Draft Environmental Assessment of a Marine Geophysical Survey (MATRIX) by the US Geological Survey in the Northwestern Atlantic Ocean, August 2018

Prepared by the U.S. Geological Survey, Coastal and Marine Geology Program

March 2018
# Table of Contents

## Abstract ........................................................................................................................... V

## List of Acronyms ............................................................................................................... VII

## I. Purpose and Need ......................................................................................................... 10

### Mission of the U.S. Geological Survey ........................................................................ 10

### Purpose of and Need for the Proposed Action ......................................................... 11

### Background for USGS Marine Seismic Research .................................................. 12

### Regulatory Setting ........................................................................................................ 12

## II. Alternatives Including Proposed Action .................................................................. 13

### Proposed Action ........................................................................................................... 13

#### (1) Project Objectives and Context ........................................................................... 13

#### (2) Proposed Activities .............................................................................................. 13

#### (3) Monitoring and Mitigation Measures ................................................................. 18

##### (a) Planning Phase ................................................................................................... 19

##### (b) Operational Phase ............................................................................................. 28

### Alternative 1: Alternative Survey Timing .................................................................... 28

### Alternative 2: No Action Alternative .......................................................................... 28

### Alternatives Considered but Eliminated from Further Analysis ............................... 29

#### 1. Alternative E1: Alternative Location ................................................................. 29

#### 2. Alternative E2: Use of Alternative Technologies ................................................ 29

## III. Affected Environment ............................................................................................... 31

#### (1) Oceanography ...................................................................................................... 32

#### (2) Protected Areas .................................................................................................. 32

#### (3) Marine Mammals ............................................................................................... 33

##### 3. Mysticetes .......................................................................................................... 34

##### 4. Odontocetes ....................................................................................................... 37

### Sea Turtles ................................................................................................................... 46

##### 1. Leatherback Turtle ............................................................................................ 46

##### 2. Loggerhead Turtle ............................................................................................. 48

##### 3. Green Turtle ...................................................................................................... 49

##### 4. Hawksbill Turtle ............................................................................................... 50

##### 5. Kemp’s Ridley Turtle ......................................................................................... 51

### Seabirds ......................................................................................................................... 52

##### 1. Bermuda Petrel .................................................................................................. 52

##### 2. Black Capped Petrel ......................................................................................... 52
# Table of Contents

3. Roseate Tern

**Fish**

- 1. ESA-listed Species
- 2. Fish Habitats
- 3. Commercial Fisheries
- 4. Recreational Fisheries

**IV. ENVIRONMENTAL CONSEQUENCES**

- Proposed Action
- 1. Direct Effects on Marine Mammals and Sea Turtles and Their Significance
- 2. Mitigation Measures
- 3. Potential Numbers of Marine Mammals Exposed to Various Received Sound Levels
- 4. Conclusions for Marine Mammals and Sea Turtles
- 5. Direct Effects on Marine Invertebrates, Fish, Fisheries, and Their Significance
- 6. Direct Effects on Seabirds and Their Significance
- 7. Indirect Effects on Marine Mammals, Sea Turtles, Seabirds, Fish, and Their Significance
- 8. Cumulative Effects
- 9. Unavoidable Impacts
- 10. Coordination with Other Agencies and Processes

**Alternative Action: Another Time**

**No Action Alternative**

**V. LIST OF PREPARERS**

**VI. LITERATURE CITED**

**APPENDICES**

- Appendix A: Backup Configuration Information and Calculations
- Appendix B: Sound Exposure Levels (SEL): Scaling Analyses and All Results
- Appendix C: Supporting Documentation for Level A Acoustic Modeling
- Appendix D: Affected Environment Text
- Appendix E: Impact of Ship Noise
- Appendix F. Direct Effects
  - (a) Effects of Sound on Marine Invertebrates
  - (b) Effects of Sound on Fish
  - (c) Effects of Sound on Fisheries
- Appendix G. Other Effects
ABSTRACT

The U.S. Geological Survey (USGS) plans to conduct a seismic survey aboard the oceanographic research vessel R/V Hugh R. Sharp, owned by University of Delaware, in the northwestern Atlantic offshore the Mid-Atlantic Bight in August 2018. The survey will take place in the U.S. Exclusive Economic Zone (EEZ) in water depths of 100 to 3500 m from 35 nm south of Hudson Canyon to approximately Cape Hatteras. The seismic study will be conducted solely from the R/V Hugh R. Sharp using as seismic sources two to four GI airguns, each with a discharge volume of 105 in\(^3\). The GI guns will generate a total air volume of 420 in\(^3\) in the base configuration and 840 in\(^3\) in the so-called GG configuration, which could be used at water depths greater than 1000 m during recording of seismic arrivals on sonobuoys. A backup configuration would use only 2 GI guns, each firing at 105 in\(^3\).

The purpose of this survey is to acquire up to 2400 line-kilometers of modern multichannel seismic data to constrain the distribution of gas hydrates and shallow gas, particularly in areas considered highly prospective for methane hydrate deposits. The data would also be used to support USGS mission goals related to the study of submarine hazards (e.g., slides). The survey will fill a gap in modern seismic data on the Mid-Atlantic part of the margin and yield data that are likely to be used by the research community on a multidecadal time scale.

The USGS will be requesting an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental, i.e., not intentional, harassment of small numbers of marine mammals (should this occur) during the seismic survey. The information in this Environmental Assessment (EA) supports the IHA application process and provides information on marine species that are not addressed by the IHA application, including seabirds and sea turtles that are listed under the U.S. Endangered Species Act (ESA) and candidate species, fish, and Essential Fish Habitat (EFH). The EA explicitly addresses the requirements of the National Environmental Policy Act (NEPA). Alternatives addressed in this EA consist of conducting the same geophysical program at a different time, along with issuance of an associated IHA; and the no action alternative, with no IHA and no seismic survey.

In accordance with priorities articulated by the Council on Environmental Quality and the Secretary of the Interior in an order of August 2017, this EA attempts to streamline to the extent possible, while also providing a document complete enough to fully represent the Proposed Action. This EA is tiered to, and incorporates by reference, material from the Final 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 (NSF and USGS 2011; termed the NSF-USGS PEIS) and the corresponding USGS Record of Decision (2013). To reduce repetition among EAs for similar actions, portions of this EA (including this abstract) are adopted with small modifications or taken verbatim from the Draft EA prepared for the 2017 NSF-funded program for low-energy seismics to be conducted by Scripps Institute of Oceanography (LGL, 2017) in the Northwestern Atlantic. That Draft EA (LGL, 2017) is also incorporated herein by reference, as are other EAs produced for U.S. Atlantic margin projects conducted by NSF and the USGS since 2014.

Numerous species of marine mammals could be present in the proposed 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. ESA-listed sea turtle species that could occur in the project area include the endangered leatherback, hawksbill, Kemp’s ridley, and loggerhead (Northeast Atlantic Ocean Distinct Population Segment or DPS) turtles and the threatened green (North Atlantic DPS) and loggerhead (Northwest Atlantic Ocean DPS) turtles. ESA-listed seabirds that could be encountered in the area include the endangered Bermuda petrel, black capped petrel, and...
roseate tern. In addition, the *endangered* Atlantic sturgeon and shortnose sturgeon could be present, as well as the *threatened* giant manta ray and oceanic whitetip shark.

Potential impacts of the seismic survey on the environment would be primarily a result of the operation of the GI airguns. A 38 kHz fisheries sonar would also be operated during the surveys at water depths shallower than ~1800 m. Impacts that could be associated with particularly the airguns are mostly due to increased underwater noise, which may result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned survey is a monitoring and mitigation program designed to (a) minimize impacts of the proposed activities on marine animals present during the proposed research and (b) 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, including high-energy airgun arrays generating air volumes over five times as large as those planned for the Proposed Action. Nor are effects likely to be caused by the other type of sound source to be used. However, despite the relatively low levels of sound emitted the GI airguns, a precautionary approach would still be taken. The planned monitoring and mitigation measures would reduce the possibility of injurious effects.

Protection measures designed to mitigate the potential environmental impacts to marine mammals, sea turtles, and seabirds would include the following: ramp ups; typically two, but a minimum of one observer maintaining a visual watch during all daytime airgun operations; two observers 30 min before and during ramp ups during the day; no start ups during poor visibility or at night unless at least one airgun (mitigation gun) has been operating; and shut downs when marine mammals or sea turtles are detected in or about to enter designated exclusion zones. The acoustic source would also be powered or shut down in the event an ESA-listed seabird were observed diving or foraging within the designated exclusion zone. Observers would also watch for any impacts the acoustic sources may have on fish. The USGS is committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other environmental impacts. Survey operations would be conducted in accordance with all applicable U.S. 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 and turtle 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 may be interpreted as falling within the U.S. MMPA definition of “Level B Harassment” for those species managed by NMFS; however, the USGS is required to request, and NMFS may issue, Level A take for some marine mammal species. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats.
## LIST OF ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEP</td>
<td>Auditory evoked potential</td>
</tr>
<tr>
<td>AMVER</td>
<td>Automated Mutual-Assistance Vessel Rescue System</td>
</tr>
<tr>
<td>ArcGIS</td>
<td>Arc-Geographic Information Systems (software)</td>
</tr>
<tr>
<td>BOEM</td>
<td>Bureau of Ocean Energy Management</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CITIES</td>
<td>Convention on International Trade in Endangered Species</td>
</tr>
<tr>
<td>COSEWIC</td>
<td>Committee on the Status of Endangered Wildlife in Canada</td>
</tr>
<tr>
<td>COST</td>
<td>Continental offshore stratigraphic test</td>
</tr>
<tr>
<td>CPA</td>
<td>Closest point of approach</td>
</tr>
<tr>
<td>CPUE</td>
<td>Catch per unit effort</td>
</tr>
<tr>
<td>CTD</td>
<td>Conductivity-temperature-depth sensor</td>
</tr>
<tr>
<td>DAA</td>
<td>Detailed Analysis Area (from the NSF-USGS PEIS)</td>
</tr>
<tr>
<td>dB</td>
<td>decibel</td>
</tr>
<tr>
<td>DD</td>
<td>data deficient</td>
</tr>
<tr>
<td>DE</td>
<td>Delaware</td>
</tr>
<tr>
<td>DOE</td>
<td>U.S. Department of Energy</td>
</tr>
<tr>
<td>DoW</td>
<td>Defenders of Wildlife</td>
</tr>
<tr>
<td>DPS</td>
<td>distinct population segment</td>
</tr>
<tr>
<td>DSV</td>
<td>Deep Submergence Vehicle</td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Assessment</td>
</tr>
<tr>
<td>EBSA</td>
<td>Ecologically or Biologically Significant Area</td>
</tr>
<tr>
<td>ECS</td>
<td>Extended Continental Shelf</td>
</tr>
<tr>
<td>EDGE</td>
<td>NSF-funded Mid-Atlantic seismic experiment 1990</td>
</tr>
<tr>
<td>EEZ</td>
<td>Exclusive Economic Zone</td>
</tr>
<tr>
<td>EFH</td>
<td>Essential Fish Habitat</td>
</tr>
<tr>
<td>EIS</td>
<td>Environmental Impact Statement</td>
</tr>
<tr>
<td>EN</td>
<td>Endangered</td>
</tr>
<tr>
<td>ENAM</td>
<td>Eastern North American Margin (2014 NSF-funded seismic experiment)</td>
</tr>
<tr>
<td>ESA</td>
<td>(U.S.) Endangered Species Act</td>
</tr>
<tr>
<td>EZ</td>
<td>Exclusion Zone</td>
</tr>
<tr>
<td>GARFO</td>
<td>Greater Atlantic Regional Fishery Office (NOAA)</td>
</tr>
<tr>
<td>GG</td>
<td>Generator-generator mode on a GI gun</td>
</tr>
<tr>
<td>GI</td>
<td>Generator-Injector</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GOM</td>
<td>Gulf of Mexico</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HAPC</td>
<td>Habitat of Particular Concern</td>
</tr>
<tr>
<td>HF</td>
<td>High Frequency</td>
</tr>
<tr>
<td>IHA</td>
<td>Incidental Harassment Authorization (under MMPA)</td>
</tr>
<tr>
<td>IHAA</td>
<td>IHA Application</td>
</tr>
<tr>
<td>IMG</td>
<td>Imagine raster file</td>
</tr>
<tr>
<td>IODP</td>
<td>Integrated Ocean Drilling Program</td>
</tr>
<tr>
<td>ITS</td>
<td>Incidental Take Statement</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>IUCN</td>
<td>International Union for the Conservation of Nature</td>
</tr>
<tr>
<td>IWC</td>
<td>International Whaling Commission</td>
</tr>
<tr>
<td>kHz</td>
<td>kiloHertz</td>
</tr>
<tr>
<td>kJ</td>
<td>kiloJoule</td>
</tr>
<tr>
<td>km</td>
<td>kilometer</td>
</tr>
<tr>
<td>kt</td>
<td>knot</td>
</tr>
<tr>
<td>LC</td>
<td>Least Concern</td>
</tr>
<tr>
<td>L-DEO</td>
<td>Lamont-Doherty Earth Observatory</td>
</tr>
<tr>
<td>LF</td>
<td>Low Frequency</td>
</tr>
<tr>
<td>LORAN</td>
<td>long-range navigation</td>
</tr>
<tr>
<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>MAB</td>
<td>Mid-Atlantic Bight</td>
</tr>
<tr>
<td>MAFMC</td>
<td>Mid-Atlantic Fishery Management Council</td>
</tr>
<tr>
<td>MATRIX</td>
<td><strong>Proposed Action: Mid-Atlantic Resource Imaging Experiment (USGS 2018)</strong></td>
</tr>
<tr>
<td>MCS</td>
<td>multichannel seismic</td>
</tr>
<tr>
<td>MD</td>
<td>Maryland</td>
</tr>
<tr>
<td>MDAT</td>
<td>Marine-life Data and Analysis Team</td>
</tr>
<tr>
<td>MMPA</td>
<td>(U.S.) Marine Mammal Protection Act</td>
</tr>
<tr>
<td>MPA</td>
<td>Marine Protected Area</td>
</tr>
<tr>
<td>MRFSS</td>
<td>Marine Recreational Fisheries Statistics Survey (NMFS)</td>
</tr>
<tr>
<td>MRIP</td>
<td>Marine Recreational Information Program (NMFS)</td>
</tr>
<tr>
<td>NAMMCO</td>
<td>North Atlantic Marine Mammal Commission</td>
</tr>
<tr>
<td>NAMSS</td>
<td>National Archive of Marine Seismic Surveys (walrus.wr.usgs.gov/NAMSS/)</td>
</tr>
<tr>
<td>NC</td>
<td>North Carolina</td>
</tr>
<tr>
<td>NEFSC</td>
<td>Northeast Fisheries Science Center</td>
</tr>
<tr>
<td>NEPA</td>
<td>(U.S.) National Environmental Policy Act</td>
</tr>
<tr>
<td>NJ</td>
<td>New Jersey</td>
</tr>
<tr>
<td>NL</td>
<td>not listed (for ESA)</td>
</tr>
<tr>
<td>NMFS</td>
<td>(U.S.) National Marine Fisheries Service</td>
</tr>
<tr>
<td>NOAA</td>
<td>(U.S.) National Oceanographic and Atmospheric Administration</td>
</tr>
<tr>
<td>NODES</td>
<td>(U.S.) Navy OPAREA Density Estimates</td>
</tr>
<tr>
<td>NOPP</td>
<td>National Oceanographic Partnership Program</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>NY</td>
<td>New York</td>
</tr>
<tr>
<td>OBIS</td>
<td>Ocean Biographic Information System</td>
</tr>
<tr>
<td>ODP</td>
<td>Ocean Drilling Program</td>
</tr>
<tr>
<td>OEIS</td>
<td>Overseas Environmental Impact Statement</td>
</tr>
<tr>
<td>OPR</td>
<td>Office of Protected Resources (NMFS)</td>
</tr>
<tr>
<td>OW</td>
<td>Otariids underwater</td>
</tr>
<tr>
<td>p or pk</td>
<td>peak</td>
</tr>
<tr>
<td>PEIS</td>
<td>Programmatic Environmental Impact Statement</td>
</tr>
<tr>
<td>PTS</td>
<td>Permanent Threshold Shift</td>
</tr>
<tr>
<td>PSO</td>
<td>Protected Species Observer</td>
</tr>
<tr>
<td>PW</td>
<td>Phocids underwater</td>
</tr>
<tr>
<td>QAA</td>
<td>Qualitative Analysis Area</td>
</tr>
<tr>
<td>rms</td>
<td>root-mean-square</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>ROD</td>
<td>Record of Decision</td>
</tr>
<tr>
<td>ROV</td>
<td>Remotely-operated vehicle</td>
</tr>
<tr>
<td>R/V</td>
<td>Research vessel</td>
</tr>
<tr>
<td>s</td>
<td>second</td>
</tr>
<tr>
<td>SAFMC</td>
<td>South Atlantic Fishery Management Council</td>
</tr>
<tr>
<td>SEL</td>
<td>Sound Exposure Level</td>
</tr>
<tr>
<td>SIGH</td>
<td>Seismic Imaging of Gas Hydrate (USGS Gulf of Mexico, 2013)</td>
</tr>
<tr>
<td>SIO</td>
<td>Scripps Institute of Oceanography</td>
</tr>
<tr>
<td>SL</td>
<td>Sound level</td>
</tr>
<tr>
<td>SPL</td>
<td>Sound pressure level</td>
</tr>
<tr>
<td>TED</td>
<td>turtle excluder device</td>
</tr>
<tr>
<td>TEWG</td>
<td>Technical Expert Working Group—Greater Atlantic Regional Fisheries</td>
</tr>
<tr>
<td>TTS</td>
<td>Temporary Threshold Shift</td>
</tr>
<tr>
<td>UNOLS</td>
<td>University-National Oceanographic Laboratory System</td>
</tr>
<tr>
<td>U.S.</td>
<td>United States of America</td>
</tr>
<tr>
<td>USGS</td>
<td>U.S. Geological Survey</td>
</tr>
<tr>
<td>USFWS</td>
<td>U.S. Fish and Wildlife Service</td>
</tr>
<tr>
<td>μPa</td>
<td>microPascal</td>
</tr>
<tr>
<td>VA</td>
<td>Virginia</td>
</tr>
<tr>
<td>VU</td>
<td>vulnerable</td>
</tr>
</tbody>
</table>
I. PURPOSE AND NEED

