) during seismic operations compared with periods when the seismic source was not active; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland, (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment. However, Heide-Jørgensen et al. (2021) did report avoidance reaction at distances >11 km from an active seismic vessel, as well as an increase in travel speed and changes in direction at distances up to 24 km from a seismic source. No long-term effects were reported. Tervo et al. (2021) reported that narwhal buzzing rates decreased in response to concurrent ship noise and airgun pulses (being 50% at 12 km from ship), and that the whales discontinued to forage at 7–8 km from the vessel, and that exposure effects could still be detected >40 km from the vessel.

The beluga, however, is a species that (at least at times) shows long-distance (10s of km) avoidance of seismic vessels (e.g., Miller et al. 2005). Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys, but the animals tolerated high received levels of sound before exhibiting aversive behaviors (e.g., Finneran et al. 2000, 2002, 2005). Schlundt et al. (2016) also reported that bottlenose dolphins exposed to multiple airgun pulses exhibited some anticipatory behavior.

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). Winsor et al. (2017) outfitted sperm whales in the GoM with satellite tags to examine their spatial distribution in relation to seismic surveys. They found no evidence of avoidance or changes in orientation by sperm whales to active seismic vessels. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015; Stone et al.

2017). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2017), could have significant consequences on individual fitness. Preliminary data from the GoM show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it would be likely that most beaked whales would also show strong avoidance of an approaching seismic vessel. Observations from seismic vessels off the U.K. from 1994–2010 indicated that detection rates of beaked whales were significantly higher ($p<0.05$) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015; Stone et al. 2017). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015; Stone et al. 2017). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015; Stone et al. 2017). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 μPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 $\mu Pa_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB $\mu Pa^2 \cdot s$. One porpoise moved away from the sound source but returned to natural movement patters within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017; Tyack and Thomas 2019).

Sea Turtles

Several recent papers discuss the morphology of the turtle ear (e.g., Christensen-Dalsgaard et al. 2012; Willis et al. 2013) and the hearing ability of sea turtles (e.g., Martin et al. 2012; Piniak et al. 2012a,b; Lavender et al. 2014). The limited available data indicate that sea turtles will hear airgun sounds and sometimes exhibit localized avoidance. In additional, Nelms et al. (2016) suggest that sea turtles could be excluded from critical habitats during seismic surveys.

DeRuiter and Doukara (2012) observed that immediately following an airgun pulse, small numbers of basking loggerhead turtles (6 of 86 turtles observed) exhibited an apparent startle response (sudden raising of the head and splashing of flippers, occasionally accompanied by blowing bubbles from the beak and nostrils, followed by a short dive). Diving turtles (49 of 86 individuals) were observed at distances from the center of the airgun array ranging from 50–839 m. The estimated sound level at the median distance of 130 m was 191 dB re 1 μPa_{peak}. These observations were made during ~150 h of vessel-based monitoring from a seismic vessel operating an airgun array (13 airguns, 2440 in^3) off Algeria; there was no corresponding observation effort during periods when the airgun array was inactive (DeRuiter and Doukara 2012).

Based on available data, it is likely that sea turtles will exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate would likely have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of the year. However, a number of mitigation measures can, on a case-by-case basis, be considered for application in areas important to sea turtles (e.g., Pendoley 1997; van der Wal et al. 2016).

***Hearing Impairment and Other Physical Effects*.—**Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed by Southall et al. 2007; Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b, 2020a,b,c,d,e,f, 2021a,b, 2022; Supin et al. 2016).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 µPa2 · s (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015; Schlundt et al. 2016).

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL_{cum} of 188 and 191 $\mu Pa^2 \cdot s$, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

Popov et al. (2016) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016; Nachtigall et al. 2018; Finneran 2020; Kastelein et al. 2020g).

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga. Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans (*cf.* Southall et al. 2007; NMFS 2016b; 2018). Some cetaceans could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Based on studies that exposed harbor porpoises to one-sixth-octave noise bands ranging from 1 to 88.4 kHz, Kastelein et al. (2019c,d, 2020d,e,f) noted that susceptibility to TTS increases with an increase in sound less than 6.5 kHz but declines with an increase in frequency above 6.5 kHz. At a noise band centered at 0.5 kHz (near the lower range of hearing), the SEL required to elicit a 6 dB TTS is higher than that required at frequencies of 1 to 88.4 kHz (Kastelein et al. 2021a). Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 µPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB. For the harbor porpoise, Tougaard et al. (2015) suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{eq\text{-}fast}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). Simulation modeling to assess the risk of sound exposure to marine mammals (gray seal and harbor porpoise) showed that SEL is most strongly influenced by the weighting function (Donovan et al. 2017).

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor porpoises when using single airguns in shallow water. SPLs for impulsive sounds are generally lower just below the water surface, and seals swimming near the surface are likely to be exposed to lower sound levels than when swimming at depth (Kastelein et al. 2018). However, the underwater sound hearing sensitivity for seals is the same near the surface and at depth (Kastelein et al. 2018). It is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. However, Gedamke et al. (2011), based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, suggested that some baleen whales whose CPA to a seismic vessel is 1 km or more could experience TTS.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

Noise exposure criteria for marine mammals that were released by NMFS (2016b, 2018) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). Tougaard et al. (2022) indicate that there is empirical evidence to support the thresholds for very-high frequency cetaceans, but caution that above 10 kHz for porpoise, there are differences between the TTS thresholds and empirical data.

Nowacek et al. (2013a) concluded that current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. Also, many marine mammals and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves would reduce or (most likely) avoid any possibility of hearing impairment. Aarts et al. (2016) noted that an understanding of animal movement is necessary in order to estimate the impact of anthropogenic sound on cetaceans.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array.

Williams et al. (2022) reported an increase in energetic cost of diving by narwhals that were exposed to airgun noise, as they showed marked cardiovascular and respiratory reactions.

It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2016). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 72 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2023f). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and GoM, and the greater activity of oil and gas exploration in the GoM. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

Non-auditory effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales and some odontocetes, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Sea Turtles

There is substantial overlap in the frequencies that sea turtles detect versus the frequencies in airgun pulses. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. In the absence of relevant absolute threshold data, we cannot estimate how far away an airgun array might be audible. Moein et al. (1994) and Lenhardt (2002) reported TTS for loggerhead turtles exposed to many airgun pulses. This suggests that sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs (see Nelms et al. 2016). However, exposure duration during the proposed surveys would be much less than during the aforementioned studies. Also, recent monitoring studies show that some sea turtles do show localized movement away from approaching airguns. At short distances from the source, received sound level diminishes rapidly with increasing distance. In that situation, even a small-scale avoidance response could result in a significant reduction in sound exposure.

The U.S. Navy has proposed the following criteria for the onset of hearing impairment for sea turtles: 232 dB re 1 µPa SPL (peak) and 204 dB re 1 $\mu Pa^2 \cdot s$ SEL_{cum} (weighted) for PTS; and 226 dB peak and 189 dB weighted SEL for TTS (DoN 2017). Although it is possible that exposure to airgun sounds could cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014), especially because sea turtles appear to be resistant to explosives

(Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 dB_{peak} for sounds from seismic airguns; however, these criteria were largely based on impacts of pile-driving sound on fish.

The PSOs would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.

4.1.1.2 Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals and/or sea turtles include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear.

Vessel noise from the source vessel could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014; Kyhn et al. 2019; Landrø and Langhammer 2020); low levels of high-frequency sound from vessels have been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have also been shown to affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018). Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2018). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017; Branstetter and Sills 2022). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016; Oakley et al. 2017). Based on modeling, Halliday et al. (2017) suggested that shipping noise can be audible more than 100 km away and could affect the behavior of a marine mammal at a distance of 52 km in the case of tankers.

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey areas during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance (Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986). Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016) and killer whales (Williams et al. 2021). Fin whale sightings in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or have had little or no recent exposure to ships (Richardson et al. 1995). Dolphins of many species tolerate and sometimes approach vessels (e.g., Anderwald et al. 2013). Some dolphin species approach moving vessels to ride the bow or stern waves (Williams et al. 1992). Physical presence of vessels, not just ship noise, has been shown to disturb the foraging activity of bottlenose dolphins (Pirotta et al. 2015) and blue whales (Lesage et al. 2017). Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015).

There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. Tyson et al. (2017) suggested that a juvenile green sea turtle dove during vessel passes and remained still near the sea floor.

Survey vessel sounds would not be at levels expected to cause anything more than possible localized and temporary behavioral changes in marine mammals or sea turtles, and would not be expected to result in significant negative effects on individuals or at the population level. In addition, in all oceans of the world, large vessel traffic is currently so prevalent that it is commonly considered a usual source of ambient sound.

Another concern with vessel traffic is the potential for striking marine mammals or sea turtles (e.g., Redfern et al. 2013). Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but would be extremely unlikely, because of the relatively slow operating speed (typically ~7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel.

Entanglement of sea turtles in seismic gear is also a concern (Nelms et al. 2016). There have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore from West Africa (Weir 2007); however, these tailbuoys are significantly different than those used on the source vessel for the proposed project. In April 2011, a dead olive ridley turtle was found in a deflector foil of the seismic gear on R/V *Langseth* during equipment recovery at the conclusion of a survey off Costa Rica by L-DEO where sea turtles were numerous. Such incidents are possible, but that was the only case of sea turtle entanglement in seismic gear for R/V *Langseth*, which has conducted seismic surveys since 2008, or for its predecessor, R/V *Maurice Ewing*, during 2003–2007. Towing the seismic equipment during the proposed surveys would not be expected to significantly interfere with sea turtle movements, including migration.

4.1.1.3 Mitigation Measures

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activity. These measures include the following: ramp ups; two dedicated observers maintaining a visual watch during all daytime airgun operations; two observers for 30 min before and during ramp ups; PAM during the day and night to complement visual monitoring (unless the system and back-up systems are damaged during operations); shut downs when marine mammals are detected in or about to enter the designated EZ; and shut downs when ESA-listed sea turtles or seabirds (diving/foraging) are detected in or about to enter EZ. These mitigation measures are described earlier in this document, in Section 2.1.3. The fact that the airgun array, because of its design, would direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure. In addition, mitigation measures to reduce the potential of bird strandings on the vessel include downward-pointing deck lighting and curtains/shades on all cabin windows. Previous and subsequent analysis of the potential impacts takes account of these planned mitigation measures. It would not be meaningful to analyze the effects of the planned activity without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activity and would be implemented under the Proposed Action.

4.1.1.4 Potential Number of Level B Takes by Harassment for Marine Mammals and Sea Turtles

All takes would be anticipated to be Level B “takes by harassment” involving temporary changes in behavior. Further, for this Draft EA, with respect to sea turtles, Level B is used in the same definition as found in the MMPA. No injurious takes (Level A) would be expected; Level A modeling for the two GI guns was previously done by L-DEO for the Ross Sea (LGL Ltd. 2022). No long-term or significant effects would be expected on individual marine mammals or sea turtles, the populations to which they belong, or their habitats.

In the sections below, we describe methods to estimate the number of potential exposures to Level B sound levels and present estimates of the numbers of marine mammals and sea turtles that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals or sea turtles that could be harassed or disturbed appreciably by Level B sound levels by the seismic surveys in the GoM. The main sources of distributional and numerical data used in deriving the estimates are summarized below.

The numbers of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) on one or more occasions have been estimated using a method recommended by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day (~222 km). The area expected to be ensonified on one day was determined by multiplying the number of line km possible in one day by two times the 160-dB radius plus adding endcaps to the start and beginning of the line. The daily ensonified area was then multiplied by the number of survey days (10 days). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as the source vessel approaches. A similar approach was employed for sea turtles using a received level of ≥175 dB re 1 μPa_{rms}. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound.

To determine the number of marine mammals and sea turtles expected in the survey area we used recently developed habitat-based density estimates for the GoM (Garrison et al. 2022). The habitat-based models provide predicted marine mammal and sea turtle densities within 40 km^2 hexagons (~3.9 km sides and ~7 km across) covering the entire GoM for each month. To calculate expected densities specific to the survey area we created a 7-km perimeter around the survey area and used that to select the density hexagons for each species in each month. The 7-km distance was chosen for the perimeter to ensure that at least one full density hexagon outside the survey area in all directions was selected, providing a more robust sample for the calculations. We then calculated the mean of the predicted densities from the selected cells for each species and month. The highest mean monthly density was chosen for each species from the months of September to December.

