Draft Environmental Assessment/Analysis of Marine Geophysical Surveys by R/V *Marcus G. Langseth* off North Carolina, Northwest Atlantic Ocean

Prepared for

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ABSTRACT

Researchers from the University of Texas at Austin (UT) and Lamont-Doherty Earth Observatory (L-DEO) of Columbia University, with funding from the U.S. National Science Foundation (NSF), and in collaboration with international and domestic researchers including the United States Geological Survey (USGS), propose to conduct research, including high-energy seismic surveys from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*) of the Cape Fear submarine slide complex off North Carolina, in the northwestern Atlantic Ocean (Proposed Action). The majority of the proposed two-dimensional (2-D) seismic surveys would occur within the Exclusive Economic Zone (EEZ) of the U.S., but a small portion (~10%) would occur in International Waters. The surveys would use an 18-airgun towed array with a total discharge volume of ~3300 in^3 in water depths ranging from ~200 m to 5500 m.

NSF has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…". The proposed seismic surveys would collect data in support of a collaborative research proposal that was reviewed under the NSF merit review process and identified as an NSF program priority. The seismic surveys would examine tsunami hazards associated with large submarine landslide behavior off North Carolina.

This Draft Environmental Assessment/Analysis (EA) addresses NSF's requirements under the National Environmental Policy Act (NEPA) for the proposed NSF federal action within the U.S. EEZ and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", for the proposed NSF federal action in International Waters. Due to their involvement with the Proposed Action, the USGS requested to be a Cooperating Agency. As owner and operator of R/V *Langseth*, L-DEO on behalf of itself, NSF, and UT have requested 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 that are 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. This document tiers to the Programmatic 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 (June 2011) and Record of Decision (June 2012), referred to herein as PEIS. This document also tiers to an EA prepared for a similar seismic survey by R/V *Langseth* in 2014 titled, "Environmental Assessment of a Marine Geophysical Survey by the R/V *Marcus G. Langseth* in the Atlantic Ocean off Cape Hatteras, September–October 2014" (referred to herein as the 2014 EA; LGL 2014), and an EA for a USGS seismic survey titled, "Final Environmental Assessment for Seismic Reflection Scientific Research Surveys During 2014 and 2015 in Support of Mapping the US Atlantic Seaboard Extended Continental Margin and Investigating Tsunami Hazards" (RPS 2014a).

Numerous species of marine mammals inhabit the proposed marine project area in the Northwest Atlantic Ocean. Under the U.S. ESA, several of these species are listed as ***endangered***, including the North Atlantic right, sei, fin, blue, and sperm whales, which are managed by NMFS. The West Indian manatee is listed as ***threatened*** and managed by the U.S. Fish and Wildlife Service (USFWS); it can occur along the coast of North Carolina during the warmer summer months. However, as all activities would occur in water deeper than 100 m, manatees are not expected to be encountered or impacted during the proposed surveys and therefore are not considered further in this Draft EA. ESA-listed sea turtle species that could occur in the survey area include the ***endangered*** leatherback, hawksbill, and Kemp's ridley sea turtles, and the ***threatened*** Northwest Atlantic distinct population segment (DPS) of loggerhead sea turtle and North Atlantic DPS of green sea turtle. ESA-listed fish species that are known to occur off North Carolina include the ***threatened*** oceanic whitetip shark and giant manta ray, and the ***endangered*** smalltooth sawfish, sturgeon, shortnose sturgeon, and the Carolina DPS of Atlantic sturgeon. The shortfin mako shark is a candidate species for listing under the ESA and could also occur in the survey area. The ***endangered*** roseate tern and Bermuda petrel could also occur in the survey area; in addition, the black-capped petrel is proposed for listing as ***threatened***.

Potential impacts of the proposed seismic surveys on the environment would be primarily a result of the operation of the airgun array. A multibeam echosounder (MBES), split beam echosounder (SBES), and sub-bottom profiler (SBP) would also be operated during the surveys. Impacts from the Proposed Action 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 arrays 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, sea turtles, and ESA-listed seabirds include the following: ramp ups; two dedicated observers maintaining a visual watch during all daytime airgun operations; two observers before and during ramp ups during the day; passive acoustic monitoring (PAM) via towed hydrophones during both day and night to complement visual monitoring during the high-energy surveys; and shut downs when marine mammals are detected in or about to enter designated exclusion zones (EZ). The acoustic source would also be shut down in the event an ESA-listed sea turtle or seabird (diving/foraging) would be observed within the designated EZ. Observers would also watch for impacts the acoustic sources may have on fish. L-DEO and its contractors are committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other potential environmental impacts. 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.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals would be anticipated as falling within the Marine Mammal Protection Act (MMPA) definition of "Level B Harassment" for those species managed by NMFS. No long-term or significant effects would be expected on individual marine mammals, seabirds, fish, the populations to which they belong, or their habitats. NSF followed the National Oceanic and Atmospheric Administration's (NOAA) *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018) to estimate Level A takes for marine mammal species, although Level A takes are very unlikely. No significant impacts would be expected on the populations of those species for which a Level A take is permitted.

LIST OF ACRONYMS

~	approximately
2-D	two-dimensional
ADCP	Acoustic Doppler Current Profiler
AEP	Auditory Evoked Potential
AFTT	Atlantic Fleet Testing and Training
AMVER	Automated Mutual-Assistance Vessel Rescue
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
DAA	Detailed Analysis Area
dB	decibel
DFO	Canadian Department of Fisheries and Oceans
DoN	Department of the Navy
DPP	Draft Proposed Program
DPS	Distinct Population Segment
EA	Environmental Assessment/Analysis
EBSA	Ecologically or Biologically Significant Marine Areas
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EO	Executive Order
ESA	(U.S.) Endangered Species Act
EZ	Exclusion Zone
FAO	Food Agricultural Organization
FM	Frequency Modulated
FMP	Fishery Management Plan
FONSI	Finding of No Significant Impact
G&G	geological and geophysical
GIS	Geographic Information System
h	hour
HAPC	Habitat Area of Particular Concern
hp	horsepower
HRG	high-resolution geophysical
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)
LME	Large Marine Ecosystem
m	meter
MAFMC	Mid-Atlantic Fishery Management Council
MBES	Multibeam Echosounder
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCS	Multi-Channel Seismic

MFA	Mid-frequency Active (sonar)
min	minute
MMC	Marine Mammal Commission
MMPA	(U.S.) Marine Mammal Protection Act
MPA	Marine Protected Area
ms	millisecond
MTD	mass transport deposits
NAMMCO	North Atlantic Marine Mammal Commission
NCDEQ	North Carolina Environmental Quality
NCWD	North Carolina Wreck Diving
NEPA	National Environmental Policy Act
NEFSC	Northeast Fisheries Science Center
NMFS	(U.S.) National Marine Fisheries Service
nmi	nautical mile
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
ROD	Record of Decision
R/V	research vessel
s	second
SAFMC	South Atlantic Fishery Management Council
SBES	Split Beam Echosounder
SBP	Sub-bottom Profiler
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
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

I PURPOSE AND NEED

Researchers from the University of Texas at Austin (UT) and Lamont-Doherty Earth Observatory (L-DEO) of Columbia University, with funding from the U.S. National Science Foundation (NSF), and in collaboration with international and domestic researchers including the United States Geological Survey (USGS), propose to conduct research, including high-energy seismic surveys from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*) of the Cape Fear submarine slide complex off North Carolina, in the northwestern Atlantic Ocean (Proposed Action). This Draft Environmental Assessment/Analysis (EA) was prepared pursuant to the National Environmental Policy Act (NEPA) and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions". The Draft EA tiers to the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. This document also tiers to an EA prepared for a similar seismic survey conducted by R/V *Langseth* in 2014 titled, "Environmental Assessment of a Marine Geophysical Survey by the *R/V Marcus G. Langseth* in the Atlantic Ocean off Cape Hatteras, September–October 2014" (referred to herein as the 2014 EA; LGL 2014), and to an EA for a seismic survey conducted by USGS titled, "Final Environmental Assessment for Seismic Reflection Scientific Research Surveys During 2014 and 2015 in Support of Mapping the US Atlantic Seaboard Extended Continental Margin and Investigating Tsunami Hazards" (RPS 2014a). 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 an airgun array during the proposed seismic surveys. Due to their involvement with the Proposed Action, the USGS requested to be a Cooperating Agency.

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 "take by harassment" of small numbers of marine mammals[1] during the proposed seismic surveys. Following the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), Level A takes will be requested for the remote possibility of low-level physiological effects; however, 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 are considered highly unlikely.

1.1 Mission of NSF

The National Science Foundation (NSF) was established by Congress with the National Science Foundation Act of 1950 (Public Law 810507, as amended) and is the only federal agency dedicated to the support of fundamental research and education in all scientific and engineering disciplines. Further details on the mission of NSF are described in § 1.2 of the PEIS.

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[1] 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.

1.2 Purpose of and Need for the Proposed Action

As noted in the PEIS, § 1.3, NSF and USGS have a continuing need to fund seismic surveys that enable scientists to collect data essential to understanding the complex Earth processes beneath the ocean floor. The purpose of the proposed seismic surveys would be to examine tsunami hazards associated with large submarine landslide behavior off North Carolina. The surveys would collect data in support of a research proposal that was reviewed through the NSF merit review process and identified as an NSF program priority to meet the agency's critical need to foster an understanding of Earth processes.

1.3 Background of NSF-funded Marine Seismic Research

The background of NSF-funded and USGS conducted marine seismic research is described in § 1.5 and § 1.6 of the PEIS, respectively.

1.4 Regulatory Setting

The regulatory setting of this EA is described in § 1.8 of the PEIS, including the

- Executive Order 12114 – *Environmental effects abroad of major Federal actions*;
- *National Environmental Protection Act* (NEPA) of 1969 (42 United States Code [USC] §4321 *et seq*.); the Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (Title 40 Code of Federal Regulations [CFR] §§ 1500–1508 (1978 *et seq*.); NSF procedures for implementing NEPA and CEQ regulations (45 CFR 640);
- *Marine Mammal Protection Act* (MMPA) of 1972 (16 USC 1631 *et seq*.);
- *Endangered Species Act* (ESA) of 1973 (16 USC ch. 35 §1531 *et seq.*);
- *Coastal Zone Management Act* (CZMA) of 1972 (16 USC §§1451 *et seq.*); and
- *Magnuson-Stevens Fishery Conservation and Management Act* – Essential Fish Habitat (EFH) (Public Law 94-265; 16 USC ch. 38 §1801 *et seq*.).

II ALTERNATIVES INCLUDING PROPOSED ACTION

In this Draft EA, two alternatives are evaluated: (1) Proposed Action: conducting the proposed research, including seismic surveys and associated issuance of an associated IHA and (2) No Action alternative. Two additional alternatives were considered 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

Principal Investigators (PIs) from L-DEO and UT have proposed to conduct research, including seismic surveys using R/V *Langseth* off North Carolina in the Northwest Atlantic Ocean (Fig. 1). The main goal of the high-energy seismic program proposed by the PIs Drs. H. Daigle (UT), and A. Bécel and C. Grall (L-DEO), is to investigate the Cape Fear submarine slide complex off North Carolina.

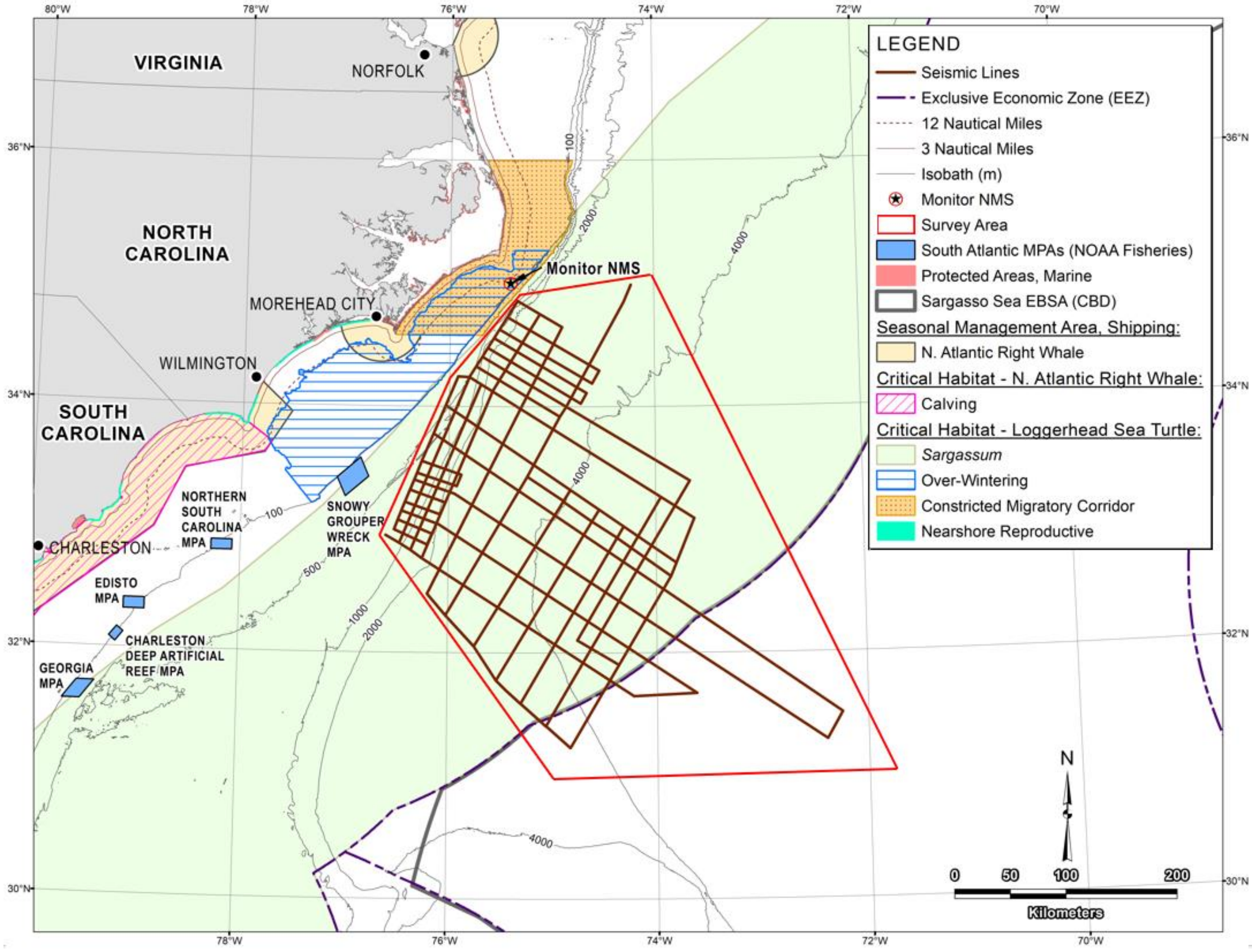

FIGURE 1. Location of the proposed North Carolina seismic surveys, marine conservation areas, and marine critical habitat in the Northwest Atlantic Ocean. Representative survey tracklines are included in the figure; however, the tracklines could occur anywhere within the survey area. MPA = marine protected area; EBSA = Ecologically or Biologically Significant Marine Areas. CBD = Convention on Biological Diversity

Additional collaborators (not funded through NSF) from the U.S. include N. Miller (USGS), J. Kluesner (USGS), K. Shukla (Brown University), D. Sawyer (Ohio State University), M.B. Magnani (Southern Methodist University), M. Occhi (Virginia Department of Mines, Minerals and Energy), and L. Worthington (University of New Mexico). L. Ruffine (Ifremer) would be an international collaborator (not funded through NSF) on the project.

To achieve the project goals, the researchers propose to conduct seismic surveys utilizing the airgun capabilities of R/V *Langseth*, along with echosounders, piston and gravity cores, and magnetic, gravity, and heat flow measurements to examine large submarine landslide behavior over the past 23 million years in a region offshore North Carolina that has experienced large, recent submarine landslides.

Submarine landslides are a common seafloor feature of the North Atlantic passive margin on both sides of the ocean; their presence on the Eastern North American Margin is the rule rather than the exception. They threaten large population centers along these coasts with possible tsunamis and move material from the shallow to the deep-sea during margin evolution. Despite their high prevalence on passive margins and in particular on the U.S. east coast, very little about their causes, mechanical behavior, and frequency is understood, and their role in the development of the passive margin as it exists today has not been examined. The project would improve understanding of how slope failures operate through time and the manner in which past events might influence subsequent events. The proposed study would provide new constraints for examining tsunami hazards associated with submarine landslides.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed research would occur within the survey area depicted in Figure 1, ~31–35°N, ~72–75°W, within the Exclusive Economic Zone (EEZ) of the U.S. and International Waters, in water depths ranging from ~200–5500 m. Representative seismic survey tracklines are shown in Figure 1. As described further in this document; however, some deviation in actual tracklines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the research activities, including the seismic surveys, could occur anywhere within the survey area and the coordinates noted above. However, the closest approach of the proposed research to the 100-m isobath would be ~5 km, to state waters (5.6 km [3 n.mi.]) would be ~35 km, and to the coast would be ~40 km (Cape Hatteras, North Carolina).

2.1.2.2 Description of Activities

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys conducted by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Langseth*, which would tow an 18-airgun array with a discharge volume of ~3300 in^3 at a depth of 6 m. The receiving system would consist of a 5-km solid-state hydrophone streamer towed at a 6-m depth and a 600-m long solid-state hydrophone streamer (solid flexible polymer - not gel or oil filled) towed at a depth of 2–3 m. The airguns would fire at a shot interval of 25 m (~10 s) during the multi-channel seismic (MCS) reflection surveys. As the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system.

Approximately 6083 km of seismic acquisition are proposed. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations (see § 4.1.1.5), 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. All survey effort would occur in water deeper than 100 m deep, with 10% (629 km) in intermediate water (100–1000 m) and 90% (5454 km) in deep water (>1000 m). Approximately 10% of seismic acquisition would occur in International Waters.

In addition to the operations of the airgun array, other acoustic sources, including a split beam echosounder (SBES), multibeam echosounder (MBES), sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP), would be operated from R/V *Langseth* continuously during the seismic surveys, including during transit. All planned marine-based geophysical data acquisition activities would be conducted by L-DEO 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.

Approximately 10–20 cores would be collected via R/V *Langseth* throughout the survey area above locations where strong Bottom Simulating Reflectors (BSRs) have been imaged and/or near the locations of seafloor gas seeps; the locations would be determined during the cruise based on the seismic data collected. Coring operations would include collection of gravity and piston cores at coring sites. Thermal data would be collected with outrigger temperature probes mounted to the outside of a piston core barrel. The core data would allow for the documentation of sediment physical properties and pore fluids. Depending upon logistics, availability of staff, and other considerations, coring activities may take place in a separate, future cruise.

2.1.2.3 Schedule

The proposed high-energy survey with the 18-airgun array would take place in spring or summer 2023 (May–September) for a period of ~33 days, including ~28 days of seismic operations, ~3 days of piston coring and heat flow measurements, and ~2 days of transit. R/V *Langseth* would likely leave out of and return to port in Norfolk, Virginia (~200 km to the survey area). Equipment deployment and recovery times would vary and occur anytime during the planned survey, except not likely during transit. L-DEO strives to schedule its operations in the most efficient manner possible; schedule efficiencies are achieved when regionally occurring research projects are scheduled consecutively and non-operational transits are minimized. Because of the nature of the NSF merit review process and the long timeline associated with the ESA Section 7 consultation and IHA processes, not all research projects or 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 *Langseth* is described in § 2.2.2.1 of the PEIS; the gross tonnage of R/V *Langseth* is 3834 t. The vessel speed during seismic operations with the 18-airgun array would be ~5 kts (~9.3 km/h) during the surveys. When R/V *Langseth* tows the airgun array and a longer hydrophone streamer, the turning rate of the vessel would be limited to five degrees per minute. Thus, the maneuverability of the vessel would be especially limited during operations with the longer streamer. PSOs would have a 360 degree view from the vessel's observation tower.

2.1.2.5 Airgun Description

During the seismic surveys, R/V *Langseth* would tow two strings with 18 airguns (plus 2 spares); the strings would be spaced 6 m apart. The airgun array consists of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The two airgun strings would be distributed across an area of ~6 x16 m behind the *Langseth* and would be towed ~140 m behind the vessel. During the surveys, the two strings of 18 active airguns with a total discharge volume of 3300 in^3 would be used. The array would be towed at a depth of 6 m, and the shot interval would be 25 m (~10 s). The airgun array and its source level and frequency components are described in § 2.2.3.1 of the PEIS and summarized below, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. The firing pressure of the airguns would be 1900 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, airguns would be operated 24/7 for multiple days to meet science objectives unless maintenance or mitigation measures warranted.

18-Airgun Array Specifications

Energy Source	Eighteen 1900 psi Bolt airguns of 40–360 in^3, in two strings each containing nine operating airguns
Source output (downward)	0-pk: 252 dB re 1 µPa·m; pk-pk: 259 dB re 1 µPa·m
Air discharge volume	~3300 in^3
Dominant frequency components	2–188 Hz

2.1.2.6 Additional Acoustical Data Acquisition Systems

Along with the airgun operations, four additional acoustical data acquisition systems (an MBES, SBES, SBP, and ADCP) would be operated from R/V *Langseth* continuously during the proposed surveys, including during transits. The ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. These sources, along with the ADCP, are described in § 2.2.3.1 of the PEIS as well below.

The Simrad EK80 SBES would be provided by USGS CMHRGP to collet mid-water echosounding data. It operates at a frequency of 38 kHz with a 7° beamwidth and at a frequency of 18 kHz with a beamwidth of 11°. The pulse duration would be8 ms and the ping repetition rate would be 1 s. It has a source level of 212–229 dB re 1 µPa-m.

The MBES is a hull-mounted system operating at 10.5 to 13 kHz (usually 12 kHz). The transmitting beamwidth would be one or two degrees fore-aft and 150 degrees (maximum) athwartship or perpendicular to the ship's line of travel. The maximum sound source level would be 242 dB re 1 µPa-m. Each ping consists of eight (in water > 1000 m) or four (in water <1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends one degree fore-aft. Continuous-wave signals increase from 2–15 milliseconds long in water depths up to 2600 m, and frequency modulated chirp signals up to 100 milliseconds long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of ~150 degrees, with two millisecond gaps between the pings for successive sectors.

The Knudsen 3260 SBP would be operated to provide information about the near sea floor sedimentary features and the bottom topography that would be mapped simultaneously by the MBES. The beam would be transmitted as a 27-degree cone, which would be directed downward by a 3.5-kHz tansducer in the hull of R/V *Langseth*. The nominal power output would be 10 kilowatts, but the actual maximum radiated power would be 3 kilowatts or 222 dB$_{rms}$ re 1 µPa at 1 m. The ping duration would be up to 64 milliseconds, and the ping interval would be one second. A common mode of operation is to broadcast five pulses at one-second intervals followed by a five-second pause. The SBP would be capable of reaching depths of 10,000 m.

A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. It would operate at a frequency of 35–1200 kHz, with a maximum source level of 224 dB re 1µPa-1 m over a conically-shaped 30° beam and a ping rate of 0.7 Hz.

2.1.2.7 Additional Non-acoustic Equipment

The piston corer would consist of a 12-m long core pipe that takes a core sample ~10 cm in diameter and a weight stand. The core pipe would weigh ~70 kg and the weight stand would weigh ~1270 kg and is ~90 cm in diameter. A piston corer would be lowered by wire to near the seabed where a tripping mechanism would release the corer and allow it to fall to the seabed, where the heavy weight stand would drive the core pipe into the seabed. A sliding piston inside the core barrel would reduce inside wall friction with the sediment and assists in the evacuation of displaced water from the top of the corer. The gravity corer would consist of a 3-m long core pipe that takes a core sample ~10 cm in diameter, a head weight ~45 cm in diameter, and a stabilizing fin. It would "free fall" from the vessel, and its stabilizing fin would ensure that the corer penetrates the seabed in a straight line. The coring equipment would be deployed over the side of the vessel with standard oceanographic wire. The wire would be taut with the weight of the equipment preventing species entanglements. Thermal data would be collected with passive outrigger temperature probes mounted to the outside of a piston core barrel. Some substitution in equipment may be necessary; however, any substituted equipment would be similar generally in size and operation. Equipment would be retrieved after use.

2.1.3 Monitoring and Mitigation Measures

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.1.1 and 2.4.2 of the PEIS and would occur in two phases: pre-cruise planning and operations. The following sections describe the efforts during both stages for the proposed activities. 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.

2.1.3.1 Planning Phase

As discussed in § 2.4.1.1 of the PEIS, 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 than the 18-airgun source. The 18-airgun energy source was determined to be the lowest practical source to meet the scientific objectives. Although the scientific objectives for the proposed high-energy surveys could not be met using a smaller source, the proposed source would be half the size of the 36-airgun array that would be typically used by L-DEO. A relatively large airgun source would be required to penetrate the crustal depths that would address the project goals.

Survey Location and Timing**.—**The PIs, along with L-DEO and NSF, 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, equipment, and optimal timing for other proposed seismic surveys using R/V *Langseth*. Most species of marine mammals are expected to occur in the proposed survey area throughout the year (DoN 2008a,b); baleen whales appear to be most common off North Carolina during winter. The occurrence of North Atlantic right whales appears to peak during February–March off North Carolina, but they are unlikely to occur in the deep waters of the offshore survey area. Hurricane season typically occurs during June–November. Late spring/summer was determined to be the most practical timing for the proposed surveys based on the occurrence of marine mammals, weather conditions, other operational requirements, and availability of researchers.

Mitigation Zones**.—**During the planning phase, mitigation zones for the proposed marine seismic survey were not derived from the farfield signature but calculated based on modeling by L-DEO for the exclusion zones (EZ) for Level A takes and for the Level B (160 dB re 1µPa$_{rms}$) threshold. The background information and methodology for this are provided in Appendix A. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the airgun source down to a maximum depth of 2000 m (see Appendix A), as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. Table 1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 18-airgun array. 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 1µPa$_{rms}$ sound level is expected to be received for the 18-airgun array; this level is used by NMFS, based on U.S. DoN (2017), to determine behavioral disturbance for sea turtles.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals and sea turtles for impulsive sounds use dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are available for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2016a, 2018), and sea turtles (DoN 2017). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances for marine mammals. Here, SEL$_{cum}$ is used for turtles and LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups (Table 2).

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). For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for shut downs and to monitor an additional 500-m buffer zone beyond the EZ for marine mammals and a 150-m EZ for sea turtles. Enforcement of mitigation zones via shut downs would be implemented as described below.

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 the PEIS and 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) passive acoustic monitoring (PAM); (3) PSO data and documentation; and (4) mitigation during operations (speed or course alteration; shut down and ramp up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats). 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.

Mitigation measures that would be adopted during the proposed surveys include (1) shut down procedures, and (2) ramp up procedures. These measures are proposed by L-DEO based on past experience and for consistency with the PEIS.

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 during the proposed surveys off North Carolina. 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	Tow Depth (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
2 strings, 18 airguns, 3300 in^3	6	>1000 m	2,886[1]	606[1]
		100–1000 m	4,329[2]	909[2]

[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.

TABLE 2. Level A (PTS) threshold distances for different marine mammal hearing groups for the 18-airgun array based on a shot interval of 25 m at 5 knots. Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances. Per NMFS, the same approach was applied for sea turtles.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PTS SEL$_{cum}$	**101.9**	0	0.5	4.2	0	**11.8**
PTS Peak	23.3	**11.2**	**116.9**	**25.3**	**9.95**	9.95

Shut down Procedures.—The operating airgun(s) would be shut down if a marine mammal was seen within or approaching the EZ. Shut downs would not be required for small dolphins that are most likely to approach the vessel. The airgun array would be shut down if ESA-listed sea turtles or seabirds (diving/foraging) were observed within a 150-m designated EZ.