This Environmental Analysis (EA) provides information needed to assess the potential environmental impacts associated with the U.S. Geological Survey’s (USGS’s) Proposed Northwest Atlantic Action, which includes the use of as many as four Generator-Injector (GI) airguns operated mostly at 420 to 840 in3 during seismic surveying in August 2018. The EA was prepared under the National Environmental Policy Act (NEPA). In accordance with CFR §46.120 and §46.140, this EA tiers to the Final Programmatic Environmental Impact Statement (EIS)/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; henceforth referred to as the NSF-USGS PEIS) and USGS Record of Decision on the NSF-USGS PEIS (USGS, 2013; henceforth referred to as the USGS ROD). This draft EA incorporates by reference the “Draft Environmental Analysis of a Low-Energy Marine Geophysical Survey by R/V Atlantis in the Northwest Atlantic Ocean, June-July 2018,” (LGL Report FAO139-1, 2017) as prepared for Scripps Institute of Oceanography and the National Science Foundation and as submitted to NMFS in December 2017.” That Draft EA is henceforth referred to at the “Draft Scripps EA (LGL, 2017).” Long passages of this EA are taken verbatim from the Draft Scripps EA or used verbatim with small modifications to represent the USGS activity. Passages from other EAs prepared for research seismic programs on the U.S. Atlantic margin are also used here verbatim or with small modifications.

This 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, as well as other species of concern in the area, including sea turtles, seabirds, fish, and marine invertebrates. The Draft EA will also be used in support of an application for an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service (NMFS) and Section 7 consultations under the Endangered Species Act (ESA). The requested IHA would, if issued, allow the non-intentional, non-injurious “take by harassment” of small numbers of marine mammals during the proposed seismic surveys conducted by the USGS on R/V Hugh R. Sharp in the Northwest Atlantic Ocean during August 2018. Per NMFS requirement, small numbers of 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.

To be eligible for an IHA under the U.S. 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.

Mission of the U.S. Geological Survey

The U.S. Geological Survey (USGS) is a science mission agency within the U.S. Department of the Interior and has no regulatory responsibility. The USGS mission is to “provide reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.” The objectives of this proposed seismic research program also coincide with the goals articulated in the USGS Energy and Minerals Science Strategy (Ferrero et al., 2012). This strategy states that the USGS conducts research to enhance understanding of the geologic occurrence, formation, and evolution of oil, gas, coal, and uranium resources. The USGS is responsible for applying the results of this research to the assessment of the economic
and environmental impact of development of these resources and making this knowledge public. As an agency whose mission is entirely scientific, the USGS has no authority to exploit natural resources.

Purpose of and Need for the Proposed Action

The USGS intends to conduct a seismic survey aboard the R/V Hugh R. Sharp, a University National Oceanographic Laboratory (UNOLS) federal fleet vessel that is owned and operated by the University of Delaware, during a cruise up to 22 days long on the northern U.S. Atlantic margin in August 2018. The program is named MATRIX, for “Mid-Atlantic Resource Imaging Experiment.” The seismic survey will take place in water depths ranging from ~100 m to 3500 m, entirely within the U.S. Exclusive Economic Zone (EEZ), and acquire dip lines (roughly perpendicular to the orientation of the shelf-break) and strike lines (roughly parallel to the shelf-break) roughly between 35 nm south of Hudson Canyon on the north and Cape Hatteras on the south (Figure 1).

The purpose of the Proposed MATRIX Action is to collect data to constrain the lateral and vertical distribution of gas hydrates and shallow natural gas in marine sediments relative to seafloor gas seeps, slope failures, and geological and erosional features. The Proposed Action would be conducted in partial fulfillment of the scientific objectives of the USGS Gas Hydrates Project, which has contributed to the advancement of the understanding of natural gas hydrate systems at the national and international level for more than three decades. The USGS Gas Hydrates Project is jointly supported by the USGS Coastal and Marine Geology Program in the Natural Hazards Mission and by the USGS Energy Resources Program within the Energy and Minerals Mission.

The Proposed Action is primarily funded by the USGS Coastal and Marine Geology Program, and the USGS is the action agency responsible for planning the activity, conducting the work at sea, and processing the data after the cruise. Additional funding is provided by the Resource Evaluation Division of the Bureau of Ocean Energy Management (BOEM), U.S. Department of the Interior, and the U.S. Department of Energy’s National Energy Technology Laboratory, which manages the National Methane Hydrates R&D Program. BOEM has a long history of involvement in assessing gas hydrate resources (e.g., BOEM, 2012a) and participating in activities to investigate the resource potential of these deposits in the northern Gulf of Mexico and on the Atlantic, and Pacific. The U.S. DOE has been the agency charged with implementing the National Methane Hydrates Act of 2000 and its renewal in 2005.

The need for this activity is related to the inadequacy of existing seismic data to characterize geologic structures and shallow gas and gas hydrate deposits within the study area. The proposed survey fills a gap in modern multichannel seismic data (MCS) between roughly 36.2°N (surveyed by the NSF Eastern North American Margin (ENAM) project in 2014; RPS, 2014c) and 39.2°N (surveyed by the USGS Extended Continental Shelf in 2014; RPS, 2014a). In the area of the proposed survey, the most recent non-industry airgun surveys were acquired by the USGS in the 1970s and earliest 1980s with the exception of the NSF-funded EDGE survey, which was acquired in 1990. Into the early 1980s, industry acquired a dense series of airgun surveys in the proposed study area. These data, which have been released by the Bureau of Ocean Energy Management (BOEM) through the USGS National Archive of Marine Seismic Surveys (Trienzenberg et al., 2016; NAMSS; walrus.er.usgs.gov/NAMSS/), extend seaward to only ~2000 m water depth in most cases, suffer from irreconcilable navigation errors for some surveys, often lack velocity control, and are typically of such poor quality that features related to gas hydrates cannot be easily delineated or traced laterally. The modern airgun data that the USGS would collect as part of the Proposed Action will be acquired using state-of-the-art source and receiver technology and modern navigation techniques and will extend the seaward reach of high-quality MCS data to 3500 m water depth. If these data are not acquired, most of the mid-Atlantic part of the U.S. Atlantic margin will remain characterized only by seismic information that is 35 to 45 years old. Thus, this Proposed Action fills a national need for better characterization of the U.S. Atlantic continental margin.
Background for USGS Marine Seismic Research

The background for USGS-led and NSF-funded marine seismic research is described in § 1.6 of the NSF-USGS PEIS.

Regulatory Setting

The regulatory setting of this EA is described in § 1.8 of the NSF-USGS PEIS, including
- National Environmental Protection Act (NEPA);
- Marine Mammal Protection Act (MMPA); and
- Endangered Species Act (ESA).

Figure 1. Exemplary seismic lines (yellow) to be acquired by the USGS during the Proposed Action, superposed on the USGS high-resolution bathymetric grid (Andrews et al., 2016). Red dashed lines are linking/transit/interseismic lines, and data will be acquired along only half of these lines. The dashed curve on the right side denotes the EEZ.
II. ALTERNATIVES INCLUDING PROPOSED ACTION

In this Draft EA, three alternatives are evaluated: (1) the proposed seismic survey and issuance of an associated IHA; (2) a corresponding seismic survey at an alternative time, along with issuance of an associated IHA; and (3) no action alternative. Additionally, two alternatives were considered but were eliminated from further analysis. A summary table of the proposed action, alternatives, and alternatives eliminated from further analysis is provided at the end of this section.

Proposed Action

The project objectives and context, activities, and mitigation measures for USGS’s planned seismic survey are described in the following subsections.

(1) Project Objectives and Context

USGS scientists propose to conduct a seismic survey (MATRIX) in the northwest Atlantic Ocean (Fig. 1) to acquire data on ~6 exemplary dip lines (down the continental slope) and ~3 exemplary strike lines parallel to the shelf-break from the R/V Hugh R. Sharp. The goal of the proposed research is to characterize marine gas hydrates and associated shallow free gas deposits and their connection to widespread seafloor methane seepage, large-scale slope failures and erosional processes, and other geological features. To achieve the program’s goals, Drs. Carolyn Ruppel and Nathan C. Miller, both of the USGS Woods Hole Coastal and Marine Science Center, propose to collect up to 9 long (80 nm or more) high-resolution MCS profiles and linking/transit/interseismic lines constituting up to ~2400 km total of new seismic data.