Table 9 shows estimated densities for cetacean and sea turtle species that could occur in the proposed survey area. Densities for those species not included in Table 9 are either estimated or assumed to be zero. There is uncertainty about the representativeness of the data and the assumptions used to estimate exposures below. Thus, for some species, the densities derived from the abundance models described above may not precisely represent the densities that would be encountered during the proposed seismic surveys.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 10 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details), along with the *Requested Take Authorization*. It should be noted that the exposure estimates assume that the proposed surveys would be completed. Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes. The 160-dB_{rms} criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013b). The context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (e.g., Ellison et al. 2012; NMFS 2013; Hastie et al. 2021; Hückstädt et al. 2020; Southall et al. 2021; Miller et al. 2022). Southall et al. (2021) provide a detailed framework for assessing marine mammal behavioral responses to anthropogenic noise and note that use of a single threshold can lead to large errors in prediction impacts due to variability in responses between and within species.

4.1.1.5 Conclusions for Marine Mammals and Sea Turtles

The proposed seismic surveys would involve towing a small source, up to two 105-in^3 GI airguns, that introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic surveys, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". Although airgun operations, even with implementation of monitoring and mitigation measures, could result in a small number of Level B behavioral effects in some cetaceans, Level A effects are highly unlikely.

TABLE 9. Monthly densities (# of individuals/km^2) of marine mammals and sea turtles, based on Garrison et al. (2022) for the proposed survey area off Texas, Northwestern Gulf of Mexico. Potential months when surveys could occur are highlighted in gray – maximum densities used to calculate takes are in bold.

Species Densities (#/km^2)	Atlantic spotted dolphin	Bottlenose dolphin	Green sea turtle	Kemp's Ridley sea turtle	Leatherback sea turtle	Loggerhead sea turtle
Month						
Jan	0.00068	0.34649	0.00066	0.25374	0.00023	0.03215
Feb	0.00074	0.33106	0.00070	0.34786	0.00029	0.03912
Mar	0.00062	0.30827	0.00073	0.17091	0.00004	0.04452
Apr	0.00049	0.14815	0.00086	0.06423	0.00001	0.03080
May	0.00060	0.15856	0.00228	0.03386	0.00003	0.01874
Jun	0.00078	0.27244	0.00425	0.04922	0.00022	0.01428
Jul	0.00113	0.28724	0.00786	0.05971	0.00068	0.02227
Aug	0.00141	0.27804	0.00909	0.06591	0.00105	0.02972
Sep	0.00071	0.27660	**0.00276**	0.04790	**0.00017**	0.01430
Oct	**0.00082**	0.18019	0.00253	0.03636	0.00006	0.01724
Nov	0.00078	0.16519	0.00164	0.06550	0.00007	0.03671
Dec	0.00069	**0.34024**	0.00079	**0.19854**	0.00004	**0.05006**

TABLE 10. Estimates of the possible numbers of individual mid-frequency (MF) cetaceans and sea turtles that could be exposed to Level B thresholds during the proposed seismic surveys off Texas, Northwestern Gulf of Mexico.

Species	Estimated Density (#/km^2)	Level B Ensonified Area (km^2)	Level B Takes	% of Pop.[1]	% of Pop.[2]	Requested Take Authorization[3]
MF Cetaceans						
Risso's dolphin	0	7,866	0	0.32	0.67	**10**
Rough-toothed dolphin	0	7,866	0	0.29	0.29	**14**
Bottenose dolphin	0.3402	7,866	2,676	1.93	1.72	2,676
Pantropical spotted dolphin	0	7,866	0	0.08	0.11	**71**
Atlantic spotted dolphin	0.0008	7,866	6	0.05	0.42	**26**
Spinner dolphin	0	7,866	0	1.13	2.74	**152**
Striped dolphin	0	7,866	0	0.94	0.82	**46**
Clymene dolphin	0	7,866	0	0.81	1.94	**90**
Fraser's dolphin	0	7,866	0	3.90	3.90	**65**
Short-finned pilot whale	0	7,866	0	1.26	0.91	**25**
Killer whale	0	7,866	0	3.78	N.A.	**7**
False killer whale	0	7,866	0	0.87	N.A.	**28**
Pgymy killer whale	0	7,866	0	0.89	N.A.	**19**
Melon-headed whale	0	7,866	0	1.49	1.64	**100**
Sea Turtle						
Hawksbill sea turtle	0	1,263	N.A.	N.A.	N.A.	N.A.
Kemp's ridley sea turtle	0.1985	1,263	251	N.A.	N.A.	251
Loggerhead sea turtle	0.0501	1,263	63	N.A.	N.A.	63
Green sea turtle	0.0028	1,263	3	N.A.	N.A.	3
Leatherback sea turtle	0.0002	1,263	0	N.A.	N.A.	0

N.A. means not available. [1] Requested take authorization provided as percent of population, based on NMFS (2023). [2] Requested take authorization provided as percent of population, based on Roberts et al. (2016a). [3] Requested takes are calculated Level B takes, except those in bold which are based on mean group size for the GoM from Maze-Foley and Mullin (2006).

Marine Mammals.—Airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some odontocetes, but Level A effects are highly unlikely. In this analysis, estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are low percentages of the regional population sizes (Table 9).

The proposed activities would have no effect on ESA-listed marine mammal species, as these species are unlikely to be encountered in the proposed survey area. Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The Level B estimates are thought to be conservative; thus, not all animals detected within this threshold distance would be expected to have been exposed to actual sound levels >160 dB.

***Sea Turtles*.—**With implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations on sea turtle populations in the analysis area are expected; any effects are likely to be limited to short-term behavioral disturbance and short-term localized avoidance of an area of unknown size near the active airguns. Nonetheless, the proposed activities are likely to adversely affect all ESA-listed sea turtles species for which takes were calculated (Table 11), as well as those sea turtle species that have the potential to occur within the proposed survey area.

Although sound levels >175 dB would occur in the loggerhead *Sargassum* critical habitat, they are not expected to impact the habitat or survivability of loggerheads that may occur there as the activities are only proposed for the short-term (~10 days), the sound pulses are intermittent, and the proposed survey would only overlap a small portion of the *Sargassum* critical habitat. Thus, the proposed activities may affect, but are unlikely to adversely affect, the critical habitat of loggerhead turtles.

4.1.2 Direct Effects on Marine Invertebrates, Fish, and Fisheries, and Their Significance

Relevant studies on the effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed below.

Although research on the effects of exposure to airgun sound and other noise on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015, 2020; Carroll et al. 2017; Popper and Hawkins 2019; Wale et al. 2021; Popper et al. 2022), including how particle motion rather than sound pressure levels affect invertebrates and fishes that are exposed to sound (Hawkins and Popper 2017; Popper and Hawkins 2018, 2019). It is important to note that while all invertebrates and fishes are likely sensitive to particle motion, no invertebrates and not all fishes (e.g., sharks) are sensitive to the sound pressure component. Rogers et al. (2021) found that sounds from a seismic survey measured above ambient conditions up to 10 km away for particle acceleration and up to 31 km for sound pressure.

Substrate vibrations caused by sounds may also affect the epibenthos, but sensitivities are largely unknown (Roberts and Elliott 2017). Nonetheless, several studies have found that substrate-borne vibration and sound elicit behavioral responses in crabs (e.g., Roberts et al. 2016b) and mussels (Roberts et al. 2015). Solan et al. (2015) also reported behavioral effects on sediment-dwelling invertebrates during sound exposure. Wang et al. (2022) reported that the amphipod *Corophium volutator* exhibited lower bioturbation rates when exposed to low-frequency noise, and they found potential stress responses by the bivalve *Limecola balthica*. Activities directly contacting the seabed would be expected to have localized impacts on invertebrates and fishes that use the benthic habitat. A risk assessment of the potential impacts of airgun surveys on marine invertebrates and fish in Western Australia concluded that the greater the intensity of sound and the shallower the water, the greater the risk to these animals (Webster et al. 2018).

TABLE 11. ESA determination for sea turtle species that could be encountered during the proposed surveys in the Northwestern Gulf of Mexico.

Species	ESA Determination		
	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Leatherback Turtle			√
Hawksbill Turtle			√
Green Turtle (South Atlantic DPS)			√
Green Turtle (North Atlantic DPS)			√
Loggerhead Turtle (Northwest Atlantic DPS)			√
Kemp's ridley Turtle			√

In water >250 m deep, the impact of seismic surveying on fish and marine invertebrates was assessed as acceptable, while in water <250 m deep, risk ranged from negligible to severe, depending on depth, resource-type, and sound intensity (Webster et al. 2018). Immobile organisms, such as mollusks, were deemed to be the invertebrates most at risk from seismic impacts.

4.1.2.1 Effects of Sound on Marine Invertebrates

Effects of anthropogenic sounds on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses including stress, injuries, mortalities (Wale et al. 2013a,b; Aguilar de Soto 2016; Edmonds et al. 2016; Carroll et al. 2017; Weilgart 2017b; Elliott et al. 2019; Day et al. 2021) and stress (Celi et al. 2013; Vazzana et al. 2020). Jézéquel et al. (2021) recently reported that shipping noise can mask sounds produced by European lobster (*Homarus gammarus*), and that they may change sound production in response to noise.

Fields et al. (2019) conducted laboratory experiments to study effects of exposure to airgun sound on the mortality, predator escape response, and gene expression of the copepod *Calanus finmarchicus* and concluded that the airgun sound had limited effects on the mortality and escape responses of copepods exposed within 10 m of the airgun source but no measurable impact beyond that distance. McCauley et al. (2017) conducted a 2-day study to examine the potential effects of sound exposure of a 150 in^3 airgun on zooplankton off the coast of Tasmania; they concluded that exposure to airgun sound decreased zooplankton abundance compared to control samples and caused a two- to three-fold increase in adult and larval zooplankton mortality. They observed impacts on the zooplankton as far as 1.2 km from the exposure location – a much greater impact range than previously thought; however, there was no consistent decline in the proportion of dead zooplankton as distance increased and received levels decreased. The conclusions by McCauley et al. (2017) were based on a relatively small number of zooplankton samples, and more replication is required to increase confidence in the study findings.

Richardson et al. (2017) presented results of a modeling exercise intended to investigate the impact of exposure to airgun sound on zooplankton over a much larger temporal and spatial scale than that employed by McCauley et al. (2017). The exercise modeled a hypothetical survey over an area 80 km by 36 km during a 35-day period. Richardson et al. (2017) postulated that the decrease in zooplankton abundance observed by McCauley et al. (2017) could have been due to active avoidance behavior by larger zooplankton. The modeling results did indicate that there would be substantial impact on the zooplankton populations at a local spatial scale but not at a large spatial scale; zooplankton biomass recovery within the exposure area and out to 15 km occurred 3 days after completion of the seismic survey.

Fewtrell and McCauley (2012) exposed captive squid (*Sepioteuthis australis*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 dB re 1 μPa^2 • s SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 μPa^2 • s; the squid were seen to discharge ink or change their swimming pattern or vertical position in the water column. Solé et al. (2013a,b) exposed four cephalopod species held in tanks to low-frequency (50–400 Hz) sinusoidal wave sweeps (with a 1-s sweep period for 2 h) with received levels of 157 ± 5 dB re 1 μPa and peak levels up to 175 dB re 1 μPa. Besides exhibiting startle responses, all four species examined received damage to the statocyst, which is the organ responsible for equilibrium and movement. The animals also showed stressed behavior, decreased activity, and loss of muscle tone (Solé et al. 2013a). To examine the contribution from near-field particle motion from the tank walls on the study, Solé et al. (2017) exposed common cuttlefish (*Sepia officinalis*) in cages in their natural habitat to 1/3 octave bands with frequencies centered at 315 Hz and 400 Hz and levels ranging from 139–141 re 1 μPa^2. The study animals still incurred acoustic trauma and injury to statocysts, despite not being held in confined tanks with walls.

When New Zealand scallop (*Pecten novaezelandiae*) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited body abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (Aguilar de Soto et al. 2013). Their experiment used larvae enclosed in 60-mL flasks suspended in a 2-m diameter by 1.3-m water depth tank and exposed to a playback of seismic sound at a distance of 5–10 cm.