Following a shut down, airgun activity would not resume until the marine mammal, ESA-listed seabird, or sea turtle 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, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

The airgun array would be ramped up gradually after a shut down for marine mammals but would not be required for ESA-listed sea turtles or seabirds. Ramp-up procedures are described below.

Ramp up Procedures.—A ramp up procedure would be followed when the airgun array 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 has not cleared the EZ as described earlier. As previously noted, for shut downs implemented for sea turtles and ESA-listed seabirds, no ramp up would be required, as long as the animal is no longer observed within the EZ.

Ramp up would begin with the smallest airgun in the array. Ramp up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. 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, respectively, as though the full array were operational. Ramp up would only commence at night or during poor visibility if the EZ has been monitored acoustically with PAM for 30 min prior to the start of operations without any marine mammal detections during that period.

The proposed operational mitigation measures are standard for seismic cruises, per the PEIS. Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours. During the high-energy surveys, one observer would conduct PAM during day- and night-time seismic operations. Monitoring and mitigation measures are further described in the IHA application. 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 (Table 3). Under the “No Action” alternative, NSF would not support L-DEO to conduct the proposed research operations. 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, L-DEO 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 § 4.3.

2.3 Alternatives Considered but Eliminated from Further Analysis

Table 3 provides a summary of the Proposed Action and the alternatives.

2.3.1 Alternative E1: Alternative Location

The Cape Fear region is an ideal location for a study of submarine landslide history on the Eastern North American Margin through the Neogene during passive margin evolution due to existing evidence of a long history of slope failure that is intricately linked with margin building processes. The unknowns in the history and dynamics of buried mass transport deposits (MTDs) on the mid-Atlantic margin clearly merit more study, particularly since future landslides and landslide-generated tsunamis pose a risk to

TABLE 3. Summary of Proposed Action, Alternative Considered, and Alternatives Eliminated.

Proposed Action	Description
Proposed Action: Conduct marine research (e.g, seismic surveys) off North Carolina	Under this action, research activities are proposed to study Earth processes and would involve marine seismic surveys, coring, etc. Active seismic operations would be expected to take ~28 days, and additional operational days would be expected for transit; equipment deployment, maintenance, and retrieval; weather; marine mammal activity; and other contingencies. The affected environment, environmental consequences, and cumulative impacts of the proposed activities are described in § III and IV. The standard monitoring and mitigation measures identified in the PEIS would apply, along with any additional requirements identified by regulating agencies in the U.S. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.
Alternatives	Description
Alternative 1: No Action	Under this Alternative, no proposed activities would be conducted, and seismic data would not be collected. While this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the Proposed Action. Geological data of scientific value that would provide new constraints for examining tsunami hazards associated with submarine landslides would not be collected, and the collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. No permits and authorizations, including an IHA, would be needed from regulatory bodies, as the Proposed Action would not be conducted.
Alternatives Eliminated from Further Analysis	Description
Alternative E1: Alternative Location	The Cape Fear region is an ideal location for a study of submarine landslide history on the Eastern North American Margin through the Neogene during passive margin evolution due to existing evidence of a long history of slope failure that is intricately linked with margin building processes. Landslides and landslide-generated tsunamis pose a risk to seafloor infrastructure and coastal populations. Despite their prevalence on the mid-Atlantic margin, very little is understood about their causes, mechanical and kinetic behavior, and frequency in the context of passive margins. The densely spaced, high resolution seismic grid collected could be integrated with the sparse existing seismic and IODP drilling data to allow for the identification of source regions for the MTD material, date key horizons, and constrain rock physical properties. The proposed science underwent the NSF merit review process, and the science, including the site location, was determined to be meritorious.
Alternative E2: Use of Alternative Technologies	Under this alternative, L-DEO would use alternative survey techniques, such as marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the PEIS, § 2.6. At this time, however, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need.

seafloor infrastructure and coastal populations. Despite their prevalence on the mid-Atlantic margin, very little is understood about their causes, mechanical and kinetic behavior, and frequency in the context of passive margins. The newly acquired densely-spaced, high resolution seismic grid can be integrated with the sparse existing seismic and International Ocean Discovery Program (IODP) drilling data to allow for the identification of source regions for the MTD material, date key horizons, and constrain rock physical properties.

2.3.2 Alternative E2: Use of Alternative Technologies

As described in § 2.6 of the PEIS, alternative technologies to the use of airguns were investigated to conduct high-energy seismic surveys. At this time, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2014a).

III AFFECTED ENVIRONMENT

As described in the PEIS, Chapter 3, 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 § III, and the potential impacts to these resources are discussed in § IV. 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. To reduce impacts on air quality, R/V *Langseth* uses Ultra-Low Sulfur fuel (<15 ppm Sulfur) and employs a Ship Energy Efficiency Management Plan to reduce and minimize fuel consumption (e.g., speed optimization) resulting in overall lower emissions.
- *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 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, temporary disturbances to seafloor sediments from gravity and piston cores. 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. During operations, the vessel would not be within the viewshed of the coast.
- *Socioeconomic 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. Although there are a number of shore-accessible SCUBA diving sites along the coast of North Carolina (see Section 3.9), the proposed activities would occur in water depths >100 m, outside the range for typical recreational SCUBA diving. Other human activities in the area around the survey vessel would include fishing, other vessel traffic, and whale watching. Most whale watching activities are conducted close to the coast. Given the distance from shore to the survey area, the likely distance from any marine mammal

watching activities, and the short and temporary duration of the surveys, it would be unlikely that the marine mammal watching industry would be affected by the Proposed Action. For these reasons, this issue is only considered in the context of cumulative effects (See 4.1.6.6). 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 water off the U.S. east coast consists of three water masses: coastal or shelf waters, slope waters, and the Gulf Stream. Coastal waters off Canada, which originate mostly in the Labrador Sea, move southward over the continental shelf until they reach Cape Hatteras, where they are entrained between the Gulf Stream and slope waters. The salinity of shelf water usually increases with depth and is generally lower than the salinity of water masses farther offshore primarily because of the low-salinity outflow from rivers and estuaries. The waters of the Navy’s Cherry Point Operating Area (CHPT OPAREA), which overlaps the proposed survey area, are relatively warm and salty with an average temperature of 25°C and an average salinity of 34 to 35 practical salinity units (DoN 2008b).

The continental margin, the area between the continental and oceanic crusts consisting of the continental shelf, slope and rise, extends ~322 km from shore along the coast of North Carolina (see DoN 2008a,b). The continental margin off the southeastern U.S. is known as the South Atlantic Bight. It stretches from Cape Hatteras off North Carolina, south over the broad shelf of the Carolinas and Georgia, and down to the narrow Florida Straits at Cape Canaveral. The South Atlantic Bight is part of the Southeast U.S. Continental Shelf Large Marine Ecosystem (LME) which is a Class II ecosystem with moderate productivity of 150–300 $gCm^{-2}yr^{-1}$ (Aquarone 2009). The continental shelf is very narrow off Cape Hatteras, broadening southward to form the Florida-Hatteras Shelf. The Florida-Hatteras Shelf gives way to the relatively steep Florida-Hatteras Slope at 100–500 m depths and then to the Blake Plateau (see DoN 2008a,b).

The Gulf Stream is a strong ocean current that brings warm water from the Gulf of Mexico into the Atlantic Ocean. It flows through the Straits of Florida and then parallel to the continental margin, becoming stronger as it moves northward. It has a mean speed of 1 m/s, and the surface speed is higher in summer than in winter. It turns seaward near Cape Hatteras and moves northeast into the open ocean. Slope waters in the mid-Atlantic are a mixture of water from the shelf and the Gulf Stream. North of Cape Hatteras, an elongated cyclonic gyre of slope water that forms because of the southwest flow of coastal water and the northward flowing Gulf Stream is present most of the year and shifts seasonally relative to the position of the north edge of the Gulf Stream. The Gulf stream works as an oceanographic barrier separating the warm tropical waters found to the south. Slope water eventually merges with the Gulf Stream (see DoN 2008a,b; NOAA SciJinks 2022). The Southeast U.S. shelf is protected from subarctic influences because the Gulf Stream convergences with the coast near Cape Hatteras (Aquarone 2009).

3.2 Protected Areas

3.2.1 MPAs, Marine Sanctuaries, and EBSAs

There are no marine protected areas (MPAs) within the proposed survey area, but one MPA (Snowy Grouper Wreck) and a marine sanctuary (Monitor National Marine Sanctuary) are located within 50 km of the proposed survey area (Fig. 1). Although the proposed activities are not likely to have any effect on MPAs or the marine sanctuary as these are located at least 15 km away and would not be exposed to sound levels >160 dB, we describe them below.

The NOAA Office of National Marine Sanctuaries is the trustee for 15 marine sanctuaries and two marine national monuments in U.S. waters (NOAA 2022a). One site, the Monitor National Marine Sanctuary, is located ~15 km north of the proposed survey area (Fig. 1). The Monitor National Marine Sanctuary was the first National Marine Sanctuary designated in the U.S. (ONMS 2022). This Sanctuary protects the site of the 1862 Civil War ironclad wreck, USS *Monitor*, and is located 26 km southeast of Cape Hatteras (ONMS 2022). The *Monitor* wreck site was discovered during 1974 and received presidential approval for designation as a National Marine Sanctuary the following year in order to conserve this cultural resource and its importance for maritime heritage (ONMS 2022). Airgun sounds would have no effects on solid structures such as the *Monitor*. The Sanctuary hosts an abundance of marine species, ranging from plankton and benthic invertebrates, including corals and at least 40 species of sponges, fishes, and loggerhead sea turtles (ONMS 2008). Scientific research and educational activities are allowed within the Sanctuary once the appropriate general permits are obtained (NOAA 2022c). Recreational diving may occur within the Sanctuary with the provision of special use permits (NOAA 2022b). During 2016, NOAA proposed an expansion to the boundaries of this Sanctuary to include several additional historic wreck sites, including those from World War II's Battle of the Atlantic (ONMS 2022). Public scoping for this proposed expansion has already occurred; in response to this scoping, NOAA is currently analyzing various expansion boundary options and proposed regulations and developing draft documents (EIS, Management Plan, and Regulations) in preparation for public and advisory council review. NOAA will announce a final decision regarding boundary expansion following consultations and public comments on the proposed final rulemaking (ONMS 2022).

During 2009, eight MPAs were designated in water depths between ~50 and 200 m along the southeastern U.S. coast by the South Atlantic Fishery Management Council (SAFMC) (NOAA 2021a). The northernmost of these MPAs, the Snowy Grouper Wreck MPA, is located ~30 km west of the proposed survey area; the other South Atlantic MPAs are located at least 130 km away and are not discussed further (Fig. 1). The Snowy Grouper Wreck MPA, located east of Cape Fear, features a shipwreck that historically supported snowy grouper spawning aggregations and possibly some other smaller wrecks, and encompasses a 500 km^2 area with water depths of 150–300 m (MPA 2022; SAFMC 2022). Following the wreck's discovery during the 1990s, the site was rapidly overfished but, with protection, its hard-bottom substrate may support various deepwater and snapper grouper species and other mid-shelf species (MPA 2022). Benthic fish species currently known to occur within the MPA include snowy grouper, speckled hind, gag, red porgy, red grouper, graysby, and hogfish (MPA 2022). Fishing for or possession of any snapper grouper species is prohibited within the MPA, as is the use of shark bottom longline gear (SAFMC 2022). Commercial and recreational vessels with stowed fishing gear and snapper grouper species on board may undertake direct, non-stop transits through the MPA, and trolling for pelagics (e.g., tuna, dolphin, mackerel, billfish) is permitted (SAFMC 2022).

The Convention on Biological Diversity (CBD) classifies biologically important oceanic areas around the world as Ecologically and Biologically Significant Areas (EBSAs) based on uniqueness and rarity; importance for life stages for marine species; importance for threatened, endangered, or declining species/habitats; vulnerability, fragility, sensitivity, or recovery rate; biological productivity and diversity; and naturalness (CBD 2021). The Sargasso Sea EBSA partially overlaps the southeastern portion of the proposed survey area. It is comprised of open water within the North Atlantic Subtropical Gyre, and its boundaries are defined by major clockwise oceanic currents around the Gyre's perimeter (CBD 2015). Seabed components of the Sargasso Sea EBSA include at least two large seamount chains, with numerous additional seamounts thought to occur there based on predictive modelling. This EBSA hosts the only holopelagic algae in the world, the floating *Sargassum* seaweeds, and features high productivity and species diversity, including at least 10 endemic species. The EBSA serves as essential habitat for important life stages of a variety of marine species and is the only known breeding ground for European eel and American eel (see CBD 2015). This EBSA is also an important migration route for marine mammals, sea turtles, sharks, rays, tunas, swordfishes, and seabirds (CBD 2015). The proposed activities are not expected to have any impact on *Sargassum* seaweeds, and therefore no impacts are anticipated from the proposed activities on this habitat and its availability and use for marine species.

3.2.2 Critical Habitat and Seasonal Management Areas

Marine species listed under the U.S. ESA must undergo consideration by NOAA Fisheries for the determination of critical habitat, which includes specific areas considered essential for the conservation of a species (NOAA 2022c). Critical habitat and seasonal management areas (SMA) for North Atlantic right whales occur west of the proposed survey area, and critical *Sargassum* habitat for loggerhead sea turtles occurs within a substantial amount of the proposed survey area (Fig. 1).

During 2016, NMFS designated 102,084 km^2 of combined critical habitat for North Atlantic right whales in the Gulf of Maine and Georges Bank region (Unit 1) and off the Southeast U.S. coast (Unit 2) (NMFS 2016b). The 2016 final ruling incorporated a southward extension of Unit 2 such that it now includes nearshore and offshore waters from Cape Fear to south of Cape Canaveral, Florida. Unit 2 has been recognized as critical for calving right whales, and mother-calf pairs are consistently observed there, particularly during January and February. The Unit 2 critical habitat may require special management considerations/protections for offshore energy development, large-scale offshore aquaculture operations, and global climate change. The northern portion of Unit 2 of the calving critical habitat occurs more than 100 km west of the proposed survey area in water <100 m deep.

To reduce the occurrence of fatal or serious collisions with vessels, NOAA Fisheries encourages all mariners/boaters to reduce vessel speed to ≤10 knots within areas that North Atlantic right whales are likely present and to preemptively check the following NOAA resources for the latest sighting information and active right whale safety zones, including Seasonal and Dynamic Management Areas: NOAA Right Whale Sightings Advisory System, Whale Alert App, Right Whale Slow Zones, and ‘recent whale sightings near your location’ (NOAA 2022d). Two North Atlantic right whale SMAs for shipping occur in water depths <100 m at least 45 km west of the proposed survey area – the Mid-Atlantic Morehead City/Beaufort and Mid-Atlantic U.S. (South) SMAs (NOAA 2022e). These areas are active from 1 November to 30 April (NOAA 2022e). In addition to avoiding North Atlantic right whale critical habitat, the Proposed Action would avoid the SMA and associated SMA timeframe. Within active SMAs, it is mandatory that all vessels ≥65 feet must travel at ≤10 knots (NOAA 2022f); this speed restriction is also being proposed for vessels ≥35 feet and <65 feet (NMFS 2022). R/V *Langseth* maximum cruising speed would be ~10 knots, and during seismic operations it would be ~5 knots.

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, and four critical habitat types occur near or within the proposed survey area, including *Sargassum*, over-wintering, constricted migratory corridor, and nearshore reproductive critical habitats (Fig. 1). *Sargassum* algae provides essential foraging and shelter habitat for loggerheads, particularly post-hatchlings and juveniles. This habitat overlaps much of the proposed survey area. Over-wintering habitat includes warm waters (>10ºC) on the continental shelf (20–100 m depth) south of Cape Hatteras that host a high abundance of juveniles and adults during the winter; this habitat would be located ~5 km west of the survey area. Constricted migratory corridor habitat includes important migratory corridors that are limited in width by land and the continental shelf edge/Gulf Stream; this habitat would be located ~1 km from the survey area. Nearshore reproductive habitat includes coastal waters of nesting beaches that hatchlings use for open-water egress and that nesting females use to traverse between the beach and open water. The closest nearshore reproductive critical habitat would be >50 km from the proposed survey areas, near Morehead City and Wilmington, NC.

3.3 Marine Mammals

Thirty-one cetacean species (6 mysticetes and 25 odontocetes) could occur near the proposed survey area (Table 4). Six of the 31 species are listed under the U.S. Endangered Species Act (ESA) as ***endangered***: the North Atlantic right, humpback, blue, fin, sei, and sperm whales. Bryde's whale (*Balaenoptera brydei*) would be unlikely to occur in the proposed survey area, because its distribution generally does not extend as far north as ~31–35°N. An additional three cetacean species likely would not be found near the proposed survey area because their ranges generally do not extend as far south; these include the northern bottlenose whale (*Hyperoodon ampullatus*), Sowerby's beaked whale (*Mesoplodon bidens*), and white-beaked dolphin (*Lagenorhynchus albirostris*). Although there has been a stranding record of a white-beaked dolphin for North Carolina, and acoustic detections of Sowerby's beaked whales just north of the proposed survey area (Rafter et al. 2021), these species along with the northern bottlenose whale, are not considered further.

Harp seals (*Pagophilus groenlandicus*), hooded seals (*Cystophora cristata*), and gray seals (*Halichoerus grypus*) are considered extralimital off North Carolina, and harbor seals (*Phoca vitulina*) are considered rare (DoN 2008b). In addition, harbor seals are unlikely to occur in the deeper waters of the proposed survey area. There are no records of pinnipeds within the proposed survey area (DoN 2008b); thus, pinnipeds are not discussed further. The Florida subpopulation of the West Indian manatee (*Trichechus manatus latirostris*) is known to occur in shallow water along the east coast of the U.S. As all proposed activities would occur in water deeper than 100 m, manatees are not expected to be encountered or impacted during the proposed surveys and therefore are not considered further. The survey area would be located at least 40 km from coast.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of cetaceans are given in § 3.6.1 and § 3.7.1 of the PEIS. The general distributions of mysticetes and odontocetes in this region of the Northwest Atlantic Ocean are discussed in the Northwestern Atlantic Detailed Analysis Area (DAA) in § 3.6.2.1 and § 3.7.2.1 of the PEIS, respectively. Additionally, information on marine mammals in this region is included in § 4.2.2.1 of the Bureau of Ocean Energy Management (BOEM) Final PEIS for Atlantic OCS Proposed Geological and Geophysical Activities, Mid-Atlantic and South Atlantic Planning Areas (BOEM 2014), and in § 3.7.2 of the Final EIS/OEIS for the Virginia Capes and the Cherry Point Range Complexes (DoN 2009a,b). The rest of this section focuses on species distribution in and near the proposed survey area in offshore waters of North Carolina.

3.3.1 Mysticetes

3.3.1.1 North Atlantic Right Whale (*Eubalaena glacialis*)

The North Atlantic right whale occurs primarily in the continental shelf waters of the eastern U.S. and Canada, from Florida to Nova Scotia, including off North Carolina (Winn et al. 1986; Jefferson et al. 2015; Hayes et al. 2022). There is a general seasonal north-south migration between feeding and calving areas (Gaskin 1982). The migration route between the Cape Cod spring/summer feeding grounds and the Georgia/Florida winter calving grounds is known as the mid-Atlantic corridor, and whales move through these waters regularly in all seasons (Reeves and Mitchell 1986; Winn et al. 1986; Kenney et al. 2001;

TABLE 4. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed project area off North Carolina in the Northwest Atlantic Ocean.

Species	Habitat	Occurrence in Survey Area[1]	Abundance in Western North Atlantic[2]	US ESA[3]	IUCN[5]	CITES[6]
Mysticetes						
North Atlantic right whale	Coastal	Rare	368	E	CR	I
Fin whale	Coastal, pelagic	Uncommon	6,802	E	VU	I
Blue whale	Pelagic	Rare	402[8]	E	EN	I
Sei whale	Pelagic	Rare	6,292[9]	E	EN	I
Minke whale	Coastal waters	Uncommon	21,968[10]	NL	LC	I
Humpback whale *West Indies DPS*	Mainly nearshore and banks	Uncommon	1,396[11] 11,570[12]	NL	LC[7]	I
Odontocetes						
Sperm whale	Usually pelagic and deep seas	Common	4,349[13]	E	VU	I
Pygmy sperm whale	Deeper waters off the shelf	Uncommon	7,750[14]	NL	DD	II
Dwarf sperm whale	Deeper waters off the shelf	Uncommon	7,750[14]	NL	DD	II
Cuvier’s beaked whale	Pelagic	Uncommon	5,744	NL	LC	II
Gervais' beaked whale	Pelagic	Rare	10,107[15]	NL	DD	II
Blainville’s beaked whale	Pelagic	Rare	10,107[15]	NL	DD	II
True’s beaked whale	Pelagic	Rare	10,107[15]	NL	LC	II
Rough-toothed dolphin	Mostly pelagic	Uncommon	136[16]	NL	LC	II
Bottlenose dolphin	Continental shelf, coastal, offshore	Common	62,851[17]	NL	LC	II
Atlantic white-sided dolphin	Shelf and slope	Rare	93,233	NL	LC	II
Pantropical spotted dolphin	Mainly pelagic	Uncommon	6,593	NL	LC	II
Atlantic spotted dolphin	Mainly coastal waters	Common	39,921	NL	LC	II
Spinner dolphin	Coastal, pelagic	Rare	4,102	NL	LC	II
Clymene dolphin	Pelagic	Rare	4,237	NL	LC	II
Striped dolphin	Off the continental shelf	Uncommon	67,036	NL	LC	II
Fraser’s dolphin	Water >1000 m	Rare	492[18]	NL	LC	II
Risso’s dolphin	Waters 400-1000 m	Common	35,215	NL	LC	II
Common dolphin	Shelf, pelagic	Common	172,974			
Melon-headed whale	Oceanic	Rare	1,175[18]	NL	LC	II
Pygmy killer whale	Oceanic	Rare	N.A.	NL	LC	II
False killer whale	Pelagic	Rare	1,791	NL	NT	II
Killer whale	Widely distributed	Uncommon	6,600[19]	NL	DD	II
Short-finned pilot whale	Mostly pelagic	Common	28,924	NL	LC	II
Long-finned pilot whale	Mostly pelagic	Uncommon	39,215	NL	LC	II
Harbor porpoise	Mostly coastal	Rare	95,543	NL	LC	II

N.A. = not available.

[1] Occurrence in area at the time of the survey; based on professional opinion and available data including sightings and densities.

[2] Abundance for North Atlantic from U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment (Hayes et al. 2022) unless otherwise indicated.

[3] U.S. Endangered Species Act: E = endangered, NL = not listed.

[5] International Union for the Conservation of Nature Red List of Threatened Species version 2022-1: VU = vulnerable; NT = near threatened; LC = least concern; DD = data deficient.
[6] Convention on International Trade in Endangered Species of Wild Fauna and Flora: Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[7] Global status.
[8] Minimum population size for Western North Atlantic.
[9] Nova Scotia.
[10] Canadian East Coast.
[11] Gulf of Maine.
[12] Entire North Atlantic (Stevick et al. 2003).
[13] North Atlantic.
[14] Estimate includes dwarf and pygmy sperm whales.
[15] Estimate includes all Mesoplodont whales in the North Atlantic, including Sowerby's beaked whale.
[16] Hayes et al. (2019) noted that this abundance estimate for the Western North Atlantic is highly uncertain as it is based on a single sighting; the abundance estimate for the Gulf of Mexico stock is 624. Roberts et al. (2016a) reported an abundance estimate of 4,989 for the Gulf of Mexico.
[17] Offshore stock.
[18] Roberts et al. (2016a).
[19] Estimate for North Atlantic (Iceland and Faroese Islands; Reyes 1991).

Reeves 2001; Knowlton et al. 2002; Whitt et al. 2013). The majority of sightings (94%) along the migration corridor are within 56 km of shore (Knowlton et al. 2002).

North Atlantic right whales are found at feeding grounds off the northeastern U.S. during early spring and summer. The highest abundance in Cape Cod Bay is in February and April (Winn et al. 1986; Hamilton and Mayo 1990) and from April to June in the Great South Channel east of Cape Cod (Winn et al. 1986; Kenney et al. 1995). Throughout the remainder of summer and into fall (June–November), they are most commonly seen farther north on feeding grounds in Canadian waters, with a peak abundance during August, September, and early October (Gaskin 1987). Jeffrey's Ledge, off the coast of northern Massachusetts, New Hampshire, and Maine, could also be an important fall feeding area and summer nursery area for right whales (Weinrich et al. 2000). Morano et al. (2012) and Mussoline et al. (2012) indicated that right whales are present in the southern Gulf of Maine year-round and that they occur there over longer periods than previously thought. Some right whales, including mothers and calves, remain on the feeding grounds through the fall and winter. However, most right whales leave the feeding grounds for unknown wintering habitats and returns when the cow-calf pairs return.

The majority of the right whale population is unaccounted for on the southeastern U.S. winter calving ground, and not all reproductively-active females return to the area each year (Kraus et al. 1986; Winn et al. 1986; Kenney et al. 2001). Other wintering areas have been suggested, based on sparse data or historical whaling logbooks; these include the Gulf of St. Lawrence, Newfoundland and Labrador, coastal waters of New York and between New Jersey and North Carolina, Bermuda, and Mexico (Payne and McVay 1971; Aguilar 1986; Mead 1986; Lien et al. 1989; Knowlton et al. 1992; Cole et al. 2009; Patrician et al. 2009). Surveys off North Carolina during the winter of 2001 and 2002 reported eight calves, suggesting that there could be a calving area as far north as Cape Fear (Hayes et al. 2022).

Knowlton et al. (2002) provided an extensive and detailed analysis of survey data, satellite tag data, whale strandings, and opportunistic sightings along State waters of the mid-Atlantic migratory corridor[2], from the border of Georgia/South Carolina to south of New England, spanning the period from 1974 to

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[2] Multi-year datasets for the analysis were provided by the New England Aquarium (NEAQ), North Atlantic Right Whale Consortium (NARWC), Oregon State University, Coastwise Consulting Inc, Georgia Department of Natural Resources, University of North Carolina Wilmington (UNCW), Continental Shelf Associates, Cetacean and Turtle Assessment Program (CETAP), NOAA, and University of Rhode Island.

2002. The majority of sightings (94%) along the migration corridor were within 56 km of shore, and more than half (64%) were within 18.5 km of shore. Water depth preference was for shallow waters; 80% of all sightings were in depths <27 m, and 93% were in depths <45 m (Knowlton et al. 2002). Most sightings farther than 56 km from shore occurred at the northern end of the corridor, off New York and south of New England. North of Cape Hatteras, most sightings were reported for March–April; south of Cape Hatteras, most sightings occurred during February–April. Similarly, sighting data analyzed by Winn et al. (1986) dating back to 1965 showed that the occurrence of North Atlantic right whales in the Cape Hatteras region, including the proposed survey area, peaked in March; in the mid-Atlantic area, it peaked in April. Acoustic detections have been made off North Carolina in all seasons with peak occurrence during winter; no detections were made off North Carolina south of Cape Hatteras during the months of May–July (Hodge et al. 2015; Davis et al. 2017; Palka et al. 2021), although some detections were made off Florida during those months (Palka et al. 2021). However, there were a few acoustic detections relatively close to the survey area during the months of August–October (Hodge et al. 2015; Davis et al. 2017).

On WhaleMap, there are 56 definite sightings and 29 definite acoustic detection records of North Atlantic right whales off North Carolina between 2010 and 2022; all sightings were made between January and March (Johnson et al. 2021). There were no sightings or detections in the proposed survey area, although there were some records in the shallower water adjacent to it (Johnson et al. 2021). Similarly, Hayes et al. (2022) showed several sightings on the shelf off North Carolina for 2015–2019, but no sightings within the proposed survey area. In contrast, DoN (2008a,b) reported single sightings within or near the proposed survey area during fall, winter, and spring. Right whales had the greatest occurrence off North Carolina during the winter (December–April), with fewer sightings during spring and fall, and no sightings during summer (DoN 2008a,b). There are no records of right whales for the proposed survey area off North Carolina in the OBIS database (OBIS 2022). However, there are 47 OBIS records for coastal waters of North Carolina, including sightings made during the 1978–1982 CETAP surveys (CETAP 1982); most records occurred during March. The North Atlantic right whale is expected to be rare in the proposed survey area at the time of the survey, and it spends most of its time in nearshore areas.