(2) Proposed Activities

(a) Location of the Activities

The survey is bound within the region ~34.75ºN–40ºN, ~71–75ºW in the northwest Atlantic Ocean (Fig. 1), with the closest approach to the U.S. coastline 70 km (North Carolina) to 130 km (New Jersey). The survey area starts 35 nm south of Hudson Canyon on the north and is bound by Cape Hatteras on the south, the nominal shelf break (~100 m water depth) on the west, and the ~3500 m bathymetric contour on the east. The seismic survey will be conducted entirely within the U.S. EEZ, with airgun operations scheduled to occur for up to 19 days of a cruise that may be as long as 22 days, departing port on August 8, 2018. Some minor deviation from these dates is possible, depending on logistics and especially weather.

(b) Description of the Activities

The survey will involve one source vessel, the R/V Hugh R. Sharp. The source vessel will deploy two to four low-energy Generator-Injector (GI) airguns (each has discharge volume of 105 in³) as an energy source. An 120-channel, 1.2-km-long hydrophone streamer will be continuously towed to receive the seismic signals. In addition, up to 90 disposable sonobuoy receivers will be deployed only at water depths greater than 1000 m to provide velocity control and possibly wide-angle reflections along the highest priority transects.

The energy to the airguns is compressed air supplied by compressors on board the source vessel. As the airguns are towed along the survey lines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the on-board processing system. The sonobuoys, which will be deployed as frequently as every 15 km along high-priority lines, record the returning acoustic signals at larger offsets than are possible with the streamer and transmit the information at radio frequencies to receivers on the ship. A maximum of ~2400 km of data will be collected (Fig. 1). Most lines are oriented subperpendicular to the strike of the
margin (dip lines), but data will be acquired along some linking/interseismic lines oriented roughly parallel to the margin (strike lines) and along short strike interseismic/linking lines that connect the dip lines. Table 1 summarizes the survey plan.

The **Optimal Survey** for the Proposed Action would acquire the portion of the solid lines greater than 1000 m water depth as shown in Figure 1 using the GI-guns in “GG” mode. In this mode, the 4 GI guns would produce a total of 840 in³ of air (see (e) below), and sonobuoys would be deployed to passively record data at long distances. The rest of the survey, including the portion shallower than 1000 m water depth on the uppermost slope and the interseismic linking lines (dashed red in Figure 1), would be acquired with 4 GI guns operated in normal mode, producing a total of 420 in³ of air.

The **Base Survey** assumes that all of the solid lines in Figure 1, as well as all of the interseismic connecting lines, would be acquired using 4 GI guns operating in GI mode (see (e) below), producing a total air volume of 420 in³.

Note that only a maximum of half of the dashed lines in Figure 1 would be acquired and that these lines are longer and geometrically more complex at the deepwater side than near the shelf-break. To allow operational flexibility, takes are calculated in this EA assuming **all** of the linking/interseismic lines would be shot, yielding an overestimate of takes, but also ensuring that the linking lines that make the most sense based on weather, sea state, and other logistical considerations could be the ones actually completed.

Table 1. General characteristics of exemplary survey scenarios for the Proposed Action.

<table>
<thead>
<tr>
<th></th>
<th>GI mode (4x105 in³)</th>
<th>GG mode (4x210 in³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optimal Survey</strong></td>
<td>100-1000 m water depth on exemplary lines AND 50% of interseismic, linking lines</td>
<td>~750 km Greater than 1000 m on exemplary lines</td>
</tr>
<tr>
<td><strong>Base Survey</strong></td>
<td>Exemplary lines plus 50% of interseismic, linking lines</td>
<td>2350 km</td>
</tr>
</tbody>
</table>

During the cruise, the USGS would continuously use its fisheries echosounder (EK60/EK80) with 38 kHz transducer at water depths less than ~1800 m to locate water column anomalies associated with seafloor seeps emitting gas bubbles. The 38 kHz transducer would be mounted in the *R/V Sharp*’s retractable keel and would typically ping 0.5 to 2 Hz with pings of 0.256 to 1.024 ms duration. The returned signals would be detected on an EK60 or EK80 (broadband) transceiver. Based on past USGS experience with this instrument, it is unlikely to acquire useful data at water depths greater than 1800 m, although it could be used in passive mode at these depths to record broadband ambient signals in the water column.

All planned geophysical data acquisition activities would be conducted by the USGS PIs, technical staff, and marine operations group, with support from UNOLS technical staff for use of borrowed streamer sections. The vessel will be self-contained, and the scientific party and crew will live aboard the vessel for the entire cruise.

**(c) Schedule**

The survey would commence on 8 August and may continue as long as 26 August. Total time during which the airguns would be fired is anticipated to be < 390 hours. The remainder of the cruise would consist of transits, including transits to refuel once or twice at either Norfolk or Lewes, Delaware, depending on the...
combined fuel needs of the ship and the compressors. The exact dates of the activities depend on logistics and weather conditions.

(d) Source Vessel Specifications

The R/V Hugh R. Sharp would be used for this survey. The R/V Hugh R. Sharp has an overall length of 46 m, a beam of 9.8 m, and a full load draft of 2.95 m (3.9 m with retractable keel positioned at 1 m down). The vessel is equipped with four Cummins KTA-19D diesel engines. Diesel-electric power is provided by two Schottel SRP 330 Z-drives. The ship also has a Schottel tunnel bow thruster operated with the S Green dynamic positioning system. An operation speed of up to ~7.4 km/h (4 kt) will be used during seismic acquisition. When not towing seismic survey gear, the R/V Hugh R. Sharp typically cruises at 14.8 to 16.7 km/h (8-9 kt). It has a normal operating range of ~6500 km (~3500 nm).

The R/V Hugh R. Sharp will also serve as the platform from which vessel-based protected species observers (PSOs) will watch for marine mammals and sea turtles before and during airgun operations. The PSO platform is an area covered by an awning and equipped with chairs and Big Eye binocular stands, located on the flying bridge of the R/V Hugh R. Sharp, 10.6 m above the water’s surface. This area has previously been used by NMFS scientists for beaked whale observations during research cruises (e.g., Cholewiak, September 2017). The vantage point provides a 360° view of the water’s surface. During inclement weather too challenging to remain on the flying bridge, the PSOs have access to the bridge of the vessel for their activities. In addition, crew members on the bridge and on other parts of the vessel will be instructed to keep a watch for protected species.

Other details of the R/V Hugh R. Sharp include the following:

<table>
<thead>
<tr>
<th>Details</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>University of Delaware</td>
</tr>
<tr>
<td>Operator</td>
<td>University of Delaware</td>
</tr>
<tr>
<td>Flag</td>
<td>United States of America</td>
</tr>
<tr>
<td>Launch Date</td>
<td>2006</td>
</tr>
<tr>
<td>Domestic Tonnage</td>
<td>256 T</td>
</tr>
<tr>
<td>Accommodation Capacity</td>
<td>22, including 14 scientists</td>
</tr>
</tbody>
</table>

(e) Airgun Description

The R/V Hugh R. Sharp will tow two or four 105-in³ Sercel generator-injector (GI) airguns at a time as the primary energy source following exemplary survey lines and transit/linking/interseismic lines between the primary exemplary lines. Seismic pulses for the GI guns will be emitted at intervals of ~12 s. At speeds of ~7.4 km/h (4 kt), the shot intervals correspond to a spacing of ~25 m.

In standard GI mode, the generator chamber of each GI airgun is the primary source, the one responsible for introducing the sound pulse into the ocean, is 105 in³. The 105 in³ injector chamber injects air into the previously-generated bubble to reduce bubble reverberations and does not introduce more sound into the water. When shooting to sonobuoys during the Proposed Action, the GI guns will also sometimes be operated with both chambers releasing air simultaneously (i.e., “generator-generator” or “GG” mode). In GG mode, each gun simultaneously releases an air volume of 105 in³ + 105 in³ = 210 in³. On this cruise, four GI guns will be operated either in base mode (4x105 in³) or GG mode (4x210 in³) as long as compressors are functioning correctly. If compressors are not functioning properly, a backup mode consisting of two GI guns will be used. The backup mode is described in Appendix A. The text below describes the two preferred modes for operations.
The **Base Configuration, Configuration 1**, will use 4 GI guns and generate 420 in\(^3\) total volume, as shown in Figure 2. Guns will be towed at 3 m water depth, two on each side of the stern, with 8.6 m lateral (athwartships) separation between the pairs of guns and 2 m front-to-back separation between the guns on each stern tow line.

![Figure 2. Base configuration (Source configuration 1): 420 in\(^3\) total volume consisting of 4x105/105in\(^3\) GI guns (S#G*, where # is the side and * is the gun number) firing in standard GI mode.](image)

The **GG Configuration, Configuration 2**, will use 4 GI guns and generate 840 in\(^3\) total volume, as shown in Figure 3. In this configuration, the guns will be fired in GG mode, as described above. Guns will be towed at 3 m water depth, two on each side of the stern, with 8.6 m lateral (athwartships) separation between the pairs of guns and 2 m front-to-back separation between the guns on each stern tow line. The GG configuration would be used **only at greater than 1000 m water depth** and on specific exemplary lines on which sonobuoy data are being collected.
As the GI airguns are towed along the survey line, the towed hydrophone array receives the reflected signals and transfers the data to the on-board processing system. Given the short streamer length behind the vessel (1200 m), the turning rate of the vessel while the gear is deployed is much higher than the limit of five degrees per minute for a seismic vessel towing a streamer of more typical length (e.g., 6 km or more). Thus, the maneuverability of the vessel is not strongly limited during operations.

**GI Airgun Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Source</td>
<td>Two (backup configuration, Appendix A) to four (base and GG configuration) GI airguns of 105 in³ each</td>
</tr>
<tr>
<td>Tow depth of energy source</td>
<td>3 m</td>
</tr>
<tr>
<td>Air discharge volume</td>
<td>Total volume ~210 in³ (backup configuration, Appendix A) to 840 in³ (limited use GG configuration at greater than 1000 m)</td>
</tr>
<tr>
<td>Back-to-front separation of pairs of guns</td>
<td>2 m</td>
</tr>
<tr>
<td>Side-to-side separation of pairs of guns</td>
<td>8.6 m</td>
</tr>
<tr>
<td>Dominant frequency components</td>
<td>0–188 Hz</td>
</tr>
</tbody>
</table>

Figure 3. GG Configuration (Source configuration 2): 840 in³ total volume consisting of 4x105/105 in³ GI guns firing both chambers simultaneously (i.e. GG mode). Guns are labelled as S#G*, where # is the side and * is the gun number.
The source levels for the GI gun configurations can be derived from the modeled farfield source signature, which was determined for the USGS by L-DEO using the PGS Nucleus software. Modeling information is provided below, with more complete details in Appendices B and C.

(f) Sonobuoy Description and Deployment

The Proposed Action would deploy up to 72 disposable sonobuoys from the R/V Hugh R. Sharp during surveys along higher priority seismic lines at water depths greater than 1000 m (Fig. 1). These sonobuoys consist of hydrophones suspended ~30-90 m below the surface from a free-floating buoy. Data are transmitted to the ship via radio frequency.

(g) EK60/80 Fisheries Split-Beam Echosounder (38 kHz)

During the cruise, the USGS would continuously monitor the water column at water depths less than 1800 m using its EK80 broadband transceiver or an EK60 transceiver. The active acoustic component is a 38 kHz split-beam transducer mounted in the retractable keel of the R/V Hugh R. Sharp. These sources have been extensively used in fisheries science for estimating biomass and are routinely used by NOAA, the USGS, and other research agencies for detecting fish, whales, and water column anomalies, such as bubbles emitted from the seafloor at seeps. The sound source level for the EK60/80 transducers is nominally 228 dB/1 µPa. Modeling of the 38 kHz signal yields the sound pressure levels (SPL) shown in Figure 4. The area ensonified at >160 dB is 0.0407 km², corresponding to a maximum of ~72 m athwartship and ~650 m below the ship.

![Figure 4. 160 dB SEL modeled for the 38 kHz transducer for the EK60/EK80 system.](image)

(3) Monitoring and Mitigation Measures

Section § 2.4.4.1 of the NSF-USGS PEIS describes standard monitoring and mitigation measures for seismic surveys and the two phases: pre-cruise planning and during operations. The sections below describe the measures taken in each phase for the 2018 USGS Proposed Action. Some of the text below is adapted or taken verbatim from the Draft Scripps EA (LGL, 2017).
(a) Planning Phase

The initial mitigation of the impacts of the Proposed Action occurred during planning.

Energy Source.—The energy source was chosen to be the lowest practical to meet the scientific objectives. Since the dataset to be acquired during MATRIX (Proposed Action) is expected to be used for 30 years or more, the USGS also assessed how to minimize the source size while ensuring maximum penetration, highest resolution, and appropriate imaging of the hydrate stability zone and shallow natural gas distributions and to produce data of high enough quality for the results to still be considered useful in the multidecadal timeframe. The USGS settled on a range of sources and potential configurations, with the base configuration of four airguns operated at 105 in^3. The largest source that could be used is four airguns operated at 210 in^3 and towed at 3 m depth, which would be used only at water depths > 1000 m when recording data on sonobuoys. The total air volume associated with these sources is ~6 to 17% of those used for most modern 2D and 3D seismic programs (usually > 6000 in^3).