There have been several *in situ* studies that have examined the effects of seismic surveys on scallops. Although most of these studies showed no short-term mortality in scallops (Parry et al. 2002; Harrington et al. 2010; Przeslawski et al. 2016, 2018), one study (Day et al. 2016a,b, 2017) did show adverse effects including an increase in mortality rates. Przeslawski et al. (2016, 2018) studied the potential impacts of an industrial seismic survey on commercial (*Pecten fumatus*) and doughboy (*Mimachlamys asperrima*) scallops. *In situ* monitoring of scallops took place in the Gippsland Basin, Australia, using dredging, and autonomous underwater vehicle deployment before the seismic survey, as well as two, and ten months after the survey. The airgun array used in the study was a single 2530 in^3 array made up of 16 airguns operating at 2000 psi with a maximum SEL of 146 dB re 1 μPa^2 • s at 51 m depth. Overall, there was little to no detectable impact of the seismic survey on scallop health as measured by scallop shell size, adductor muscle diameter, gonad size, or gonad stage (Przeslawski et al. 2016). No scallop mortality related to airgun sounds was detected two or ten months after the seismic survey (Przeslawski et al. 2016, 2018).

Day et al. (2016a,b, 2017) exposed scallops (*P. fumatus*) and egg-bearing female spiny rock lobsters (*Jasus edwardsi*) at a location 10–12 m below the surface to airgun sounds. The airgun source was started ~1–1.5 km from the study subjects and passed over the animals; thus, the scallops and lobsters were exposed to airgun sounds as close as 5–8 m away and up to 1.5 km from the source. Three different airgun configurations were used in the field: 45 in^3, 150 in^3 (low pressure), and 150 in^3 (high pressure), each with maximum peak-to-peak source levels of 191–213 dB re 1 μPa; maximum cumulative SEL source levels were 189–199 dB re 1 μPa^2 • s. Exposure to seismic sound was found to significantly increase mortality in the scallops, especially over a chronic time scale (i.e., months post-exposure), although not beyond naturally occurring rates of mortality (Day et al. 2017). Non-lethal effects were also recorded, including changes in reflex behavior time, other behavioral patterns, haemolymph chemistry, and apparent damage to statocysts (Day et al. 2016b, 2017). However, the scallops were reared in suspended lantern nets rather than their natural environment, which can result in higher mortality rates compared to benthic populations (Yu et al. 2010).

The female lobsters were maintained until the eggs hatched; no significant differences were found in the quality or quantity of larvae for control versus exposed subjects, indicating that the embryonic development of spiny lobster was not adversely affected by airgun sounds (Day et al. 2016a,b). No mortalities were reported for either control or exposed lobsters (Day et al. 2016a,b). Day et al. (2019, 2021, 2022) exposed rock lobster to the equivalent of a full-scale commercial seismic survey passing within 500 m, adult and juvenile lobsters exhibited impaired righting and damage to the sensory hairs of the statocyst. Lobsters that were exposed at a more distance range showed recovery, whereas those exposed at closer range had persistent impairment (Day et al. 2019, 2021, 2022). Day et al. (2021, 2022) noted that there was indication for slowed growth and physiological stress in juvenile lobsters after exposure. Adult lobsters that were collected from areas with high anthropogenic noise were shown to have pre-existing damage to the statocysts which were not damaged further upon exposure to airgun sounds (Day et al. 2020). However, lobsters from noisy environments appeared to be better able to cope with the damage than noise naïve lobsters; they did not show any disruption to the righting reflex (Day et al. 2020).

Fitzgibbon et al. (2017) also examined the impact of airgun exposure on spiny lobster through a companion study to the Day et al. (2016a,b, 2017) studies; the same study site, experimental treatment methodologies, and airgun exposures were used. The objectives of the study were to examine the haemolymph biochemistry and nutritional condition of groups of lobsters over a period of up to 365 days post-airgun exposure. Overall, no mortalities were observed across both the experimental and control groups; however, lobster total haemocyte count decreased by 23–60% for all lobster groups up to 120 days post-airgun exposure in the experimental group when compared to the control group. A lower haemocyte count increases the risk of disease through a lower immunological response. The only other haemolyph parameter that was significantly affected by airgun exposure was the Brix index of haemolymph at 120 and 365 days post-airgun exposure in one of the experiments involving egg-laden females. Other studies conducted in the field have shown no effects on Dungeness crab (*Cancer magister*) larvae or snow crab (*Chionoecetes opilio*) embryos to seismic sounds (Pearson et al. 1994; DFO 2004; Morris et al. 2018).

Payne et al. (2015) undertook two pilot studies which (i) examined the effects of a seismic airgun recording in the laboratory on lobster (*Homerus americanus*) mortality, gross pathology, histopathology, serum biochemistry, and feeding; and (ii) examined prolonged or delayed effects of seismic air gun pulses in the laboratory on lobster mortality, gross pathology, histopathology, and serum biochemistry. For experiment (i), lobsters were exposed to peak-to-peak and root-mean-squared received sound levels of 180 dB re 1 µPa and 171 dB re 1 μPa_{rms} respectively. Overall there was no mortality, loss of appendages, or other signs of gross pathology observed in exposed lobster. No differences were observed in haemolymph, feeding, ovary histopathology, or glycogen accumulation in the heptapancreas. The only observed differences were greater degrees of tubular vacuolation and tubular dilation in the hepatopancreas of the exposed lobsters. For experiment (ii), lobsters were exposed to 20 airgun shots per day for five successive days in a laboratory setting. The peak-to-peak and root-mean-squared received sound levels ranged from ~176–200 dB re 1 µPa and 148–172 dB re 1 μPa_{rms}, respectively. The lobsters were returned to their aquaria and examined after six months. No differences in mortality, gross pathology, loss of appendages, hepatopancreas/ovary histopathology or glycogen accumulation in the hepatopancreas were observed between exposed and control lobsters. The only observed difference was a slight statistically significant difference for calcium-protein concentration in the haemolymph, with lobsters in the exposed group having a lower concentration than the control group.

Cote et al. (2020) conducted a study using the multi-year Before-After/Control-Impact (BACI) approach in the Carson and Lilly Canyons to evaluate the potential of industry-scale seismic exposure to modify movement behavior of free-ranging adult male snow crab. The crabs were exposed to a commercial seismic array, with a total volume of 4880 in^3, horizontal SPL_{0-p} of 251 dB re 1 µPa, and SEL of 229 dB re 1 $\mu Pa^2 \cdot s$ (the same seismic source as used by Morris et al. 2018, noted below). The movements of the snow crabs were tracked using a hyperbolic acoustic positioning array. In total, 201 and 115 snow crabs were tagged in Carson and Lilly canyons, respectively. Before, during, and after exposure periods to a single seismic surveying line of 5 to 8 hours in duration, were matched in time across control and test sites—each site monitored an area 4 km^2. There were no obvious effects of seismic exposure on the movement ecology of adult male snow crab; variation in snow crab movement was primarily attributable to individual variation and factors like handling, water temperature, and time of day. The authors concluded that seismic exposure did not have any important effects on snow crab movement direction, and any variance in the results were shown to be individual-specific. Snow crabs are known to display highly variable movement behavior and individual-specific tendencies can explain experimental variance (Cote et al. 2020). Snow crab have also been considered to be less vulnerable to physiological damages from noise due to their absence of gas filled organs such as swim bladders that are sensitive to seismic exposures (Cote et al. 2020). There was also no evidence of physical damage to internal organs based on histological examinations (Morris et al. 2021).

In total, 201 and 115 snow crab were tagged in Carson and Lilly canyons, respectively. Before, During, and After exposure periods to a single 2D seismic surveying line (5–8 hours duration) were matched in time across Control and Test sites—each site monitored an area 4 km^2. There were no obvious effects of seismic exposure on the movement ecology of adult male snow crab; variation in snow crab movement was primarily attributable to individual variation and factors like handling, water temperature and time of day. The authors concluded that the effects of seismic exposure on the behavior of adult male snow crab, are at most subtle and are "not likely to be a prominent threat to the fishery." There was also no evidence of physical damage to internal organs based on histological examinations (Morris et al. 2021). The study concluded that seismic exposure did not have any important effects on snow crab movement direction, and any variance in the results were shown to be individual-specific. Snow crab have also been considered to be less vulnerable to physiological damages from noise due to their absence of gas filled organs such as swim bladders that are sensitive to seismic exposures (Cote et al. 2020).

Hall et al. (2021) collected tissue samples to investigate the potential impact of seismic surveying on the transcriptome responses of snow crab hepatopancreas. The hepatopancreas is an organ that aids in the absorption and storage of nutrients and produces important digestive enzymes and is therefore assumed to be an indicator suitable for determining the effect of sound exposure effects on crab physiology and health. Snow crabs were subjected to 2-D seismic noise in 2016 for 2 h and sampled before, and 18 h and three weeks after exposure. In 2017, 2-D seismic exposure was repeated, and samples were collected prior to seismic testing, and 1 day, 2 days, and 6 weeks after exposure. Additionally, in 2017 snow crabs were subjected 3-D seismic noises for 2 months and were sampled 6 weeks after exposure. Hall et al. (2021) identified nine transcripts with significantly higher expression after 2-D seismic exposure, and 14 transcripts with significant differential expression between the test and control sites. These included transcripts with functional annotations related to oxidation-reduction, immunity, and metabolism. Significant changes for these transcripts were not observed during the 2017. Thus, although transcript expression changes were detected in snow crab in response to seismic survey sound, the response was variable across years. Hall et al. (2021) concluded that although candidate molecular biomarkers identified in one field season (2016), they were not reliable indicators in the next year (2017), and further study is warranted.

Leite et al. (2016) reported observing a dead giant squid (*Architeuthis dux*) while undertaking marine mammal observation work aboard a seismic vessel conducting a seismic survey in offshore Brazil. The seismic vessel was operating 48-airgun array with a total volume of 5085 in^3. As no further information on the squid could be obtained, it is unknown whether the airgun sounds played a factor in the death of the squid.

Heyward et al. (2018) monitored corals *in situ* before and after exposure to a 3-D seismic survey; the maximum SEL and SPL $_{0\text{-pk}}$ were 204 dB re 1 µPa^2·s and 226 dB re 1 µPa. No macroscopic effects on soft tissues or the skeleton were noted days or months after the survey.

4.1.2.2 Effects of Sound on Fish

Popper et al. (2019a) and Popper and Hawkins (2021) recently reviewed the hearing ability of fishes, and potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), Fay and Popper (2012), Weilgart (2017b), Hawkins and Popper (2018), Popper et al. (2019b), and Slabbekoorn et al. (2019); they include pathological, physiological, and behavioral effects. Radford et al. (2014), Putland et al. (2017), and de Jong et al. (2020) noted that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Mauro et al. (2020) concluded that noise exposure may have significant effects on fish behavior which may subsequently affect fitness and survival).

Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed include mortality, mortal injury, recoverable injury, temporary threshold shift, masking, and behavioral effects. Seismic sound level thresholds were discussed in relation to fish without swim bladders, fish with swim bladders, and fish eggs and larvae. Hawkins and Popper (2017) and Hawkins et al. (2020) cautioned that particle motion as well as sound pressure should be considered when assessing the effects of underwater sound on fishes.

Bruce et al. (2018) studied the potential behavioral impacts of a seismic survey in the Gippsland Basin, Australia, on three shark species: tiger flathead (*Neoplatycephalus richardsoni*), gummy shark (*Mustelus antarcticus*), and swellshark (*Cephaloscylum laticeps*). Sharks were captured and tagged with acoustic tags before the survey and monitored for movement via acoustic telemetry within the seismic area. The energy source used in the study was a 2530 in^3 array consisting of 16 airguns with a maximum SEL of 146 dB re 1 µPa^2 · s at 51 m depth. Flathead and gummy sharks were observed to move in and around the acoustic receivers while the airguns in the survey were active; however, most sharks left the study area within 2 days of being tagged. The authors of the study did not attribute this behavior to avoidance, possibly because the study area was relatively small. Overall, there was little conclusive evidence of the seismic survey impacting shark behavior, though flathead shark did show increases in swim speed that was regarded by the authors as a startle response to the airguns operating within the area.

Peña et al. (2013) used an omnidirectional fisheries sonar to determine the effects of a 3-D seismic survey off Vesterålen, northern Norway, on feeding herring (*Clupea harengus*). They reported that herring schools did not react to the seismic survey; no significant changes were detected in swimming speed, swim direction, or school size when the drifting seismic vessel approached the fish from a distance of 27 km to 2 km over a 6-h period. Peña et al. (2013) attributed the lack of response to strong motivation for feeding, the slow approach of the seismic vessel, and an increased tolerance to airgun sounds.