3.3.1.2 Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the World (Clapham 2018). Based on genetic data, there could be three subspecies occurring in the North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). It is highly migratory, undertaking one of the world's longest mammalian migrations by traveling between mid- to high-latitude waters where it feeds during spring to fall and low-latitude wintering grounds over shallow banks, where it mates and calves (Winn and Reichley 1985; Bettridge et al. 2015). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Calambokidis et al. 2001; Garrigue et al. 2002, 2015; Zerbini et al. 2011).

In the western North Atlantic, the humpback whale occurs from Greenland to Venezuela (Würsig et al. 2000). Based on modeling for the western North Atlantic, higher densities of humpbacks are expected to occur north of 35°N during the summer; very low densities are expected south of 35°N (Mannocci et al. 2017; Palka et al. 2021). For most North Atlantic humpbacks, the summer feeding grounds range from the northeast coast of the U.S. to the Barents Sea (Katona and Beard 1990; Smith et al. 1999). In the winter, the majority of humpback whales migrate to wintering areas in the West Indies (Smith et al. 1999); this is known as the West Indies Distinct Population Segment (DPS) (Bettridge et al. 2015). Some individuals from the North Atlantic migrate to Cape Verde to breed (e.g., Wenzel et al. 2009); however, a small proportion of the Atlantic humpback whale population remains in high latitudes in the eastern North

Atlantic during winter (e.g., Christensen et al. 1992). Feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016c). According to Hayes et al. (2020), NMFS is reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (e.g., NMFS 2016c).

In the North Atlantic, a Gulf of Maine stock of the humpback whale is recognized off the northeastern U.S. coast as a distinct feeding stock (Palsbøll et al. 2001; Vigness-Raposa et al. 2010). Whales from this stock feed during spring, summer, and fall in areas ranging from Cape Cod to Newfoundland. In summer, the greatest concentrations of humpback whales occur in the southern Gulf of Maine and east of Cape Cod (Clapham et al. 1993; Hayes et al. 2020). Off North Carolina, most sightings have been reported for winter and mostly nearshore (DoN 2008a,b; Conley et al. 2017); there were fewer sightings in spring, most along the shelf break or in deep, offshore water (DoN 2008a,b). There were no sightings in summer, and several sightings occurred nearshore during fall (DoN 2008a,b). Summer surveys by the Northeast Fisheries Science Center (NEFSC) and Southeast Fisheries Science Center (SEFSC) showed no sightings for North Carolina (Hayes et al. 2020). One satellite-tagged humpback whale transited through the study area during January 2021 (DoN 2022). Davis et al. (2020) detected humpback whales acoustically off North Carolina during all seasons, with the greatest number of detections during winter and spring; summer (May–July) and fall (August–October) had fewer detections. There are three records in the OBIS database for the proposed survey area – one each during April, May, and July (OBIS 2022).

3.3.1.3 Common Minke Whale (*Balaenoptera acutorostrata scammoni*)

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring/summer and southward migration in autumn (Stewart and Leatherwood 1985). There are four recognized minke whale populations in the North Atlantic largely based on feeding grounds: Canadian east coast, west Greenland, central North Atlantic, and northeast Atlantic (Donovan 1991). Although some minke whale populations have been well studied on summer feeding grounds, information on wintering areas and migration routes is lacking (Risch et al. 2014).

Based on modeling for the western North Atlantic, higher densities are expected to occur north of 35°N, with lower densitiessouth of 35°N (Mannocci et al. 2017; Palka et al. 2021). Minke whales are common off the U.S. east coast over continental shelf waters during spring to fall (CETAP 1982; DoN 2008a,b; Hayes et al. 2022). Seasonal movements in the Northwest Atlantic are apparent, with animals moving south and into offshore waters from late fall through early spring (DoN 2008a,b; Hayes et al. 2022). Risch et al. (2014) deployed acoustic detectors throughout the North Atlantic to detect minke whale occurrence. They found that minke whales migrate north of 30°N from March to April, and migrate south from mid-October to early November. During spring migration, animals migrate along the continental shelf, whereas they migrate farther offshore during fall. In the southeastern U.S., minke whales were commonly detected during winter. At a recorder in Onslow Bay, North Carolina, detections were from December through April, with no detections during the summer. Similarly, Kiehbadroudinezhad et al. (2021) detected minke whales in the deep water off the outer continental shelf, just west of the proposed survey area, from December through April. A lack of acoustic detections in the region during summer indicates either absence of minke whales at that time of year, or a change in vocal behavior at different times of the year (Risch et al. 2014); detections were made in Canadian waters during the summer, suggesting most minke whales likely occur there during the summer. Off North Carolina, there were no records for fall, only one sighting during summer, two offshore sightings for spring, and a few stranding records for winter (DoN 2008a,b). Summer surveys by NEFSC and SEFSC found no sightings off North Carolina (Hayes et al. 2022). There are three records in the OBIS database for the proposed survey area, all of which occurred in January (OBIS 2022).

3.3.1.4 Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2018) but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). On summer feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987). Habitat suitability models indicate that sei whale distribution is related to cool water with high chlorophyll levels (Palka et al. 2017; Chavez-Rosales eta al. 2019). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985). A small number of individuals have been sighted in the eastern North Atlantic between October and December, indicating that some animals may remain at higher latitudes during winter (Evans 1992). Sei whales have been seen from South Carolina south into the Gulf of Mexico and the Caribbean during winter (Rice 1998); however, the location of sei whale wintering grounds in the North Atlantic is unknown (Víkingsson et al. 2010). Based on modeling for the western North Atlantic, higher densities are expected to occur north of 35°N during the summer; very low densities are expected south of 35°N (Mannocci et al. 2017; Palka et al. 2021).

Three stocks are currently recognized in the North Atlantic: the Nova Scotia, Iceland-Denmark Strait, and Eastern North Atlantic stocks; a third stock off Labrador was proposed by Donovan (1991), but was never designated (Huijser et al. 2018). Although Huijser et al. (2018) did not a high degree of genetic divergence between the current North Atlantic stocks, they noted that multiple stocks could occur. The Nova Scotia stock has a distribution that includes continental shelf waters from the northeastern U.S. to areas south of Newfoundland (Hayes et al. 2022). The southern portion of the Nova Scotia stock's range includes the Gulf of Maine and Georges Bank during spring and summer (Hayes et al. 2022). Mitchell and Chapman (1977) suggested that this stock moves from spring feeding grounds on or near Georges Bank to the Scotian Shelf in June and July, eastward to Newfoundland and the Grand Banks in late summer, back to the Scotian Shelf in fall, and offshore and south in winter. During summer, most sei whale sightings occur in feeding grounds of the eastern Scotian Shelf or Grand Banks; however, they may occur in the proposed survey area from fall through spring, although no sightings were reported for the CHPT OPEREA (DoN 2008b).

Sei whales have been detected acoustically from southern New England to the Scotian Shelf primarily during spring and summer (Davis et al. 2020), and off North Carolina and Blake Plateau mainly during winter (Davis et al. 2020; Palka et al. 2021); fewer detections were made off North Carolina during summer and fall (Davis et al. 2020; Palka et al. 2021). There have been no sightings off North Carolina during summer surveys conducted by NEFSC and SEFSC (Hayes et al. 2022). There are three sightings in the OBIS database for the proposed survey area, which were recorded in January–February (OBIS 2022).

3.3.1.5 Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). Fin whales most commonly occur offshore but can also be found in coastal areas (Jefferson et al. 2015). Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar and García-Vernet 2018). Some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The northern and southern fin whale populations likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015).

In the North Atlantic, fin whales are found in summer from Baffin Bay, Spitsbergen, and the Barents Sea, south to North Carolina and the coast of Portugal (Rice 1998). In winter, they have been sighted from Newfoundland to the Gulf of Mexico and the Caribbean, and from the Faroes and Norway south to the Canary Islands (Rice 1998). Based on geographic differences in fin whale calls, Delarue et al. (2014) suggested that there are four distinct stocks in the Northwest Atlantic, including a central North Atlantic stock that extends south along the Mid-Atlantic Ridge. The four feeding stocks in the Northwest Atlantic currently recognized by the North Atlantic Marine Mammal Commission (NAMMCO 2022) are located off West Iceland (in the Central Atlantic), Eastern Greenland, Western Greenland, and Eastern Canada; there are an additional three stocks in the eastern Atlantic.

In the western North Atlantic, higher densities are typically found north of 35°N especially during spring and summer, with lower densities south of 35°N (Edwards et al. 2015; Mannocci et al. 2017; Hayes et al. 2022). Fin whales occur off the eastern U.S. year-round, but generally north of Cape Hatteras (Davis et al. 2020; Hayes et al. 2022). During winter, fin whales are sighted more frequently on the shelf than any other large whale (DoN 2008a,b). Based on acoustic detections using the U.S. Navy's Sound Surveillance System (SOSUS), fin whales are believed to move south during the fall and north during the spring (Clark 1995). However, not all individuals likely follow an annual migration (Hayes et al. 2022). During spring and summer, the majority of fin whales occur on feeding grounds off New England and Gulf of St. Lawrence (Hayes et al. 2022).

Fin whales are most frequently sighted off North Carolina during winter, with some sightings also reported for spring (Conley et al. 2017). There is a single sighting record for the CHPT OPAREA which was reported during winter and numerous strandings have been reported during the winter (DoN 2008a,b). One sighting has been made during NEFSC and SEFSC summer surveys off North Carolina (Hayes et al. 2022). Fin whales have been detected acoustically off North Carolina during all seasons, with the greatest number of detections during winter; there were no detections south of Cape Hatteras during summer (May–July) (Davis et al. 2020; Palka et al. 2021). There are three records in the OBIS database for the proposed survey area, all of which were reported for April (OBIS 2022).

3.3.1.6 Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Blue whales are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). Generally, blue whales are seasonal migrants between high latitudes in summer, where they feed, and low latitudes in winter, where they mate and give birth

(Lockyer and Brown 1981). Their summer range in the North Atlantic extends from Davis Strait, Denmark Strait, and the waters north of Svalbard and the Barents Sea, south to the Gulf of St. Lawrence and the Bay of Biscay (Rice 1998). Although the winter range is mostly unknown, some occur near Cape Verde at that time of year (Rice 1998). The acoustic detections during the SOSUS program tracked blue whales throughout most of the North Atlantic, including deep waters east of the U.S. Atlantic EEZ and subtropical waters north of the West Indies (Clark 1995).

In the western North Atlantic, higher densities are typically found north of 40°N especially during summer, with lower densities south of 40°N (DoN 2008a,b). Several sightings were reported during NEFSC and SEFSC summer surveys off the northeastern U.S. coast and in particular Canada, but none were reported off North Carolina (Hayes et al. 2020). Wenzel et al. (1988) suggested that it is unlikely that blue whales occur regularly in the shelf waters off the U.S. east coast. Similarly, Hayes et al. (2020) suggested that the blue whale is, at best, an occasional visitor in the U.S. Atlantic EEZ. However, blue whales have been detected acoustically off North Carolina during all seasons, with the greatest number of detections during fall and winter (Davis et al. 2020; Palka et al. 2021). At least one satellite-tagged blue whale was recorded moving through the northern portion of the proposed survey area during January–February 2015 (Lesage et al. 2017b). There are no records in the OBIS database for the proposed survey area (OBIS 2022).

3.3.2 Odontocetes

3.3.2.1 Sperm Whale (*Physeter macrocephalus*)

The sperm whale is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (Whitehead 2018). In general, it is distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jaquet and Whitehead 1996). Its distribution and relative abundance can vary in response to prey availability, most notably squid (Jaquet and Gendron 2002). Females generally inhabit waters >1000 m deep at latitudes <40º where sea surface temperatures are <15ºC; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds (Whitehead 2018).

In the Northwest Atlantic, the shelf edge, oceanic waters, seamounts, and canyon shelf edges are predicted habitats of sperm whales (Waring et al. 2001). Off the eastern U.S. coast, they are also known to concentrate in regions with well-developed temperature gradients, such as along the edges of the Gulf Stream and warm core rings, which may aggregate their primary prey, squid (Jaquet 1996). Based on modeling, sperm whales are expected to occur throughout the deeper offshore waters of the western North Atlantic (Mannocci et al. 2017; Palka et al. 2021).

Sperm whales appear to have a well-defined seasonal cycle in the Northwest Atlantic (CETAP 1982; Stanistreet et al. 2018). In winter, most historical records are in waters east and northeast of Cape Hatteras, with few animals north of 40ºN; in spring, they shift the center of their distribution northward to areas east of Delaware and Virginia, but they are widespread throughout the central area of the Mid-Atlantic Bight and southern tip of Georges Bank (DoN 2005; Hayes et al. 2020). During summer, they expand their spring distribution to include areas east and north of Georges Bank, the Northeast Channel, and the continental shelf south of New England (Hayes et al. 2020). By fall, sperm whales are most common south of New England on the continental shelf but also along the shelf edge in the Mid-Atlantic Bight (DoN 2005; Hayes et al. 2020). Numerous sightings have been made off North Carolina, including the proposed survey area, during NEFSC and SEFSC summer surveys (Hayes et al. 2020). DoN (2008a,b) also reported sperm whale sightings in the northern portion of the proposed survey area from winter through spring, and Conley et al. (2017) reported sperm whales in the northern portion of the survey area during summer. Four sightings were made between 16 September–18 October 2014 during an L-DEO survey that overlapped the proposed survey area (RPS 2015). Acoustic detections have also been made off North Carolina during most of the year; however, the months of May–July have not monitored (Stanistreet et al. 2018). There are 252 records in the OBIS database for the proposed survey area, which were reported throughout the year (OBIS 2022).

3.3.2.2 Pygmy and Dwarf Sperm Whales (*Kogia breviceps and K. sima*)

Pygmy and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). It has been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993). *Kogia* spp. are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). When they are observed, both *Kogia* species are found primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). However, McAlpine (2018) noted that dwarf sperm whales may be more pelagic than pygmy sperm whales. Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas.

In the western North Atlantic, pygmy sperm whales are known to occur from Nova Scotia to Cuba, and dwarf sperm whales are distributed from Virginia to the Caribbean (Würsig et al. 2000; Würsig 2017). Based on modeling for the western North Atlantic, higher densities of *Kogia* sp. are expected to occur south of 40°N compared to northern regions (Maannocci et al. 2017; Palka et al. 2021). Hayes et al. (2020) reported numerous sightings off the U.S. east coast during NEFSC and SEFSC, including within the proposed survey area. DoN (2008a,b) only reported sightings within the proposed survey area during winter, but strandings were reported throughout the year. Between 2013 and 2017, there were 46 dwarf sperm whale strandings recorded from Massachusetts to Florida, 20 of which were for North Carolina; there were 120 strandings of pygmy sperm whales, 16 of which were reported for North Carolina (Hayes et al. 2020). Acoustic detections of *Kogia* sp. were made just east of the survey area during 2016 (Palka et al. 2021) and north of the survey area between October 2019 and October 2020 (Rafter et al. 2021). There are five records for dwarf sperm whales for May–August and 10 Kogia sp. (all in August) in the OBIS database within the proposed survey area (OBIS 2022).

3.3.2.3 Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 2018a). Cuvier's beaked whale is found in deep water in the open ocean and over and near the continental slope (Gannier and Epinat 2008; Baird 2018a). It is rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep (Carwardine 1995). Its inconspicuous blows, deep-diving behavior, short surfacing intervals, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006; Shearer et al. 2019).

In the western North Atlantic, these whales typically occur from Massachusetts to Florida, the West Indies, and the Gulf of Mexico (Würsig et al. 2000), although sightings have also been made to the north (Hayes et al. 2020). Most sightings in the Northwest Atlantic occur in late spring or summer, particularly along the continental shelf edge in the mid-Atlantic region (CETAP 1982; Waring et al. 2001), with likely lower densities south of Virginia, based on modeling (Palka et al. 2021).

Shearer et al (2019) and Foley et al. (2021) tagged Cuvier's beaked whales off Cape Hatteras. The whales kept to the outer continental shelf and slope waters off Cape Hatteras, and some whales were recorded diving in the deeper sections of proposed survey area. The whales performed frequent dives and median surface intervals where only 2.2 min. The time spent at the surface was not prolonged even when performing deep extended dives, often to depths >1500 m. Cuvier's beaked whales have been detected acoustically around Cape Hatteras during most months (Stanistreet et al. 2017; Rafter et al. 2021). They were also detected acoustically and visually near the survey area during 2016 (Palka et al. 2021). McLelland et al. (2018) made several Cuvier's beaked whale sightings at the northwestern edge of the proposed survey area during aerial surveys conducted from May 2011 to November 2015; they concluded that Cape Hatteras is an important year-round habitat for beaked whales. DoN (2008a,b) reported sightings for the proposed survey area for winter and summer, and just north of the survey area off North Carolina during spring and fall Satellite-tagged whales were reported within the survey area during studies in 2021 (DoN 2022). There are 30 records for the proposed survey area in the OBIS database which were made throughout the year (OBIS 2022).

3.3.2.4 Gervais' Beaked Whale (*Mesoplodon europaeus*)

Although Gervais' beaked whale is generally considered to be a North Atlantic species, it likely occurs in deep waters of the temperate and tropical Atlantic Ocean in both the northern and southern hemispheres (Jefferson et al. 2015). Its distribution is primarily known from stranding records. Strandings may be associated with calving, which takes place in shallow water (Würsig et al. 2000). Gervais' beaked whale usually inhabits deep waters (Davis et al. 1998). It is more frequent in the western than the eastern Atlantic (Mead 1989). Off the U.S. east coast, it occurs from Cape Cod Bay, Massachusetts (Moore et al. 2004) to Florida, with a few records in the Gulf of Mexico (Mead 1989). McLelland et al. (2018) made several Gervais' beaked whale sightings at the northwestern edge of the proposed survey area during aerial surveys conducted from May 2011 to November 2015; they concluded that Cape Hatteras is an important year-round habitat for beaked whales. DoN (2008a,b) mapped one sighting for the proposed survey area during spring. Gervais' beaked whales were detected acoustically between 2011 and 2013 around Cape Hatteras and Onslow Bay during most months (Stanistreet et al. 2017; Rafter et al. 2021), as well as within the survey area during 2016 (Palka et al. 2021). There is one record for July for the survey area in the OBIS database (OBIS 2022).

3.3.2.5 Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans; it has the widest distribution throughout the world of any *Mesoplodon* species (Pitman 2018). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). It is rarely sighted, and most of the knowledge on the distribution of this species is derived from stranding data. There is no evidence that Blainville's beaked whales undergo seasonal migrations, although movements into higher latitudes are likely related to warm currents, such as the Gulf Stream in the North Atlantic. Like other beaked whales, Blainville's beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). However, it may also occur in coastal areas, particularly where deep-water gullies come close to shore. In the western North Atlantic, it is found from Nova Scotia to Florida, the Bahamas, and the Gulf of Mexico (Würsig et al. 2000). There are numerous stranding records along the east coast of the U.S. (Macleod et al. 2006; DoN 2008a,b). Blainville's beaked whales were detected acoustically within the proposed survey area during 2016 (Palka et al. 2021). There are no confirmed records for the survey area in the OBIS database (OBIS 2022).

3.3.2.6 True's Beaked Whale (*Mesoplodon mirus*)

True's beaked whale is mainly oceanic and occurs in warm temperate waters of the North Atlantic and southern Indian oceans (Pitman 2018). In the western North Atlantic, strandings have been recorded from Nova Scotia (~46°N) to Florida (~27°N; MacLeod et al. 2006). True's beaked whales were potentially detected acoustically between October 2019 and October 2020 north of Cape Hatteras (Rafter et al. 2021). One sighting was reported on the shelf break off North Carolina and within the proposed survey area during spring (DoN 2008a,b), and there are three stranding records of True's beaked whale for North Carolina (DoN 2008a,b). Macleod et al. (2006) reported numerous other stranding records for the east coast of the U.S. There are no confirmed records of True's beaked whale in the proposed survey area in the OBIS database (OBIS 2022).

3.3.2.7 Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994). It generally occurs in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2015). In the western Atlantic, this species occurs between the southeastern U.S. and southern Brazil (Jefferson et al. 2015). During NEFSC and SEFSC summer surveys, four sightings were made off North Carolina (Hayes et al. 2019), including within the proposed survey area. DoN (2008b) reported no sightings off North Carolina, but a stranding each during summer and winter. There are three records for May for the survey area in the OBIS database (OBIS 2022).

3.3.2.8 Atlantic white-sided dolphin (*Lagenorhynchus acutus*)

The Atlantic white-sided dolphin occurs in cold temperate and subpolar waters in the North Atlantic; in the western Atlantic, its range is from ~38°N to southern Greenland (Jefferson et al. 2015). It appears to prefer deep waters of the outer shelf and slope, but can also occur in shallow and pelagic waters (Jefferson et al. 2015). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, densities are highest north of 40°N, with densities gradually decreasing to the south. Along the eastern coast of the U.S., it ranges south to ~37ºN (CETAP 1982). There are seasonal shifts in its distribution off the northeastern U.S. coast, with low numbers in winter from Georges Basin to Jeffrey's Ledge and high numbers in spring in the Gulf of Maine (CETAP 1982; DoN 2005). In summer, Atlantic white-sided dolphins are mainly distributed northward of Cape Cod (DoN 2005). Sightings south of ~40ºN are infrequent during all seasons (CETAP 1982; DoN 2005). Nonetheless, DoN (2008a) mapped one sighting off North Carolina during spring, and several strandings during spring and winter. During the CETAP (1982) surveys and NEFSC and SEFSC surveys (Hayes et al. 2022), no sightings were made off North Carolina. There are two OBIS sighting records for April in the proposed survey area off North Carolina (OBIS 2022).

3.3.2.9 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). In the Northwest Atlantic, these dolphins occur from Nova Scotia to Florida, the Gulf of Mexico, 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). Coastal common bottlenose dolphins exhibit a range of movement patterns including seasonal migration, year-round residency, and a combination of long-range movements and repeated local residency (Wells and Scott 2018).

There are regional and seasonal differences in the distribution of the offshore and coastal forms of bottlenose dolphins off the U.S. east coast. Evidence of year-round or seasonal residents and migratory groups exist for the coastal form of bottlenose dolphins, with the northern migratory coastal stock occurring from north of Cape Hatteras to New Jersey, but only during summer and in waters <25 m deep (Hayes et al. 2020). The offshore form appears to be most abundant along the shelf break and is differentiated from the coastal form by occurring in waters >34 m deep and >34 km from shore (Torres et al. 2003). Bottlenose dolphin records in the Northwest Atlantic suggest that they can occur year-round from the continental shelf to deeper waters over the abyssal plain, from the Scotian Shelf to North Carolina (DoN 2005, 2008a,b). However, based on modeling, densities are expected to be relatively low throughout the deep offshore waters of the western North Atlantic (Mannocci et al. 2017; Palka et al. 2021). Numerous sightings have been made off North Carolina, including the survey area, throughout the year (DoN 2008a,b; Conley et al. 2017), and during NEFSC and SEFSC summer surveys (Hayes et al. 2020). Nine sightings of 67 individuals were made between 16 September–18 October 2014 during an L-DEO survey that overlapped the proposed survey area; they were also detected acoustically (RPS 2015). There are 149 records within the proposed survey area in the OBIS database that were made throughout the year (OBIS 2022).

3.3.2.10 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 south to the equator (Würsig et al. 2000). However, modeling shows that sighting rates are expected to be very low in the region (DoN 2008b). There are several sightings off North Carolina, and within the survey area, based on NEFSC and SEFSC summer surveys (Hayes et al. 2020). DoN (2008a,b) showed two winter sightings west of the proposed survey area. There is one OBIS record for the survey area in August (OBIS 2022).

3.3.2.11 Atlantic Spotted Dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is one of the most abundant cetaceans and is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). In the North Atlantic, it occurs from Brazil to New England and to the coast of Africa (Jefferson et al. 2015). 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). In the western Atlantic, the distribution extends from southern New England, south to the Gulf of Mexico, and the Caribbean to Venezuela (Leatherwood et al. 1976; Perrin et al. 1994a; Rice 1998). Based on modeling, Atlantic spotted dolphins occur at low densities in the offshore waters of the proposed survey area (DoN 2008b; Mannocci et al. 2017), although several sightings have been reported there during summer (Hayes et al. 2020). One sighting of six individuals was made between 16 September–18 October 2014 during an L-DEO survey that overlapped the proposed survey area; they were also detected acoustically (RPS 2015). There are 18 records within the proposed survey area in the OBIS database for winter, spring, and summer (OBIS 2022).

3.3.2.12 Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, including oceanic tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2015). It is generally considered a pelagic species (Perrin 2018b) but can also be found in coastal waters and around oceanic islands (Rice 1998). The distribution of spinner dolphins in the Atlantic is poorly known, but in the western North Atlantic, it occurs from South Carolina to Florida, the Caribbean, Gulf of Mexico, and southward to Venezuela (Würsig et al. 2000). Sightings off the northeast U.S. coast have occurred exclusively in offshore waters >2000 m; one sighting was made off North Carolina, just to the north of the survey area (Hayes et al. 2020). There are bycatch and sighting records off North Carolina for winter and spring; one sighting was reported in the study area during winter (DoN 2008b). There is one OBIS record for March in the proposed survey area (OBIS 2022).

3.3.2.13 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 is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). In the Northwest Atlantic, the striped dolphin occurs from Nova Scotia to the Gulf of Mexico and south to Brazil (Würsig et al. 2000). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected in offshore waters north of ~35°N, with the lowest densities south of ~32°N. Similarly, DoN (2008b) showed the highest densities north of ~35°N during April–July. Off the northeastern U.S. coast, striped dolphins occur along the shelf edge and over the continental slope from Cape Hatteras to the southern edge of Georges Bank (Hayes et al. 2020). In all seasons, striped dolphin sightings have been centered along the 1000-m depth contour (CETAP 1982); sightings have been associated with the north edge of the Gulf Stream and warm core rings (see Hayes et al. 2020). No sightings were reported in the proposed survey area by DoN (2008b), but there were several stranding records along the coast of North Carolina throughout the year. There are no records for the proposed survey area in the OBIS database (OBIS 2022).

3.3.2.14 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 Gulf of Mexico, and south to Venezuela and Brazil (Würsig et al. 2000; Fertl et al. 2003). Sightings off the U.S. east coast are rare, with only 10 reported since 1995 (Hayes et al. 2020); some of these have been made along the slope adjacent to the western part of the proposed survey area. DoN (2008b) reported two sightings in the proposed survey area for April–July. There are four records within the proposed survey area in the OBIS database for May–July (OBIS 2022).

3.3.2.15 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). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018). In the western Atlantic, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999).

Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 35°N; densities off North Carolina are expected to be low. Risso's dolphins occurs along the edge of the Mid-Atlantic shelf of the U.S. year-round (Payne et al. 1984). Off the northeast coast, Risso's dolphins are distributed along the continental shelf edge from Cape Hatteras to Georges Bank during spring, summer, and autumn (CETAP 1982; Payne et al. 1984), but they range to the Mid-Atlantic Bight and into oceanic waters during winter (Payne et al. 1984). Risso's dolphin sightings off the U.S. east coast suggests that they could occur year-round from the Scotian Shelf to the coast of the southeastern U.S. in waters extending from the continental shelf to the continental rise (Hayes et al. 2022). Several sightings have been reported off North Carolina, including within the proposed survey area (DoN 2008b; Jefferson et al. 2014; Conley et al. 2017; Hayes et al. 2022), from spring through fall (DoN 2008b). There are 15 records within the proposed survey area in the OBIS database throughout the year (OBIS 2022).