Survey Timing.—When choosing the timing of the survey, the USGS took into consideration environmental conditions (e.g., the seasonal presence of marine mammals), weather, vessel availability, and optimal timing for this and other proposed research cruises on the R/V Hugh R. Sharp. Some marine mammal species are expected to occur in the area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species.

Mitigation Zones.

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion and safety zones. Received sound levels have been predicted by L-DEO’s model (Diebold et al. 2010, provided as Appendix H in the NSF-USGS PEIS), as a function of distance from the airguns, for the three potential airgun configurations: (1) Base configuration: 4 GI guns producing a total of 420 in^3 of air; (2) GG configuration: 4 GI guns producing a total of 840 in^3 of air, which will be used only to shoot to sonobuoys along certain lines at water depths greater than 1000 m; and (3) Backup configuration: 2 GI guns producing a total of 210 in^3 of air. To streamline this Draft EA, all information about the backup configuration has been moved to Appendix A.

The L-DEO 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 (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

For deep and intermediate-water cases, the field measurements in the Gulf of Mexico cannot be easily used to derive mitigation radii. This is due to the fact that, at those sites, the calibration hydrophone for the 36-gun study 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. Figures 2 and 3 in Appendix H of the NSF-USGS 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 NSF-USGS 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 NSF-USGS 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 NSF-USGS 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 NSF-USGS PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) for the 36-airgun array at a tow depth of 6 m can be used to derive mitigation radii. (Note, however, that none of the Proposed Action would be carried out at less than 100 m water depth.)

The proposed survey would acquire data with up to four airguns, each with 210 in³ of air, operated at a tow depth of 3 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 (Figures 5 through 7). 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 NSF-USGS PEIS).

Although the USGS does not intend to operate the source at less than 100 m water depth, shallow-water radii were still calculated by scaling the empirically derived measurements from the GoM calibration survey (Appendix B) to account for the differences in volume and tow depth between the calibration survey (6600 cu.in at 6 m tow depth) and the proposed surveys (three different configurations; backup configuration information is Appendix A); whereas the shallow water GOM may not exactly replicate the shallow water environment at the proposed survey sites, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths derived from the deep-water L-DEO model. These isopleths are essentially a measure of the energy radiated by the source array

For the **Base Configuration** (Configuration 1):

- the 150-decibel (dB) Sound Exposure Level (SEL)\(^1\) corresponds to deep-water maximum radii of 1090.6 m for the four 105 in³ airguns at 3 m tow depth (Fig. 5), and 7,244 m for the 6600 in³ airgun array at 6-m tow depth (Appendix B), yielding scaling factors of 0.151 to be applied to the shallow-water 6-m tow depth results.
- the 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 193.94 m for the four 105 in³ airguns at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.151 to be applied to the shallow-water 6-m tow depth results.

---

\(^1\) SEL (measured in dB re 1 \(\mu\)Pa\(^2\) · s) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO’s model.
- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 109.72 for the four 105 in³ airguns at 3 m tow depth (Fig. 2) and 719 m for the 6600 in³ at 6-m tow depth (Fig. 4), yielding the same 0.152 scaling factor.

- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 19.89 m for the four 105 in³ at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.157 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 190- and 195-dB re 1µPa rms distances in shallow water for the 36-airgun R/V Langseth array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the USGS Proposed Action Base Configuration, the 420 cu.in airgun array at 3 m tow depth yields distances of 2.642 km, 429 m, 243 m, 71 m and 38 m, respectively.

For the GG Configuration (Configuration 2):

- the 150-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 1,244 m for the four 210 in³ airguns at 3 m tow depth (Fig. 6), and 7,244 m for the L-DEO 6600 in³ airgun array at 6-m tow depth (Fig. 8), yielding scaling factors of 0.172 to be applied to the shallow-water 6-m tow depth results.

- the 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 219.54 m for the four 210 in³ airguns at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.171 to be applied to the shallow-water 6-m tow depth results.

- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 124.72 for the four 210 in³ airguns at 3 m tow depth (Fig. 2) and 719 m for the 6600 in³ at 6-m tow depth (Fig. 4), yielding the same 0.173 scaling factor.

- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 22.69 m for the four 210 in³ at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.179 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1µPa rms distances in shallow water for the 36-airgun R/V Langseth array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 840 cu.in airgun array at 3 m tow depth yields distances of 3.01 km, 485 m, 277 m, 80 m and 43 m, respectively.

Information for the Backup Configuration is given in Appendix A.
Figure 5. Modeled deep-water received sound exposure levels (SELs) from the Base Configuration (Configuration 1; four 105 in² GI-guns) towed at 3-m depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths, respectively. The top diagram is a blow-up of the bottom one.
Figure 6. Modeled deep-water received sound exposure levels (SELS) from the GG configuration (Configuration 2), with four 210 in³ GI-guns towed at 3-m depth and generating a total of 840 in³. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths, respectively. The upper plot is a zoomed-in version of the lower plot.
Table 2 shows the distances at which the 160- and 175-dB re 1µPa rms sound levels are expected to be received for the Base and GG source configurations. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals; a 175-dB level is used by the National Marine Fisheries Service (NMFS) to determine behavioral disturbance for sea turtles.

It should be noted that the RMS (root mean square; average pressure over a pulse duration) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak (p or 0–p) or peak to peak (p–p) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature. A measured received sound pressure level (SPL) of 160 dB re 1 µPa rms in the far field would typically correspond to ~170 dB re 1 µPa p or 176–178 dB re 1 µPa p–p, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

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 *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, analysis (Crone et al., 2017) of data collected 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 the *Langseth* hydrophone streamer were similarly 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 have confirmed that the L-DEO model generated conservative exclusion zones, resulting in significantly larger EZs than necessary.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. In July 2015, NOAA published a revised version of its 2013 draft guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2015). At the time of preparation of this Draft EA, the content of the final guidelines and how they would be implemented are uncertain. As such, this Draft EA has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Enforcement of mitigation zones via power ramp-up procedures and shut downs would be implemented in the Operational Phase.

---

2 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 2015, L-DEO, pers. comm.)
II. Alternatives Including Proposed Action

Table 2. Predicted distances to which sound levels ≥ 175- and 160-dB re 1 μPa rms would be expected to be received during the proposed surveys in the Northwest Atlantic Ocean for the Base and GG configuration. Refer to Appendix A for the Backup Configuration. The Proposed Action would not involve ensonifying the seafloor at water depths shallower than 100 m. Further calculations and information are given in Appendix B.

<table>
<thead>
<tr>
<th>Source and Volume</th>
<th>Tow Depth (m)</th>
<th>Water Depth (m)</th>
<th>Predicted RMS Radii (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>175 dB</td>
<td>160 dB</td>
</tr>
<tr>
<td><strong>Base Configuration</strong> (Configuration 1) Four 105 in³ G-guns</td>
<td>3</td>
<td>&gt;1000 m</td>
<td>194$^1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>291$^2$</td>
</tr>
<tr>
<td><strong>GG Configuration</strong> (Configuration 2) Four 210 in³ G-guns</td>
<td>3</td>
<td>&gt;1000 m</td>
<td>220$^1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>330$^2$</td>
</tr>
</tbody>
</table>

$^1$ Distance is based on L-DEO model results.
$^2$ Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
$^3$ Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.

In July 2016, the National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service (NMFS) released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a). 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). Onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{cum}$ and SPL$_{flat}$, respectively. For impulsive sounds, such airgun pulses, the new guidance incorporates marine mammal auditory weighting functions (Fig. 4) 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). As required by NMFS (2016a), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) would be used as the EZ and for calculating takes. For LF cetaceans the PTS SEL$_{cum}$ criterion is used. For MF and HF cetaceans, the Peak SPL$_{flat}$ yields a larger exclusion zone and is therefore used. Pinnipeds are not considered since they do not occur in the area of the Proposed Survey.

The SEL$_{cum}$ and Peak SPL (Appendix C) for the planned airgun configurations are 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 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 only in the vertical direction. In the horizontal direction, the sound pressure does not always constructively interfere and stack coherently, 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 interactions of the two airguns that occur near the source center and is calculated as a point source (single airgun), the modified farfield signature is a more appropriate measure of the sound source level for large arrays. For this smaller array, the modified farfield changes will be correspondingly smaller as well, but we use this method for consistency across all array sizes.

To estimate SEL\textsubscript{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 to provide better resolution in both the inline and depth directions, with results shown in Appendix C. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays. This is done by 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 default values and calculating individual adjustment factors (dB) 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\textsubscript{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014). The methodology (input) for calculating the distances to the SEL\textsubscript{cum} PTS thresholds (Level A) for the airgun array is shown in Table 2.

Appendix C provides detailed information about the acoustic modeling used for Level A takes, including NMFS spreadsheet-based calculations. Appendix C also gives a summary of all of the SEL SL modeling with and without applying the weighting function for the 5 hearing groups and the full calculations for the PTS SEL\textsubscript{cum} and the Peak SPL\textsubscript{flat}.

**TABLE 3. SEL\textsubscript{cum} Methodology Parameters (Sivle et al. 2014).**

<table>
<thead>
<tr>
<th>Airgun Configuration</th>
<th>Source Velocity (meters/second)</th>
<th>1/Repetition rate(^\text{a}) (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Configurations</td>
<td>2.05778(^*)</td>
<td>12.149(^&amp;)</td>
</tr>
</tbody>
</table>

\(^\dagger\)Methodology assumes propagation of 20 log R; Activity duration (time) independent

\(^*\)Time between onset of successive pulses.

\(^\text{E}\)quivalent to 4 kts

\(^\&\)The USGS intends to use a nominal shot interval of 25 m (~12 s at 4 kts).

As shown in Appendix A, a new adjustment value is determined by computing the distance from the geometrical center of the source to where the 183 dB SEL\textsubscript{cum} isopleth is the largest for LF cetaceans. The modeling is first run for one single shot without applying any weighting function. The maximum 183dB SEL\textsubscript{cum} isopleth is located at 34.35 m, 39.42 m, and 17.98 m from the source for source Configurations 1 through 3, respectively. We then run the modeling for one single shot with the low frequency cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL\textsubscript{cum} isopleth is located at 15.7 m, 17.7 m, and 9.2 m from the source for source Configurations 1 through 3, respectively. The difference between
these values for each of the source configurations yields adjustment factors of -6.8 dB, -6.9 dB, and -5.8 dB, respectively, assuming a propagation of 20\log_{10}R.

For MF and HF cetaceans, 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 4. Summary Level A acoustic thresholds in meters for each source configuration and hearing group relevant to the Proposed Action.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>183 dB (SEL_{cum})</td>
<td>230 dB (Peak SPL_{flat})</td>
<td>202 dB (Peak SPL_{flat})</td>
</tr>
<tr>
<td>Base Configuration</td>
<td>31.0 m</td>
<td>0.0</td>
<td>70.43 m</td>
</tr>
<tr>
<td>GG Configuration</td>
<td>39.5 m</td>
<td>0.0</td>
<td>80.5 m</td>
</tr>
</tbody>
</table>

The NSF-USGS PEIS defined a low-energy source as any towed acoustic source whose received level is \(\leq 180\) dB re 1 \(\mu Pa_{rms}\) (the Level A threshold under the former NMFS acoustic guidance) at 100 m. Table 3 of Appendix F of the NSF-USGS PEIS shows that a quadrilateral (4 GI gun) array of 105 in\(^3\) guns would meet the low-energy criteria if towed at 3 m depth and separated by 8 m. Based on the modeling in Table 1 and the fact that the quadrilateral array of guns to be used for the Proposed Action would be separated by only 2 m front to back and 8.6 m side to side (and will be operated occasionally in GG mode, which generates 210 in\(^3\) of air per GI gun), the Proposed Action slightly exceeds the criteria of a low-energy activity according to the NSF-USGS PEIS. Note that the sources to be used for the Proposed Action at maximum generate less than 20% of the air (usually > 6000 in\(^3\)) typically used for seismic surveys by a range of research and private sector operators.

In § 2.4.2 of the NSF-USGS PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-m EZ for low-energy acoustic sources in water depths >100 m. For the Proposed Action, which does not meet the \(\leq 180\) dB re 1 \(\mu Pa_{rms}\) Level A criterion formerly applied by NMFS and outlined in Appendix F of the NSF-USGS PEIS, the actual calculated EZ (Table 4 and Appendix C) based on the 2016 NMFS Acoustic Guidelines are substantially smaller than this prescribed 100 m EZ. Adopting the calculated EZ instead of the prescribed 100 m EZ would therefore result in a less conservative approach to protection of marine mammals (and turtles) and higher actual takes during the Proposed Action. Thus, the Proposed Action will voluntarily adopt a 100 m EZ for marine mammals.