Miller and Cripps (2013) used underwater visual census to examine the effect of a seismic survey on a shallow-water coral reef fish community in Australia. The census took place at six sites on the reef before and after the survey. When the census data collected during the seismic program were combined with historical data, the analyses showed that the seismic survey had no significant effect on the overall abundance or species richness of reef fish. This was in part attributed to the design of the seismic survey (e.g., ≥400 m buffer zone around reef), which reduced the impacts of seismic sounds on the fish communities by exposing them to relatively low SELs (<187 dB re 1 µPa^2 · s). Meekan et al. (2021) also reported that a commercial seismic source had no short- or long-term effects on the tropical demersal fish community on the North west Shelf of Western Australia, as no changes on species composition, abundance, size structure, behavior, or movement were reported. The source level of the airgun array was estimated as 228 dB SEL and 247 dB re 1 µPa m peak-to-peak pressure.

Fewtrell and McCauley (2012) exposed pink snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the fish swam faster and formed more cohesive groups in response to the airgun sounds.

Hastings and Miksis-Olds (2012) measured the hearing sensitivity of caged reef fish following exposure to a seismic survey in Australia. When the auditory evoked potentials (AEP) were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at water depth of 5 m, there was no evidence of TTS in any of the fish examined, even though the cumulative SELs had reached 190 dB re 1 $\mu Pa^2 \cdot s$.

Davidsen et al. (2019) outfitted Atlantic cod (*Gadus moruha*) and saithe (*Pollachius virens*) with acoustic transmitters to monitor their behaviors (i.e., swimming speed, movement in water column) in response to exposure to seismic airgun sound. The study was conducted in Norway using a large sea cage with a 30 m diameter and 25 m depth. Both sound pressure and particle motion were measured within the sea cage. An airgun firing every 10 s was towed toward the sea cage from an initial distance of 6.7 km from the cage to a minimum distance of 100 m from the cage. The SEL_{cum} ranged from 172–175 dB re 1 $\mu Pa^2 \cdot s$. Both the cod and saithe changed swimming depth and horizontal position more frequently during exposure to the sound. The saithe became more dispersed in response to elevated sound levels. Both species exhibited behavioral habituation to the repeated exposures to sound.

van der Knaap et al. (2021) investigated the effects of a seismic survey on the movement behavior of free-swimming Atlantic cod in the southern North Sea. A total of 51 Atlantic cod were caught and tagged with acoustic transmitters and released in the southern North Sea where they were exposed to a towed airgun array 2.5 km from the tagged location over 3.5 days. The airgun array consisted of 36 airguns with a total volume of 2950 in^3, which fired every 10 s during operation in continuous loops, with parallel tracks of 25 km. The cumulative sound exposure level (SEL_{cum} re 1 $\mu Pa^2 s$) over the 3.5-day survey period at the receiver position was 186.3 dB in the 40–400 Hz band. During sound exposure, cod became less locally active (moving small distances, showing high body acceleration) and more inactive (moving small distances, showing low body acceleration) at dawn and dusk which interrupted their diurnal activity cycle. The authors concluded that seismic surveying has the potential to affect energy budgets for a commercial fish species, which may have population-level consequences.

Hubert et al. (2020) exposed Atlantic cod in an aquaculture net pen to playback of seismic airgun sounds to determine the effect on swimming patterns and behavioral states. The fish were exposed to sound recordings of a downscaled airgun with a volume of (10 in^3) and a pressure of 800 kPa. During the experimental trials, the fish were exposed to mean zero-to-peak sound pressure levels ($SPL_{0\text{-}p}$) of 174, 169, and 152 dB re 1 µPa (0-pk) (100–600 Hz bandpass filter) with the speaker at 2, 7.8, and 20 m from the net pen, respectively. They found that individual cod within the net pen did not immediately change their swimming patterns after sound exposure; however, several individuals did change the amount of time they spent in three different behavioral states (transit, locally active, inactive) during the 1 h exposure.

McQueen et al. (2022) exposed wild Atlantic cod outfitted with acoustic transmitters on their spawning grounds to SELs up to 145 dB re 1 during a 1-week period of intermittent seismic shooting using two 40 in^3 airguns. The survival of cod or departure rates from the spawning grounds did not differ significantly between seismic exposure and control periods, indicating that cod were not displaced from spawning grounds after exposure to airgun sounds comparable to a survey several kilometers away from the site.

Kok et al. (2021) found that fish exposed to the seismic survey at a wind farm changed their school cohesion during compared with before exposure; there were also fewer schools detected during exposure. Nonetheless, they noted that no firm conclusions could be drawn from the studies, as fish behaved similarly at a control site.

Radford et al. (2016) conducted experiments examining how repeated exposures of different sounds to European seabass (*Dicentrarchus labrax*) can reduce the fishes' response to that sound. They exposed post-larval seabass to playback recordings of seismic survey sound (single strike SEL 144 dB re 1 $\mu Pa^2 \cdot s$) in large indoor tanks containing underwater speakers. Their findings indicated that short-term exposure of seismic sound increased the ventilation rate (i.e., opercular beat rate [OBR]) of seabass that were not previously exposed to seismic relative to seabass in controlled, ambient sound conditions. Fish that were reared in tanks that were repeatedly exposed to seismic sound over a 12-week period exhibited a reduced OBR response to that sound type, but fish exposed over the same time period to pile-driving noise displayed a reduced response to both seismic and pile-driving noise. An increased ventilation rate is indicative of greater stress in seabass; however, there was no evidence of mortality or effects on growth of the seabass throughout the 12-week study period.

Popper et al. (2016) conducted a study that examined the effects of exposure to seismic airgun sound on caged pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*); the maximum received peak SPL in this study was 224 dB re 1 µPa. Results of the study indicated no mortality, either during or seven days after exposure, and no statistical differences in effects on body tissues between exposed and control fish.

Andrews et al. (2014) conducted functional genomic studies on the inner ear of Atlantic salmon (*Salmo salar*) that had been exposed to seismic airgun sound. The airguns had a maximum SPL of ~145 dB re 1 μPa^2/Hz and the fish were exposed to 50 discharges per trial. The results provided evidence that fish exposed to seismic sound either increased or decreased their expressions of different genes, demonstrating that seismic sound can affect fish on a genetic level.

Sierra-Flores et al. (2015) examined broadcast sound as a short-term stressor in Atlantic cod (*Gadus morhua*) using cortisol as a biomarker. An underwater loudspeaker emitted SPLs ranging from 104–110 dB re 1 μPa_{rms}. Plasma cortisol levels of fish increased rapidly with sound exposure, returning to baseline levels 20–40 min post-exposure. A second experiment examined the effects of long-term sound exposure on Atlantic cod spawning performance. Tanks were stocked with male and female cod and exposed daily to six noise events, each lasting one hour. The noise exposure had a total SPL of 133 dB re 1 µPa. Cod eggs were collected daily and measured for egg quality parameters as well as egg cortisol content. Total egg volume, floating fraction, egg diameter and egg weight did not appear to be negatively affected by sound exposure. However, fertilization rate and viable egg productivity were reduced by 40% and 50%, respectively, compared with the control group. Mean egg cortisol content was found to be 34% greater in the exposed group as compared to the control group. Elevated cortisol levels inhibit reproductive physiology for males and can result in a greater frequency of larval deformities for spawning females.

4.1.2.3 Effects of Sound on Fisheries

Handegard et al. (2013) examined different exposure metrics to explain the disturbance of seismic surveys on fish. They applied metrics to two experiments in Norwegian waters, during which fish distribution and fisheries were affected by airguns. Even though the disturbance for one experiment was greater, the other appeared to have the stronger SEL, based on a relatively complex propagation model.

Handegard et al. (2013) recommended that simple sound propagation models should be avoided and that the use of sound energy metrics like SEL to interpret disturbance effects should be done with caution. In this case, the simplest model (exposures per area) best explained the disturbance effect.

Hovem et al. (2012) used a model to predict the effects of airgun sounds on fish populations. Modeled SELs were compared with empirical data and were then compared with startle response levels for cod. This work suggested that in the future, particular acoustic-biological models could be useful in designing and planning seismic surveys to minimize disturbance to fishing. Their preliminary analyses indicated that seismic surveys should occur at a distance of 5–10 km from fishing areas, in order to minimize potential effects on fishing.

In their introduction, Løkkeborg et al. (2012) described three studies in the 1990s that showed effects on fisheries. Results of a study off Norway in 2009 indicated that fishes reacted to airgun sound based on observed changes in catch rates during seismic shooting; gillnet catches increased during the seismic shooting, likely a result of increased movement of exposed fish, whereas longline catches decreased overall (Løkkeborg et al. 2012).

Streever et al. (2016) completed a BACI study in the nearshore waters of Prudhoe Bay, Alaska in 2014 which compared fish catch rates during times with and without seismic activity. The air gun arrays used in the geophysical survey had sound pressure levels of 237 dB re 1μPa_{0-p}, 243 dB re 1μPa_{p-p}, and 218 dB re 1μPa_{rms}. Received SPL_{max} ranged from 107–144 dB re 1 μPa, and received SEL_{cum} ranged from 111–141 dB re 1μPa^2-s for air gun pulses measured by sound recorders at four fyke net locations. They determined that fyke nets closest to air gun activities showed decreases in catch per unit effort (CPUE) while nets further away from the air gun source showed increases in CPUE.

Bruce et al. (2018) studied the potential impacts of an industrial seismic survey in the Gippsland Basin, Australia, on catches in the Danish seine and gillnet fishing sectors for 15 fish species. Catch data were examined from three years before the seismic survey to six months after completion of the survey in an area 13,000 km^2. Overall, there was little evidence of consistent adverse impacts of the seismic survey on catch rates. Six of the 15 species were found to have increased catch rates.

Paxton et al. (2017) examined the effects of seismic sounds on the distribution and behavior of fish on a temperate reef during a seismic survey conducted in the Atlantic Ocean on the inner continental shelf of North Carolina. Hydrophones were set up near the seismic vessel path to measure SPLs, and a video camera was set up to observe fish abundances and behaviors. Received SPLs were estimated at ~202–230 dB re 1 μPa. Overall abundance of fish was lower when undergoing seismic activity as opposed to days when no seismic occurred. Only one fish was observed to exhibit a startle response to the airgun shots. The authors claim that although the study was based on limited data, and no post-seismic evaluation was possible, it contributes evidence that normal fish use of reef ecosystems is reduced when they are impacted by seismic sounds.

Morris et al. (2018) conducted a two-year (2015–2016) BACI study examining the effects of 2-D seismic exploration on catch rates of snow crab along the eastern continental slope (Lilly Canyon and Carson Canyon) of the Grand Banks of Newfoundland, Canada. The airgun array used was operated from a commercial seismic exploration vessel; it had a total volume of 4880 in^3, horizontal SPL_{0-p} of 251 dB re 1 μPa, and SEL of 229 dB re 1 μPa^2·s. The closest approach of the survey vessel to the treatment site in 2015 (year 1 of the study) was 1465 m during 5 days of seismic operations; in 2016 (year 2), the vessel passed within 100 m of the treatment site but the exposure lasted only 2 h. Overall, the findings indicated that the sound from the commercial seismic survey did not significantly reduce snow crab catch rates during days or weeks following exposure. Morris et al. (2018) attributed the natural temporal and spatial variations in the marine environment as a greater influence on observed differences in catch rates between control and experimental sites than exposure to seismic survey sounds. Similarly, Cote et al. (2020) noted that the effects of seismic exposure on the behavior of adult male snow crab, are at most subtle and are "not likely to be a prominent threat to the fishery."

In 2017 and 2018, Morris et al. (2020, 2021) conducted another BACI study to investigate the effect of industrial 3-D seismic exposure on the catch rate of snow crab on the slope of the Grand Banks, at Carson Canyon with a control site at Lilly Canyon. The duration of potential seismic exposure by the 4130 in^3 airgun array was nine and five weeks in 2017 and 2018, respectively. Catch rates were inconsistent during the surveys; the catch rate at the experimental site was reduced in 2017, and higher catch rates were seen in 2018 in response to long-duration exposure. The study concluded the observed effects of seismic surveying on snow crab catch rates were driven by spatiotemporal variation external to seismic exposure. The authors acknowledged that there is a possibility that seismic surveying may affect catch rates, but that any effects remain unpredictable in magnitude and direction, and that effects occur at short temporal and localized spatial scales.

4.1.2.4 Conclusions for Invertebrates, Fish, Fisheries, EFH, and HAPC

Although there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, there would be no significant impacts of the proposed marine seismic research on populations. The seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on fisheries would not be significant. Interactions between the proposed surveys and fishing operations in the study area are expected to be limited. The marine seismic survey would not preclude fisheries from operating within or around the survey area. Two possible conflicts in general are the streamers entangling with fishing gear and the temporary displacement of fishers from the survey area. Fishing activities could occur within the proposed survey area; a safe distance would need to be kept from the source vessel and the towed seismic equipment. Conflicts would be avoided through Notice to Mariners and communication with the fishing community during the surveys. PSOs would also watch for any impacts the acoustic sources may have on fish during the survey.

Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect (including ESA-listed) marine invertebrates, marine fish (Table 12), and their fisheries, including commercial and recreational fisheries. The proposed activities would have no effect on HAPC, as this is located >100 km from the survey area. Although the proposed activities may affect EFH, no adverse effects on EFH are expected; airgun sound pulses would be intermittent, and activities overall would be of short-term duration (approximately 10 days).

TABLE 12. ESA determination for fish species expected to be encountered during the proposed surveys in the Northwestern Gulf of Mexico.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Giant manta ray		√	
Nassau grouper	√		
Oceanic Whitetip Shark		√	

4.1.3 Direct Effects on Seabirds and Their Significance

The underwater hearing of seabirds (including loons, scaups, gannets, and ducks) has been investigated by Crowell (2016), and the peak hearing sensitivity was found to be between 1500 and 3000 Hz. The best sensitivity of underwater hearing for great cormorants was found to be at 2 kHz, with a hearing threshold of 71 dB re 1 μPa_{rms} (Hansen et al. 2017). Great cormorants were also found to respond to underwater sounds and may have special adaptations for hearing underwater (Johansen et al. 2016; Hansen et al. 2017). African penguins (*Spheniscus demersus*) outfitted with GPS loggers showed strong avoidance of preferred foraging areas and had to forage further away and increase their foraging effort when a seismic survey was occurring within 100 km of the breeding colony (Pichegru et al. 2017). However, the birds resumed their normal behaviors when seismic operations concluded.

There could be potential effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds but these would be transitory disturbance, and there would be no significant impacts of the proposed marine seismic research on seabirds or their populations. The acoustic source would be shut down in the event an ESA-listed seabird was observed diving or foraging within the designated EZ. Given the proposed activities, avoidance measures and unlikelihood of encounter, no effects to ESA-listed seabirds would be anticipated from the proposed action (Table 13).

TABLE 13. ESA determination for seabird species expected to be encountered during the proposed surveys in the Northwestern Gulf of Mexico.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Piping plover	√		

4.1.4 Indirect Effects on Marine Mammals, Sea Turtles, Seabirds and Fish and Their Significance

The proposed seismic operations would not result in any permanent impact on habitats used by marine mammals, sea turtles, seabirds, fish, or marine invertebrates or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated anthropogenic sound levels and the associated direct effects on these species, as discussed above.

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned. No significant indirect impacts on marine mammals, sea turtles, seabirds, or fish would be expected.

4.1.5 Direct Effects on Cultural Resources, Tourism, and Their Significance

There are several shipwrecks in the survey area. Airgun sounds would have no effects on solid structures; no significant impacts on shipwrecks would be expected. The proposed activities are of short duration (approximately 10 days). No adverse impacts to cultural resources are anticipated.

There do not appear to be any recreational dive sites in the proposed survey area, but dolphin watching could occur in the area. A safe distance would need to be kept from the seismic source vessel and the towed seismic equipment. Potential conflicts with SCUBA divers and tour operators would be avoided through Notice to Mariners and communication with tour operators during the surveys. No adverse impacts to SCUBA diving or other tourism activities, such as dolphin watching.

4.1.6 Cumulative Effects

Cumulative effects refer to the impacts on the environment that result from a combination of past, existing, and reasonably foreseeable projects and human activities. Cumulative effects can result from multiple causes, multiple effects, effects of activities in more than one locale, and recurring events. Human activities, when conducted separately or in combination with other activities, could affect marine animals in the proposed survey area. However, understanding cumulative effects is complex because of the animals' extensive habitat ranges, and the difficulty in monitoring populations and determining the level of impacts that may result from certain activities.

According to Nowacek et al. (2015), cumulative impacts have a high potential of disturbing marine mammals. Wright and Kyhn (2014) and Lonsdale et al. (2020) proposed practical management steps to limit cumulative impacts, including new procedures for assessing cumulative impacts from human activity on the marine environment, and minimizing exposure by reducing exposure rates and levels. No significant cumulative effects to marine resources from the proposed marine seismic surveys are expected. Here we focus on activities (e.g., research, oil and gas, vessel traffic, and fisheries) that could impact animals specifically in the proposed survey area. Dolphin watching trips are also offered by several operators out of Texas. However, the combination of the proposed surveys with the existing operations in the region would be expected to produce only a negligible increase in overall disturbance effects on marine mammals and sea turtles. Hart et al. (2018) noted a hot spot of anthropogenic threats for Kemp's ridley and loggerhead sea turtles near the survey area, due to anthropogenic activities such as commercial fishing, shipping, and oil and gas activities.

Implementation of the proposed project would not affect, beneficially or adversely, socioeconomic resources, environmental justice, or the protection of children. No changes in the population or additional need for housing or schools would occur. Human activities in the area around the survey vessel would be limited to fishing activities, other vessel traffic, and perhaps dolphin watching. However, no significant impacts on fishing, vessel traffic, or dolphin watching would be anticipated particularly because of the short duration of the proposed activities. No other socioeconomic impacts would be anticipated as a result of the proposed activities.

4.1.6.1 Oil and Gas Industry

Oil production in the GoM has increased annually since 2013, ranking second only to Guyana as one of the world's most prospective offshore regions for discoveries since 2015 with >5 billion barrels of oil equivalent, worth an estimated $1.9 billion USD (Rystad Energy 2019). Offshore oil production accounts for 15% of total U.S. crude oil production (EIA 2022). The oil and gas industry in the GoM is characterized by seismic surveys, production platforms, aircraft, support vessel, and tanker ship traffic, and platform removal from expired lease areas via the use of explosives (Offshore Environment 2003). Potential sources of pollution to the GoM's marine environment from oil and gas-related activities may include routine (e.g., muds, cuttings, and produced water) or accidental discharges, oil spills, overflows, blowouts, or pollutants resulting from platform fires (Offshore Environment 2003). The GoM also features considerable input of oil hydrocarbons from natural liquid and gaseous seeps (Offshore Environment 2003). As demonstrated by the April 2010 *Deepwater Horizon* spill in the northern GoM, the U.S.' largest offshore oil spill in history, that released 134 million gallons of oil into the GoM over 87 days and that contaminated marine habitat and killed thousands of marine mammals, sea turtles, and seabirds, pollution from oil and gas-related activities can affect the health or ecology of marine fish and fish habitat, marine mammals, sea turtles, seabirds, and sensitive ecosystems, such as coral reefs or mangrove forests (Offshore Environment 2003; DWH NRDA Trustees 2016; Takeshita et al. 2017; Wallace et al. 2017; NOAA 2023g).

Due to the effects from the *Deepwater Horizon*, NMFS declared an UME from March 2010 to July 2014 that involved 1141 marine mammals (NOAA 2019b). Based on total stock sizes, the highest percent of any species killed by the spill were bay, sound, and estuary, and coastal bottlenose dolphins (up to 59% of the stock), followed by Bryde's whale (17%), spinner dolphin (16%), and rough-toothed dolphin (14%); mortalities were also reported for most other cetacean species (DWH NRDA Trustees 2016). The trustees estimated that 4900–7600 adult and large juvenile sea turtles, and 55,000–160,000 small juvenile sea turtles were killed by the oil spill; Kemp's ridley small juveniles showed the greatest mortality (up to 20% of the small hatchling population), followed by green, loggerhead, and hawksbill turtles (DWH NRDA Trustees 2016). Although leatherbacks were likely exposed to oil and suffered mortalities, this species could not be assessed quantitatively (DWH NRDA Trustees 2016). In addition, nearly 35,000 hatchlings (mostly Kemp's ridley turtles) were injured during clean up of the oil spill, and lost reproduction was estimated at up to 95,000 Kemp's ridley hatchings (DWH NRDA Trustees 2016). A total of 8500 dead and oiled birds were recorded after the spill, but total mortality was estimated at 51,600–84,500 birds; in addition, lost reproduction was estimated at 4600–17,900 fledglings (DWH NRDA Trustees 2016). Ninety-three bird species were impacted, including the bridled tern, for which up to 80 mortalities were estimated; the species with the highest mortalities were the laughing gull (up to 36,642 birds) and brown pelican (up to 27,613) (DWH NRDA Trustees 2016).

Approximately 1.8 million bpd of crude oil were produced in U.S. GoM Federal Offshore waters during 2018, and an average of 1.9 and 2.0 million bpd were expected for 2019 and 2020 (EIA 2019). In 2021, 1.7 million bpd were produced (EIA 2022). The Bureau of Ocean Energy Management (BOEM) oversees numerous blocks for oil and gas activities on the Outer Continental Shelf (OCS) of the Gulf of Mexico Western Planning Area (5240 blocks), Central Planning Area (12,409 blocks), and Eastern Planning Area (11,537 blocks), with 315 active leases in the Western Planning Area off Texas (BOEM 2022a). As a component of the *Gulf of Mexico Energy Security Act, 2006*, a moratorium on drilling was implemented by the U.S. Congress until June 2032 for most of the Eastern Planning Area and a portion of the Central Planning Area; the Western Planning Area does not have any withdrawals (BOEM 2022b).

4.1.6.2 Past and Future Seismic Surveys/Research Activities in the Area

The GoM has been subject to oil and gas exploration and geophysical surveys for over a century (TGS 2021). Numerous geophysical surveys have occurred in the central, northern, and northwestern portions of the GoM, including conventional 2-D and 3-D seismic surveys, Wide Azimuth (WAZ), and StagSeis™ (staggered vessel configuration, full-azimuth) seismic surveys (e.g., Kramer and Shedd 2017; TGS 2021, 2022; CGG 2022; NCEI 2022b; USGS 2022a). However, most of these surveys have taken place in water deeper than 20 m. The waters off San Luis Pass have previously been surveyed during a seismic study supported by DOE during 2012 and 2013. Consequently, the existence of the previous surveys at the site would provide a good test of the novel positioning technology because the previous surveys were acquired using standard positioning technology. Recent research in the GoM has also been associated with assessing the effects from the *Deepwater Horizon* explosion and oil spill. Other scientific research includes aerial and vessel surveys for marine mammals and sea turtles, and tagging studies.

The research organization (BEG-UT-Austin) is funded to collect multiple additional marine 3D seismic surveys via the same sponsor (DOE NETL) that use the same technology in similar marine enviornments (shallow, inner shelf, waters managed by the State of Texas). Consideration for this assessment is likely to also be relevant for those additional surveys.

4.1.6.3 Naval Activities

The eastern GoM is used by the U.S. Department of Defense (DoD) to conduct military training and test activities, serving as a surrogate environment for its activities in the Northern Arabian Gulf and Indo-Pacific Theater (DoD 2018). All newly built naval vessels from the Alabama and Mississippi shipyards undergo weapons, sonar, propulsion, and maneuverability testing in the eastern GoM, with training routes carefully planned to avoid interaction with civilian vessels, infrastructure, and sensitive marine resources (DoD 2018). Anti-ship mine warfare systems are also tested within the eastern GoM (DoD 2018).

4.1.6.4 Vessel traffic

Vessel traffic throughout the proposed survey area can more than 400 thousand routes per 2.45 km^2 per year (Fig. 5; MarineTraffic 2022). During September 2022, >50 vessels transited near the proposed survey area (USGS 2022b). When MarineTraffic was accessed 30 November 2022, the majority of vessels within and near the proposed survey area were tankers and fishing vessels, but tugs/special crafts and cargo vessels were also reported (MarineTraffic 2022). The time spent by the source vessel within the survey area (10 days) would be relatively minimal compared with the other vessels operating in the area during fall 2023. The addition of the proposed survey operations to existing vessel traffic is expected to result in a negligible increase in overall vessel disturbance effects on marine mammals and sea turtles.

4.1.6.5 Fisheries Interactions

The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve direct and indirect removal of prey items, sound produced during fishing activities, and potential entanglement (Reeves et al. 2003).