3.3.2.16 Common Dolphin (*Delphinus delphis delphis*)

The common dolphin is distributed in tropical to cool temperate waters of the Atlantic and the Pacific oceans from 60ºN to ~50ºS (Jefferson et al. 2015). It is common in coastal waters 200–300 m deep (Evans 1994), but it can also occur thousands of kilometers offshore; the pelagic range in the North Atlantic extends south to ~35ºN (Jefferson et al. 2015). It appears to have a preference for areas with upwelling and steep sea-floor relief (Doksæter et al. 2008; Jefferson et al. 2015).

Off the U.S. east coast, the common dolphin occurs from Cape Hatteras to Georges Bank during mid-January–May, moves onto Georges Bank and the Scotian Shelf during mid-summer and fall, and has been observed in large aggregations on Georges Bank in fall (CETAP 1982; Selzer and Payne 1988; Payne et al. 1984; Hayes et al. 2022). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities occur in offshore areas north of ~35°N; very low densities are expected south of 35°N. It is less commonly sighted south of Cape Hatteras, although there have been several sightings as far south as 32°N (Jefferson et al. 2009). Sightings off North Carolina including within the proposed survey area were made during all seasons, with most sightings during winter and spring (DoN 2008a,b; Conley et al. 2017); sightings were on the shelf, near the shelf break, and in offshore water (DoN 2008a,b). Hayes et al. (2022) reported several sightings off North Carolina during NEFSC and SEFSC summer surveys, just north of the proposed survey area. One sighting of six individuals was made between 16 September–18 October 2014 during an L-DEO survey that overlapped the proposed survey area (RPS 2015). There are three records in the proposed survey area in the OBIS database for February, March, and December (OBIS 2022).

3.3.2.17 Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical oceanic species distributed between 30°N and 30°S that generally inhabits deep oceanic water (Dolar 2018). The distribution of this species in the Atlantic is poorly understood, but it is known to occur from the Gulf of Mexico to Uruguay in the western Atlantic (Rice 1998). Sightings of this species in the northwestern Atlantic are rare; there has been a single sighting during NMFS surveys which was recorded off North Carolina, just north of the proposed survey area (Hayes et al. 2020). There are no records for the proposed survey area in the OBIS database (OBIS 2022).

3.3.2.18 Short-finned Pilot Whale (*Globicephala macrorhynchus*) and Long-finned Pilot Whale (*G. melas*)

There are two species of pilot whale, both of which could occur in the survey area. The long-finned pilot whale (*G. melas*) is distributed antitropically, whereas the short-finned pilot whale (*G. macro-rhynchus*) is found in tropical, subtropical, and warm temperate waters (Olson 2018). The ranges of the two species overlap in the shelf/shelf-edge and slope waters of the northeastern U.S. between New Jersey and Cape Hatteras, with long-finned pilot whales mainly occurring to the north (Bernard and Reilly 1999). In the Northwest Atlantic, pilot whales often occupy areas of high relief or submerged banks and associated with the Gulf Stream edge or thermal fronts along the continental shelf edge (Waring et al. 1992). Pilot whales are generally nomadic and occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson 2018).

In the western North Atlantic, short-finned pilot whales occur from Virginia to northern South America, including the Caribbean and Gulf of Mexico (Würsig et al. 2000). Long-finned pilot whales are distributed from North Carolina northwards to Iceland (Hayes et al. 2022). Based on density modeling by Mannocci et al. (2017), very low densities of pilot whales are expected to occur in the proposed survey area. Most pilot whale sightings south of Cape Hatteras are likely to be short-finned pilot whale (see Garrison and Rosel 2017 *in* Hayes et al. 2022). DoN (2008b) reported sightings of pilot whales in the proposed survey area throughout the year; most sightings were made from April–July. Eighteen sightings of 182 *Globicephela* sp. were made between 16 September–18 October 2014 during an L-DEO survey that overlapped the proposed survey area (RPS 2015). There are four OBIS records of long-finned pilot whales for the proposed survey area for May, and 11 records of short-finned pilot whales for the survey area for winter, spring, and summer (OBIS 2022).

3.3.2.19 Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales tend to be more common in nearshore areas and at higher latitudes (Jefferson et al. 2015). 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 Gulf of Mexico (Würsig et al. 2000). Based on historical sightings and whaling records, killer whales apparently were most often found along the shelf break and offshore in the Northwest Atlantic (Katona et al. 1988). They are considered uncommon or rare in waters of the U.S. Atlantic EEZ (Katona et al. 1988). One sighting was reported for the proposed survey area by DoN for April–July (DoN 2008b). There is one record for July for the proposed survey area in the OBIS database (OBIS 2022).

3.3.2.20 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 rare to uncommon throughout its range (Baird 2018b). 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 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). In the Northwest Atlantic, it occurs from Maryland to the Gulf of Mexico and the Caribbean (Würsig et al. 2000). Very few false killer whales have been sighted off the U.S. northeast coast, but at least two sightings have been made off North Carolina (DoN 2005, 2008a,b; Hayes et al. 2022), including one within the proposed survey area (DoN 2008b). For the proposed survey area, there are no records in the OBIS database (OBIS 2022).

3.3.2.21 Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical waters (Baird 2018c). It is found in nearshore areas where the water is deep and in offshore waters (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 Gulf of Mexico (Würsig et al. 2000). There is no abundance estimate for the pygmy killer whale off the U.S. east coast because it is rarely sighted during surveys (Hayes et al. 2022). No records have been reported for the proposed survey area (DoN 2008b; Hayes et al. 2022; OBIS 2022), although one stranding was reported for the coast of North Carolina (DoN 2008b).

3.3.2.22 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). Occasional occurrences in temperate waters are extralimital, likely associated with warm currents (Perryman et al. 1994). It occurs most often in deep offshore waters and occasionally in nearshore areas where deep oceanic waters occur near the coast (Perryman and Danil 2018). In the western Atlantic, its typical range extends from the Gulf of Mexico to southern Brazil (Rice 1998); sightings are rare north of the Gulf of Mexico (Hayes et al. 2020). There are stranding records from Florida to South Carolina, as well as Virginia and New Jersey (Hayes et al. 2020). Off the east coast of the U.S., two sightings have been made off Cape Hatteras in waters >2500 m deep (Hayes et al. 2020); no sightings have been made in the proposed survey area (DoN 2008b; Hayes et al. 2020). For the proposed survey area, there are no records in the OBIS database (OBIS 2022).

3.3.2.23 Harbor porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits cool temperate to subarctic waters of the Northern Hemisphere (Jefferson et al. 2015). Most animals are found over the continental shelf, but some are also encountered over deep water (Westgate et al. 1998). There are likely four populations in the western North Atlantic: Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, Newfoundland, and Greenland (Gaskin 1984, 1992). Individuals found off the eastern U.S. coast likely would be almost exclusively from the Gulf of Maine/Bay of Fundy stock. Mannocci et al. (2017) reported relatively high densities in offshore waters north of ~35°N; very low densities are expected to occur south of ~35°N.

Harbor porpoises concentrate in the northern Gulf of Maine and southern Bay of Fundy during July–September, with a few sightings ranging as far south as Virginia and North Carolina (Hayes et al. 2020). During October–December and April–June, harbor porpoises mainly occur from New Jersey to Maine, although there are lower densities at the northern and southern extremes (DoN 2005; Hayes et al. 2020). During January–March, harbor porpoises concentrate farther south, from New Jersey to North Carolina, with lower densities occurring from New York to New Brunswick (DoN 2005, 2008b; Hayes et al. 2020). A harbor porpoise that was rehabilitated and released in Maine traveled to the northwestern portion of the proposed survey area between January and March 2004; no other sightings have been made within the survey area (DoN 2008b). For the proposed survey area, there are no records in the OBIS database (OBIS 2022).

3.4 Sea Turtles

Five species of sea turtles including the leatherback, loggerhead, green, Kemp's ridley, and hawksbill turtles could occur in the proposed survey area off the U.S. east coast. Loggerhead, green, Kemp's ridley, and leatherback turtles are commonly found along the U.S. east coast while hawksbill turtles are considered rare. A sixth species, olive ridley turtle, has been reported around the southern tip of Florida but would be unlikely to occur within the survey area and is not discussed further (DoN 2008b,c). Under the ESA, the leatherback, hawksbill and Kemp's ridley sea turtles are listed as ***endangered***; the Northwest Atlantic DPS of loggerhead turtle and the North Atlantic DPS of the green sea turtle are listed as ***threatened*** (Table 5).

TABLE 5. The habitat, occurrence, and conservation status of sea turtles that could occur in or near the proposed project area in the Northwest Atlantic Ocean.

Species	Habitat	Occurrence in Study Area[1]	US ESA[2]	IUCN[3]	CITES[4]
Leatherback sea turtle	Beaches (nesting females); oceanic (juveniles and foraging adults)	Uncommon	E	LC[5]	I
Loggerhead sea turtle Northwest Atlantic DPS	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults); oceanic (migration)	Uncommon	T	LC[6]	I
Green sea turtle North Atlantic DPS	Beaches (nesting females); oceanic (juveniles and migrating adults); coastal (foraging adults)	Uncommon	T	EN	I
Hawksbill sea turtle	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults)	Rare	E	CR	I
Kemp's ridley sea turtle	Coastal/oceanic (juveniles and immatures foraging and migrating)	Uncommon	E	CR	I

NL = Not Listed. *Based on professional opinion.

[1] Occurrence in area at the time of the survey; based on professional opinion and available data.

[2] U.S. Endangered Species Act: E = Endangered, T = Threatened.

[3] International Union for the Conservation of Nature Red List of Threatened Species, version 2022-1: CR = critically endangered, EN = endangered, VU = vulnerable, LC = least concern.

[4] Convention on International Trade in Endangered Species: Appendix I, species that are the most endangered and are considered threatened with extinction.

[5] Globally, the leatherback turtle is listed as vulnerable, but the Northwest Atlantic population is considered least concern.

[6] Globally, the loggerhead is listed as vulnerable, but the North West Atlantic population is considered least concern.

The U.S. is a signatory of the Inter-American Convention (IAC) for the Protection and Conservation of Sea Turtles. The IAC complies with CITES and prohibits the deliberate take or harvesting of sea turtles or their eggs (IAC 2015). Leatherback, loggerhead, green, Kemp's ridley, and hawksbill sea turtles nest in the Wider Caribbean Region (WCR) (Piniak and Eckert 2011; Eckert and Eckert 2019), and some of these species also nest along the east coast of the U.S. (Seaturtle.org 2022).

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles are given in § 3.4.1 of the PEIS. The general distribution of sea turtles in the Northwest Atlantic is discussed in § 3.4.2.1 of the PEIS, § 4.2.3.1 of the BOEM Final PEIS (BOEM 2014), and in § 3.8.2 of the Final EIS/OEIS for the Virginia Capes and the Cherry Point Range Complexes (DoN 2009a,b). The rest of this section focuses on their distribution off North Carolina.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). In the western Atlantic Ocean, leatherbacks are known to range from Greenland to Argentina. Leatherback turtles commonly occur along the eastern U.S. coast and as far north as New England (Eckert 1995a). During the non-breeding season, the leatherback turtle 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). The number of nesting females in the Northwest Atlantic is 20,659 (NMFS and USFWS 2020). Although important nesting areas occur only as far north as Florida, nesting has also been reported along the coast of North Carolina (NMFS and USFWS 2020).

The species is known to traverse entire ocean basins (Valverde and Holzwart 2017) and has the longest migrations (up to 5000 km) of any reptile. Juveniles 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 (Musick and Limpus 1997; Plotkin 2002; Eckert et al. 2012). Adults remain oceanic but many individuals have been shown to be seasonally associated with continental shelfs and slopes (Eckert 2006; Doyle et al. 2008; Dodge et al. 2014). Leatherback foraging is affected by the distribution of its gelatinous prey (e.g., James and Herman 2001; Houghton et al. 2006; Hays et al. 2009; Heaslip et al. 2012).

Leatherbacks tagged off Cape Breton and mainland Nova Scotia during summer remained off eastern Canada and the northeastern U.S. coast before most began migrating south in October (James et al. 2005). Some of the tags remained attached long enough to observe northward migrations, with animals leaving nesting grounds during February–March and typically arriving north of 38ºN during June, usually in areas within several hundred km of where they were observed in the previous year. Individuals tagged outside Cape Cod mostly remained along the U.S. continental shelf before dispersing later (Dodge et al. 2014).

Leatherback turtle sightings off North Carolina are frequent during summer, although sightings have been reported for all seasons; most sightings were on the shelf, with fewer along the shelf break and in offshore waters (DoN 2008a,b; Conley et al. 2017; Palka et al. 2021). Sighting per unit effort (SPUE) modeling based on line transects and platform of opportunity data shows some overlap of leatherback occurrence with the northeastern portion of the proposed survey area (DoN 2008b). During CETAP (1982) surveys, leatherback turtles were sighted off North Carolina during spring, summer, and fall. Some leatherbacks tagged outside of Cape Cod seemed to forage relatively close to the coast of North Carolina during the summer; in the autumn and spring, they showed longer distance movements and movement offshore, including over the proposed study area (Dodge et al. 2014). Tagged leatherback turtles have been tracked moving through the survey area (Palka et al. 2021; Rider et al. 2022; SWOT 2022). Modeling of the active dispersal of juvenile leatherback turtles in the North Atlantic suggests that two- to six-year-old leatherback turtles could occur in the waters offshore from North Carolina including the survey area, but at low densities (Lalire and Gaspar 2019). One individual was seen between 16 September–18 October 2014 during an L-DEO survey just north of the proposed survey area (RPS 2015). In 2019, an interaction between a leatherback turtle and longline fishery was reported for within the proposed survey area (Garrison and Stokes 2021). There are 22 records for the North Carolina survey area in the OBIS database, for January to August (OBIS 2022).

3.4.2 Green Turtle (*Chelonia mydas*)

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). In the North Atlantic, major nesting sites are located in Central America and the Caribbean Sea; nesting also occurs in substantial numbers in Florida (SWOT 2022). Green turtles have also been reported to nest in North Carolina (Seaturtle.org 2022). Oceanic waters are used by juveniles and migrating adults, and sometimes for foraging by adults. Seasonal migrations by adult turtles between nesting and foraging areas cover distances as much as thousands of kilometers (Lageux 2001). Nesting occurs at intervals of two to four years, and females average three clutches per nesting season (Lageux 2001). In 2016, the species was divided into 11 DPSs globally for ESA-listing purposes

(NMFS 2016d). Bjorndal et al. (2017) found that mean growth rates of green turtles in the West Atlantic decreased by 26% between 1999 and 2015, likely partially due to increased water temperatures.

Important feeding areas for green turtles in U.S. waters are primarily located in Florida and southern Texas, but Long Island Sound and inshore waters of North Carolina appear to be important to juveniles during summer months (NMFS and USFWS 2007). Immature green turtles aggregate in certain neritic areas to forage. Modeling of young sea turtle dispersal after hatching showed relatively high abundances of young green turtles on the U.S. Atlantic coast (ages 0.5–1.5 yr.) and within the Sargasso Sea (ages 2.5–3.5 yr.) (Putman et al 2019). Tracking and modeling of neonate green turtle movements suggests that newly hatched turtles move north along the U.S. east coast in deep water and mainly forage in water >200 m (Putman et al. 2019; Mansfield et al 2021).

There are few sighting records for the northeastern U.S., but DoN (2005) suggested that small numbers could be found from spring to fall as far north as Cape Cod Bay. Although sightings are limited and most records are of strandings or bycatch, relatively high concentrations of green turtles are expected to occur offshore from North Carolina in the spring, summer, and autumn based on SPUE modeling (DoN 2008ab). Most sightings between 2010 and 2017 were made on the shelf during the summer (Palka et al. 2021). Modeling based on line transects and platform of opportunity data shows little overlap of green turtle occurrence in the proposed study area (DoN 2008a,b). There are four records of green turtles off the coast of North Carolina in the OBIS database, for December to February (OBIS 2022). Juvenile green turtles are the second most commonly bycaught turtle species by the pound in net fisheries in the Pamlico Sound (Epperly et al. 1995; Epperly et al. 2007). Modeling and tagging of young (and harder to spot) green turtles suggest that there might be more individuals in the proposed study area than indicated by observational data for older age classes.

3.4.3 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 Wider Caribbean Region (Valverde and Holzwart 2017). Juveniles, sub-adults, and adults forage in coastal waters primarily in coral reefs, but also around rocky outcrops, high energy shoals, mangrove-fringed bays, and estuaries (summarized in Amorocho 2001). Long-distance international movements indicate that this species is migratory (e.g., Meylan 1999a; Van Dam et al. 2008). Bjorndal et al. (2017) noted that mean growth rates of hawksbill turtles in the West Atlantic decreased by 18% between 1997 and 2013, likely as a result from increased water temperatures. Many populations in the Caribbean are thought to be declining (Meylan 1999b). In the Atlantic Ocean, most nesting beaches are in the Caribbean Sea as far north as Cuba and the Bahamas (NMFS and USFWS 2013), although two nests have been reported in North Carolina (Seaturtle.org 2022). Hawksbill turtle is considered very rare and possibly extralimital in the Northwest Atlantic (Lazell 1980; Eckert 1995b). Several sightings have been reported off the coasts of Virginia and North Carolina throughout the year, with the fewest sightings in fall; most sightings occurred on the shelf (DoN 2008a,b; Palka et al. 2021). There are no records in the proposed survey area off North Carolina in the OBIS database (OBIS 2022).

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

Kemp's ridley turtle has a more restricted distribution than other sea turtles, with adults primarily located in the Gulf of Mexico; some juveniles also feed along the U.S. east coast, including Chesapeake Bay, Delaware Bay, Long Island Sound, and waters off Cape Cod (Spotila 2004). Nesting occurs primarily along the central and southern Gulf of Mexico coast during May–late July (Morreale et al. 2007). There have also been some rare records of females nesting on Atlantic beaches of Florida, North Carolina, and

South Carolina (Plotkin 2002). After nesting, female Kemp's ridley turtles travel to foraging areas along the coast of the Gulf of Mexico, typically in waters <50 m deep from Mexico's Yucatan Peninsula to southern Florida; males tend to stay near nesting beaches in the central Gulf of Mexico year-round (Morreale et al. 2007). Only juvenile and immature Kemp's ridley turtles appear to move beyond the Gulf of Mexico into more northerly waters along the U.S. east coast.

Hatchlings are carried by the prevalent currents off the nesting beaches and do not reappear in the neritic zone until they are about two years old (Musick and Limpus 1997). Those juvenile and immature Kemp's ridley turtles that migrate northward past Cape Hatteras probably do so in April and return southward in November (Musick et al. 1994). North of Cape Hatteras, juvenile and immature Kemp's ridleys prefer shallow-water areas, particularly along North Carolina and in Chesapeake Bay, Long Island Sound, and Cape Cod Bay (Musick et al. 1994; Morreale et al. 1989; Danton and Prescott 1988; Frazier et al. 2007).

Numerous sightings have been reported off North Carolina in all seasons (DoN 2008a,b; Palka et al. 2021), with most in winter and summer (DoN 2008a,b). Strandings have also been reported during all seasons but winter, mostly in spring and fall (DoN 2008a,b). Modelling of young sea turtle dispersal after hatching showed a portion of Kemp's ridley turtles age 1.5 years concentrating mainly in shelf waters off North Carolina (Putman et al 2019). SPUE modeling based on line transects and platform of opportunity data showed little overlap of Kemp's ridley occurrence and the proposed survey area (DoN 2008b,c). However, one sighting was reported for the survey area by (DoN 2008b) during summer, and one sighting was recorded off North Carolina during 1978–1982 CETAP surveys (CETAP 1982). Rehabilitated Kemp's ridley turtles that were released off Long Island and tracked using satellite tags where recorded in the study area from December to June (Robinson et al 2020). There are two records in the OBIS databased for the North Carolina survey area – one was made in May and the other in August (OBIS 2022).

3.4.5 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). It is the most abundant turtle in U.S. waters (Witherengton et al 2006 *in* DoN 2008b,c; 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. This species' distribution extends into more temperate waters than other sea turtles. Bjorndal et al. (2013) found that mean growth rates of loggerhead turtles in the West Atlantic decreased between 1997 to 2007, but then leveled off or even increased.

The Northwest Atlantic Ocean DPS was estimated to consist of a minimum of 30,096 adult females, with most of these occurring off peninsular Florida and perhaps a few thousand in the rest of the WCR (Richards et al. 2011). The nesting season for the Northwest Atlantic loggerhead DPS is from April through September (Valverde and Holzwart 2017). Major nesting areas for loggerheads in the western North Atlantic are located in the southeastern U.S., principally southern Florida, but also as far north as the Carolinas and occasionally Virginia; the nesting season is from May to August (Spotila 2004). Most females tagged on North Carolina nesting beaches traveled north to forage at higher latitudes (primarily off New Jersey, Maryland, and Delaware) during summer, and south to wintering grounds off the southeastern U.S. in the fall (Hawkes et al. 2007). Some juveniles make seasonal foraging migrations into temperate latitudes as far north as Long Island, New York (Shoop and Kenney 1992 *in* Musick and Limpus 1997). SPUE modelling of young sea turtle dispersal after hatching showed relatively high numbers of loggerhead turtles along the eastern U.S. coast and northwestern Atlantic (0.5 yr) and within the Sargasso Sea (ages 1.5–3.5 yr) (Putman et al 2019).

NMFS proposed (2013a) and designated (2014) 38 areas of critical habitat in the range of the Northwestern Atlantic Ocean DPS of the loggerhead turtle, from Virginia to the Gulf of Mexico. The areas contain one or more of nearshore reproductive habitat, wintering area, breeding areas, constricted migratory corridors, and *Sargassum* habitat. In the proposed survey area, only *Sargassum* habitat occurs, which extends from the 200-m contour to the edge of the EEZ. Over-wintering habitat extends from 20 to 100 m from shore, and migratory habitat extends from shore to 200 m depth; these habitats are located west of the survey area.

DoN (2008a,b) mapped numerous sightings of loggerheads off the coasts of North Carolina, especially during spring and summer; most records are for shelf waters, but there are also sightings on the shelf break and farther offshore; sightings of loggerhead turtles were by far the most numerous of any sea turtle. Palka et al. (2021) also showed sightings of loggerhead turtles on the shelf off North Carolina during all seasons. Females stay closer to the shore after nesting but move farther offshore towards the end of summer (Hopkins-Murphy et al 2003). SPUE modeling based on line transects and platform of opportunity data shows some overlap of occurrence of loggerhead turtles with the proposed study area (DoN 2008b,c). Tagged loggerhead turtles have been tracked moving through the survey area (Palka et al. 2021; SWOT 2022). Four sightings of seven individuals were made between 16 September–18 October 2014 during an L-DEO survey off Cape Hatteras; only one sighting overlapped the proposed survey area (RPS 2015). They are the most common sea turtle caught as bycatch by the pound net fisheries in Pamlico Sound (Epperly et al 2007), to the west of the survey area. There are 86 OBIS records for the North Carolina study area that were made throughout the year (OBIS 2022).

3.5 Seabirds

Two ESA-listed seabird species could occur in or near the project area: the ***endangered*** roseate tern and Bermuda petrel. The ***threatened*** piping plover also occurs along the coast of North Carolina, but only in nearshore waters; therefore, it is not discussed further here. The black-capped petrel is proposed for listing as ***threatened*** and could occur in the region (Table 6). General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of seabird families are given in § 3.5.1 of the PEIS.

3.5.1 Roseate Tern (*Sterna dougallii*)

The roseate tern has a worldwide distribution mainly in tropical and subtropical oceans. Roseate tern is a strictly marine species, either coastal or more pelagic in nature, feeding on small fish. In nearshore waters it forages over tide-rips, sand shoals and sandbars, and in deeper offshore waters it feeds over schools of predatory fish which flush prey fish species to the surface (BirdLife International 2022). It is a shallow plunge diver and usually does not fully submerge beneath the surface. Roseate terns typically feed in shelf waters, but they are also known to forage up to 30 km from nesting sites.

In North America, roseate terns breed on islands in southern Nova Scotia, along the northeast coast of the U.S. from New York to Maine and throughout the Caribbean, as well as Florida (USFWS 1998, 2010, 2020; Conley et al. 2017; BirdLife International 2022). Roseate terns migrate north and south through the survey area in spring and fall, respectively. The northward migration is expected to take place mainly during May. It is unknown if migrating roseate terns transverse directly through the study area or linger enroute. Non-breeding sub-adult roseate terns could also occur within the study area beyond the migration period.

TABLE 6. 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 North Carolina in the Northwest Atlantic Ocean.

Species	**Occurrence in Study Area**[1]	**U.S. ESA**[2]	**IUCN**[3]	**CITES**[4]
Roseate Tern	Scarce, migrating individuals head north during spring	EN	LC	NL
Bermuda Petrel	Rare, pelagic	EN	EN	NL
Black-capped Petrel	Uncommon, pelagic	T (Proposed)	EN	NL

NL = Not Listed.

[1] Occurrence based on available data and professional opinion.

[2] U.S. Endangered Species Act; EN = Endangered; T = Threatened.

[3] International Union for the Conservation of Nature Red List of Threatened Species, version 2022-1: EN = endangered, LC = least concern.

[4] Convention on International Trade in Endangered Species.

3.5.2 Bermuda Petrel (*Pterodroma cahow*)

The Bermuda petrel was thought to be extinct by the 17th century until it was rediscovered in 1951, at which time the population consisted of 18 pairs; by 2011, the population had reached 98 nesting pairs (Birdlife International 2022). Currently, all known breeding pairs breed on islets in Castle Harbour, Bermuda (Madeiros et al. 2012). In the non-breeding season (mid-June–mid October), it is thought that birds move west to follow the warm waters on the edge of the Gulf Stream. During this time, the Bermuda petrel has been observed in Gulf Stream waters from North Carolina to Massachusetts.

Results from geolocator tags showed that individuals have been recorded outside of the Gulf Stream, north to the Bay of Fundy, into the Gulf of St. Lawrence and over the Grand Banks of Canada (Madeiros 2009; Birdlife International 2022). It surface feeds, securing small fish and cephalopods and other small marine life by sitting on the water and dipping bill into surface waters. Small numbers of Bermuda petrels could be encountered in the proposed survey area throughout the year.

3.5.3 Black-capped Petrel (*Pterodroma hasitata*)

The black-capped petrel nests in the countries of Haiti and the Dominican Republic from October to May (Carboneras et al. 2020). The nest is at the end of a burrow dug into the soft earth; the birds enter and leave the nest only under the cover of darkness. Deforestation due to human dependence on wood-based cooking fuel and clearing for agricultural purposes are the biggest risks to the black-capped petrel. The population is estimated at no more than 1000 breeding pairs, but perhaps as few as 500, and a total population of 2000–4000 birds (BirdLife International 2022). The black-capped petrel is highly pelagic, occurring in offshore waters beyond the shelf edge from the Caribbean to North Carolina. There are a few sightings beyond the Gulf Stream waters as far north as Massachusetts (Flood and Fisher 2013). It likely would be a year-round resident in the survey area. It is primarily nocturnal and crepuscular, feeding on squid, fish and crustaceans at the surface of the water. The distribution of black-capped petrel is most influenced by the position of the Gulf Stream, a dynamic current system, and not sea surface temperature or depth (BirdLife International 2022). The black-capped petrel can be expected in low densities within the study area year-round.