The 100-m EZ would also be used as the EZ for sea turtles, although current guidance by NMFS suggests a Level A criterion of 195 dB re 1 \(\mu Pa_{rms}\) or a maximum EZ of 21 m in deep water for the most impulsive (GG configuration) airgun array. If marine mammals or sea turtles are detected in or about to enter the EZ, the airguns would be shut down immediately. Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. This Draft EA has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices.
noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015). For the 160-dB “Safety Zone,” L-DEO model results for the GI gun configurations are used here to determine the 160-dB radius (Table 1).

(b) Operational Phase

The operational mitigation measures to be implemented by the USGS are described in §2.4.1.1 of the NSF-USGS PEIS and include:

- monitoring by PSOs for marine species (including marine mammals, sea turtles, and ESA-listed seabirds diving near the vessel and also observing for potential impacts of acoustic sources on fish);
- PSVO data and documentation; and
- mitigation during operations (speed or course alteration; shut-down and ramp-up procedures, including for threatened/endangered seabirds; avoidance of concentrations of large whales; directional shooting to maximize protection of mammals in certain habitats).

The proposed operational mitigation measures are standard for all seismic cruises, per the NSF-USGS PEIS, and therefore are not discussed further here. Special mitigation measures were considered for this cruise. It is unlikely that concentrations of large whales would be encountered, but if so, they would be avoided.

Marine mammals and sea turtles are known to occur in the proposed project area. However, the number of individual animals expected to be approached closely during the proposed activities would be relatively small in relation to regional population sizes, as shown in §IV. With the proposed monitoring and mitigation provisions, potential effects on most if not all individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals and on the associated species and stocks. Survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements.

Alternative 1: Alternative Survey Timing

An alternative to issuing the IHA for the period requested and to conducting the project then would be to conduct the project at an alternative time, implementing the same monitoring and mitigation measures as under the Proposed Action, and requesting an IHA to be issued for that alternative time (Table 5). The proposed August 2018 timing for the cruise is the most suitable time logistically for R/V Hugh R. Sharp and the participating scientists. If the IHA is issued for another period, it could result in significant delay and disruption not only of this cruise, but also of additional studies that are planned using the equipment or the vessel in 2018 and beyond. An evaluation of the effects of this Alternative Action is given in §IV.

Alternative 2: No Action Alternative

An alternative to conducting the proposed activities is the “No Action” alternative, i.e., do not conduct the research operations; an IHA and ITS would not be necessary (Table 5). 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, action proponents 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 from the proposed activities. The “No Action” alternative does not address the national need for new data about the distribution of gas hydrates on the Mid-Atlantic margin. The U.S. would continue to rely on data more than 30 years old to delineate
these gas hydrate resources and associated shallow gas. The U.S. would not acquire data that could also be used for analysis of submarine slide hazards in this area.

The “No Action” alternative could also potentially affect other research community studies that would be carried out on the *R/V Hugh R. Sharp* in 2018 and later, depending on the timing of the decision. Not conducting this cruise (no action) would result in the U.S. continuing to lack modern multichannel seismic data for a significant portion of the mid-Atlantic margin and not having access to suitable information to constrain the distribution of methane hydrates and shallow gas. Data collection would be an essential first step for a much greater effort to analyze and report information related to the geological structure and distribution of gas/gas hydrate on the mid-Atlantic part of the U.S. Atlantic margin. The dataset that the USGS proposes to collect will likely be used for at least three decades into the future based on past experience. Effects of this Alternative Action are evaluated in § IV.

**Alternatives Considered but Eliminated from Further Analysis**

1. **Alternative E1: Alternative Location**

   The survey area has been chosen based on an analysis of the locations of existing high-resolution modern multichannel seismic data, older “legacy” data, known gas hydrate features identified by BOEM (2012a) and the USGS (Ruppel et al., 2015), and the published locations of known methane seeps (Skarke et al., 2014). The U.S. Mid-Atlantic margin is the highest priority area for surveys delineating the locations of gas hydrate and free gas in sediments, studying the links between gas hydrate systems and widespread methane seeps, and acquiring modern MCS data. While there are other areas on the margin where surveys could be carried out, they have lower priority at present due either to the availability of more recently acquired MCS data, the highly-eroded nature of the sediments, and/or the absence of known methane hydrates/methane seeps.

2. **Alternative E2: Use of Alternative Technologies**

   As described in § 2.6 of the NSF-USGS PEIS, alternative technologies to the use of airguns are typically investigated to conduct marine geophysical research. At the present time, these technologies are still not feasible, widely available, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2013) for the 2013 Gulf of Mexico Gas Hydrates Project (SIGH). Table 5 provides a summary of the proposed action, alternatives, and alternatives eliminated from further analysis.
II. Alternatives Including Proposed Action

### TABLE 5. Summary of Proposed Action, Alternatives Considered, and Alternatives Eliminated.

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>Description/Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Action: Conduct marine geophysical surveys and associated activities in the Northwest Atlantic Ocean</td>
<td>Under this action, the use of GI gun seismic sources is proposed. When considering mobilization, demobilization, equipment maintenance, weather, marine mammal activity, and other contingencies, the proposed activities would be expected to be completed in a maximum of 22 days. The affected environment, environmental consequences, and cumulative impacts of the proposed activities are described in Sections III, IV, and V, respectively. The standard monitoring and mitigation measures identified in the NSF-USGS PEIS would apply, along with any additional requirements identified by regulating agencies. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Description/Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1: Alternative Survey Timing</td>
<td>Under this Alternative, the USGS would conduct survey operations at a different time of the year to reduce potential impacts on marine resources and users, and improve monitoring capabilities. However, except for some migratory species, most marine mammal species occur in the project area year-round, so altering the timing of the proposed project likely would result in no net benefits for those species and could make it more likely that survey time is lost due to weather, meaning that surveys would have to be repeated in the future (greater sound exposure for mammals). Further, consideration would be needed for constraints for vessel operations and availability of equipment (including the vessel) and personnel. Limitations on scheduling the vessel include the additional research studies planned on the vessel for 2018 and beyond and the lack of equipment availability within the U.S. research fleet at other times. The standard monitoring and mitigation measures identified in the NSF-USGS PEIS would apply and are described in further detail in this document (Section II [3]) along with any additional requirements identified by regulating agencies. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.</td>
</tr>
<tr>
<td>Alternative 2: No Action</td>
<td>Under this Alternative, no proposed activities would be conducted and seismic data would not be collected. Whereas this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the proposed action. The collection of new data, interpretation of these data, and introduction of new results into the greater scientific community would not be achieved. No permits and authorizations, including an IHA, would be necessary from regulatory bodies as the proposed action would not be conducted.</td>
</tr>
<tr>
<td>Alternative E1: Alternative Location</td>
<td>The Survey Areas in the Northwest Atlantic Ocean are those in which modern MCS data on the distribution of gas hydrates and shallow natural gas are lacking, yet studies by BOEM and the USGS have identified areas likely to host widespread gas hydrate deposits. Since this is the part of the margin with the most active methane seepage, but lacking modern seismic data, a different site does not serve the goal of acquiring new data in the mid-Atlantic data gap.</td>
</tr>
<tr>
<td>Alternative E2: Alternative Survey Techniques</td>
<td>Under this alternative, the USGS would use alternative survey techniques, e.g., marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the NSF-USGS PEIS, § 2.6. At the present time, these technologies are still in the testing phase. They are still not feasible, viable for routine seismic data acquisition, or appropriate to meet the Purpose and Need.</td>
</tr>
</tbody>
</table>
III. AFFECTED ENVIRONMENT

Parts of this section are adopted verbatim from the Draft Scripps EA (LGL, 2017). Based on the NSF-USGS 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 marine biological resources because the short-term seismic activities proposed by the USGS for the Northwest Atlantic in 2018 have the potential to affect marine biological resources within the project area. These resources are identified below in the following parts of § III, and the potential impacts on these resources are discussed in § IV. Initial review and analysis of the proposed project activities determined that the following resource issues did not require further analysis in this EA:

- **Transportation**—Only the R/V Hugh R. Sharp will be used during the seismic survey. This single ship represents a negligible amount of additional ship traffic in the analysis area, which is heavily used for commercial and military vessels;

- **Air Quality/Greenhouse Gases**—Vessel emissions would result from the proposed activities; 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 survey area. Per EPA requirements, the R/V Hugh R. Sharp is a low emissions vessel.

- **Land Use**—All activities are proposed to occur in the marine environment. Therefore, no changes to current land uses or activities within the survey area would result from the proposed activities;

- **Safety and Hazardous Materials and Management**—With the exception of lithium-ion batteries needed to power components of “birds” that stabilize the streamer and marine diesel fuel used to power the compressors, no hazardous materials would used during the Proposed Action. All Project-related wastes would be disposed of in accordance with applicable laws.

- **Geological Resources (Topography, Geology and Soil)**—The Proposed Action would not result in the displacement or disruption of seafloor sediment. Proposed activities would not adversely affect geologic resources as only minor impacts would occur;

- **Water Resources**—There are no proposed discharges to the marine environment that would adversely affect marine water quality. Therefore, there would be no impacts to water resources resulting from the proposed Project activities;

- **Terrestrial Biological Resources**—All proposed Project activities would occur in the marine environment and would not affect terrestrial biological resources;

- **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. Human activities in the area around the survey vessel are expected to be limited to commercial and recreational fishing, shipping, and military traffic;

- **Visual Resources**—No visual resources should be negatively affected because the area of operation is significantly outside of the land and coastal view shed; and

- **Cultural Resources**—While the surveys may cross shipwrecks, no impacts are expected, nor will the sensing technology used even be able to locate these shipwrecks. For example, the ship will not be conducting bathymetric or backscatter surveys of the seafloor. The proposed activities will not disturb shipwrecks.
III. Affected Environment

(1) Oceanography

The Study Area lies offshore the Mid-Atlantic Bight (MAB), a 621 mi (1,000 km) coastal region stretching from Massachusetts to North Carolina. The Proposed Action is within the southern half of the MAB, with the northern edge located 35 nm south of Hudson Canyon and Cape Hatteras representing the southern extent. The western edge of the Study Area lies at the shelf-break and includes the heads of large shelf-breaking canyons, including Baltimore Canyon, Washington Canyon, and Norfolk Canyon. The eastern edge is wholly within the US EEZ.

Much of the information below has been taken verbatim or adapted from the “Final Environmental Assessment for Seismic Reflection Scientific Research Surveys During 2014 and 2015 in Support of Mapping the U.S. Atlantic Seaboard Extended Continental Margin and Investigating Tsunami Hazards,” prepared for the U.S. Geological Survey in 2014 (RPS, 2014a) or from the Draft ENAM EA (RPS, 2014c).

The area of the Proposed Action is greatly influenced by the Gulf Stream, although the core of the Gulf Stream heads northeast and lies farther offshore with increasing distance north of Cape Hatteras. The Gulf Stream is a powerful, warm, and swiftly flowing Western Boundary Current current that carries warm equatorial waters into the North Atlantic (Pickard and Emery, 1990; Verity et al., 1993). Eddies often spin off the Gulf Stream and carry warm-cored water masses toward and sometimes onto the shelf. Between the Gulf Stream’s main flow and the location of the shelf break, counterclockwise gyres often develop, entraining warm water from the Gulf Stream and colder waters from near the shelf-break. Landward of these systems, currents can be complicated. The shelf-break current (primarily the Scotian current) flows southward in much of the study area, but near-surface waters sometimes locally reverse direction. Upwelling along the Atlantic coast is both wind-driven and a result of dynamic uplift (Shen et al., 2000; Lentz et al., 2003).

In addition to these currents, currents originating from the outflow of both the Chesapeake and Delaware Bays influence the surface circulation in the MAB. The Chesapeake Bay plume flows seaward from the mouth of the Bay and then turns south to form a coastal jet that can extend as far as Cape Hatteras. Similarly, the Delaware Coastal Current begins in Delaware Bay and flows southward along the Delmarva Peninsula before being entrained into the Chesapeake Bay plume.

The climate for the Study Area is that of a typical marine environment. It is influenced to varying degrees year–round by passing systems, prevailing winds, and warm Gulf Stream waters. Three atmospheric pressure systems control the wind patterns and climate for this region: The Bermuda-Azores High, the Icelandic Low, and the Ohio Valley High (Blanton et al., 1985). The Bermuda-Azores High dominates the climate in the region from approximately May through August, and produces south-easterly winds of <6 m/s (<20 ft/s) (BOEM, 2012b). Persistent high levels of humidity and moisture during this time can increase precipitation levels and increase fog.

The proposed Study Area is susceptible to tropical and sub-tropical cyclones, which can greatly influence the weather and sea state. During the summer and fall, tropical cyclones are severe, but infrequent (BOEM 2012b). In contrast, during the winter and spring, extra-tropical cyclones occur frequently. Most storms, including hurricanes, occur during the North Atlantic hurricane season from June through November. Between 1815 and 2015, Atlantic tropical storms and hurricanes were most frequent in September, followed by August then October according to data from the National Hurricane Center cited by NOAA’s Atlantic Oceanographic and Meteorological Laboratory (http://www.aoml.noaa.gov/hrd/tcfaq/E17.html).