Marine mammals.—Entanglement in fishing gear can lead to serious injury or mortality of marine mammals. Section 118 of the MMPA requires all commercial fisheries to be placed in one of three categories based on the level of incidental take of marine mammals relative to the Potential Biological Removal (PBR) for each marine mammal stock. Category I, II, and III fisheries are those for which the combined take is ≥50%, 1–50%, and <1%, respectively, of PBR for a particular stock. In 2021, GoM longline fisheries for large pelagics was listed as a Category I fishery, mainly due to takes of bottlenose dolphins; the GoM gillnet, shrimp trawl, stone crab trap/pot, and menhaden purse seine fisheries were listed as Category II, and all other fisheries were listed as Category III (NOAA 2021c). In the most recent stock assessment for each delphinid species in the northern GoM, the following mean annual mortality rates for 2015–2019 due to fishery-related issues were reported: Atlantic spotted dolphin (36), bottlenose dolphin (continental shelf, 64.6; western coastal, 32.4; eastern coastal, 8.8; northern coastal, 7.9), rough-toothed dolphin (0.8), and short-finned pilot whale (0.4); all other toothed whales had either unknown or zero annual mortality rates (Hayes et al. 2022).

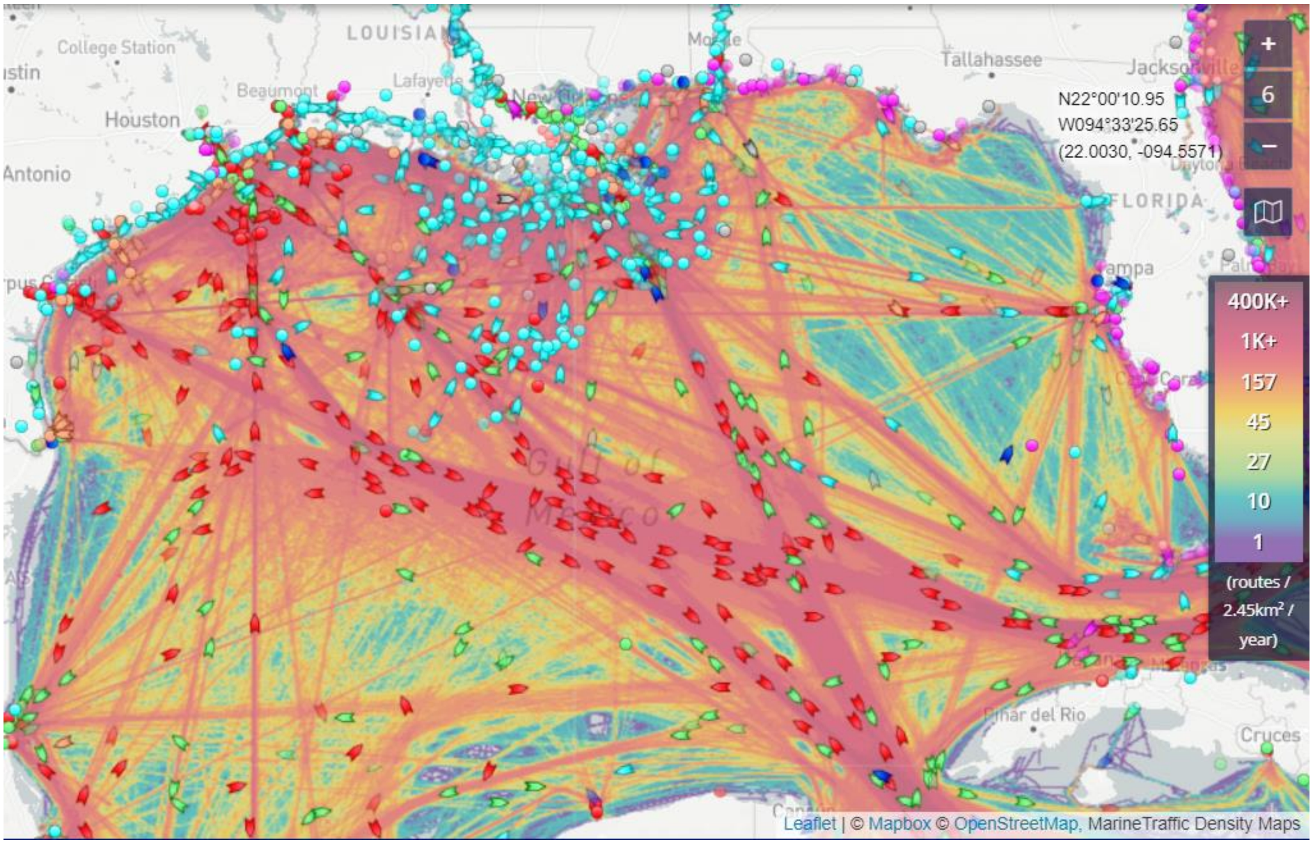

FIGURE 5. Annual vessel traffic density in the Gulf of Mexico, 2021 (Data source: MarineTraffic 2022).

Sea turtles.—Lewison et al. (2014) reported relatively high bycatch of sea turtles in the GoM for the longline fishery. The shrimp trawl fishery in the GoM is a major source of mortality for loggerhead and Kemp's ridley sea turtles (e.g., Shaver et al. 2013). The Southeast/GoM shrimp trawl fishery accounts for up to 98% of sea turtle bycatch in the U.S., with a mean annual turtle bycatch rate of 133,400 turtles and a mean mortality rate of 3700 turtles from 2003–2007, after regulations were put in place regarding turtle excluder device enlargements (Finkbeiner et al. 2011). In addition, over that same period, there were ~1400, 600, and 10 bycatch interactions for the Atlantic/GoM pelagic longline, GoM reef fish, and GoM hook and line fisheries, respectively, including 20, 200, and 0 mortalities, respectively (Finkbeiner et al. 2011). The majority of mortalities in the Atlantic during 2003–2007 have been of loggerheads, followed by Kemp's ridley turtles, most of which were attributed to the Southeast/GoM shrimp trawl fishery; however, leatherback, green, and hawksbill turtle mortalities were also reported (Finkbeiner et al. 2011).

Entanglement of sea turtles in seismic gear is also a concern; there have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore of West Africa (Weir 2007). However, such incidents are not possible with the pair of GI airguns that would be towed during the proposed survey. Towing of hydrophone streamers or other equipment is not expected to significantly interfere with sea turtle movements, including migration, unless they were to become entrapped as indicated above.

Seabirds.—Entanglement in fishing gear and hooking can also lead to mortality of seabirds. Li et al. (2016) reported that seabirds are by-caught in the Atlantic/GoM pelagic longline fishery, although bycatch has only been reported for the northern GoM. Species that have been caught incidentally in the GoM include the brown pelican (*Pelecanus occidentalis*) and laughing gull (*Larus atricilla*) (Li et al. 2016).

4.1.6.6 Summary of Cumulative Impacts to Marine Mammals, Sea Turtles, Seabirds, and Fish

Impacts of the proposed activities are expected to be no more than a minor (and short-term) increment when viewed in light of other human activities within the proposed project area. Unlike some other ongoing and routine activities in the area (e.g., commercial fishing), the proposed activities are not expected to result in injuries or deaths of marine mammals, sea turtles, or seabirds. Seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on commercial and recreation fisheries would not be significant. Interactions between the proposed surveys and fishing operations in the proposed project area are expected to be limited, mostly because of the short duration of the activity. Two possible conflicts in general are streamer entangling with fishing gear and the temporary displacement of fishers from the proposed project area. Fishing activities could occur within the proposed project area; however, a safe distance would need to be kept from the source vessel and the towed seismic equipment. During the surveys, the towed equipment is quite short (25 m), so this distance would be small. Conflicts would be avoided through communication with the fishing community during the surveys. Given the proposed activities, impacts would not be anticipated to adversely affect fisheries.

Although the airgun sounds from the seismic surveys would have higher source levels than do the sounds from most other human activities in the area, airgun operations during the surveys would last a maximum of 10 days, in contrast to those from many other sources that have lower peak pressures but occur continuously over extended periods. Thus, the combination of the proposed operations with the existing shipping and fishing activities would be expected to produce only a negligible increase in overall disturbance effects on marine mammals and turtles.

4.1.7 Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and sea turtles occurring in the proposed survey area would be limited to short-term, localized changes in behavior of individuals. For marine mammals, some of the changes in behavior may be considered to fall within the MMPA definition of "Level B Harassment" (behavioral disturbance; no serious injury or mortality). TTS, if it occurs, would be limited to a few individuals, is a temporary phenomenon that does not involve injury, and is unlikely to have long term consequences for the few individuals involved. No long-term or significant impacts would be expected on any of these individual marine mammals or sea turtles, or on the populations to which they belong. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.8 Coordination with Other Agencies and Processes

Potential impacts to marine mammals, endangered species, and critical habitat have also been assessed in the document; therefore, it will be used to support the ESA Section 7 and EFH consultation processes with NMFS. A letter was sent to NMFS on 11 January 2023 advising that the Draft EA was being prepared (Appendix B). On 11 January 2023, DOE sent a letter to USFWS (see Appendix C) requesting its concurrence with DOE's determination that the proposed activities would have no effect on ESA-listed species, such as the piping plover and Florida manatee, and critical habitat under USFWS jurisdiction pursuant to Section 7 of the ESA of 1973 (16 U.S.C. 1531-1544), as amended, and that no further consultation is required. This document will also be used as supporting documentation for an IHA application submitted by UT, on behalf of itself and DOE, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic surveys. A CZMA Consistency Determination will be submitted to the Texas General Land Office who administers the Texas Coastal Management Program.

4.2 No Action Alternative

An alternative to conducting the proposed activity is the "No Action" Alternative. Under the No Action Alternative, DOE would not provide funding for this research and there would be no need to issue an IHA for the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine species attributable to the proposed activity. However, data of scientific value that would be used to validate novel dynamic acoustic positioning technology for improving the accuracy in time and space of high-resolution 3-dimensional (HR3D) marine seismic technology would not be obtained. The No Action Alternative would not meet the purpose and need for the proposed activity.

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APPENDIX A: DETERMINATION OF MITIGATION ZONES[1]

[1] Prepared by L-DEO.

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for the Level B (160 dB re 1µPa$_{rms}$) threshold. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H *in* NFS and USGS 2011). as a function of distance from the airguns, for the two 105-in^3 GI airguns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor).

Propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the GoM in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010). For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth (~2000 m) for marine mammals (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the NSF and USGS (2011) PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant.

In deep and intermediate-water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) for the 36-airgun array at a tow depth of 6 m can be used to derive mitigation radii.

The proposed surveys would acquire data with two 105-in^3 GI guns (separated by up to 2.4 m) at a tow depth of ~3–4 m. Table A-1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound level is expected to be received for the 2-GI airgun configuration (totaling 210 in^3) at a 4-m tow depth. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. A-1 and A-2). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS).

The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in volume and tow depth between the calibration survey (6600 in^3 at 6 m tow depth) and the proposed survey (210 in^3 at 4 m tow depth). A simple scaling factor is calculated from the ratios of the isopleths calculated by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array:

- 150 decibel (dB) Sound Exposure Level (SEL)[1] corresponds to deep-water maximum radii of 725.96 m for the two 105 in^3 GI-guns at 4 m tow depth (Fig. A-1), and 7,244 m for the 6600 in^3 at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.10 to be applied to the shallow-water 6-m tow depth results.
- 165 dB SEL corresponds to deep-water maximum radii of 128.2 m for the two 105 in^3 GI-guns at a 4 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.10 to be applied to the shallow-water 6-m tow depth results.
- 170 dB SEL corresponds to deep-water maximum radii of 72.7 for the two 105 in^3 GI-guns at a 4 m tow depth (Fig. A-1), and 719 m for the 6600 in^3 at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.10.
- 185 dB SEL corresponds to deep-water maximum radii of 12.86 m for the two 105 in^3 at 4-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.11 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1µPa_{rms} distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factor to account for the tow depth and discharge volume differences between the 6600 in^3 airgun array at 6 m tow depth and the 210 in^3 GI airgun array at 4 m tow depth yields distances of 1.75 km, 284 m, 160 m, 46 m, and 26 m, respectively.

Table A-1 shows the distances at which the 160-, 175-, 180-, 190 and 195-dB re 1µPa_{rms} sound levels are expected to be received for the two 105 in^3 GI-guns at 4 m tow depth. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals; a 175-dB level is used by the National Marine Fisheries Service (NMFS), based on U.S. DoN (2017), to determine behavioral disturbance for sea turtles.

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[1] SEL (measured in dB re 1 µ$Pa^2 \cdot s$) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO's model.