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 occur in the proposed survey area, including the giant manta ray, oceanic whitetip shark, and Nassau grouper (Table 7). An additional three fish species listed as ***endangered*** could also potentially occur in the survey area although they typically prefer shallower water: smalltooth sawfish, Carolina DPS of the Atlantic sturgeon, and the shortnose sturgeon (Table 7). The largetooth sawfish (*Pristis pristis*) is also listed as *endangered* under the ESA, but occurs in shallow water <100 m where no survey effort would occur, and no farther north than the Gulf of Mexico. The Central & Southwest Atlantic DPS of scalloped hammerhead shark (*Sphyrna lewini*) is also listed as *threatened* under the ESA, but the northern boundary of its geographic range is ~28° N, well south of the survey area (NOAA 2014). The survey area falls within the waters of the U.S. eastern seaboard EEZ, where the Northwest Atlantic and Gulf of Mexico DPS of scalloped hammerhead sharks occurs, which is not listed under the ESA (NOAA 2014). Thus, these two species will not be discussed further. The shortfin mako shark is a candidate species for listing under the ESA and could also occur in the survey area. There are no ESA-listed invertebrates species that could occur within the survey area. The queen conch (*Strombus gigas*) is another candidate species for listing under the ESA, but it typically does not occur as far north as the survey area, so it is not discussed further.

TABLE 7. The habitat, occurrence, and conservation status of fish species of conservation concern that could occur in or near the proposed project area off North Carolina in the Northwest Atlantic Ocean.

Species	**Habitat[1]**	**Occurrence in Study Area[2]**	**US ESA[3]**	**IUCN[4]**	**CITES[5]**
Giant Manta Ray	Coastal, pelagic, migratory; deep-diving	Likely	T	EN	II
Oceanic Whitetip Shark	Pelagic, open ocean, migratory	Likely	T	CR	II
Nassau Grouper	Reef structures <130 m	Unlikely	T	CR	NL
Smalltooth Sawfish	Freshwater, estuarine, shallow coastal water <100 m	Unlikely, due to shallow water preference	E	CR	I
Shortnose Sturgeon	Freshwater, estuarine, shallow coastal water <50 m; spends little time in ocean[7]	Unlikely, due to shallow water preference	E	EN[6]	I
Atlantic Sturgeon *Carolina DPS*	Freshwater, estuarine, shallow coastal water, <50 m	Unlikely, due to shallow water preference	E	EN[8]	NL
Shortfin Mako Shark	Coastal, shelf, pelagic; highly migratory; deep-diving	Likely	Candidate	EN	II

NL = Not Listed.

[1] Froese and Pauly (2022), unless otherwise indicated. [2] Occurrence based on available data and professional opinion.

[3] U.S. Endangered Species Act; E = Endangered; T = Threatened.

[4] International Union for the Conservation of Nature Red List of Threatened Species, version 2022-1: CR = critically endangered, EN = endangered, VU = vulnerable.

[5] Convention on International Trade in Endangered Species of Wild Fauna and Flora: Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[6] North and South Carolina subpopulation.

[7] NOAA 2022g.

[8] Carolina subpopulation.

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 2022h).

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 2022i).

3.6.1.3 Nassau Grouper (*Epinephelus striatus*)

The Nassau grouper’s range includes Bermuda, Florida, the Bahamas, and the Caribbean. It would be unlikely to occur within the study area, but confirmed reports of the species have occurred as far north as North Carolina (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).

3.6.1.4 Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)

Five DPSs of the Atlantic sturgeon are listed under the U.S. ESA, one as ***threatened*** and four as ***endangered***, including the Carolina DPS. It is a long-lived, late maturing (11–21 years in the Hudson River), anadromous fish. Spawning adults migrate upriver in spring, beginning in April–May in the mid-Atlantic. The Carolina DPS primarily uses the Roanoke River, Tar and Neuse rivers, Cape Fear, and Winyah Bay for spawning. Following spawning, males can remain in the river or lower estuary until fall, and females usually exit the rivers within 4–6 weeks. Juveniles move downstream and inhabit brackish waters for a few months before moving into nearshore coastal waters (NOAA 2022j). Most Atlantic sturgeon captured in sampling are caught in depths <20 m, making it unlikely that they would be encountered in the survey area (Dunton et al. 2010). Numerous rivers are designated as critical habitat in North Carolina and adjacent states (NOAA 2022j).

3.6.1.5 Shortnose Sturgeon (*Acipenser brevirostrum*)

The shortnose sturgeon is an anadromous species that spawns in coastal rivers along the east coast of North America from Canada to Florida. The shortnose sturgeon prefers the nearshore marine, estuarine, and riverine habitats of large river systems, and apparently does not make long-distance offshore migrations (NOAA 2022g). It would be unlikely to occur in the deep waters of the proposed survey area.

3.6.1.6 Smalltooth Sawfish (*Pristis pectinata*)

The smalltooth sawfish is found in tropical seas and estuaries. It spends the first two years of life in coastal estuaries, moving farther offshore after attaining a size of ~2.1 m. After leaving the estuary, it inhabits coastal waters near deep-water reefs. Smalltooth sawfish mature at age seven. In the U.S., it primarily occurs in southwest Florida from Charlotte Harbor to the Everglades (NOAA 2022k). It mainly occurs in water <100 m and therefore would be unlikely to occur in the proposed survey area.

3.6.1.7 Shortfin Mako Shark (*Isurus oxyrinchus*)

The shortfin mako occurs in temperate and tropical waters around the globe. It can occur in nearshore, shelf, and slope areas as well as open ocean far offshore, with juveniles and immature individuals often occurring along the coast (Rogers et al. 2015; Francis et al. 2019). This species is highly migratory, making extensive long-range movements (Corrigan et al. 2018). It also shows high fidelity to regions over long periods of time (Corrigan et al. 2018).

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 entire eastern seaboard from the coast to the limits of the EEZ is EFH for one or more species or life stage for which EFH has been designated. The life stages and associated habitats for those species with EFH that would occur within the survey area are described in Table 8. Two fishery management councils, created by the 1976 Magnuson Fisheries Conservation and Management Act (renamed *Magnuson Stevens Fisheries Conservation and Management Act* in 1996) are responsible for the management of fishery resources, including designation of EFH, in federal waters of the survey area: the Mid-Atlantic Fishery Management Council (MAFMC) and the South Atlantic Fishery Management Council (SAFMC). 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 Fisheries Management Plan (FMP). The SAFMC is responsible for managing the remaining fisheries within the survey area (SAFMC 2022). It currently manages eight fisheries through FMPs. The Coastal Migratory Pelagics FMP covers cobia, king mackerel, and Spanish mackerel. The Coral and Live Bottom Habitat FMP covers corals, coral reefs, and live hard-bottom habitats. While corals are not harvested, they provide important habitat for many of the region's fisheries species. The Dolphin Wahoo FMP was approved in 2003, and covers several pelagic fish species such as common dolphin, pompano dolphin, bullet and frigate mackerel, and wahoo. The Golden Crab FMP applies only to the golden crab fishery. The Sargassum FMP places strong limitations on the commercial harvest of sargassum, which provides habitat for sea turtles as well as pelagic fishes and juvenile reef fish. The Shrimp FMP addresses the brown, white, pink, and rock shrimp fisheries within the region. The Snapper Grouper FMP covers 55 species of snappers and groupers as well as other reef fishes such as wrasse, jacks, porgies, and tilefish. The eighth FMP is the Spiny Lobster FMP.

TABLE 8. Marine species with Essential Fish Habitat (EFH) overlapping the proposed survey area.

	Life stage[1] and habitat[2]				
Species	E	L/N	J	A	SA
Atlantic herring *Clupea harengus*			P/D	P/D	
Bluefish *Pomatomus saltatrix*	P	P	P	P	P
Butterfish *Peprilus triacanthus*	P	P	P	P	P
Black sea bass *Centropristis striata*	P	D	D	D	D
Atlantic mackerel *Scomber scombrus*	P	P	P	P	P
King mackerel *Scomberomorus cavalla*	P[3]	P[3]	P[3]	P[3]	P[3]
Spanish mackerel *Scomberomorus maculatus*	P[3]	P[3]	P[3]	P[3]	P[3]
Cobia *Rachycentron canadum*	P[3]	P[3]	P[3]	P[3]	P[3]
Snapper-Grouper[4]	P/D	P/D	P/D	P/D	P/D
Offshore hake *Merluccius albidus*	P	P	D	D	D
Red hake *Urophycis chuss*	P	P	D	D	D
Silver hake *Merluccius bilinearis*	P	P	D	D	D
White hake *Urophycis tenuis*	P	P	P/D	D	D
Scup *Stenotomus chrysops*	P[5]	P/D[5]	D	D	D
Dolphin *Coryphaena hippurus,* wahoo *Acanthocybium solanderi*	P[6]	P[6]	P[6]	P[6]	P[6]
Tilefish *Lopholatilus chamaeleonticeps*	P[7]	P[7]	B[7]	B[7]	B[7]
Monkfish *Lophius americanus*	P	P	B	B	B
Summer flounder *Paralichthys dentatus*	P	P	B	B	B
Window pane flounder *Scophthalmus aquosus*	P	P	B	B	B
Witch flounder *Glyptocephalus cynoglossus*	P	P	B	B	B
Yellowtail flounder *Limanda ferruginea*		P			
Albacore tuna *Thunnus alalunga*			P	P	
Bluefin tuna *Thunnus thynnus*		P	P	P	
Bigeye tuna *Thunnus obesus*			P	P	
Yellowfin tuna *Thunnus albacres*			P	P	
Skipjack tuna *Katsuwonus pelamis*			P	P	
Swordfish *Xiphias gladius*		P	P	P	
Blue marlin *Makaira nigricans*			P	P	
White marlin *Tetrapturus albidus*			P	P	
Sailfish *Istiophorus platypterus*	P	P	P	P	P
Longbill spearfish *Tetrapturus pfluegeri*			P	P	
Roundscale spearfish *Tetrapturus georgii*			P	P	
Clearnose skate *Raja eglanteria*			B[8]	B[8]	
Rosette skate *Leucoraja garmani*			B[10]	B[10]	
Winter skate *Leucoraja ocellata*			B[11]	B[11]	
Barndoor skate *Dipturus laevis*			B	B	
Smooth skate *Malacoraja senta*			B	B	
Thorny skate *Amblyraja radiata*			B	B	
Angel shark *Squatina dumeril*			B	B	
Atlantic sharpnose shark *Rhizoprionodon terraenovae*		B	B	B	
Bigeye thresher shark *Alopias superciliosus*		P	P	P	
Common thresher shark *Alopias vulpinus*		P	P	P	
Blue shark *Prionace glauca*			P	P	
Longfin mako shark *Isurus paucus*		P	P	P	
Shortfin mako shark *Isurus oxyrinchus*		P	P	P	
Basking shark *Cetorhinus maximus*[17]			P	P	
White shark *Carcharodon carcharias*[17]			P	P	
Spiny dogfish *Squalus acanthias*		P	P	P	
Smoothhound sharks *Mustelus canis*		P	P	P	
Tiger shark *Galeocerdo cuvier*		P	P	P	
Sand tiger shark *Carcharias taurus*		P	P	P	

Species	Life stage[1] and habitat[2]				
	E	L/N	J	A	SA
Blacknose shark *Carcharhinus acronotus*		B	B	B	
Bonnethead shark *Sphyrna tiburo*				B	
Scalloped hammerhead shark *Sphyrna lewini*		P	P	P	
Blacktip shark *Carcharhinus limbatus*		P	P	P	
Dusky shark *Carcharhinus obscurus*		P	P	P	
Night shark *Carcharhinus signatus*		P	P	P	
Oceanic whitetip shark *Carcharhinus longimanus*		P	P	P	
Sandbar shark *Carcharhinus plumbeus*		B	B	B	
Silky shark *Carcharhinus falciformis*		P	P	P	
Spinner shark *Carcharhinus brevipinna*		P	P	P	
Atlantic sea scallop *Placopecten magellanicus*	B	P	B	B	B
Atlantic surfclam *Spisula solidissima*	P[12]	P[12]	B[12]	B[12]	B[12]
Ocean quahog *Arctica islandica*	P[13]	P[13]	B[13]	B[13]	B[13]
Golden crab *Chaceon fenneri*	P[6]	P/B[6]	B[6]	B[6]	B[6]
Red crab *Chaceon quinquedens*	P[14]	P/B[14]	B[14]	B[14]	B[14]
Spiny lobster *Panulirus argus*		P[6]	B[6]	B[6]	
Shrimp	P/D[6]	P/D[6]	P/D[6]	P/D[6]	P/D[6]
Northern shortfin squid *Illex illecebrosus*	P[15]	P[15]	D/P[15]	D/P[15]	D/P[15]
Longfin inshore squid *Loligo pealeii*	B[16]	P[16]	D/P[16]	D/P[16]	D/P[16]
Coral, coral reefs and live/hard bottom[18]		D/B[6]	B[6]	B[6]	B[6]

Source: NOAA 2022l; NOAA 2022m

[1] E = eggs; L/N = larvae for bony fish and invertebrates, neonate for sharks; J = juvenile; A = adult; SA = spawning adult

[2] P = pelagic; D = demersal; B = benthic

Sources: [3] ESS 2013; [4] May include up to 70 species (NOAA 2022l); [5] Steimle et al. 1999a; [6] SAFMC 1998; [7] Steimle et al. 1999b; [8] Packer et al. 2003a; [9] Packer at al. 2003b; [10] Packer et al. 2003c; [11] Packer et al. 2003d; [12] Cargnelli et al. 1999a; [13] Cargnelli et al. 1999b; [14] Steimle et al. 2001; [15] Hendrickson and Holmes 2004; [16] Jacobson 2005

[17] EFH would be located adjacent to study area, but does not overlap it.

[18] May include black corals (*Antipatharia*) and Octocorals (including sea pens and sea pansies).

Several EFH areas in or near the proposed survey area have prohibitions in place for various gear types and/or possession of specific species/species groups: (1) Prohibitions on the use of several gear types to fish for and retain snapper-grouper species from state waters to the limit of the EEZ, including roller rig trawls, bottom longlines, and fish traps; and on the harvesting of *Sargassum* (an abundant brown algae that occurs on the surface in the warm waters of the western North Atlantic), soft corals, and gorgonians (SAFMC 2013), and (2) Prohibitions on the possession of coral species and the use of all bottom-damaging gear (including bottom longline, bottom and mid-water trawl, dredge, pot/trap, and anchor/anchor and chain/grapple and chain) by all fishing vessels in Deepwater Coral HAPC (see next section).

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 (NOAA 2020). HAPCs are designated by Fishery Management Councils. There are two HAPCs that overlap the proposed survey area – Charleston Bump Complex and Cape Lookout (Fig. 2).

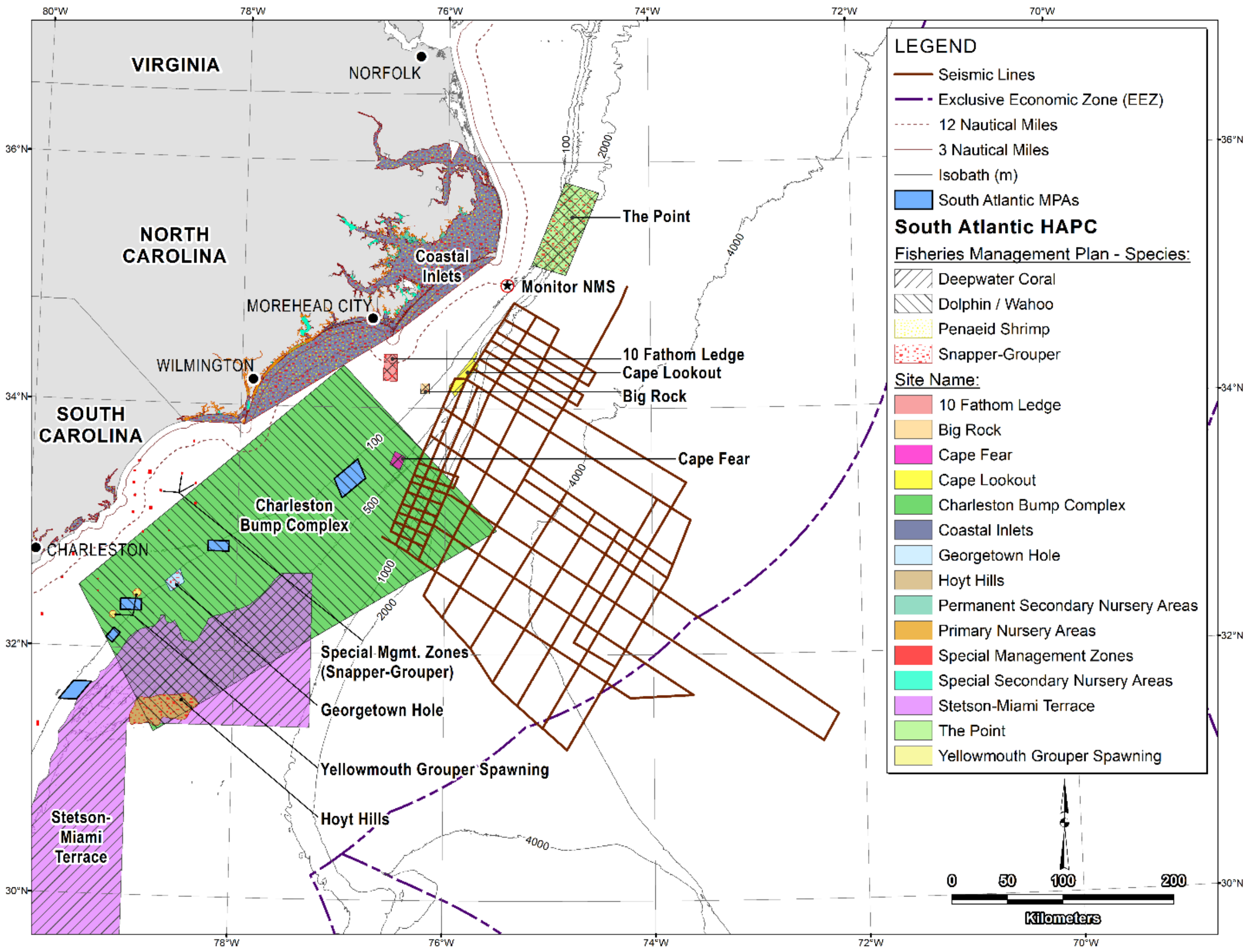

FIGURE 2. Habitat Areas of Particular Concern (HAPC) off the east coast of the U.S. (Source: NOAA 2021b).

HAPCs have been designated for six species/species groups within or near the proposed survey area:

1. Juvenile and adult summer flounder — habitat includes all native species of macroalgae, seagrasses, and freshwater and tidal macrophytes in any size bed, as well as loose aggregations, within adult and juvenile EFH, which is demersal waters over the continental shelf north of Cape Hatteras and demersal waters over the continental shelf south of Cape Hatteras to a depth of 152 m (NOAA 2022l).
2. Species in the snapper-grouper management group — habitat includes medium- to high-profile offshore hard bottoms where spawning normally occurs; localities of known or likely periodic spawning aggregations; nearshore hard-bottom areas; mangrove habitat; seagrass habitat; oyster/shell habitat; all state-designated nursery habitats of particular importance to snapper/grouper (e.g., Primary and Secondary Nursery Areas designated in North Carolina); and pelagic and benthic *Sargassum* (SAFMC and NMFS 2011). The Charleston Bump Complex HAPC is located within the southwestern portion of the survey area (Fig. 2). Other relevant HAPCs include The Point, just north of the study area, and the Coastal Inlet, 10 Fathom Ledge, and Big Rock HAPCs located to the west (Fig. 2).

3. Coastal migratory pelagics (including sharks, swordfish, billfish, and tunas) and dolphin and wahoo fish — habitat includes pelagic *Sargassum*, as well as the Gulf Stream and the Charleston Gyre (SAFMC and NMFS 2009). The Charleston Bump Complex HAPC is located within the southwestern portion of the survey area (Fig. 2). Other relevant HAPCs include The Point, north of the study area, and the 10 Fathom Ledge and Big Rock HAPCs located to the west (Fig. 2).
4. Deepwater Coral — Cape Lookout *Lophelia* Banks HAPC overlaps the northwestern edge of the survey area; Cape Fear *Lophelia* Banks HAPC would be located just to the west of the survey area (SAFMC 2013; see Fig. 2). Big Rock and 10 Fathom Ledge HAPCs also would be located to the west of the survey area, and The Point HAPC would be just to the north (SAFMC 2013; see Fig. 2). The use of specified fishing gear/methods and the possession of corals are prohibited (SAFMC 2013).
5. Sandbar shark — in and near the survey area region, important nursery and pupping grounds near Outer Banks, in areas of Pamlico Sound and adjacent to Hatteras and Ocracoke Islands, and offshore those islands (NOAA 2022l).
6. *Sargassum* — HAPC for various fish species because of mutually beneficial relationship between the fishes and algae, and commercial harvest; the top 10 m of the water column in the South Atlantic EEZ, bounded by the Gulf Stream (SAFMC and NMFS 2011; SAFMC 2013).

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).

3.7.1 Commercial Fisheries

Fisheries data from 2016 to 2020, the last year with available data, were used in the analysis of North Carolina's commercial fisheries (NOAA 2022n). In North Carolina waters, commercial fishery catches are predominantly various shellfish and finfish. Blue crab accounted for 44% of the catch weight, followed by white shrimp (17%), brown shrimp (8%), Paralichthys flounder (6%), Atlantic croaker (3%), spiny dogfish shark (3%), striped (liza) mullet (3%), bluefish (3%), catfishes (2%), Spanish mackerel (2%), kingfishes (2%), and yellowfin tuna (1%). In terms of catch value, blue crab accounted for 30% of landings, followed by white shrimp (24%), Paralichthys flounder (14%), brown shrimp (9%), and eastern oyster (6%). Numerous other fish and invertebrate species accounted for the remaining proportion of catch weight. The average annual catch weights and values, fishing season, and gear types for major commercial species are summarized in Table 9. Typical commercial fishing vessels in the North Carolina area include trawlers, gill netters, lobster/crab boats, dredgers, longliners, and purse seiners.

3.7.2 Recreational Fisheries

In 2021, marine recreational fishers in the waters of North Carolina caught ~22 million fish for harvest or bait, and over 60 million fish in catch and release programs (NOAA 2022o). These catches were taken by over more than 17.9 million trips. The majority of the trips (97%) occurred within 5.6 km from shore, outside of the survey area. The periods with the most boat-based trips (including charter and private/rental boats) were July–August (1,355,242 trips or 29% of total), followed by September–October (1,277,640 or 28%), and May–June (812,659 or 18%). The majority of shore-based trips (from beaches, jetties, banks, marshes, docks, and/or piers) occurred in July–August (3,469,844 trips or 26%), then September–October (3,182,460 or 24%),

TABLE 9. Commercial fishery catches for major marine species for North Carolina waters by weight, value, season, and gear type, averaged from 2016 to 2020.

Species	Average annual landings (mt)	% total	Average annual landings ($1000)	% total	Fishing season (peak season)	Gear Type Fixed	Gear Type Mobile
Blue Crab	8,933	44	22,313	30	Year-round (May-Nov)	Gill nets, pots, traps, pound nets	Bag nets, hand, dredge, fyke nets, hoop nets, trawls
White Shrimp	3,394	17	17,606	24	Year-round (Aug-Feb; May-Jun)	Gill nets	Bag nets, trawls, cast nets
Brown Shrimp	1,709	8	6,892	9	May-Dec (Jul-Aug)	Pots, traps	Bag nets, trawls, cast nets
Paralichthys Flounder	1,235	6	9,985	14	Year-round (Apr-Nov; Winter)	Gill nets, pots, traps	Seines, hand lines, trawls, spears
Atlantic Croaker	605	3	1,460	2	Year-round (Nov-Mar)	Gill nets, pots, traps, pound nets	Fyke nets, hoop nets, seines, hand lines, trawls, spears
Spiny Dogfish Shark	588	3	156	<1	Jan	Gill nets	N/A
Striped (Liza) Mullet	573	3	849	1	Year-round (Oct-Nov)	Gill nets, pots, traps, pound nets	Hand, cast nets, fyke nets, hoop nets, seines, hand lines, trawls, spears
Bluefish	529	3	700	1	Year-round (Jan-Apr)	Gill nets, long lines, pots, traps, pound nets	Seines, hand lines, troll lines, trawls, spears
Catfishes	484	2	266	<1	Year-round (Feb-Apr)	Gill nets, lines trot with bait, pots, traps, pound nets	Fyke nets, hoop nets, hand lines
Spanish Mackerel	360	2	1,234	2	Year-round (May-Oct)	Gill nets, pots, traps, pound nets	Bag nets, trawls, seines, hand lines, troll lines
Kingfishes	326	2	1,026	1	Year-round (Nov-Apr)	Gill nets, pots, traps, pound nets	Seines, hand lines, troll lines, trawls, spears
Yellowfin Tuna	279	1	1,592	2	Year-round (May-Oct)	Long lines	Hand lines, trawls, troll lines
Menhaden	274	1	135	<1	Year-round (Jan-Mar)	Gill nets, pots, traps, pound nets	Bag nets, cast nets, fyke nets, hoop nets, seines, hand lines, trawls, rakes
King Mackerel	262	1	1,271	2	Year-round (Oct-Apr)	Gill nets, long lines	Hand lines, troll lines
Back Sea Bass	202	1	1335	2	Year-round (Dec-Feb; Jun-Aug)	Gill nets, long lines, pots, traps	Hand lines, troll lines, trawls
Swordfish	177	1	1,319	2	Year-round (Dec-Jun)	Long lines	N/A
Spot	160	1	487	1	Year-round (May-Nov)	Gill nets, pots, traps, pound nets	Bag nets, hand, seines, hand lines, trawls, spears
Eastern Oyster	152	1	4,682	6	Year-round (Oct-Mar)	Gill nets	Hand, dredge, trawls, rakes, tongs, grabs
Total	20,242	100	73,308	100			

Source: NOAA 2022n

and May–June (2,969,3425 or 22%). North Carolina also provides a recreational commercial gear license in addition to typical recreational fishing, which allows recreational anglers to use select amounts of commercial gear to harvest for personal, non-salable consumption (DoN 2008b).

Species with 2021 recreational catch numbers exceeding one million include kingfishes (17% of total), Atlantic croaker (13%), pinfish (11%), spotted seatrout (9%), bluefish (6%), spot (4%), flounders (4%), red drum (3%), mullets (3%), Spanish mackerel (3%), black sea bass (3%), puffers (2%), Florida pompano (1.8%), pigfish (2%), skate/rays(2%), sheepshead (1%), unidentified sharks (1%), and weakfish (1%) (NOAA 2022o). Most of these species/species groups were predominantly caught within 5.6 km from shore (77% of total catch for black sea bass; 88% for unidentified sharks; >94% for all others).

3.8 SCUBA Diving, Shipwrecks, and other Cultural Sites

Wreck diving is a popular recreational activity in the waters off North Carolina, an area nicknamed the “Graveyard of the Atlantic”. Locations for dive sites, shipwrecks, marine obstructions, and artificial reefs in and near the proposed survey area were obtained from NOAA’s wreck and obstruction information system (NOAA 2022p), as well as from NCDEQ (2022), NCWD (2022), NOAA (2022p), Shipwreck World (2022), and DiveBuddy (2022). The closest dive site would be located ~9 km to the west of the proposed survey area at the *E.M. Clark* shipwreck (Fig. 3). Recreational diving typically occurs at depths <100 m.