(2) Protected Areas

The Proposed Action, contained as it is within the EEZ, does not overlap with any international Ecologically or Biologically Significant Marine Areas (EBSAs). The action lies close to the region of the North Atlantic called the Sargasso Sea, which is considered an EBSA, and intersects a U.S. Marine Protected Area (MPA) on the western side of the Sargasso Sea. More information about the Sargasso Sea is provided in the MPA section below.
The Proposed Action overlaps with several U.S. MPAs, although most of these are so designated based on restrictions in fishing activities, which are not the focus of the seismic surveys. The MPAs within the Proposed Action area include: Frank R. Lautenberg Deep Sea Coral Protection Area, Mid-Atlantic Coastal Waters Area, the Norfolk Canyon Gear Restricted Area, Offshore Trap/Pot Waters, the “Other” Northeast Gillnet Waters Area, the Pelagic Sargassum Habitat Restricted Area, the Southern Mid-Atlantic Waters Closure Area, the New Jersey offshore closure area, and the Southern Nearshore Pot-Trap Pot Waters. All of these are considered fishery management areas except the Norfolk Canyon area (gear restriction) and the Lautenberg Deep Sea Coral area, which protects corals. All areas are subject to non-MPA Programmatic Species Management Plans. Commercial fishing is restricted in all areas, while both commercial and recreational fishing are restricted in the Lautenberg Deep Sea Coral Protection Area. Some of these MPA have seasonal restrictions, while others have year-round restrictions. The surveys are not located in de facto MPAs, although the ship will transit through these without seismic gear active on the way to and from ports in Norfolk and Lewes.

**Frank R. Lautenberg Deep Sea Coral Protection Area**

The northernmost 75% of the Proposed Action lies almost completely within the boundaries of the Frank R. Lautenberg Deep Sea Coral Protection Area. The area was designated by NOAA Fisheries and the Mid-Atlantic Fishery Management Council in 2016 to protect very slow-growing deep corals that live on the outer continental shelf and in some canyon areas. Within the protected area, fishing activities that interfere with the seabed are restricted, but recreational fishing and other activities may continue. The Proposed Action does not disrupt the seabed and is not expected to have an impact on deep sea corals within the Protection Area.

**The Sargasso Sea**

The Sargasso Sea occupies the area within the Northern Atlantic Subtropic Gyre, mostly on the high seas, outside the EEZs of most countries. The area is dynamically bound on the west by the Gulf Stream and on the north by the North Atlantic Current. The northwest corner of the Sargasso Sea therefore often lies within the US EEZ, depending on the course of the Gulf Stream. Sargassum is a floating algae that occurs only in the open ocean, and the Sargasso Sea is the only place in the world this ecosystem is found. Sargassum is particularly important for turtles, particularly loggerheads, but also plays a role in the life cycles of some crustaceans, fish, and marine mammals (e.g., humpbacks). The U.S. has designated the Pelagic Sargassum Habitat Restricted Area to regulate fishing in this area. The southernmost exemplary survey lines for the Proposed Action, as well as the deepwater portions of some of the exemplary lines in the Mid-Atlantic region, intersect the designated loggerhead sea turtle (Caretta caretta) critical habitat for the Northwest Atlantic Ocean Distinct Population (see below).

(3) Marine Mammals

Much of the following section is taken verbatim from the Draft Scripps EA (LGL, 2017). Thirty-four marine mammal species could occur in the general survey area, including 7 mysticetes (baleen whales) and 27 odontocetes (toothed whales, such as dolphins) (Table 6). To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below. Five of the species that could occur in the proposed project area are listed under the ESA as endangered, including the sperm, sei, fin, blue, and North Atlantic right whales. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the NSF-USGS PEIS.
One of the detailed analysis areas (DAAs) defined in the NSF-USGS PEIS §2.3.1.1 is in the Northwest (NW) Atlantic and lies at the northernmost end of the Survey Area for this Proposed Action, encompassing the area out to 1500 m water depth. The distributions of mysticetes, odontocetes, and pinnipeds in the NW Atlantic DAA are discussed in §3.6.2.1, §3.7.2.1, and §3.8.2.1 of the NSF-USGS PEIS, respectively. The rest of this section deals specifically with species distribution in the area of the Proposed Action.

Three cetacean species occur in Atlantic arctic waters, and their ranges do not extend as far south as the proposed project area: the narwhal, *Monodon Monoceros*; the beluga, *Delphinapterus leucas*; and the bowhead, *Balaena mysticetus*. Two additional Atlantic cetacean species, the Atlantic humpback dolphin (*Souza teuszii*) found in coastal waters of western Africa, and the long-beaked common dolphin (*Delphinus capensis*) found in coastal waters of South America and western Africa, do not occur in the study area.

Pinniped species that are known to occur in North Atlantic waters, but that will not occur in the area of the Proposed Action, include the gray seal (*Halichoerus grypus*), harbor seal (*Phoca vitulina*), and bearded seal (*Erignathus barbatus*). Pinniped species are not discussed further in this EA, nor are takes calculated for these species given that they would not be encountered.

### 3. Mysticetes

The following information has mostly been copied verbatim from the Draft Scripps EA (LGL, 2017) and then modified for the specific circumstances of the USGS Proposed Action, when appropriate. Table 6 summarizes the conservation status, estimated population, habitat, and survey specific information for each species.

**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 (Winn et al. 1986; Jefferson et al. 2015). Survey data have identified seven major habitats or congregation areas for North Atlantic right whales: coastal waters of the southeastern United States; Great South Channel; Jordan Basin; Georges Basin along the northern edge of Georges Bank; Cape Cod and Massachusetts Bays; Bay of Fundy; and Roseway Basin on the Scotian Shelf (Hayes et al. 2017). 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; 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).

During the summer and into fall (June–November), right whales are most commonly seen on feeding grounds in Canadian waters off Nova Scotia, with peak abundance during August, September, and early October (Gaskin 1987). Some right whales, including mothers and calves, remain on the feeding grounds through the fall and winter. However, the majority of the right whale population leaves 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).
In more than 5000 recorded global sightings of North Atlantic right whales, there have been 11 within the polygon that bounds the exemplary surveys (OBIS, 2017). No sightings have been reported in July, August or September within the survey area (Figure 7). Given the small size of the population and their typical summer range, North Atlantic right whales should not be encountered during the USGS surveys.

**Humpback Whale (*Megaptera novaeangliae*)**

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). Although considered to be mainly a coastal species, humpbacks often traverse deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). Humpback whales migrate between summer feeding grounds in high latitudes and winter calving and breeding grounds in tropical waters (Winn and Reichley 1985; Clapham and Mead 1999; Smith et al. 1999). The summer feeding grounds in the North Atlantic range from the northeast coast of the U.S. to the Barents Sea (Katona and Beard 1990; Smith et al. 1999). Humpbacks in the North Atlantic primarily migrate to wintering areas in the West Indies (Jann et al. 2003), but some also migrate to Cape Verde (Carrillo et al. 1999; Wenzel et al. 2009). 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).

Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 40°N during the summer; very low densities are expected south of 40°N, and the USGS proposed survey is entirely south of this latitude.

Of the more than 43,000 global sightings of humpback whale individuals or groups dating back more than 50 years in the OBIS database (2017), only 79 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, fourteen sightings occurred during July, August, or September, primarily on the continental shelf between north of Washington Canyon and the mouth of Delaware Bay (Figure 7). Three of these sitings have been at or seaward of the shelf break, near the landward ends of the two northernmost exemplary USGS seismic lines.

Humpback whales could be encountered in the proposed project area during an August survey, but this would be an extremely rare occurrence.

**Minke Whale (*Balaenoptera acutorostrata*)**

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). Some populations migrate from high latitude summering grounds to lower latitude wintering grounds (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also occur in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985; Perrin and Brownell 2009). There are four recognized minke whale populations in the North Atlantic: Canadian east coast, west Greenland, central North Atlantic, and northeast Atlantic (Donovan 1991). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 40°N; very low densities are expected south of 40°N.

Most minke whale sitings south of 40°N have been on the continental shelf, at water depths shallower than the proposed USGS seismic lines. Minke whales may occasionally be encountered seaward of the shelf-break during the proposed USGS surveys. Of the more than 15,000 sightings of minke whale individuals or groups dating back more than 50 years in the OBIS database, 51 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, twelve sightings comprising 21 individuals occurred during July, August, or September (Figure 7). Only two of the sightings were seaward of the shelf break, including one near Washington Canyon and another beyond the distal, deepwater termini of the three central USGS exemplary seismic transects.
Minke whales could be encountered near the survey lines in August, but this would be a rare occurrence.

Bryde's Whale (*Balaenoptera edeni/brydei*)

Bryde’s whale is found in tropical and subtropical waters throughout the world between 40ºN and 40ºS, generally in waters warmer than 20ºC, but at minimum 15ºC (Reeves et al. 1999; Kanda et al. 2007; Kato and Perrin 2009). It can be pelagic as well as coastal (Jefferson et al. 2015). It does not undertake long north/south migrations, although local seasonal movements toward the Equator in winter and to higher latitudes in summer take place in some areas (Evans 1987; Jefferson et al. 2015). Of 914 usable sightings in the iOBIS database, none occurred within the larger box enclosing the proposed survey in any season (Figure 7). Still, Bryde’s whales could possibly be encountered in the proposed project area.

Sei Whale (*Balaenoptera borealis*)

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude temperate waters (Gambell 1985a). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001; Jefferson et al. 2015). It is found 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 1985a). 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).

There are three sei whale stocks in the North Atlantic: Nova Scotia, Iceland-Denmark Strait, and Eastern (Donovan 1991). Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 40ºN during the summer; very low densities are expected south of 40ºN, where the USGS surveys are entirely located.

Of the more than 11,000 sightings of sei whale individuals or groups dating back more than 50 years in the OBIS database, only 7 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, only two sightings, comprising three individuals in total, occurred between in July, August, or September (Figure 7). Sei whales could be encountered in the proposed project area during an August survey, but this would be an extremely rare occurrence.

Fin Whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world’s oceans in coastal, shelf, and oceanic waters, and typically occur in temperate and polar regions (Gambell 1985b; Perry et al. 1999; Gregr and Trites 2001; Jefferson et al. 2015). Fin whales tend to follow steep slope contours, either because they detect them readily or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing (Sergeant 1977). Fin whales appear to have complex seasonal movements and are seasonal migrants; they mate and calve in temperate waters during the winter and migrate to feed at northern latitudes during the summer (Gambell 1985b). They are known to use the shelf edge as a migration route (Evans 1987).

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 and extends south along the Mid-Atlantic Ridge. Similarly, the four stocks in the Northwest Atlantic currently recognized by NAMMCO (2016) are located off West Iceland (in the Central Atlantic), Eastern Greenland, Western Greenland, and Eastern Canada.

Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 40°N; very low densities are expected south of 40°N, where the USGS surveys are entirely located. Of the more than 68,000 sightings of fin whale individuals or groups dating back more than 50 years in the OBIS database, 131 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, 29 sightings, comprising 60 individuals in total, occurred during July, August, or September (Figure 7). Fin whales could be encountered during the proposed August surveys, particularly closer to the shelf edge and near the uppermost continental slope.

**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). It is most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). 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). Seamounts and other deep ocean structures may be important habitat for blue whales (Lesage et al. 2016). 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).

Of the more than 16,000 sightings of blue whale individuals or groups dating back more than 50 years in the OBIS database, only 2 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. One of these, comprising a single individual, occurred during July, August, or September and was located ~85 nautical miles offshore New Jersey, on the upper continental slope between the two northernmost exemplary USGS seismic lines to be acquired down the continental slope (dip lines) and may either be an extralimital animal or a misidentification (Figure 7). While it would be a very rare occurrence, it is possible that a blue whale could be encountered in the proposed project area during an August seismic survey.

4. Odontocetes

**Sperm Whale (Physeter macrocephalus)**

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). Sperm whale distribution is linked to social structure: mixed groups of adult females and juvenile animals of both sexes generally occur in tropical and subtropical waters, whereas adult males are commonly found alone or in same-sex aggregations, often occurring in higher latitudes outside the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2009). They are often found far from shore, but can occur closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2009).
In the OBIS database, 686 sperm whale sightings occur within a rectangular area encompassing the survey area, and 395 occurred during July through September. As shown in Figure 9, most of these sightings are seaward of the shelf-break in deepwater, overlapping the area of the Proposed Action. Thus, sperm whales are likely to be encountered in the proposed project area during August 2018.

Figure 7. Sightings of endangered cetaceans and all baleen whales simultaneously overlapping the survey area and occurring during the summer (July through September) months as compiled from the iOBIS database by the USGS based on usable records. Note that there are no relevant sightings of North American right whales or Byrde’s whales that meet the spatial and temporal criteria.

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

The pygmy sperm and dwarf sperm whales are high-frequency cetaceans distributed widely throughout tropical and temperate seas, but their precise distributions are unknown as most information on these species comes from strandings (McAlpine 2009). They are difficult to sight at sea, perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are difficult to distinguish from one another when sighted (McAlpine 2009) and are combined in the Roberts et al. (2015) density modeling under the auspices of the *Kogia* guild.

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. It has also 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). This idea is also supported by the distribution of strandings in South American waters (Muñoz-Hincapié et al. 1998).