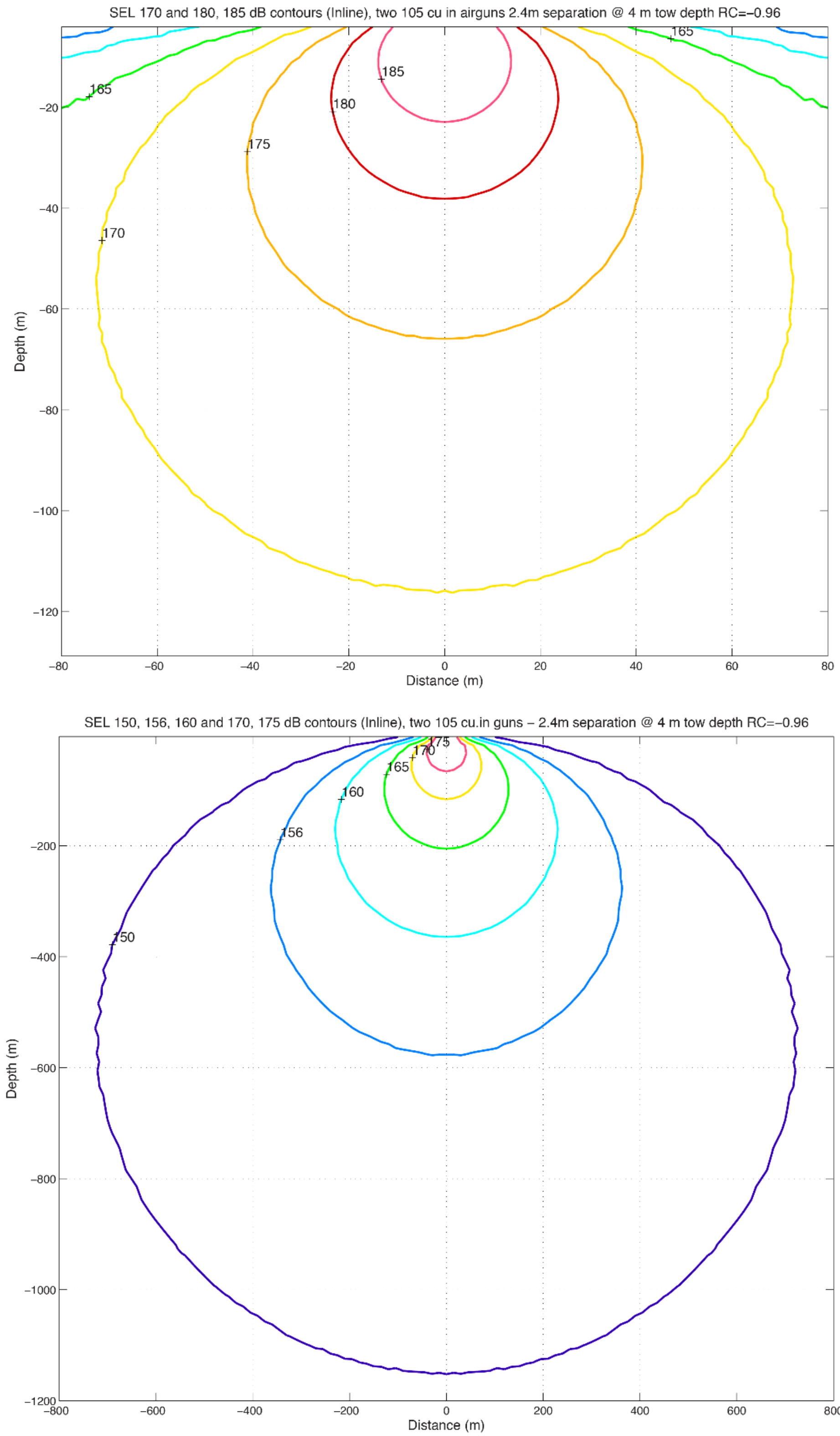

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the two 105-in³ GI guns, with a 2.4-m gun separation, planned for use during the proposed surveys at a 4-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

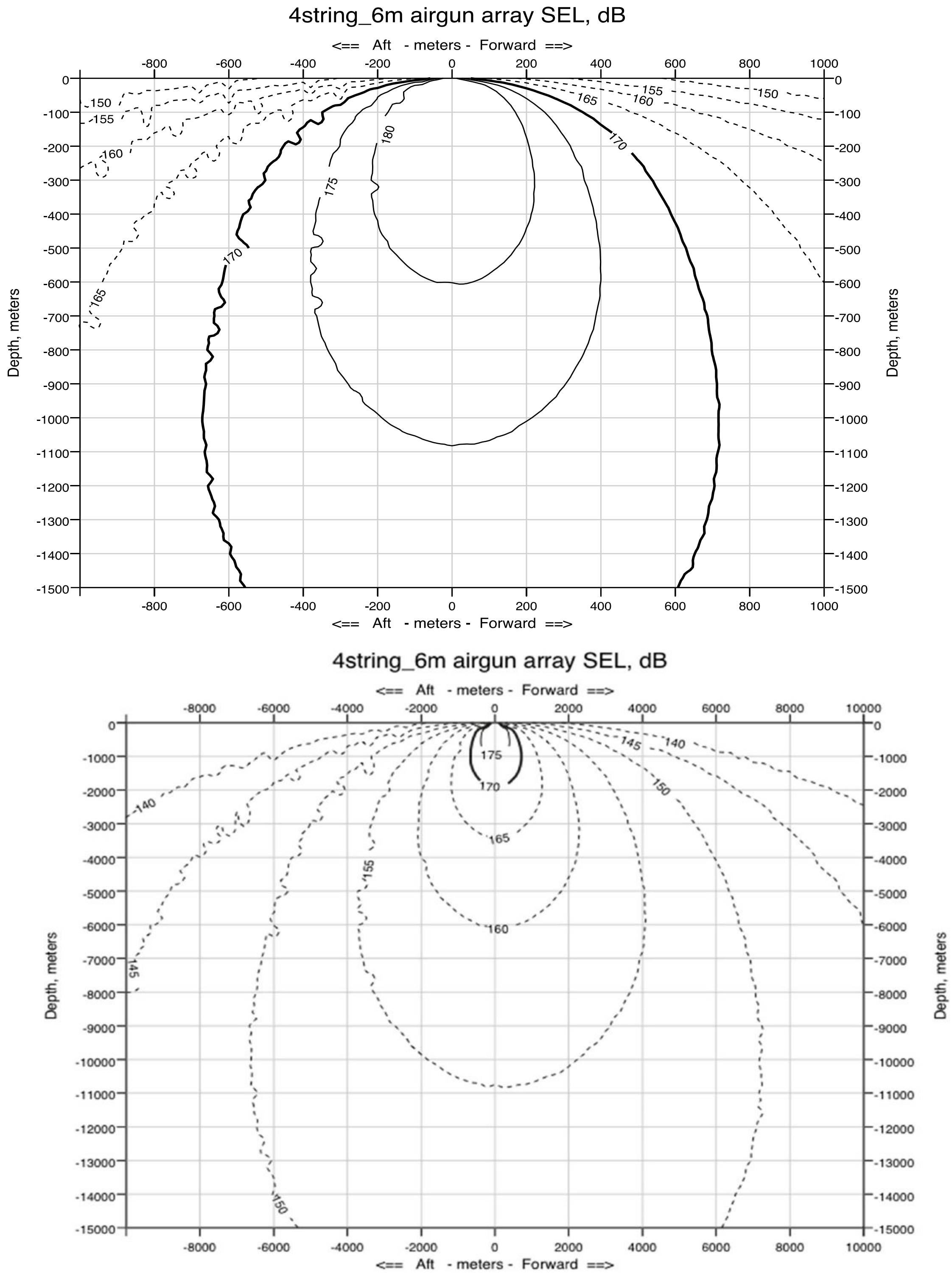

FIGURE A-2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

TABLE A-14. Level B. Predicted distances to the 160 dB and 175 dB re 1 μPa_{rms} sound levels that could be received from two 105-in^3 GI guns (separated by 2.4 m, at a tow depth of 4 m) that would be used during the seismic surveys in the Gulf of Mexico (model results provided by L-DEO).

Airgun Configuration	**Water Depth (m)[1]**	**Predicted rms Distances (m)**	
		160 dB	**175 dB**
Two 105-in^3 GI guns	>1000	726[1]	128[1]
	100-1000	1,089[2]	192[2]
	<100	1,750[3]	284[3]

[1] Distance is based on L-DEO model results.

[2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.

A recent retrospective analysis of acoustic propagation of R/V *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that in situ measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with in situ received level[3] have confirmed that the L-DEO model generated conservative mitigation zones, resulting in significantly larger zones than required by NMFS.

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species, but did not establish new thresholds for Level B Harassment. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016).

[3] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

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APPENDIX B: LETTER TO NMFS

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY
Albany, OR • Morgantown, WV • Pittsburgh, PA

NATIONAL ENERGY TECHNOLOGY LABORATORY

January 10, 2023

Mr. David Bernhart
Assistant Regional Administrator for Protected Resources
National Marine Fisheries Service, Southeast Regional Office
St. Petersburg, FL

Re: Request for Formal Consultation under section 7(a)(2) of the Endangered Species Act for an HR3D seismic survey in the northwestern Gulf of Mexico, off the coast of Texas

Dear Mr. Bernhart:

The Department of Energy's (DOE) National Energy Technology Laboratory (NETL) proposes to fund the University of Texas to conduct a high-resolution 3-dimensional (HR3D) seismic survey in the northwestern Gulf of Mexico. The seismic survey would use two 2 GI airguns towed behind the source vessel in nearshore waters off the coast of Texas (Fig. 1). The area of interest is offshore San Luis Pass, which defines the southern tip of Galveston Island, Texas, and is located approximately 22 km northeast of Freeport, TX, and 3 km from shore. The water depth at the area of interest is <20 m, and in some parts, it is as shallow as 10–12 m. The proposed surveys would occur within Texas state waters during fall 2023.

DOE is currently preparing an environmental assessment (EA) to assess the potential environmental impacts associated with the proposed Project. As part of the National Environmental Policy Act of 1969 (NEPA) process, DOE will consult with interested federal, state, regional, and local agencies. As a result, DOE requests formal consultation with the National Marine Fisheries Service (NMFS) regarding threatened and endangered species or their critical habitat in the vicinity of the Project as required under Section 7 of the Endangered Species Act (ESA). Pending further communication with the NMFS Office of Protected Resources PR1, we anticipate that the University of Texas will also be submitting a request for an Incidental Harassment Authorization (IHA) for the proposed project.

Project Details

The proposed seismic survey would use two 2 GI guns towed by the TDI-Brooks vessel R/V *Brooks McCall* (or similar) in nearshore waters off the coast of Texas. Data acquired during the proposed seismic survey would be used to validate novel dynamic acoustic positioning technology for improving the accuracy in time and space of HR3D marine seismic technology. In particular, the seismic data would be used for field validation of monitoring, verification, and account technology of offshore carbon sequestration. The source vessel would tow up to 2 GI airguns (with a volume of up to

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105 in^3 each) and a total discharge volume of approximately 210 in^3 at a depth of 3 m. The source level is up to 233.8 $dB_{0\text{-}pk}$ re 1 µPa · m. The receiving system would consist of four 25-m solid-state (solid flexible polymer – not gel or oil filled) hydrophone streamers, spaced 10-m apart (i.e., 30-m spread) and towed at a 2-m depth. The airguns would fire at a shot interval of approximately 12.5 m (5–10 s). As the airgun(s) are towed along the survey lines at a speed of approximately 4-5 knots (7.4-9.3 km/h), the hydrophone streamers would transfer the data to the on-board processing system. The University of Texas Gulf Coast Carbon Center designed and built GPS receivers that can be used to accurately position the streamer receivers and the acoustic source via tail buoys. Approximately 1704 km of seismic acquisition are proposed within an area covering approximately 222 km^2. There could be 142 possible lines 12 km long, spaced approximately 62.5 m apart. The proposed seismic survey would take place in the fall of 2023 for about 10 days of seismic acquisition. The source vessel would likely leave out of and return to port in Freeport or Galveston, TX.