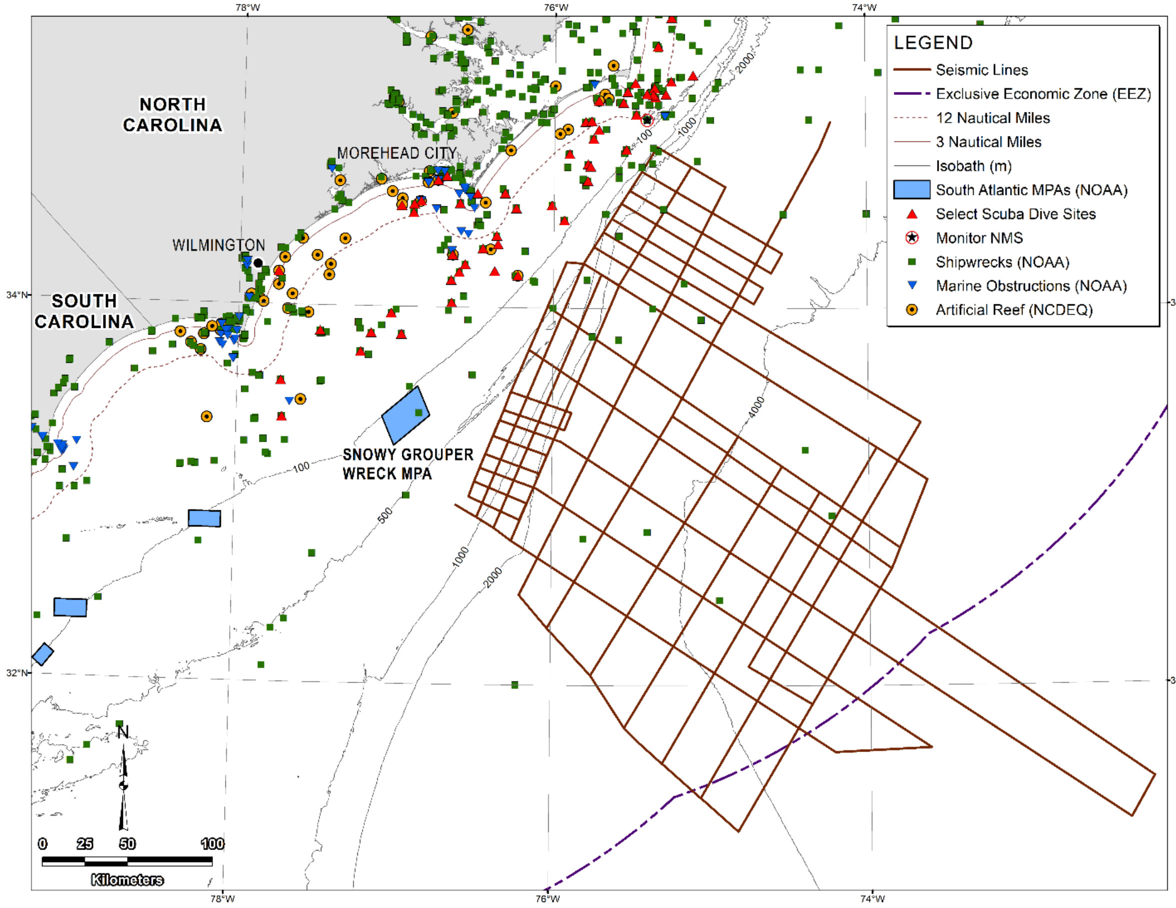

FIGURE 3. Shipwrecks, marine obstructions, artificial reefs, and dive sites off North Carolina. Sources: DiveBuddy (2022), NCDEQ (2022), NCWD (2022), NOAA (2022p), Shipwreck World (2022).

IV 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 (or lack thereof) of airgun sounds on marine mammals and sea turtles given in the PEIS, and reference to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS. Relevant background information on the hearing abilities of marine mammals and sea turtles can also be found in the 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 NSF's 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

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), 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, and (less frequently) pinnipeds 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). 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 $\mathrm{CSEL}_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, decreased at $\mathrm{CSEL}_{10\text{-min}}$ >127 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, and whales were nearly silent at $\mathrm{CSEL}_{10\text{-min}}$ >160 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$. 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 $\mu\mathrm{Pa}_{\mathrm{rms}}$ (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). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). 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). 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). 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; Stone 2015; Monaco et al. 2016). 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). 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). 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). 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).

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 Gulf of Mexico 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). 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 Gulf of Mexico 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). 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). 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). 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 µPa^2 · 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 µPa$_{0\text{-peak}}$. 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 µPa^2 · 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).

Pinnipeds

Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for gray seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of gray or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in^3 airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

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 (see PEIS, § 3.4.4.3). 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 $\mathrm{SEL}_{\mathrm{cum}}$ of 188 and 191 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, 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, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (*cf.* Southall et al. 2007).

Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

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 $L_{\text{eq-fast}}$ (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).

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001; Kastelein et al. 2013a). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. A maximum TTS >45 dB was elicited from a harbor seal exposed to 32 kHz at 191 dB SEL (Kastelein et al. 2020c). For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Harbor seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5–40 kHz (Kastelein et al. 2020a,b), but at frequencies of 2 kHz or lower, a higher SEL was required to elicit the same TTS (Kastelein et al. 2020c). Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Similarly, no TTS was measured when a bearded seal was exposed to a single airgun pulse with an unweighted SEL of 185 dB and an SPL of 207 dB; however, TTS was elicited at 400 Hz when exposed to four to ten consecutive pulses with a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). Kastelein et al. (2021b) found that susceptibility of TTS of California sea lions exposed to one-sixth-octave noise bands centered at 2, 4, and 8 kHz is similar to that of harbor seals, but at 16 kHz, California sea lion haring is less susceptible to TTS than harbor seals (Kastelein et al. 2022).

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or 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 (2016a, 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 and pinnipeds in water, but caution that above 10 kHz for porpoise and outside of 3–16 kHz for seals, 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. 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. (2022q). 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 Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico. 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, some odontocetes, and some pinnipeds, 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 (see § 3.4.4 of the PEIS). 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 stationed on R/V *Langseth* would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.

4.1.1.2 Possible Effects of Other Acoustic Sources

The Kongsberg EM 122 MBES and Knudsen Chirp 3260 SBP would be operated from the source vessel during the proposed surveys. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs and SBPs on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

Some attention has been given to the potential effects of an MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales off Madagascar (Southall et al. 2013). During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event was the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

Reference has also been made that two beaked whales stranded in the Gulf of California in 2002 were observed during a seismic survey in the region by the R/V *Ewing* (Malakoff 2002, Cox et al. 2006 *in* PEIS:3-136), which used a similar MBES system. As noted in the PEIS, however, “The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence” (Hogarth 2002, Yoder 2002 *in* PEIS:3-190).

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on R/V *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, “all ranges are multiplied by a factor of 4” (Lurton 2016:209). However, Ruppel et al. (2022) found that MBESs, SBPs, sidescan sonars, ADCPs, and pingers are unlikely to result in take of marine mammals as these sources typically operate at frequencies inaudible to marine mammals, have low source and received levels, narrow beams, downward directed transmission, and/or have low exposure (e.g., short pulse lengths, intermittency of pulses).

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior and use of habitat by Cuvier’s beaked whales during multibeam mapping with a 12 kHz MBES in southern California (Varghese et al. 2021). The studies found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, suggesting that the level of foraging and habitat use likely did not change during multibeam mapping. During an analogous study assessing naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2020).

In the fall of 2006, an Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiment was carried out in the Gulf of Maine (Gong et al. 2014); the OAWRS emitted three frequency-modulated (FM) pulses centered at frequencies of 415, 734, and 949 Hz (Risch et al. 2012). Risch et al. (2012) found a reduction in humpback whale song in the Stellwagen Bank National Marine Sanctuary during OAWRS activities that were carried out ~200 km away; received levels in the sanctuary were 88–110 dB re 1 µPa. In contrast, Gong et al. (2014) reported no effect of the OAWRS signals on humpback whale vocalizations in the Gulf of Maine. Range to the source, ambient noise, and/or behavioral state may have differentially influenced the behavioral responses of humpbacks in the two areas (Risch et al. 2014).

Frankel and Stein (2020) reported that gray whales responded to a 21–25 kHz active sonar by deflecting 1–2 km away from the sound. Sperm whales exposed to sounds from a low-frequency 1–2 kHz sonar transitioned to non-foraging and non-resting states, but did not respond to 4.7–5.1 kHz or 6–7 kHz sonar signals (Isojunno et al. 2016). Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars. Despite the aforementioned information that has recently become available, this Draft EA remains in agreement with the assessment presented in § 3.4.7, 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs, SBPs, and pingers would not be likely to impact marine mammals would not be expected to affect sea turtles, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal or sea turtle given the movement and speed of the vessel. Also, for sea turtles, the associated frequency ranges are above their known hearing range.

4.1.1.3 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 R/V *Langseth* 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. 2017b). 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.

The PEIS concluded that project 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). Information on vessel strikes is reviewed in § 3.4.4.4, § 3.6.4.4, and § 3.8.4.4 of the PEIS. 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 PEIS concluded that 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. There has been no history of marine mammal vessel strikes with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

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 R/V *Langseth*. 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, 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.

4.1.1.4 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 in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § II (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.

4.1.1.5 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" as described in § I, involving temporary changes in behavior. Further, for this Draft EA, with respect to sea turtles, Level A and Level B are used in the same definition as found in the MMPA and previously issued NMFS BiOp descriptions. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels for the high-energy survey, and we present estimates of the numbers of marine mammals and sea turtles that could be affected during the proposed seismic surveys (additional details are provided in Appendix B). The estimates are based on consideration of the number of marine mammals and sea turtles that could be harassed by sound (Level B takes) produced by the seismic surveys off North Carolina in the Northwest Atlantic Ocean.

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 (~218 km) that is roughly similar to that of the entire survey regarding proportion of water depths surveyed. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by "drawing" the applicable Level B and PTS threshold buffers around each line. The ensonified areas, increased by 25%, were then multiplied by the number of survey days (28 days). This is equivalent to adding an additional 25% to the proposed line km (Appendix B). 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 R/V *Langseth* 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. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level

A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

We used habitat-based stratified marine mammal densities for the North Atlantic for the U.S. Navy Atlantic Fleet Testing and Training (AFTT) Area from Roberts et al. (2016a); the highest mean monthly density was chosen for each species from the months of May to October. The habitat-based density models consisted of 10 km x 10 km grid cells. Average densities in the grid cells for the AFTT Area overlapping the proposed survey area (plus a 40 km buffer) were averaged for each of two water depth categories (intermediate and deep). Densities for pelagic-stage sea turtles were derived from outputs of the models described by Putman et al. (2019). The model was used to estimate the mean daily abundance of loggerhead, green, and Kemp's ridley sea turtles within the survey area in May–October for the years 2010–2017; the densities in intermediate and deep water were then calculated by dividing the abundance by the extent of the survey area in each water-depth category. Densities for leatherback turtles were derived from those reported for the Florida current (Bovery and Wyneken 2015). No densities were available for hawksbill sea turtles.

Table 10 shows estimated densities for cetacean and sea turtle species that could occur in the proposed survey area. 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 11 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; in fact, the calculated takes for cetaceans and sea turtles ***have been increased by 25%*** (see below). 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, as referenced in the NSF/USGS PEIS. 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.

TABLE 10. Densities of marine mammals and sea turtles for the proposed survey area off North Carolina, Northwest Atlantic Ocean.

	Density (#/km^2) in Survey Area[1]		**Month of Highest Density During May-Oct for Int/Deep water**
	Intermediate Water	*Deep Water*	
LF Cetaceans			
North Atlantic right whale	0.0000019800	0.0000004080	Oct/May
Humpback whale	0.0000055700	0.0000004530	May/May
Minke whale	0.0001087450	0.0002408580	May/May
Fin whale	0.0000935000	0.0000767000	May/May
Sei whale	0.0001462270	0.0001743590	Oct/Oct
Blue whale	0.0000124000	0.0000150000	Same each month
MF Cetaceans			
Sperm whale	0.0010799300	0.0099250940	June/May
Cuvier's beaked whale	0.0022108850	0.0094513570	Same each month
Mesoplodont whales	0.0015418100	0.0101752530	Same each month
Risso's dolphin	0.0118841390	0.0024666690	Aug/Aug
Atlantic white-sided dolphin	0.0000000329	0.0000000002	May/May
Rough-toothed dolphin	0.0015396020	0.0017525210	Same each month
Bottlenose dolphin	0.0742357560	0.0227156900	June/May
Pantropical spotted dolphin	0.0021302480	0.0024362170	Same each month
Atlantic spotted dolphin	0.0071106090	0.0294983990	July/same each month
Spinner dolphin	0.0008103470	0.0008658030	Same each month
Striped dolphin	0.0001105090	0.0004527330	Same each month
Clymene dolphin	0.0010329650	0.0017774040	Same each month
Fraser's dolphin	0.0012339050	0.0013183480	Same each month
Common dolphin	0.0043440580	0.0005633100	May/May
Globicephala spp.	0.0129954500	0.0071184360	Same each month
Killer whale	0.0000299000	0.0000319000	Same each month
False killer whale	0.0000221000	0.0000236000	Same each month
Pgymy killer whale	0.0001107390	0.0001183170	Same each month
Melon-headed whale	0.0011589280	0.0012382400	Same each month
HF Cetaceans			
Kogia spp.	0.0005952460	0.0175644990	Same each month
Harbor porpoise	0.0000002260	0.0000002300	May/May
Sea Turtle			
Hawksbill sea turtle	N.A.	N.A.	N.A.
Kemp's ridley sea turtle	0.001099572	0.000179786	N.A.
Loggerhead sea turtle	0.634819792	0.049096035	N.A.
Green sea turtle	0.094135614	0.019301854	N.A.
Leatherback sea turtle	0.000180000	0.000180000	N.A.

[1] Densities for marine mammals are based on Roberts et al. (2016a); densities for turtles are estimated using data from Putman et al. (2019), except leatherback turtle densities, which are derived from Bovery and Wyneken (2015).

TABLE 11. Estimates of the possible numbers of individual marine mammals and sea turtles that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys off North Carolina, Northwest Atlantic Ocean.

Species	**Level B Takes[1]**	**Level A Takes[2]**	**% of North Atlantic Populaton (Based on Total Takes)[3]**	**Requested Level A+B Take Authorization[4]**
LF Cetaceans				
Night Atlantic right whale	0.03	0	0	0
Humpback whale	0.06	0	0.21	**3**
Minke whale	10	0	0.05	10
Fin whale	4	0	0.06	4
Sei whale	8	0	0.13	8
Blue whale	1	0	0.17	1
MF Cetaceans				
Sperm whale	405	1	9.34	406
Cuvier's beaked whale	394	2	6.89	396
Beaked whales[5]	418	2	4.15	420
Blaineville's beaked whale	139	0	N.A.	139
Gervais' beaked whale	139	1	N.A.	140
True's beaked whale	139	1	N.A.	140
Risso's dolphin	189	0	0.54	189
Atlantic white-sided dolphin				
Rough-toothed dolphin	82	0	10.79	82
Bottenose dolphin	1,473	4	2.35	1,477
Pantropical spotted dolphin	114	0	1.73	114
Atlantic spotted dolphin	1,232	5	3.10	1,237
Spinner dolphin	41	0	1.00	41
Striped dolphin	19	0	0.09	**60**
Clymene dolphin	79	0	1.87	79
Fraser's dolphin	62	0	13.21	***65***
Common dolphin	56	0	11.99	**59**
Pilot whales[6]	384	1	1.33	385
Short-finned pilot whales	192	1	N.A.	193
Long-finned pilot whales	192	0	N.A.	192
Killer whale	2	0	0.11	***7***
False killer whale	1	0	0.67	**12**
Pgymy killer whale	6	0	N.A.	***19***
Melon-headed whale	58	0	8.51	***100***
HF Cetaceans				
Kogia spp.[7]	678	31	9.15	709
Dwarf sperm whale	339	16	N.A.	355
Pygmy sperm whale	339	15	N.A.	354
Harbor porpoise	0.01	0	0	**2**
Sea Turtle				
Hawksbill sea turtle	N.A.	N.A.	N.A.	N.A.
Kemp's ridley sea turtle	3	0	N.A.	3
Loggerhead sea turtle	390	19	N.A.	1,310
Green sea turtle	287	7	N.A.	295
Leatherback sea turtle	2	0	N.A.	2

N.A. means not applicable or not available. [1] Level B takes, based on the 160-dB criterion for marine mammals and 175 dB for sea turtles, excluding exposures to sound levels equivalent to PTS thresholds. [2] Level A takes if there were no mitigation measures. [3] Requested take authorization expressed as % of population for the North Atlantic (see Table 4), except for rough-toothed dolphin, for which abundance in North Atlantic and Gulf of Mexico were added together. [4] Requested take authorization is Level A plus Level B calculated takes unless indicated in bold. Bold takes have been increased to mean group size from Palka (2020); when group size was not available from Palka (2020), takes in bold and italics were increased to mean group size from Maze-Foley and Mullin (2006). [5] Assigned 1/3 of the Level B takes to the three species of beaked whales. [6] Takes for *Globicephala* sp. were equally assigned between the two species. [7] Takes for *Kogia* spp. were equally assigned to *K. sima* and *K. breviceps*.

Estimates of the numbers of marine mammals and sea turtles that could be exposed to seismic sounds from the 18-airgun array with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs observe animals approaching or inside the EZs), are also given in Table 11. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

4.1.1.6 Conclusions for Marine Mammals and Sea Turtles

The proposed seismic surveys would involve towing an airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute “taking”.

Marine Mammals.—In § 3.6.7, § 3.7.7, § 3.8.7, and § 3.9.7 of the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, and pinniped species, and that Level A effects were highly unlikely. Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for the Proposed Action involving the high-energy survey; however, following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys. For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g., NMFS 2019a,b).

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 A and/or B harassment are low percentages of the regional population sizes (Table 4). The proposed activities are likely to adversely affect ESA-listed marine mammal species for which takes are being requested (Table 12). However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Because of the distance from the proposed survey area from North Atlantic right whale critical habitat (>100 km), the proposed activities would have no effect on critical habitat.

In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by R/V *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by R/V *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014b). 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.

TABLE 12. ESA determination for marine mammal species expected to be encountered during the proposed surveys off North Carolina in the Northwest Atlantic Ocean.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
North Atlantic Right Whale	√		
Sei Whale			√
Fin Whale			√
Blue Whale			√
Humpback Whale (West Indies DPS)			√
Sperm Whale			√

***Sea Turtles*.—**In § 3.4.7, the PEIS concluded that with implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations are likely to sea turtle populations in any of the analysis areas, and that 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. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related sea turtle injuries or mortality.

The proposed activities are likely to adversely affect ESA-listed sea turtles species for which takes were calculated (leatherback, loggerhead, Kemp's ridley, and green sea turtles), as well as for hawksbill sea turtles for which no densities were available (Table 13).

Under Section 7 of the ESA, no federally-regulated activities may occur within loggerhead critical habitat that may destroy or adversely modify the habitat or threaten the survival of the species (NMFS 2014). Vessel activities that are included in the Federal Register list of human activities that may impact loggerhead critical habitat (NMFS 2014) are lights in the water from the survey vessel (nearshore reproductive critical habitat; constricted migratory corridor habitat) and noise that may "alter habitat conditions needed for efficient passage" (constricted migratory corridor habitat). However, R/V *Langseth* would not transit through or approach reproductive critical habitat closer than 50 km, and no research activities would occur within 1 km of the constricted migratory corridor; thus, vessel lighting is not expected to have any impact on these designated habitats.

Sound levels >175 dB that could potentially harass sea turtles are not expected to reach the over-wintering, reproductive, or constricted migratory corridor critical habitats due to the distance of the proposed activities from these habitats. Thus, the proposed activities would have no effect on these types of critical habitat. Although survey noise would reach levels >175 dB in the *Sargassum* critical habitat, the sound levels 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 (~1 month), the noise pulses are intermittent, and the proposed survey would only overlap a 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

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the PEIS are summarized below. Although research on the effects of exposure to airgun sound and other

TABLE 13. ESA determination for sea turtle species expected to be encountered during the proposed surveys off North Carolina in the Northwest Atlantic Ocean.

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

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).

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 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; 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 $\mu Pa^2 \cdot s$ 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 $\mu\text{Pa}^2 \cdot \text{s}$. 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$_{0\text{-}p}$ of 251 dB re 1 µPa, and SEL of 229 dB re 1 µPa^2·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 $\text{SPL}_{\text{0-pk}}$ were 204 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ 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 $\mu\text{Pa}^2\cdot\text{s}$ 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 µPa^2 · s SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 µPa^2 · 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 µPa^2 · s.

Davidsen et al. (2019) outfitted Atlantic cod and saithe 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 µPa^2·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 µPa^{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 ($\text{SPL}_{\text{0-p}}$) 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.

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 $\mu\text{Pa}^2 \cdot \text{s}$) 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 $\mu\text{Pa}^2/\text{Hz}$ 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 $\mu\text{Pa}_{\text{rms}}$. 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$_{0\text{-}p}$, 243 dB re 1µPa$_{p\text{-}p}$, 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 $SPL_{0\text{-}p}$ of 251 dB re 1 µPa, and SEL of 229 dB re 1 $\mu Pa^2 \cdot s$. 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

The newly available information does not affect the outcome of the effects assessment as presented in the PEIS. The PEIS concluded that 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, but that there would be no significant impacts of NSF-funded marine seismic research on populations. The PEIS also concluded that 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. Two possible conflicts in general are R/V *Langseth*'s streamer 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 R/V *Langseth* 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 14), and their fisheries, including commercial and recreational fisheries. The proposed survey effort would occur beyond state waters and the 12 n.mi. limit, in mostly deep water, and would not affect recreational fishing. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew

TABLE 14. ESA determination for fish species expected to be encountered during the proposed surveys off North Carolina in the Northwest Atlantic Ocean.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Giant manta ray		√	
Smalltooth sawfish	√		
Nassau grouper	√		
Shortnose Sturgeon	√		
Atlantic Sturgeon (Carolina DPS)	√		
Oceanic Whitetip Shark		√	

members have not observed any seismic sound-related fish or invertebrate injuries or mortality. In addition, although the proposed activities may affect EFH and HAPC, no adverse effects on EFH or HAPC are expected; any bottom disturbance from coring are expected to be minimal, airgun sound pulses would be intermittent, and activities overall would be of short-term duration (~28 days).

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.

Potential effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded 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 15). In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related seabird injuries or mortality.

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.

TABLE 15. ESA determination for seabird species expected to be encountered during the proposed surveys off North Carolina in the Northwest Atlantic Ocean.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Roseate tern	√		
Bermuda petrel	√		

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 and Their Significance

There are numerous ship wrecks 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 (~28 days), and most of the wrecks (and SCUBA dive sites) are in shallower water <100 m deep (Fig. 3). Waters <100 m would not be ensonified to sound levels >160 dB during the proposed surveys. However, SCUBA divers in shallower, nearshore areas could be exposed to sound levels up to 160 dB. Conflicts with SCUBA divers would be avoided through Notice to Mariners and communication with dive operators during the surveys. No adverse impacts to cultural resources or SCUBA diving activities are anticipated.

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. The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research, including the combined use of airguns with MBES, SBP, and acoustic pingers. However, the PEIS also stated that, "A more detailed, cruise-specific cumulative effects analysis would be conducted at the time of the preparation of the cruise-specific EAs, allowing for the identification of other potential activities in the areas of the proposed seismic surveys that may result in cumulative impacts to environmental resources." Here we focus on activities (e.g., research, vessel traffic, and fisheries) that could impact animals specifically in the proposed survey area. 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.

4.1.6.1 Past and Future Research Activities

There are many seismic data sets available for the continental shelf and slope of the eastern U.S. However, the currently available data is too sparse to meet the goals of the proposed project to determine the role that slope failures play in building a passive margin, including failure frequency, spatial relationships between younger and antecedent failures, and processes that precondition or trigger failure, particularly shallow fluid migration.

In 2000, high-resolution pseudo 3-D multichannel seismic survey was performed onboard R/V *Ewing*. A total of 370 km^2 was collected using a 4-km streamer and two high-frequency 105/105 in^3 generator-injector (GI) airguns. In 2014, R/V *Langseth* supported an NSF-funded 3-D seismic survey off the coast of New Jersey to study sea-level changes. This cruise was to cover ~4900 km of track lines, but only a partial survey was conducted in July 2014 due to mechanical issues; it was completed in June–July 2015. In 2014–2015, R/V *Langseth* conducted a 2-D seismic survey for the USGS in support of the delineation of the U.S. Extended Continental Shelf (ECS) along the east coast. A total of 5400 km of MCS data were collected during August 2014 and between April and August 2015. During September–October 2014, R/V *Langseth* conducted the 2-D Eastern North American Margin (ENAM) community seismic experiment (CSE) off Cape Hatteras, North Carolina; 4816 km of MCS data were collected with an airgun array of 3300–6600 in^3. Broadband seismometers were also deployed on the seafloor along the coast of North Carolina as part of an NSF collaborative ENAM research activity. The broadband seismometers recorded distant earthquakes for one year (April 2014 to April 2015). Recordings of the seismic waves from far away earthquakes can be used to image the mantle beneath the eastern edge of North America, which can provide information on deep processes during continental breakup, including the generation of magmas and extension of the lithosphere. Together with the EarthScope USArray seismometers onshore, these data were used to enable continuous imaging of the North American lithosphere across the shoreline.

Other scientific seismic research activities and other studies may be conducted in this region in the future. At the present time, the proponents of the survey are not aware of other marine research activities planned to occur in the proposed survey area during 2023.

4.1.6.2 Military Activities

The proposed survey is located within the U.S. Navy's CHPT OPAREA and within the southern portion of the Virginia Capes Operating Area (VACAPES OPAREA). The Virginia Capes, Cherry Point, Charleston/Jacksonville (located west of the proposed survey area) OPAREAs are collectively referred to as the Southeast OPAREA. The VACAPES OPAREA is located in the coastal and offshore waters off Delaware, Maryland, Virginia, and North Carolina, from the entrance to Chesapeake Bay south to just north of Cape Hatteras. The CHPT OPAREA is located in the coastal and offshore waters off North Carolina from just north of Cape Hatteras to southeast of Cape Fear at 32.1°N. The types of activities that could occur in the OPAREAs include aircraft carrier, ship and submarine operations; anti-air and surface gunnery, missile firing, anti-submarine warfare, mine warfare, and amphibious operations; all weather flight training, air warfare, refueling, UAV flights, rocket and missile firing, and bombing exercises; and fleet training and independent unit training (DoN 2008a,b).

A ship shock trial area is located within the VACAPES OPAREA adjacent to the northern tip of the proposed survey area. Portions of the proposed study area overlap with the Navy's designated sinking exercise area. Several military installations, located to the west of the proposed survey area, often use waters of the OPAREA for training operations (DoN 2008a,b). Thus, various naval activities could occur within the proposed survey area. L-DEO and NSF are coordinating, and would continue to coordinate, with the U.S. Navy to ensure there would be no conflicts.

4.1.6.3 Offshore Energy Development

The proposed survey area is within BOEM's Outer Continental Shelf (OCS) Mid-Atlantic and South Atlantic Planning Areas for proposed geological and geophysical (G&G) activities, for which a Final PEIS was published in February 2014 (BOEM 2014) and a Record of Decision (ROD) was signed in July 2014. The 2014 ROD was the last oil and gas document signed for the development of the Mid-Atlantic and South Atlantic region. At present, there are no oil and gas leases in the Atlantic area. The 5-year period that was covered by the Draft Proposed Program (DPP) proposed nine lease sales for the Atlantic region; however, subsequent to publication of the DPP, leasing consideration for waters off of North Carolina, South Carolina, Georgia, and Florida were withdrawn.

The Mid-Atlantic and South Atlantic Planning Areas are now being developed for offshore wind. The Central Atlantic Call Area for offshore wind development spans from offshore Delaware south to Cape Hatteras, North Carolina. Two leases for offshore wind development have been issued south of Cape Hatteras in the Carolina Long Bay Area (offshore North and South Carolina). However, the proposed survey area is located further offshore than the two BOEM lease areas; thus, no spatial overlap is expected. BOEM recently published a final Supplemental Environment Assessment (SEA) considering new information relevant to environmental considerations excluded from the 2015 revised Environmental Assessment for the Commercial Wind Lease Issuance and Site Assessment Activities on the Atlantic Outer Continental Shelf Offshore North Carolina (BOEM 2015, 2021). In the SEA, BOEM describes its intent to authorize offshore wind development in support of BOEM's renewable energy and marine minerals programs. The activities assessed in the SEA include:

- Site characterization activities such as shallow hazards, geological, geotechnical, archaeological, and biological surveys of the lease area and potential cable routes;
    - High-resolution geophysical (HRG) surveys used to detect geohazards, archaeological resources, and certain types of benthic communities.
    - geological and geotechnical bottom sampling used in both program areas to assess the suitability of seafloor sediments for supporting structures (e.g., platforms, cables, wind turbines) or to evaluate the quantity and quality of sand for beach nourishment projects.
- Site assessment activities including the installation and operation of meteorological buoys associated with issuing wind energy leases.