Only four of the pygmy sperm whale sightings in the OBIS database occur within the general area of the survey, and three of these were during the July through September period. Pygmy and dwarf sperm whales would likely be rare in the proposed project area.
Cuvier’s Beaked Whale (*Ziphius cavirostris*)

Cuvier’s beaked whale is probably the most widespread of the beaked whales. Cuvier’s beaked whale appears to prefer steep continental slope waters (Jefferson et al. 2015) and is most common in water depths >1000 m (Heyning 1989). It is mostly known from strandings and strandings more commonly than any other beaked whale (Heyning 1989). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006).

Of the usable records in the OBIS database, 155 sightings of Cuvier’s beaked whales overlap with the survey area, and 76 of these were during the July to September period. Cuvier’s beaked whales could be encountered in the proposed project area.

Northern Bottlenose Whale (*Hyperoodon ampullatus*)

The northern bottlenose whale is found only in the North Atlantic, from the subarctic to ~30°N (Jefferson et al. 2015). Northern bottlenose whales are most common in deep waters beyond the continental shelf or over submarine canyons, usually near or beyond the 1000-m isobath (Jefferson et al. 2015). Of the sightings in the OBIS database, one occurred within the survey area and none during July through September. Nonetheless, northern bottlenose whales could be encountered in the proposed project area.

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 2009). In the western North Atlantic, strandings have been recorded from Nova Scotia (~26°N) to Florida (46°N; MacLeod et al. 2006). Two sightings in the OBIS database occur in the general survey area, but only one of these was during the summer season that overlaps the Proposed Action. True’s beaked whale likely would be rare in the proposed project area.

Gervais’ Beaked Whale (*Mesoplodon europaeus*)

Gervais’ beaked whale is mainly oceanic and occurs in tropical and warmer temperate waters of the Atlantic Ocean (Jefferson et al. 2015). It occurs in the Atlantic from ~54°N to ~18°S (MacLeod et al. 2006). Gervais’ beaked whale is more common in the western than the eastern part of the Atlantic (Mead 1989). No OBIS sightings of the Gervais’ beaked whale have occurred in the survey area. Given the geographic and depth range of the species, though, Gervais’ beaked whale could be encountered in the proposed project area.

Sowerby’s Beaked Whale (*Mesoplodon bidens*)

Sowerby’s beaked whale occurs in cold temperate waters of the Atlantic from the Labrador Sea to the Norwegian Sea, and south to New England, the Azores, and Madeira (Mead 1989). Sowerby’s beaked whale is known primarily from strandings, which are more common in the eastern than the western North Atlantic (MacLeod et al. 2006). It is mainly a pelagic species and is found in deeper waters of the shelf edge and slope (Mead 1989). Eleven OBIS database sightings are in the polygon enclosing the larger area of the proposed surveys, and nine of these were during the summer months. Sowerby’s beaked whale could be encountered in the proposed project area.

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 all mesoplodont species and appears to be relatively common
(Pitman 2009). Like other beaked whales, Blainville’s beaked whales are generally found in deep water, 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). In the OBIS database, one sighting occurred in the survey area, and it was during the summer months. Blainville’s beaked whale could be encountered in the proposed project area.

**Rough-toothed Dolphin (Steno bredanensis)**

The rough-toothed dolphin occurs in tropical and subtropical waters, rarely ranging farther north than 40°N (Jefferson et al. 2015). It is considered a pelagic species, but it can also occur in shallow coastal waters (Jefferson et al. 2015). Nine sightings in the OBIS database occur within the survey area, and seven of these were doing the summer. Rough-toothed dolphins could occur in the proposed project area.

**Common Bottlenose Dolphin (Tursiops truncatus)**

The bottlenose dolphin is distributed worldwide in coastal and shelf waters of tropical and temperate oceans (Jefferson et al. 2015). There are two distinct bottlenose dolphin types in the Northwest Atlantic: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). In the OBIS database, 1873 sightings of bottlenose dolphins occurred within a polygon enclosing the general survey area, and 776 are within the summer months. Common bottlenose dolphins are very likely to be encountered in the proposed project area.

**Pantropical Spotted Dolphin (Stenella attenuata)**

The pantropical spotted dolphin can be found throughout tropical oceans of the world (Jefferson et al. 2015). In the Atlantic, it can occur from ~40°N to 40°S but is much more abundant in the lower latitudes (Jefferson et al. 2015). Pantropical spotted dolphins are usually pelagic, although they occur close to shore where water near the coast is deep (Jefferson et al. 2015). Of over 4200 usable sightings in the OBIS database, 48 were in the polygon encompassing the entire survey area, and 29 of these were during the summer months. Pantropical spotted dolphins could be encountered in the proposed project area.

**Atlantic Spotted Dolphin (Stenella frontalis)**

The Atlantic spotted dolphin is distributed in tropical and warm temperate waters of the North Atlantic from Brazil to New England and to the coast of Africa (Jefferson et al. 2015). 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 OBIS database, 125 sightings are in the general area of the surveys, and 58 were during the summer. Atlantic spotted dolphins would likely be encountered in the proposed project area.

**Striped Dolphin (Stenella coeruleoalba)**

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994); however, it also occurs in temperate waters as far north as 50°N (Jefferson et al. 2015). The striped dolphin is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2009). However, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). Of over 15600 sightings in the OBIS database, 183 were in the area of the survey, and 95 of these were during the summer. Striped dolphins would likely be encountered in the proposed project area.
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). In the OBIS database, 28 sightings of the Atlantic white-sided dolphin occur in the general area of the survey, and 9 of these are during the summer months. Atlantic white-sided dolphins could be encountered in the proposed project area.

White-beaked Dolphin (*Lagenorhynchus albirostris*)

The white-beaked dolphin occurs in cold temperate and subpolar regions of the North Atlantic; its range extends from Cape Cod to southern Greenland in the west and Portugal to Svalbard in the east (Kinze 2009; Jefferson et al. 2015). It appears to prefer deep waters along the outer shelf and slope, but can also occur in shallow areas and far offshore (Jefferson et al. 2015). There are four main high-density centers in the North Atlantic, including (1) the Labrador Shelf, (2) Icelandic waters, (3) waters around Scotland, and (4) the shelf along the coast of Norway (Kinze 2009). One sighting in the OBIS database of over 2700 records is of a white-beaked dolphin in the general survey area, and none occurred during the summer. White-beaked dolphins are unlikely to be encountered in the proposed project area.

Short-beaked Common Dolphin (*Delphinus delphis*)

The short-beaked 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). Fewer than 0.1% of the nearly 43,000 of short-beaked common dolphins in the OBIS database occur in the general area of the survey, and only three were during the summer months. Short-beaked common dolphins could be encountered in the proposed project area.

Risso’s Dolphin (*Grampus griseus*)

Risso’s dolphin is distributed worldwide in temperate and tropical oceans (Baird 2009), although it shows a preference for mid-temperate waters between 30° and 45° (Jefferson et al. 2014). Although it is known to occur in coastal and oceanic habitats (Jefferson et al. 2014), it appears to prefer steep sections of the continental shelf, 400–1000 m deep (Baird 2009), and is known to frequent seamounts and escarpments (Kruse et al. 1999; Baird 2009). There were 471 sightings of Risso’s dolphins in the general area of the project in the OBIS database, and 238 of these were during the summer. Risso’s dolphin is likely to be encountered in the proposed project area during August.

Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale is pantropical, inhabiting waters generally between 40ºN and 35ºS (Jefferson et al. 2015). Pygmy killer whales are usually found in deep water and rarely are found close to shore except where deepwater approaches the shore (Jefferson et al. 2015). Three sightings of pygmy killer whales are found in the OBIS database for the general area of the survey, and all of these occurred during the summer. Pygmy killer whales could occur in the survey area.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep, offshore waters (Jefferson et al. 2015). However, it is also known to occur in nearshore areas (e.g.,
Stacey and Baird 1991). The pelagic range in the North Atlantic is usually southward of ~30°N but extralimit individuals have been recorded as far north as Norway (Jefferson et al. 2015). Of more than 1100 usable sightings recorded in the OBIS database, two occurred within the rectangle enclosing the survey area, and one of those was during the summer months. False killer whales could be encountered in the proposed project area.

**Killer Whale (Orcinus orca)**

The killer whale is globally fairly abundant, and it has been observed in all oceans of the world (Ford 2009). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). In over 3000 usable killer whale sightings in the OBIS database, only 0.1% were within the larger rectangular area enclosing the survey, and none was during the summer months. Killer whales could be encountered within the proposed project area.

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

The short-finned pilot whale is found in tropical, subtropical, and warm temperate waters (Olson 2009); it is seen as far south as ~40°S and as far north as ~50°N (Jefferson et al. 2015). Pilot whales are generally nomadic, but may be resident in certain locations (Olson 2009). There is some overlap of range with *G. melas* in temperate waters (Jefferson et al. 2015). Water temperature appears to be the primary factor determining the relative distribution of these two species (Fullard et al. 2000). The short-finned pilot whale inhabits pelagic as well as nearshore waters (Olson 2009). Of over 2500 usable sightings in the OBIS database, 414 were within the rectangular area encompassing the survey lines, and 105 of these were during the summer months. Thus, short-finned pilot whales would likely be encountered in the proposed project area. Note that pilot whales are dealt with as an entire guild by Roberts et al. (2015), meaning that there are no specific model density grids applicable to short-finned pilot whales.

**Long-finned Pilot Whale (Globicephala melas)**

The long-finned pilot whale occurs in temperate and sub-polar zones (Jefferson et al. 2015). It can be found in inshore or offshore waters of the North Atlantic (Olson 2009). In the western North Atlantic, high densities of long-finned pilot whales occurred over the continental slope in winter and spring, and they move to the shelf during summer and autumn (Jefferson et al. 2015). Despite this range, which would appear to overlap with that of the Proposed Action, over 9000 records in the OBIS database yielded 51 that occurred in the rectangular box enclosing the larger survey area. Sixteen of these occurred during the summer months, mostly on the upper continental slope. The long-finned pilot whale could be encountered in the proposed study area. Note that pilot whales are dealt with as an entire guild by Roberts et al. (2015), meaning that there are no specific model density grids applicable to short-finned pilot whales.

**Melon-headed Whale (Peponocephala electra)**

The melon-headed whale is a pantropical species usually occurring between 40°N and 35°S (Jefferson et al. 2008). Occasional occurrences in temperate waters are extralimital, likely associated with warm currents (Perryman et al. 1994; Jefferson et al. 2008). Melon-headed whales are oceanic and occur in offshore areas (Perryman et al. 1994), as well as around oceanic islands. Off the east coast of the U.S., sightings have been made of two groups (20 and 80) of melon-headed whales off Cape Hatteras in waters 2500 m deep during
vessel surveys in 1999 and 2002 (NMFS 1999, 2002 in Waring et al. 2010). The OBIS database contains more than 300 sightings records for the melon-headed whale, and none of these are within the survey area.

The Roberts et al. (2015) model density grid for the melon-headed whale has only two values for abundance: zero in most of the U.S. EEZ and 0.240833 animals per 100 km² in the rest of the modeled area. There are no melon-headed whales in waters shallower than 1000 m in the model in the area of the Proposed Action, meaning that take calculations only capture potential animals in deeper waters. Melon-headed whales may be encountered during the seismic surveys, but they would likely be almost exclusively in deeper water and are more likely near the southern survey transects than the northern ones.

**Harbor Porpoise (Phocoena phocoena)**

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore, but it is occasionally sighted in deeper offshore water (Jefferson et al. 2015). The subspecies *P.p. phocoena* inhabits the Atlantic Ocean. In the western North Atlantic, it occurs from the southeastern U.S. to Baffin Island; in the eastern North Atlantic (Jefferson et al. 2015). Despite their abundance and the over 49,000 usable sightings of harbor porpoises in the OBIS database, only 7 occurred within the larger rectangular area encompassing the Proposed Action, and only 1 of these was during the summer months. Given their preference for coastal waters, harbor porpoises are expected to be seen during transits across the shelf, but are not expected to be encountered in the survey area during seismic operations.

**Fraser’s Dolphin (Lagenodelphis hosei)**

This information is compiled from the NOAA OPR website: [http://www.nmfs.noaa.gov/pr/species/mammals/dolphins/frasers-dolphin.html](http://www.nmfs.noaa.gov/pr/species/mammals/dolphins/frasers-dolphin.html). Fraser’s dolphin is a deepwater (> 1000 m) species that occurs in subtropical to tropical waters, nominally as far north as 30°N. This species can dive to substantial water depths in search of prey. The Western North Atlantic stock of Fraser’s dolphins, which is a population division recognized by NOAA, was unknown as of 2007 ([http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2007dofr-wn.pdf](http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2007dofr-wn.pdf)). The dolphins often occur in large groups (100 or more). The OBIS database has fewer than 200 sightings of Fraser dolphins. Only 3 sightings were within the larger project area, and only 2 of those were during the summer months. Fraser’s dolphins could be encountered within the survey area during the Proposed Action.

**Spinner Dolphin (Stenella longirostris)**

The following is taken verbatim from the Final EA for the ENAM project (LGL, 2014): The spinner dolphin is pantropical in distribution, with a range nearly identical to that of the pantropical spotted dolphin, including oceanic tropical and sub-tropical waters between 40°N and 40°S (Jefferson et al. 2008). The distribution of spinner dolphins in the Atlantic is poorly known, but they are thought to occur in deep waters along most of the U.S. coast; sightings off the northeast U.S. coast have occurred exclusively in offshore waters >2000 m (Waring et al. 2010). Within the OBIS database of over 2000 usable sightings, the USGS found that none occurred in the survey area in any season. However, based on the abundance grids from Roberts et al. (2016), spinner dolphins could be encountered in the survey area in August 2018. Note that spinner and Clymene dolphins are often considered together in analyses, but were separated here due to the availability of density grids for each species.