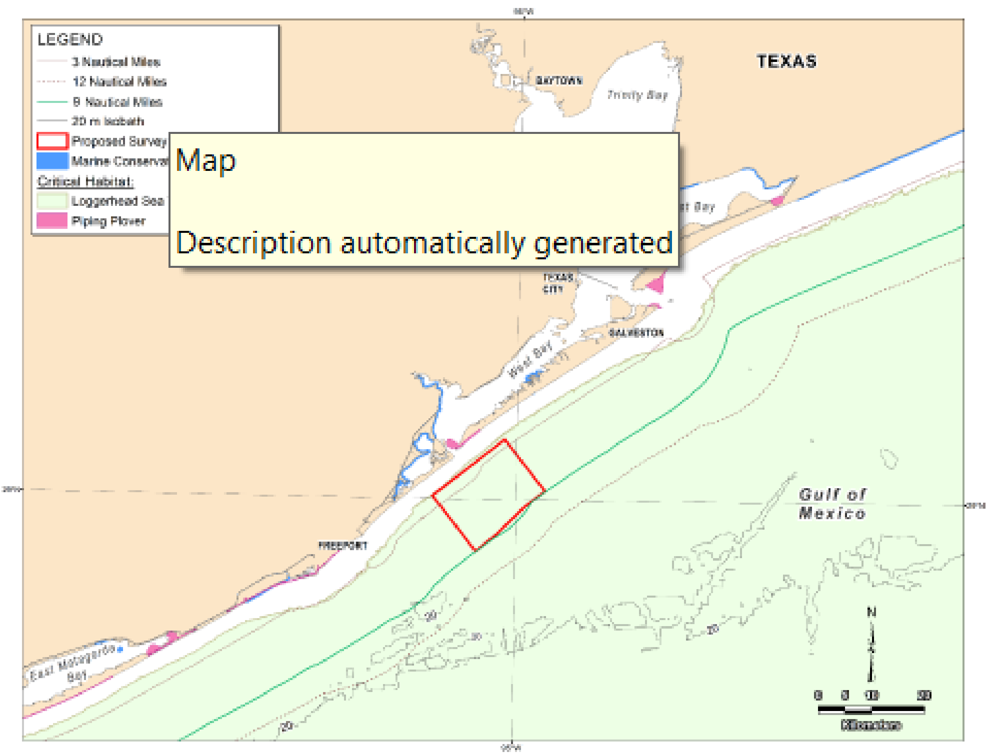

FIGURE 1. Location of the area of interest for the proposed seismic surveys off Galveston Island at San Luis Pass, northwestern Gulf of Mexico. Critical habitat for ESA-listed species is also shown, along with nearshore conservation areas.

An integral part of the planned survey would include a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed survey, and to document, as much as possible, the nature and

2

extent of any effects. Potential impacts of the proposed seismic survey on the environment would be primarily a result of the operation of the airguns. The increased underwater anthropogenic sounds associated with airgun operations could result in avoidance behavior by marine mammals and sea turtles. Injurious impacts to marine mammals and sea turtles have not been proven to occur near airguns or the other types of sound sources to be used. However, a precautionary approach would be taken, and the planned monitoring and mitigation measures would reduce the possibility of any effects. Proposed protection measures designed to mitigate the potential environmental impacts to marine mammals and sea turtles would include ramp ups of the 2-GI airgun array; at least one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers before and during startups during the day; and shutdowns when marine mammals and sea turtles are detected in or about to enter designated exclusion zones.

Potentially Affected NMFS ESA-Listed Species and Critical Habitat

Several ESA-listed species managed by NMFS could occur in the proposed survey area, including 5 species of sea turtles and 3 species of marine fish (Table 1). No ESA-listed marine mammal species are expected to occur in the shallow waters of the proposed survey area in the northwestern GoM. In addition, critical habitat for loggerhead turtles occurs within the proposed project area. Potential impacts to ESA-listed species or their critical habitat would be avoided or minimized through the monitoring and mitigation measures outlined above.

Table 1. ESA-listed marine species that could occur in the proposed survey area in the northwestern Gulf of Mexico.

Species/Distinct Population Segment (DPS)	**US ESA**
Sea Turtles	
Leatherback sea turtle (*Dermochelys coriacea*)	Endangered
Loggerhead sea turtle (*Caretta caretta*), Northwest	Threatened
Green sea turtle (*Chelonia mydas*), North Atlantic DPS	Threatened
Green sea turtle (*Chelonia mydas*), South Atlantic DPS	Threatened
Hawksbill sea turtle (*Eretmochelys imbricata*)	Endangered
Kemp's ridley sea turtle (*Lepideochelys kempii*)	Endangered
Marine Fish	
Giant Manta Ray (*Manta birostris*)	Threatened
Oceanic Whitetip Shark (*Carcharhinus longimanus*)	Threatened
Nassau Grouper (*Epinephelus striatus*)	Threatened

DOE respectfully requests guidance from NMFS concerning survey recommendations or seasonal restrictions with respect to threatened and endangered species. The information provided by NMFS will assist DOE in the preparation of the environmental assessment and with fulfillment of its regulatory responsibilities under the ESA. DOE also plans to provide a copy of the draft EA to your office for review in the near future. DOE would appreciate your assistance as soon as possible to help quickly identify potential impacts to protected species in the vicinity of the Project. You can reach me by email at

3

mark.lusk@netl.doe.gov, by telephone at (304) 285-4145, or at the address listed on the front page with any questions or comments.

Sincerely,

Mark W. Lusk
NEPA Compliance Officer

cc: Kyle Smith, NETL

APPENDIX C: LETTER TO USWFS

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY
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NATIONAL ENERGY TECHNOLOGY LABORATORY

January 10, 2023

Ms. Amy Lueders
Regional Director, Southwest Region
U.S. Fish & Wildlife Service
500 Gold Ave. SW
Albuquerque, NM 87102

Re: Proposed HR3D seismic surveys in the northern Gulf of Mexico

Dear Ms. Lueders:

The Department of Energy's (DOE) National Energy Technology Laboratory (NETL) proposes to fund the University of Texas to conduct a high-resolution 3-dimensional (HR3D) seismic survey in the northwestern Gulf of Mexico. The seismic survey would use two 2 GI airguns towed behind the source vessel in nearshore waters off the coast of Texas (Fig. 1). The area of interest is offshore San Luis Pass, which defines the southern tip of Galveston Island, Texas, and is located approximately 22 km northeast of Freeport, TX, and 3 km from shore. The water depth at the area of interest is <20 m, and in some parts, it is as shallow as 10–12 m. The proposed survey would occur within Texas state waters during fall 2023.

DOE is currently preparing an environmental assessment (EA) to assess the potential environmental impacts associated with the proposed Project. As part of the National Environmental Policy Act of 1969 (NEPA) process, DOE will consult with interested federal, state, regional, and local agencies. This letter requests the USFWS' concurrence with DOE's determination that the proposed activities would have no effect on ESA-listed species and critical habitat under USFWS jurisdiction pursuant to Section 7 of the ESA of 1973 (16 U.S.C. 1531-1544), as amended, and that no further consultation with USFWS is required.

Project Details

The proposed seismic survey would use two 2 GI guns towed by the TDI-Brooks vessel R/V *Brooks McCall* (or similar) in nearshore waters off the coast of Texas. Data acquired during the proposed seismic survey would be used to validate novel dynamic acoustic positioning technology for improving the accuracy in time and space of HR3D marine seismic technology. In particular, the seismic data would be used for field validation of monitoring, verification, and account technology of offshore carbon sequestration. The source vessel would tow up to 2 GI airguns (with a volume of up to 105 in^3 each) and a total discharge volume of approximately 210 in^3 at a depth of 3 m. The source level is up to 233.8 $dB_{0\text{-}pk}$ re 1 µPa · m. The receiving system would consist

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of four 25-m solid-state (solid flexible polymer – not gel or oil filled) hydrophone streamers, spaced 10-m apart (i.e., 30-m spread) and towed at a 2-m depth. The airguns would fire at a shot interval of approximately 12.5 m (5–10 s). As the airgun(s) are towed along the survey lines at a speed of approximately 4-5 knots (7.4-9.3 km/h), the hydrophone streamers would transfer the data to the on-board processing system. The University of Texas Gulf Coast Carbon Center designed and built GPS receivers that can be used to accurately position the streamer receivers and the acoustic source via tail buoys. Approximately 1704 km of seismic acquisition are proposed within an area covering approximately 222 km^2. There could be 142 possible lines 12 km long, spaced approximately 62.5 m apart. The proposed seismic survey would take place in the fall of 2023 for about 10 days of seismic acquisition. The source vessel would likely leave out of and return to port in Freeport or Galveston, TX.

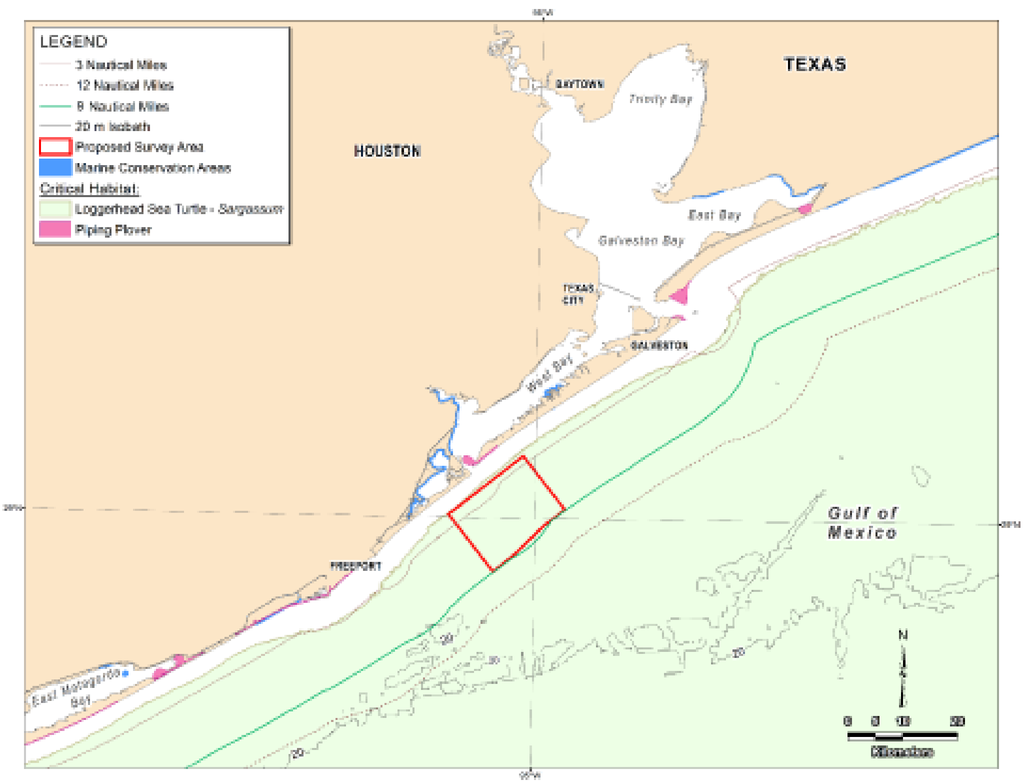

FIGURE 1. Location of the area of interest for the proposed seismic survey off Galveston Island at San Luis Pass, northwestern Gulf of Mexico. Critical habitat for ESA-listed species is also shown, along with nearshore conservation areas.

An integral part of the planned survey would include a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed survey, and to document, as much as possible, the nature and extent of any effects. Potential impacts of the proposed seismic survey on the environment would be primarily a result of the operation of the airguns. The increased underwater anthropogenic sounds associated with airgun operations could result in avoidance behavior by marine mammals and sea turtles. Injurious impacts to marine mammals and sea turtles have not been proven to occur near airguns or the other types of sound sources to be used. However, a precautionary approach would be taken, and the planned monitoring and mitigation measures would reduce the possibility of any effects. Proposed protection measures designed to mitigate the potential environmental impacts to marine mammals and sea turtles would include ramp ups of the 2-GI airgun array; at least one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers before and during startups during the day; and shutdowns when marine mammals and sea turtles are detected in or about to enter designated exclusion zones.

ESA-Listed Species under USFWS Jurisdiction and Critical Habitat

The piping plover (*Charadrius melodus*) is the only ESA-listed species managed by USFWS that is likely to occur within or near the proposed survey area. Critical habitat for this species has been designated along the coast (Figure 1), but none occurs within the proposed survey area. Although occasional sightings of the Florida manatee (*Trichechus manatus latirostris*) are also made in the northwestern Gulf of Mexico, this species is unlikely to be encountered during the proposed survey. Through avoidance, and the monitoring and mitigation measures outlined above, potential impacts of known occurrences of these two species would be avoided or minimized so that no effects are anticipated. There would be no effect on piping plover habitat, which is located outside of the survey area. Thus, DOE's determination is that the proposed activities would have no effect on ESA-listed species and critical habitat under USFWS jurisdiction.

The DOE believes we have used the best scientific data available to reach this conclusion. For discussion regarding the Proposed Action, please do not hesitate to contact me. You can reach me by email at mark.lusk@netl.doe.gov, by telephone at (304) 285-4145, or at the address listed on the front page with any questions or comments.

Sincerely,

Mark W. Lusk
NEPA Compliance Officer

cc: Kyle Smith, NETL