BOEM will conduct site-specific environmental reviews for any future offshore wind permit applications for the Atlantic. These reviews will include coordination and consultation with federal, state and tribal authorities under a suite of statutory requirements. BOEM will also require that operators receive any required authorization from NOAA Fisheries before any final authorization from BOEM is provided. NOAA will not authorize site assessment surveys or site assessment activities unless there is negligible impact and no adverse effects on recruitment or survival of marine mammal species or stocks. The decision to authorize offshore wind development activities for BOEMs renewable energy and marine minerals programs does not in turn authorize leasing for these activities in the Atlantic. BOEM is at the site assessment stage in developing the Carolina Long Bay Area, which can take up to 5 years to complete.

BOEM approved activities may occur during the proposed survey activities. Two BOEM Lease Areas (OCS-A 0545 and 0546) are located offshore North and South Carolina; however, no spatial overlap is expected with the proposed survey area. HRG survey activity within these two Lease Areas would likely begin in late 2022 or 2023 and occur intermittently for one or more years. Given that there is no spatial overlap and the expected site assessment activities (HRG surveys) have short distances to disturbance thresholds, the potential for cumulative effects is minimal.

4.1.6.4 Vessel Traffic

Based on data available through the Automated Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard, between 5 to 14 commercial vessels per month travelled through several one-degree cells (60 minutes of latitude by 60 minutes if longitude) in and around the proposed survey area from May to October 2018 and 2019. This declined to four or fewer vessels per month from May–October 2020, and for each month in 2021 and 2022 (2022 data are available for January–July, no data available for August 2021) (USCG 2022). Live vessel traffic information is available from MarineTraffic (2022), including vessel names, types, flags, positions, and destinations. Various types of vessels were in the proposed survey area when MarineTraffic (2022) was accessed on 15 August 2022, including cargo vessels (11), tugs and special craft (35, tankers (3), and a passenger vessel (1). Additional vessel types were found closer to shore including fishing vessels and pleasure craft/sailing vessels. Collisions of vessels with marine mammals have been reported for the U.S. North Atlantic, with most collisions with large whales involving humpbacks, followed by North Atlantic right whales (Hayes et al. 2022).

The total distance that would be traveled by R/V *Langseth* (~6500 km) by R/V *Langseth* would be minimal relative to total transit lengths for vessels operating in the proposed survey area at the time of the survey. Thus, the projected increases in vessel traffic attributable to implementation of the proposed activities would constitute only a negligible portion of the total existing vessel traffic in the analysis area, and only a negligible increase in overall ship disturbance effects on marine mammals.

4.1.6.5 Fisheries Interactions

The commercial and recreational fisheries in the region are described in § III. The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve direct removal of prey items, noise, and potential entanglement (Reeves et al. 2003).

***Marine mammals*.—**On the east coast of the U.S., marine mammals are bycaught in commercial longline, trawl, and gillnet fisheries (Lewison et al. 2014). In Atlantic waters of the U.S., numerous cetaceans (mostly delphinids) and pinnipeds suffer serious injury or mortality each year from fisheries. Hayes et al. (2022) reported mean annual fishery-related mortality and serious injury during 2015–2019 in U.S. Atlantic waters of 390 common dolphins, 136 short-finned pilot whales, 34 Risso's dolphins, 27 Atlantic white-sided dolphins, 9 long-finned pilot whales, 163 harbor porpoises, 1169 gray seals, and 334 harbor seals. The mean annual entanglement rates involving baleen whales for the Atlantic during 2015–2019 was 9.55 Canadian East Coast minke whales, 9.35 Gulf of Maine humpback whales, 5.65 Western North Atlantic right whales, 1.45 Western North Atlantic fin whales, and 0.6 Nova Scotian sei whales (Hayes et al. 2022). There may be some localized avoidance by marine mammals of fishing vessels near the proposed seismic survey area.

***Sea turtles*.**—On the east coast of the U.S., sea turtles are bycaught in commercial longline (Lewison et al. 2014) and pound net fisheries (Epperly et al. 2007; McNeill et al. 2018). Bycatch estimates calculated for fisheries in the southeast region (including off North Carolina) for 2005 showed that loggerhead turtles were the most commonly bycaught species, with 5209 individuals, followed by Kemp's ridley turtles with 4222 individuals, 659 green turtles, and 537 leatherback turtles (NMFS 2011). The annual average bycatch in gillnet, otter trawl, and scallop dredge fisheries was 342 loggerhead turtles in the Mid-Atlantic region between 2007 and 2014 (Benaka et al. 2019). For 2012–2016, Murray (2018) estimated that the total bycatch for sea turtles in sink gillnet gear for the Georges Bank and Mid-Atlantic regions was 705 loggerheads, 145 Kemp's ridley, 27 leatherback, and 112 unidentified turtles. In the bottom otter trawl gear fisheries in the Mid-Atlantic region for 2014–2018, it was estimated that the total bycatch was 571 loggerheads, 46 Kemp's ridley, 20 leatherback, and 16 green turtles (Murray 2020). For 2019, Garrison and Stokes (2021) estimated a total of 90.8 interactions with leatherbacks and 67.4 interactions with loggerhead for the longline fishery. Loggerhead and green turtles are the most commonly bycaught species in the pound net fisheries near the proposed survey area; however, mortality is not high as the turtles can usually surface to breathe (Epperly et al. 2007; McNeill et al. 2018).

Entanglement of sea turtles in seismic gear is also a concern; there have been anecdotal reports of turtles being trapped and killed between the gaps in tail-buoys and airgun arrays offshore of West Africa (Nelms et al. 2016). The probability of entanglements would be a function of turtle density in the proposed survey area. 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. On the east coast of the U.S., seabird bycatch was recorded in longline and gillnet fisheries (Lewison et al. 2014). In 2015, 2572 seabirds representing 10 species were taken as bycatch in commercial fisheries across seven Greater Atlantic regions (Benaka et al. 2019). Most of the bycatch took place in the Mid-Atlantic and New England gillnet fisheries, with 2215 birds bycaught in 2015. A total of 76% of the 2015 bycatch was of greater shearwaters taken by gillnets; northern fulmars, red-throated loons, and herring gulls were also commonly taken. In 2015–2016 off North Carolina, species taken included common loon, red-throated loon, double-crested cormorant, and northern gannet (Sigourney et al. 2019).

4.1.6.6 Whale Watching

One dolphin and wildlife watching tour company that operates out of North Carolina, H_2O Captain Eco-Tour Boat Excursions, is certified to operate in offshore waters and offers customizable tours with durations up to 12 h (H_2O Captain 2022). Depending on a client's wishes, it is possible, but unlikely, that the *H_2O Captain* may occur near or within the survey area. Otherwise, based on boat size and tour duration, there are several dolphin or other wildlife watching tour vessels that operate in the region but are not expected to venture far enough offshore to approach or enter the survey area (e.g., OBA 2020; BWA 2022; LSBT 2022; Nags Head 2022; PDC 2022; SDT 2022). Some tour operators in the area specify that their routes do not take them into oceanic waters (e.g., CJDT 2022; CR 2022; MCFS 2022; SC 2022; TourH2O 2022; WBST 2022; WT 2022). The season can extend from approximately May to October or November (e.g., OBA 2020; BWA 2022; H_2O Captain 2022; LSBT 2022; Nags Head 2022; PDC 2022). For these reasons, as noted in § 3, impacts to the whale watching industry are not anticipated from the Proposed Action. Furthermore, the additional vessel activity associated with the implementation of the proposed activities would constitute only a negligible portion of the total existing vessel traffic relative to whale watching and other vessel activity in the survey area.

4.1.6.7 Marine Mammal Unusual Mortality Events

As of August 2022, there are six Active Unusual Mortality Events (UME) for the U.S. Atlantic; UMEs were declared for humpback whales and North Atlantic right whales in 2017, for the Atlantic minke whale in 2018, for the Atlantic Florida manatee in 2021, and for northeast pinnipeds in 2022 (NOAA 2022q). Since June 2022, there has been increased mortality of harbor and grey seals along the coast of Maine, with 211 strandings from June through 7 August 2022 (NOAA 2022r). Some seals have tested positive for highly pathogenic avian influenza (HPAI) H5N1; there is an ongoing HPAI event in North America and it has now been confirmed in 41 U.S. States and 11 Canadian provinces, including in almost 90 species of wild birds (NOAA 2022r). Previously, there was an UME declared for northeastern seals in 2018, with 3152 strandings from Virginia to Maine from July 2018 to March 2020; this UME appeared to have been linked to phocine distemper virus (NOAA 2022s).

Since December 2020, an increase in the number of strandings of manatees has occurred along the coast of Florida; many animals were emaciated and the UME is attributed to starvation due to loss of seagrass (MMC 2022). Since January 2017, in increase in numbers of dead or seriously injured North Atlantic right whales have been reported. A total of 34 dead stranded whales have been reported; most of these (21) have occurred in Canada, but there have been 13 strandings in the U.S. There is evidence of human interaction, in particular vessel strikes and entanglements (NOAA 2022t). Since January 2017, there has also been increased mortality of minke whales along the Atlantic coast from Maine trough South Carolina. There is evidence of human interaction or diseases but the evidence is not consistent between all individuals that has been examined; NOAA notes that more research is needed (NOAA 2022u). An increased mortality of humpback whales has been reported since January 2016 along the Atlantic coast from Maine through Florida. Around half of the whales examined had evidence of human interaction either through ship strikes or entanglement but the evidence is not consistent for all individuals; NOAA notes that more research is needed (NOAA 2022v).

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; NMFS, however, requires NSF to request Level A takes. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.8 Coordination with Other Agencies and Processes

This Draft EA has been prepared by LGL on behalf of L-DEO and NSF pursuant to NEPA and Executive Order 12114. USGS is a Cooperating Agency on the Draft EA. 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 and other U.S. and international regulatory processes as appropriate. This document will also be used as supporting documentation for an IHA application submitted by L-DEO, on behalf of itself, NSF, and UT, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic surveys.

4.2 No Action Alternative

An alternative to conducting the proposed activity is the “No Action” Alternative, i.e., do not issue an IHA and do not conduct 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, valuable data about the marine environment would be lost. Geological data of scientific value that would provide new constraints for examining tsunami hazards associated with submarine landslides would not be collected, and the collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. 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

APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1µPa$_{rms}$) for Level B takes. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the 36-airgun array, two 45/105 in^3 GI airguns, and for a single 1900LL 40-in^3 airgun. Models for the 36-airgun array and 40-in^3 airgun used a 12-m tow depth, whereas the model for the two GI airguns used a 3-m tow depth. 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). In addition, 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 Gulf of Mexico in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

Typically, for deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those Gulf of Mexico 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 for marine mammals of ~2000 m (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the 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 and slope 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. The results are summarized below.

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 Gulf of Mexico 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 the 18-airgun array at a maximum tow depth of 6 m. 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 for the 18-airgun array (Fig. A-1). 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. No effort would occur in shallow water during the proposed surveys.

Table A-1 shows the distances at which the 160-dB and 175-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 18-airgun array. The 160-dB level is the behavioral disturbance criteria (Level B) that is used by NMFS to estimate anticipated takes for marine mammal. The 175-dB level is used by NMFS, based on data from the DoN (2017), to determine behavioral disturbance for turtles. 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 levels[3] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (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. 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). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{cum}$ and SPL$_{flat}$, respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-2) and dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). The largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate takes and Level A threshold distances. The dual criteria for sea turtles (DoN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re 1µPa$_{rms}$, for Level B harassment (behavior). It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise. Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups.

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[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).

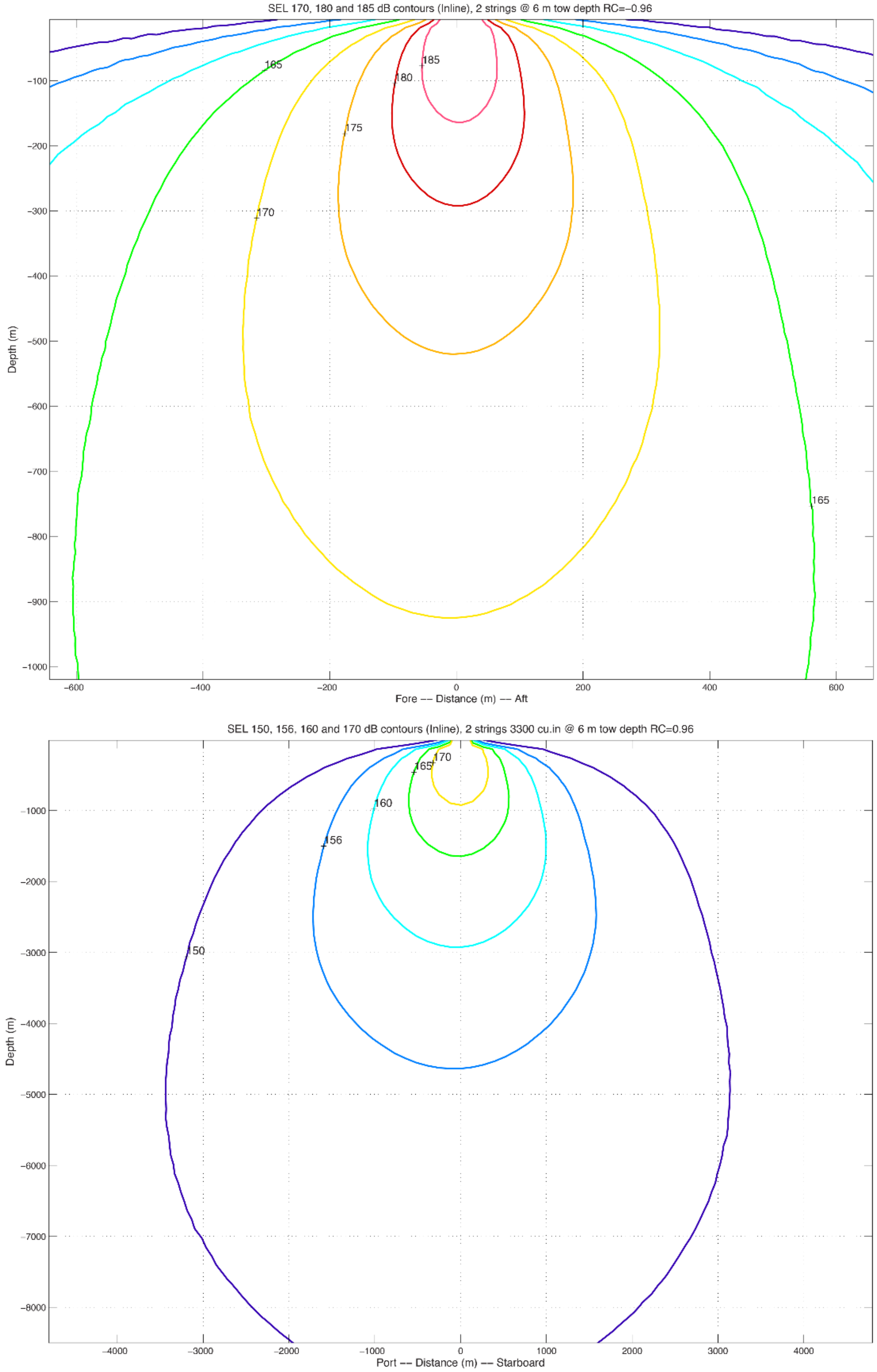


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 18-airgun array at a 6-m tow depth planned for use during the proposed surveys off North Carolina. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-16. Level B. Predicted distances to which sound levels ≥160-dB re 1 μPa_{rms} could be received during the proposed surveys off North Carolina. The 160-dB criterion applies to all hearing groups of marine mammals, and the 175-dB criterion applies to sea turtles.

Source and Volume	**Tow Depth (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**
2 strings, 18 airguns, 3300 in^3	6	>1000 m	2,886[1]	606[1]
		100–1000 m	4,329[2]	909[2]

[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.

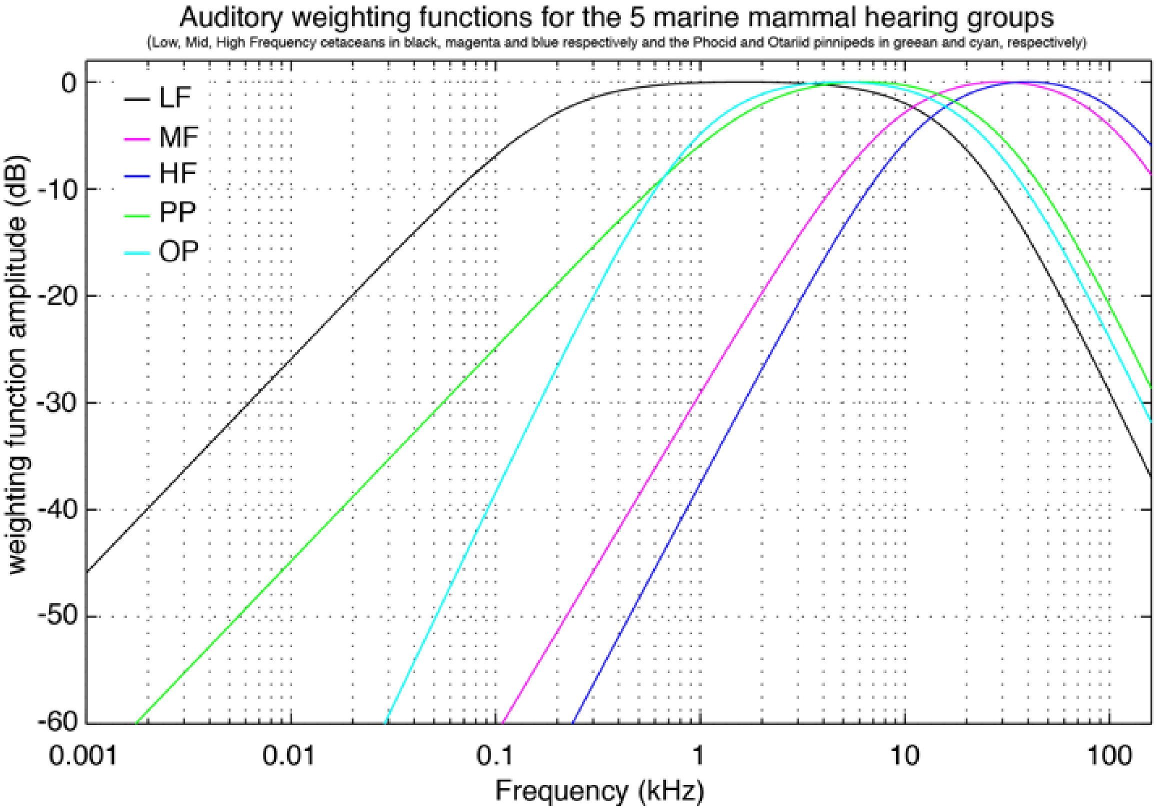


FIGURE A-2. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

The SEL_{cum} for R/V *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature.

The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

To estimate SEL_{cum} and Peak SPL, we used the acoustic modeling developed at L-DEO (same as used for Level B takes) with a small grid step in both the inline and depth directions. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays which we do using the NUCLEUS software to estimate the notional signature and the MATLAB software to calculate the pressure signal at each mesh point of a grid.

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.57222 m/s and a 1/Repetition rate of 9.719223.1 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the 18-airgun array.

For the LF cetaceans during operations with the 18-airgun array, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -13.48 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table A-2).

However, for MF and HF cetaceans, and OW and PW pinnipeds, the modeling for a single shot with the weighted function applied leads to 0-m isopleths; the adjustment factors thus cannot be derived the same way as for LF cetaceans. Hence, for MF and HF cetaceans, and OW and PW pinnipeds, the difference between weighted and unweighted spectral source levels at each frequency up to 3 kHz was integrated to actually calculate these adjustment factors in dB. These calculations also account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014).

TABLE A-2. Results for modified farfield SEL source level modeling for the 18-airgun array with and without applying weighting functions to various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**	**204***
Radial Distance (m) (no weighting	134.4679	105.5727	3525.2	105.5727	14.3405	14.585
Modified Farfield SEL	225.5724	225.4710	225.9437	225.4710	226.1313	227.2781
Radial Distance (m) (with weighting function)	28.4823	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-13.4809	N.A.	N.A.	N.A.	N.A.	N.A.

* Sea turtles. N.A. means not applicable or not available.

For the 18-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 18-airgun array are shown in Table A-3. Figure A-3 shows the impact of weighting functions by hearing group. Figures A-4–A-6 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-7 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

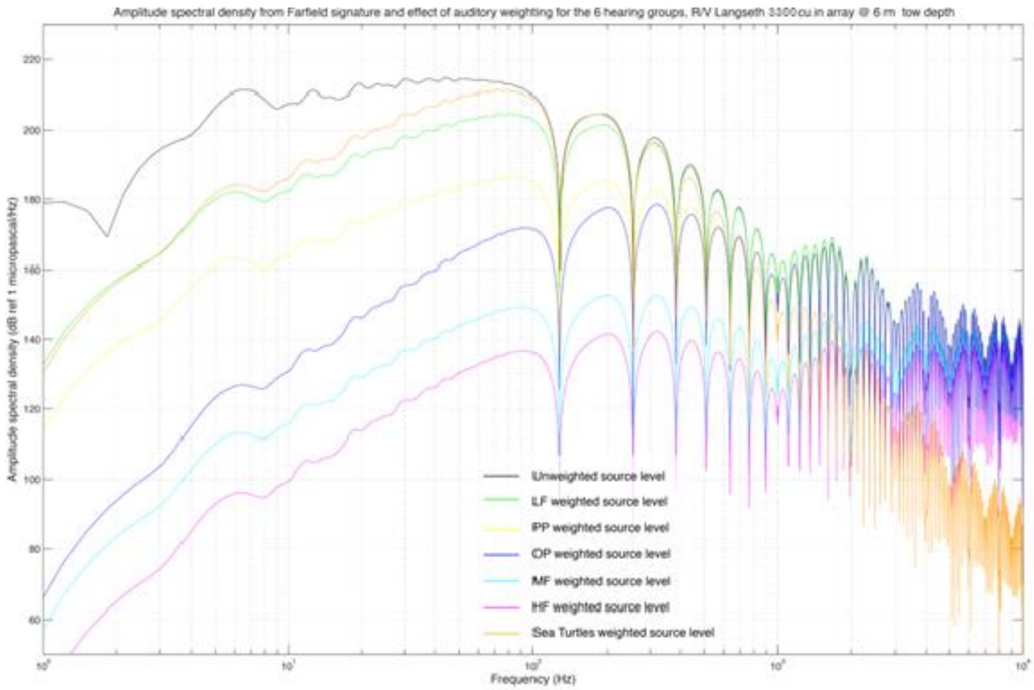
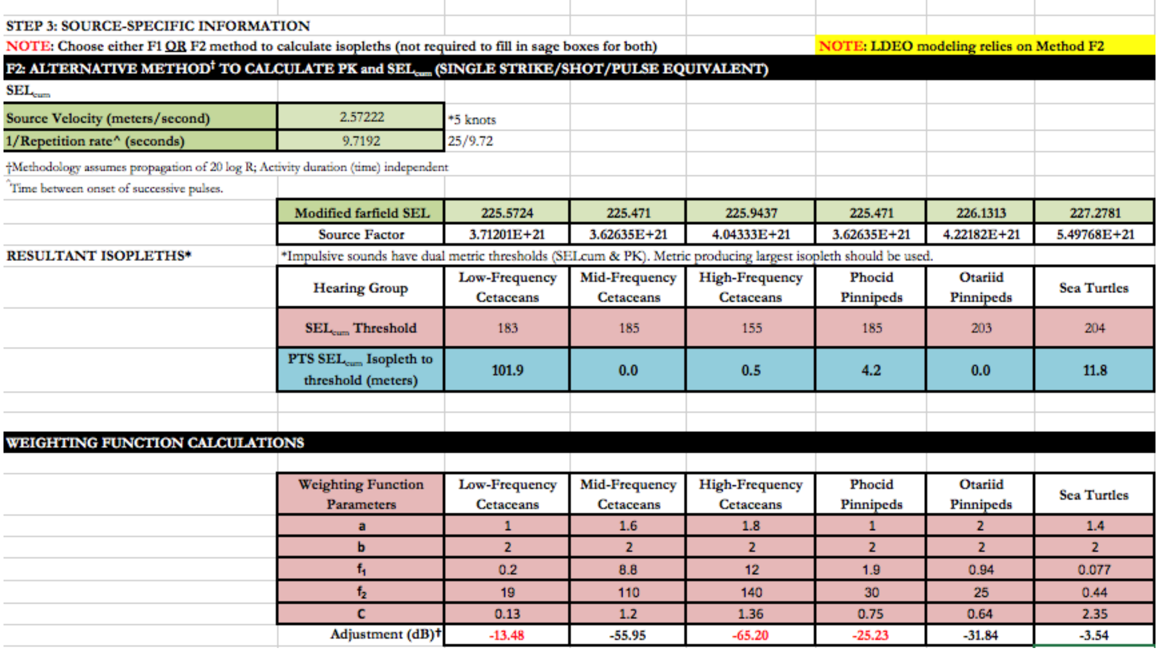


FIGURE A-3. Modeled amplitude spectral density of the 18-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-3. Results for single shot SEL source level modeling for the 18-airgun 3300 in^3 array with weighting function calculations for the SEL$_{cum}$ criteria, as well as resulting isopleths to thresholds for various hearing groups.



STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both)

NOTE: LDEO modeling relies on Method F2

F2: ALTERNATIVE METHOD† TO CALCULATE PK and SEL$_{cum}$ (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)

SEL$_{cum}$

Source Velocity (meters/second)	2.57222	*5 knots
1/Repetition rate^ (seconds)	9.7192	25/9.72

†Methodology assumes propagation of 20 log R; Activity duration (time) independent

^Time between onset of successive pulses.

Modified farfield SEL	**225.5724**	**225.471**	**225.9437**	**225.471**	**226.1313**	**227.2781**
Source Factor	**3.71201E+21**	**3.62635E+21**	**4.04333E+21**	**3.62635E+21**	**4.22182E+21**	**5.49768E+21**

RESULTANT ISOPLETHS*

*Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
SEL$_{cum}$ Threshold	183	185	155	185	203	204
PTS SEL$_{cum}$ Isopleth to threshold (meters)	**101.9**	**0.0**	**0.5**	**4.2**	**0.0**	**11.8**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
a	1	1.6	1.8	1	2	1.4
b	2	2	2	2	2	2
f_1	0.2	8.8	12	1.9	0.94	0.077
f_2	19	110	140	30	25	0.44
C	0.13	1.2	1.36	0.75	0.64	2.35
Adjustment (dB)†	-13.48	-55.95	-65.20	-25.23	-31.84	-3.54

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log$_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-3).

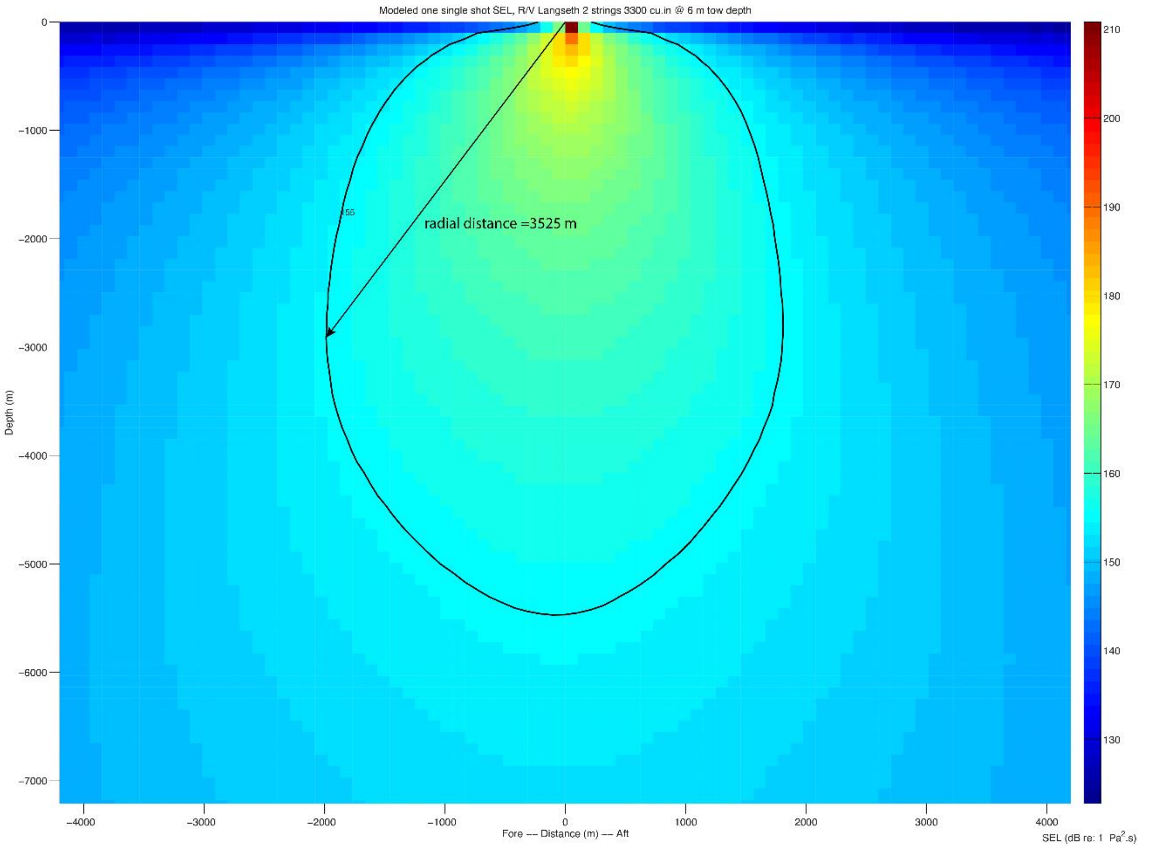


FIGURE A-4. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth. Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial distance).

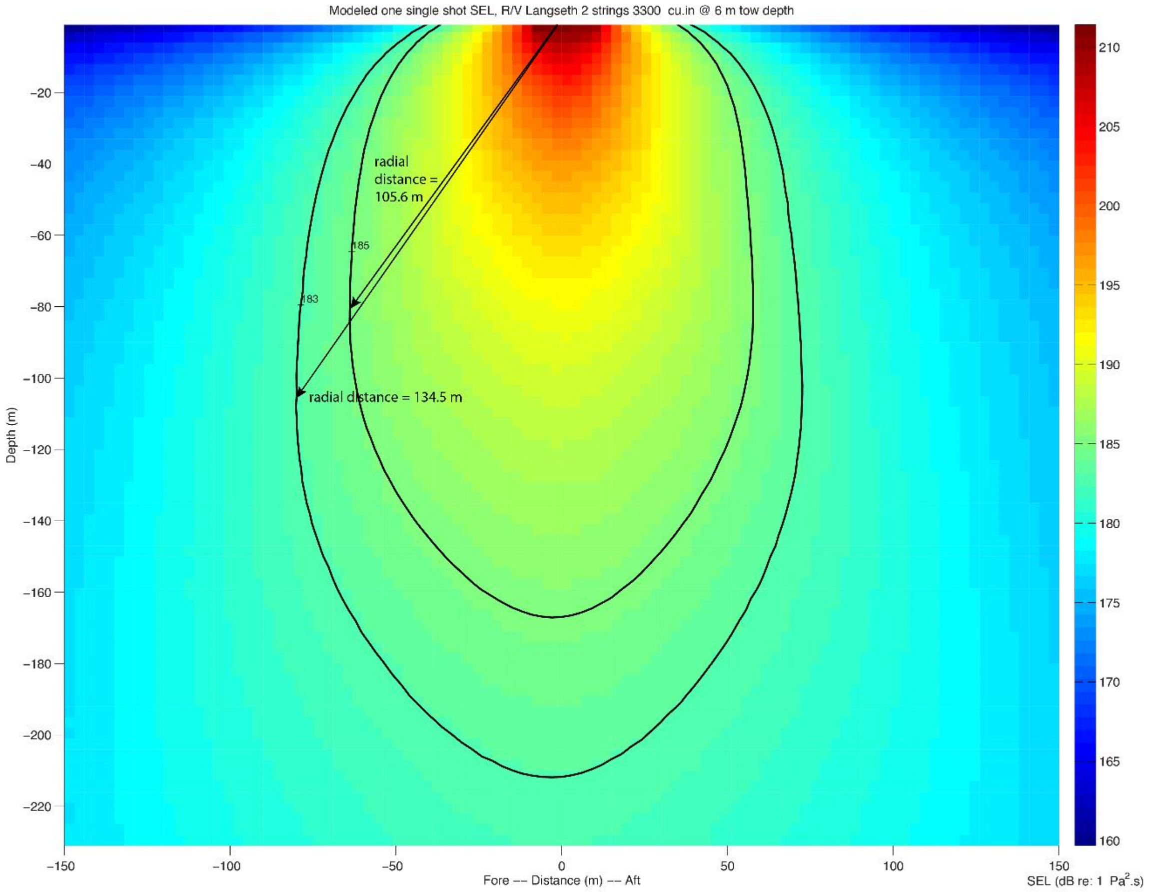


FIGURE A-5. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths.

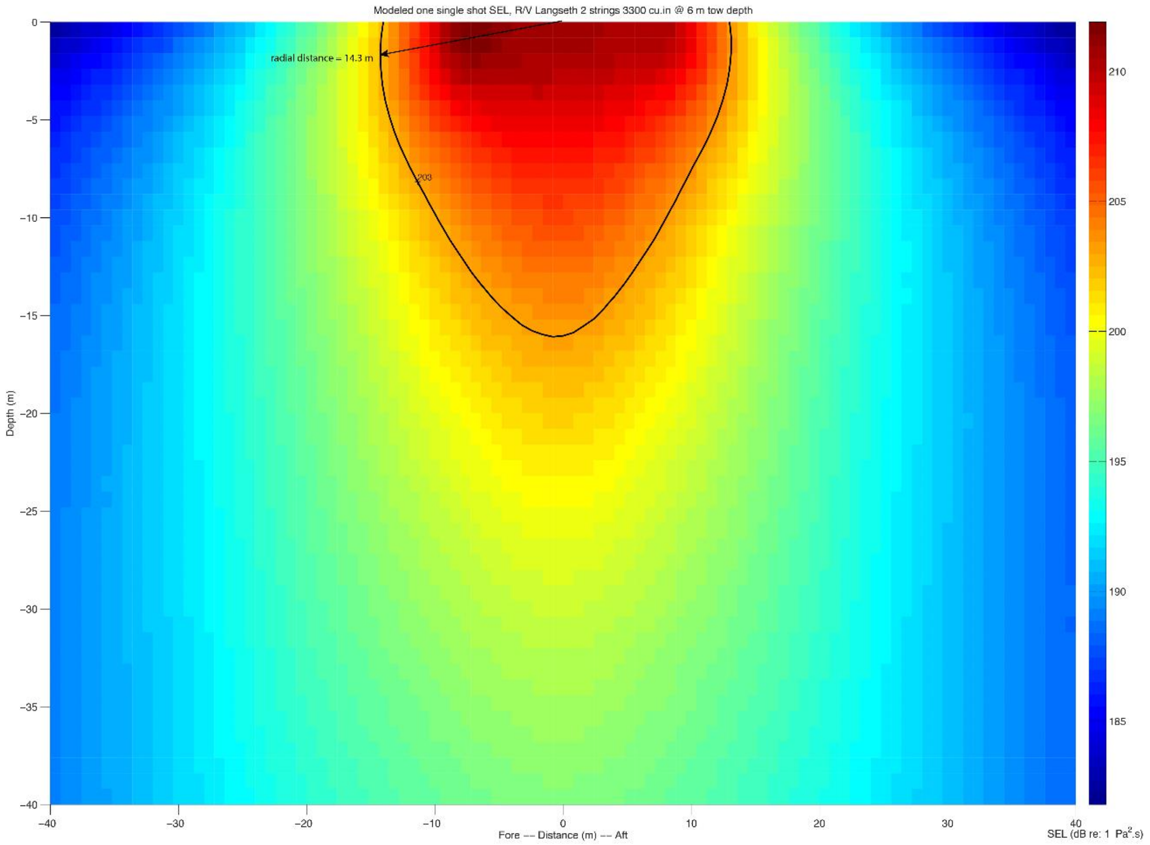


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth.

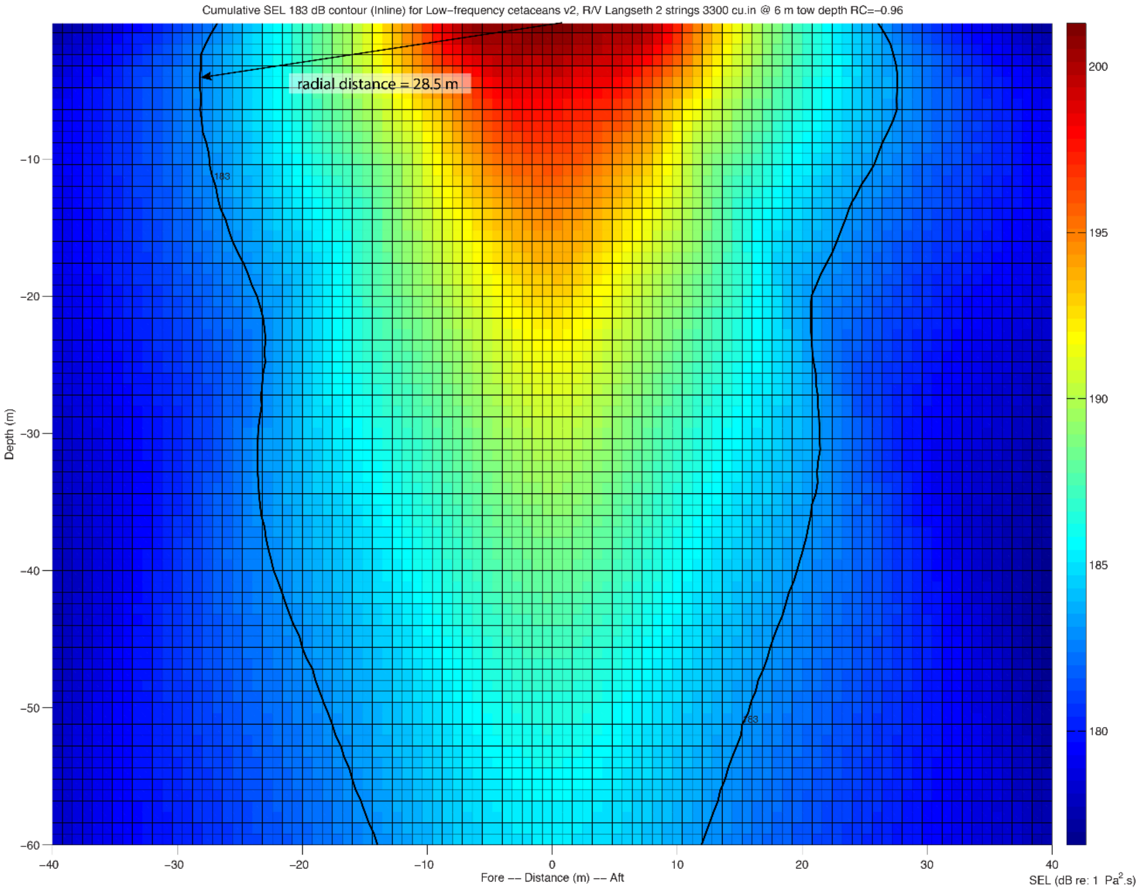


FIGURE A-7. Modeled received sound exposure levels (SELs) from the 18-airgun array at a 6-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-5 and this figure allows us to estimate the adjustment in dB.

The thresholds for Peak SPL_{flat} for the 18-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-8 to A-9 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and sea turtles and predicted distances to Level A thresholds for various hearing groups that could be received from the 18-airgun array during the proposed surveys off North Carolina.

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds/ Sea Turtles**
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	23.3	11.2	116.9	25.3	9.95
PTS Peak Isopleth (Radius) to Threshold (m)	23.4	11.2	123.2	25.4	9.95

N.A. means not applicable or not available.

TABLE A-5. Level A threshold distances for different marine mammal hearing groups and sea turtles for the 18-airgun array. Following the guidance by NMFS (2016, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
PTS SEL_{cum}	**101.9**	0	0.5	4.2	0	**11.8**
PTS Peak	23.3	**11.2**	**116.9**	**25.3**	**9.95**	9.95

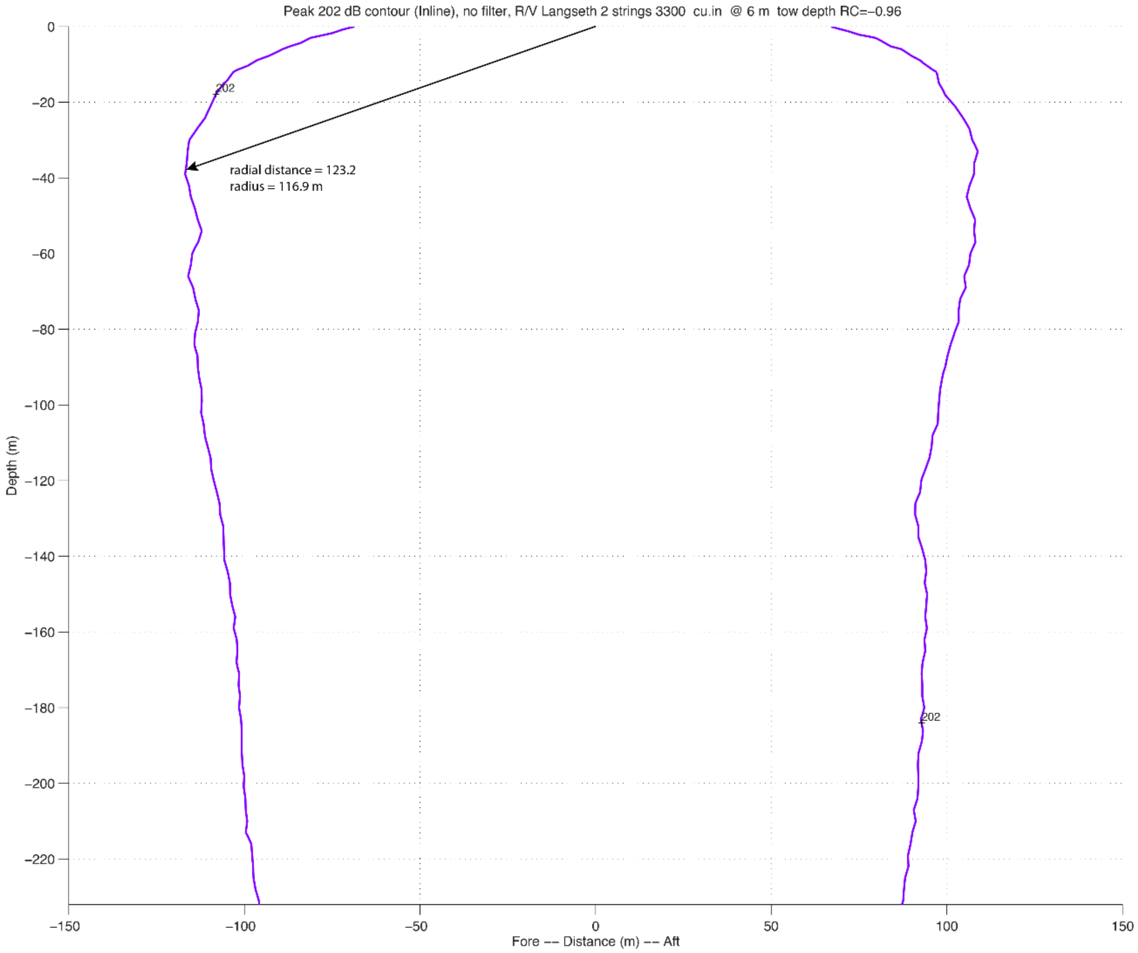


FIGURE A-8. Modeled deep-water received Peak SPL from the 18-airgun array at a 6-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

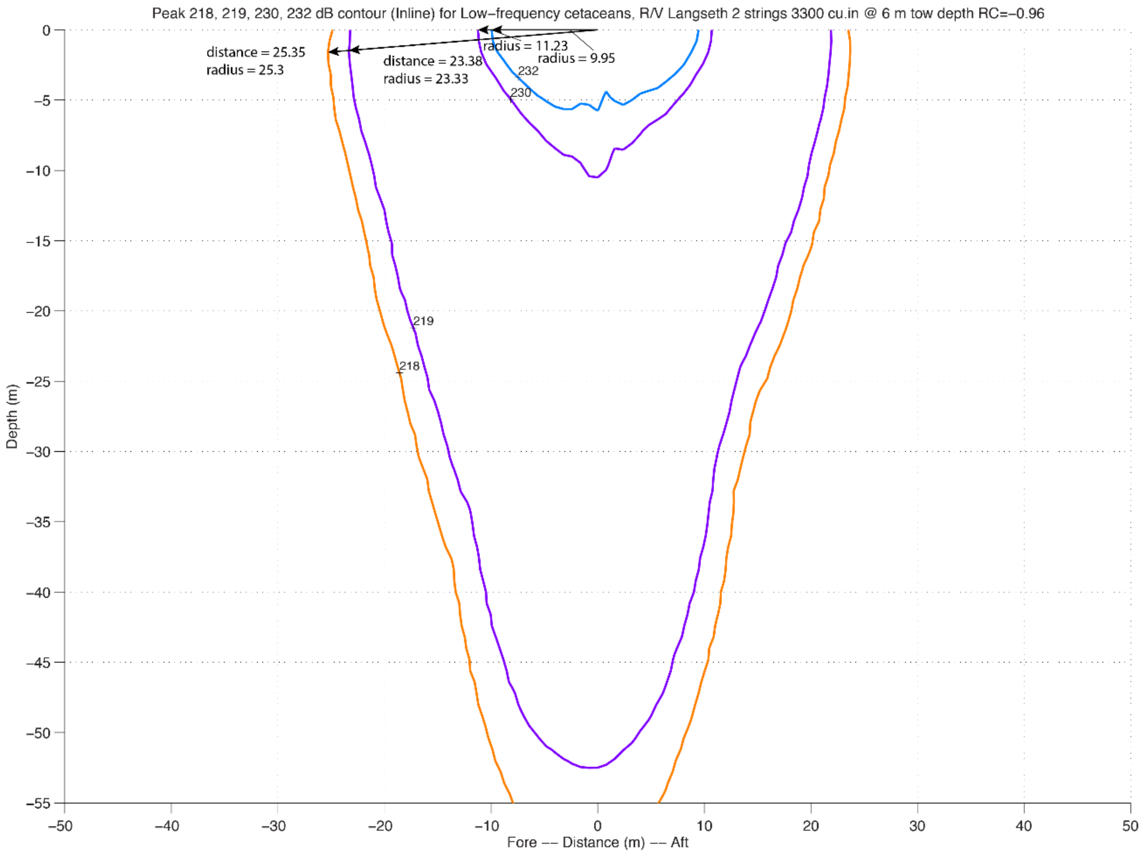


FIGURE A-9. Modeled deep-water received Peak SPL from the 18-airgun array at a 6-m tow depth. The plot provides the distances to the 218, 219, 230, and 232-dB Peak isopleths.

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APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

Level A and Level B takes were determined for the proposed seismic surveys. The ensonified areas that were used to calculate Level A and B takes are provided in Appendix C. The detailed take calculations are shown in Table B-1. The percentage of the population estimated to be taken was large based on the abundance of rough-toothed dolphins in the Western North Atlantic (Hayes et al. 2019). Hayes et al. (2019) noted that this abundance estimate for the Western North Atlantic is highly uncertain as it is based on a single sighting. Thus, in Table B-1 we added the population size for the Gulf of Mexico to that for the North Atlantic to determine percentage of the population taken; these percentages may be more representative of the proposed survey area.

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TABLE B-2. Take estimates for the proposed seismic surveys off North Carolina.

	Estimated Density (#/km^2)				Level B Ensonified Area (km^2)			Level B Takes					
Species	Intermediate 100-1000 m	Deep >1000 m	Population Size North Atlantic	Hearing Group	Intermediate 100-1000 m	Deep >1000 m	Level A Ensonified Area (km2)	Intermediate 100-1000 m	Deep >1000 m	Only Level B Takes minus Level A	Level A Takes	% of NA Pop. (Total Takes)	Requested Level A+B Take Authorization
LF Cetaceans													
Night Atlantic right whale	2.0E-06	4.1E-07	1,396	LF	7,627	40,114	1,558	0.0151	0.0164	0.0308	0.0006	0	0
Humpback whale	5.6E-06	4.5E-07	1,396	LF	7,627	40,114	1,558	0.0425	0.0182	0.0599	0.0007	0.21	**3**
Minke whale	1.1E-04	2.4E-04	21,968	LF	7,627	40,114	1,558	1	10	10	0	0.05	10
Fin whale	9.4E-05	7.7E-05	6,802	LF	7,627	40,114	1,558	1	3	4	0	0.06	4
Sei whale	1.5E-04	1.7E-04	6,292	LF	7,627	40,114	1,558	1	7	8	0	0.13	8
Blue whale	1.2E-05	1.5E-05	402	LF	7,627	40,114	1,558	0	1	1	0	0.17	1
MF Cetaceans													
Sperm whale	0.00108	0.00993	4,349	MF	7,627	40,114	172	8	398	405	1	9.34	406
Cuvier's beaked whale	0.00221	0.00945	5,744	MF	7,627	40,114	172	17	379	394	2	6.89	396
Beaked whales	0.00154	0.01018	10,107	MF	7,627	40,114	172	12	408	418	2	4.15	420
Blaineville's beaked whale	N.A.	N.A.	N.A.	MF	7,627	40,114	172	N.A.	N.A.	139	0	N.A.	139
Gervais' beaked whale	N.A.	N.A.	N.A.	MF	7,627	40,114	172	N.A.	N.A.	139	1	N.A.	140
True's beaked whale	N.A.	N.A.	N.A.	MF	7,627	40,114	172	N.A.	N.A.	139	1	N.A.	140
Risso's dolphin	0.01188	0.00247	35,215	MF	7,627	40,114	172	91	99	189	0	0.54	189
Atlantic white-sided dolphin	3.3E-08	1.7E-10	93,233										
Rough-toothed dolphin	0.00154	0.00175	760	MF	7,627	40,114	172	12	70	82	0	10.79	82
Bottenose dolphin	0.07424	0.02272	62,851	MF	7,627	40,114	172	566	911	1,473	4	2.35	1,477
Pantropical spotted dolphin	0.00213	0.00244	6,593	MF	7,627	40,114	172	16	98	114	0	1.73	114
Atlantic spotted dolphin	0.00711	0.02950	39,921	MF	7,627	40,114	172	54	1183	1,232	5	3.10	1,237
Spinner dolphin	0.00081	0.00087	4,102	MF	7,627	40,114	172	6	35	41	0	1.00	41
Striped dolphin	0.00011	0.00045	67,036	MF	7,627	40,114	172	1	18	19	0	0.09	**60**
Clymene dolphin	0.00103	0.00178	4,237	MF	7,627	40,114	172	8	71	79	0	1.87	79
Fraser's dolphin	0.00123	0.00132	492	MF	7,627	40,114	172	9	53	62	0	13.21	**65**
Common dolphin	0.00434	0.00056	492	MF	7,627	40,114	172	33	23	56	0	11.99	**59**
Pilot whales	0.01300	0.00712	28,924	MF	7,627	40,114	172	99	286	384	1	1.33	385
Short-finned pilot whales	N.A.	N.A.	N.A.	MF	7,627	40,114	172	N.A.	N.A.	192	1	N.A.	193
Long-finned pilot whales	N.A.	N.A.	N.A.	MF	7,627	40,114	172	N.A.	N.A.	192	0	N.A.	192
Killer whale	0.00003	0.00003	6,600	MF	7,627	40,114	172	0	1	2	0	0.11	**7**
False killer whale	0.00002	0.00002	1,791	MF	7,627	40,114	172	0	1	1	0	0.67	**12**
Pgymy killer whale	0.00011	0.00012	N.A.	MF	7,627	40,114	172	1	5	6	0	N.A.	**19**
Melon-headed whale	0.00116	0.00124	1,175	MF	7,627	40,114	172	9	50	58	0	8.51	**100**
HF Cetaceans													
Kogia spp.	6.0E-04	1.8E-02	7,750	HF	7,627	40,114	1,785	5	705	678	31	9.15	709
Dwarf sperm whale	N.A.	N.A.	N.A.	HF	7,627	40,114	1,785	N.A.	N.A.	339	16	N.A.	355
Pygmy sperm whale	N.A.	N.A.	N.A.	HF	7,627	40,114	1,785	N.A.	N.A.	339	15	N.A.	354
Harbor porpoise	2.3E-07	2.3E-07	95,543	HF	7,627	40,114	1,785	0.0017	0.0092	0.0105	0.0004	0	**2**
Sea Turtle													
Hawksbill sea turtle	N.A.	N.A.	N.A.	ST	1,418	8,355	385	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Kemp's ridley sea turtle	0.00110	0.00018	N.A.	ST	1,418	8,355	385	2	2	3	0	N.A.	3
Loggerhead sea turtle	0.63482	0.04910	N.A.	ST	1,418	8,355	385	900	410	390	19	N.A.	1,310
Green sea turtle	0.09414	0.01930	N.A.	ST	1,418	8,355	385	133	161	287	7	N.A.	295
Leatherback sea turtle	0.00018	0.00018	N.A.	ST	1,418	8,355	385	0	2	2	0	N.A.	2

N.A. means not available or not applicable.

APPENDIX C: ENSONIFIED AREAS USES FOR TAKE CALCULATIONS

APPENDIX C: ENSONIFIED AREAS FOR TAKE CALCULATIONS

The ensonified areas that were used to calculate Level A and B takes for the proposed seismic surveys are detailed in Table C-1.

TABLE C-1. Areas expected to ensonified during the proposed seismic surveys off North Carolina.

	Survey Zone	**Criterion**	**Daily Ensonified Area (km^2)**	**Total Survey Days**	**25% Increase**	**Total Ensonified Area (km^2)**	**Relevant Isopleth (m)**
Marine Mammals							
	Deep >1000 m	160 dB	1146.1	28	1.25	40113.5	2,886
	Int 100-1000 m	160 dB	217.9	28	1.25	7626.5	4,329
	Overall	**160 dB**	**1364.0**	**28**	**1.25**	**47740.0**	
Sea Turtles							
	Deep >1000 m	175 dB	238.7	28	1.25	8354.5	606
	Int 100-1000 m	175 dB	40.5	28	1.25	1417.5	909
	Overall	**160 dB**	**279.2**	**28**	**1.25**	**9772.0**	
Hearing Groups							
	All zones	LF Cetacean	44.5	28	1.25	1,557.5	101.9
	All zones	MF Cetacean	4.9	28	1.25	171.5	11.9
	All zones	HF Cetacean	51.0	28	1.25	1,785.0	116.9
	All zones	Sea Turtle	11.0	28	1.25	385.0	11.8

Note: Ensonified areas are adjusted for overlap and include endcaps.