**Clymene’s Dolphin (Stenella clymene)**

The following is taken verbatim from the Final EA for the ENAM project (LGL, 2014). The Clymene dolphin only occurs in tropical and subtropical waters of the Atlantic Ocean (Jefferson et al. 2008).
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). It is generally sighted in deep waters beyond the shelf edge (Fertl et al. 2003). Based on the USGS analyses, 23 sightings of the 140 that are usable in the OBIS database are within the overall rectangular area that encloses the surveys, and 14 of these are during the summer months.

Table 6. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic project area in the Northwest Atlantic Ocean. Elements of this table were adopted directly from the Draft Scripps EA (LGL, 2017) and the ENAM EA (RPS, 2014c), with supplementary information from other sources for the populations. The iOBIS information in the far right columns was compiled by the USGS for this Draft EA using a polygon that roughly enclosed the entire area of the Proposed Action. Usable iOBIS sightings exclude those with dates entered in an incorrect format. Note that some iOBIS sightings lack dates, but were included in the overall count of usable sightings. The algorithm arbitrarily assigned those sightings without dates to January. Abundance values are mostly taken from the Draft Scripps EA (LGL 2017), with some additional values added as footnoted.

<table>
<thead>
<tr>
<th>Species</th>
<th>Occurrence near survey location</th>
<th>Habitat</th>
<th>Abundance in North Atlantic</th>
<th>ESA¹</th>
<th>IUCN²</th>
<th>CITES³</th>
<th>Usable iOBIS sightings compiled by USGS</th>
<th>Subset of sightings within survey area polygon</th>
<th>Subset of sightings in area that occurred July-Sept</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Atlantic right whale</td>
<td>Rare</td>
<td>Mainly coastal and shelf</td>
<td>440-736⁴</td>
<td>EN</td>
<td>EN</td>
<td>I</td>
<td>5695</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>Uncommon</td>
<td>Mainly nearshore waters and</td>
<td>11,570⁶</td>
<td>NL24</td>
<td>LC</td>
<td>I</td>
<td>41354</td>
<td>79</td>
<td>14</td>
</tr>
<tr>
<td>Common minke whale</td>
<td>Uncommon</td>
<td>Coastal, offshore</td>
<td>157,000⁷</td>
<td>NL</td>
<td>LC</td>
<td>I25</td>
<td>15843</td>
<td>51</td>
<td>12</td>
</tr>
<tr>
<td>Bryde's whale</td>
<td>Uncommon</td>
<td>Coastal, N.A.</td>
<td>N.A.</td>
<td>NL</td>
<td>DD</td>
<td>I</td>
<td>914</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sei whale</td>
<td>Uncommon</td>
<td>Mostly pelagic</td>
<td>10,300⁸</td>
<td>EN</td>
<td>EN</td>
<td>I</td>
<td>11127</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Fin whale</td>
<td>Possible</td>
<td>Slope, mostly pelagic</td>
<td>24,887⁹</td>
<td>EN</td>
<td>EN</td>
<td>I</td>
<td>68029</td>
<td>131</td>
<td>29</td>
</tr>
<tr>
<td>Blue whale</td>
<td>Rare</td>
<td>Coastal, shelf, pelagic</td>
<td>865¹⁰</td>
<td>EN</td>
<td>EN</td>
<td>I</td>
<td>16949</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sperm whale</td>
<td>Likely</td>
<td>Usually deep pelagic, steep topography</td>
<td>13,190¹¹</td>
<td>EN</td>
<td>VU</td>
<td>I</td>
<td>53789</td>
<td>686</td>
<td>395</td>
</tr>
<tr>
<td>Pygmy sperm whale (Kogia)</td>
<td>Possible</td>
<td>Deep waters off shelf</td>
<td>3785¹²,¹³</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>432</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Dwarf sperm whale (Kogia)</td>
<td>Possible</td>
<td>Deep waters off shelf</td>
<td></td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuvier's beaked whale</td>
<td>Possible</td>
<td>Slope, pelagic</td>
<td>3532¹²</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>1675</td>
<td>155</td>
<td>76</td>
</tr>
<tr>
<td>Northern bottlenose whale</td>
<td>Possible</td>
<td>Pelagic</td>
<td>~40,000¹⁵</td>
<td>NL</td>
<td>DD</td>
<td>I</td>
<td>2293</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>True's beaked whale</td>
<td>Possible</td>
<td>Pelagic</td>
<td>7092¹²,¹⁴</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>25</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Gervais beaked whale</td>
<td>Possible</td>
<td>Pelagic</td>
<td>7092¹²,¹⁴</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>121</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sowerby's beaked whale</td>
<td>Possible</td>
<td>Pelagic</td>
<td>7092¹²,¹⁴</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>246</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Blainville's beaked whale</td>
<td>Possible</td>
<td>Pelagic</td>
<td>7092¹²,¹⁴</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>574</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rough-toothed dolphin</td>
<td>Possible</td>
<td>Mostly pelagic</td>
<td>N.A.</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>1052</td>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>
### Table 6 (continued)

<table>
<thead>
<tr>
<th>Species</th>
<th>Occurrence near survey location</th>
<th>Habitat</th>
<th>Abundance in North Atlantic</th>
<th>ESA(^1)</th>
<th>IUCN(^2)</th>
<th>CITES(^3)</th>
<th>Usable iOBIS sightings compiled by USGS</th>
<th>Subset of sightings within survey area polygon</th>
<th>Subset of sightings in area that occurred July-Sept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clymene dolphin</td>
<td>Likely</td>
<td>Deepwater</td>
<td>6068(^{21})</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>140</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>Spinner dolphin</td>
<td>Possible</td>
<td>Coastal</td>
<td>NA(^{23})</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>2278</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Common bottlenose dolphin</td>
<td>Likely</td>
<td>Coastal, shelf, pelagic</td>
<td>77,532(^{16})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>57879</td>
<td>1873</td>
<td>776</td>
</tr>
<tr>
<td>Fraser's dolphin</td>
<td>Possible</td>
<td>Deep offshore</td>
<td>492 * (sum of abundance in Roberts et al. 2016 grid)</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>177</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td>Possible</td>
<td>Shelf, slope, pelagic</td>
<td>3333(^{12})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>4240</td>
<td>48</td>
<td>29</td>
</tr>
<tr>
<td>Melon-headed whale</td>
<td>Possible</td>
<td>Seaward of continental</td>
<td>3451(^{10})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>327</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Atlantic spotted dolphin</td>
<td>Likely</td>
<td>Shelf, offshore</td>
<td>44,715(^{12})</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>7655</td>
<td>125</td>
<td>58</td>
</tr>
<tr>
<td>Striped dolphin</td>
<td>Likely</td>
<td>Off continental shelf</td>
<td>54,807(^{12})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>15620</td>
<td>183</td>
<td>95</td>
</tr>
<tr>
<td>Atlantic white-sided dolphin</td>
<td>Possible</td>
<td>Coastal, shelf</td>
<td>48,819(^{12})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>7932</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Short-beaked common dolphin</td>
<td>Likely</td>
<td>Shelf, pelagic, high relief</td>
<td>70,184(^{12})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>42829</td>
<td>43</td>
<td>3</td>
</tr>
<tr>
<td>Risso's dolphin</td>
<td>Likely</td>
<td>Shelf, slope,</td>
<td>18,250(^{12})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>7241</td>
<td>471</td>
<td>238</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td>Uncommon</td>
<td>Pelagic</td>
<td>N.A.</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>204</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>False killer whale</td>
<td>Uncommon</td>
<td>Pelagic</td>
<td>442</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>1173</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Killer whale</td>
<td>Uncommon</td>
<td>Coastal, widely distributed</td>
<td>15,014(^{17})</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>3077</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Long-finned pilot whale</td>
<td>Likely</td>
<td>Mostly pelagic</td>
<td>5636(^{12})</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>9082</td>
<td>51</td>
<td>16</td>
</tr>
<tr>
<td>Short-finned pilot whale</td>
<td>Likely</td>
<td>Mostly pelagic, high-relief</td>
<td>21,518(^{14}) 780,000(^{18})</td>
<td>NL</td>
<td>DD</td>
<td>II</td>
<td>2514</td>
<td>414</td>
<td>105</td>
</tr>
<tr>
<td>Harbor porpoise</td>
<td>Uncommon</td>
<td>Coastal and shelf, also pelagic</td>
<td>79,833(^{19})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>49502</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>White Beaked Dolphin</td>
<td>Uncommon</td>
<td>Cold waters &lt; 200 m</td>
<td>2003(^{22})</td>
<td>NL</td>
<td>LC</td>
<td>II</td>
<td>2717</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^{1}\) U.S. Endangered Species Act: EN = Endangered.  
\(^{2}\) Not available or not assessed.  NL = Not listed.  
\(^{3}\) Not available or not assessed.  NL = Not listed.
III. Affected Environment

2 Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient. Classifications are from the IUCN Red List of Threatened Species (IUCN 2017).

3 Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2017); Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

4 Based on Pettis et al. (2017), Hayes et al. (2017), and IWC (2017)

5 Doniol-Valcroze (2015)

6 West Indies breeding ground (Stevick et al. 2003)

7 Central (50,000), Northeast Atlantic (90,000), and West Greenland (17,000) populations (IWC 2017)

8 North Atlantic (Cattanach et al. 1993)

9 Central and Northeast Atlantic for 2001 (Vikingson et al. 2009)

10 Central and Northeast Atlantic for 2001 (Pike et al. 2009)

11 For the northeast Atlantic, Faroes-Iceland, and the U.S. east coast (Whitehead 2002)

12 Western North Atlantic (Hayes et al. 2017)

13 Both Kogia species

14 All Mesoplodon spp. combined

15 Eastern North Atlantic (NAMMCO 1995)

16 Offshore, Western North Atlantic (Hayes et al. 2017)

17 Northeast Atlantic (Foote et al. in NAMMCO 2016)

18 Globicephala sp. combined, Central and Eastern North Atlantic (IWC 2017)

19 Gulf of Maine/Bay of Fundy stock (Hayes et al. 2017)

20 Pilot whales in the Gulf of St. Lawrence and on the Scotian Shelf (Lawson and Gosselin 2009, 2011)

21 Waring et al. (2008); Note that the Roberts et al. (2016) abundance grid would correspond to 12526 individuals.


23 Spinner dolphins have no minimum population assessment. https://www.nefsc.noaa.gov/publications/tm/tm228/190_spinner.pdf

Sea Turtles

Much of this section is taken verbatim from the Draft Scripps EA (2017), with small modifications to adapt it to the USGS Proposed Action.

Five species of sea turtles could occur in or near the proposed project area in the Northwest Atlantic Ocean: the leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), Kemp’s ridley (*Lepidochelys kempii*), loggerhead (*Caretta caretta*), and green turtle (*Chelonia mydas*). The leatherback and loggerhead turtles are the most likely turtles to be encountered. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles are given in § 3.4.1 of the NSF-USGS PEIS. The general distribution of sea turtles in the North Atlantic and on the Mid-Atlantic Ridge is discussed in § 3.4.3.1 and § 3.4.3.4 of the NSF-USGS PEIS. The rest of this section deals specifically with their distribution near the proposed project area.

1. Leatherback Turtle

The leatherback is listed as *endangered* under the ESA; however, a petition to designate the Northwest Atlantic subpopulation as a DPS and to list the DPS as *threatened* under the ESA is currently being considered by NOAA (2017a). Globally, the leatherback turtle is designated as *vulnerable* on the IUCN Red List of Threatened Species, but the Northwest Atlantic Ocean subpopulation is considered *least concern*. TEWG (2007) estimated the North Atlantic population at 34,000–94,000 adults. The leatherback is the largest and most widely distributed sea turtle, ranging far from its tropical and subtropical breeding grounds to feed (Plotkin 2003; Spotila 2004). In the Atlantic, the largest nesting beaches are in Gabon, Africa, and in French Guiana; leatherbacks also nest in the Caribbean and Florida (NOAA 2016a). Hatchling leatherbacks are pelagic, but virtually nothing is known about their distribution for the first four years (Musick and Limpus 1997). Eckert (2002) determined that juvenile leatherbacks (<100 cm in carapace length) only occur in waters warmer than 26°C, while slightly larger juveniles (107 cm) are found in waters as cold as 12°C. Outside of the nesting season, leatherbacks are highly migratory and feed in areas of high productivity, such as convergence zones, and upwelling areas in the open ocean, along continental margins, and in archipelagic waters (Morreale et al. 1994; Eckert 1995). Leatherbacks move over large ranges in the
III. Affected Environment

ocean and occur in pelagic regions of the North Atlantic where they forage between April and December on gelatinous zooplankton (Hays et al. 2006; COSEWIC 2012).

Figure 8. Compilation of the usable turtle sightings in the iOBIS database within a large polygon bounding all of the proposed seismic survey lines during the months of July, August, and September. No sightings of the hawksbill turtle met these criteria, so this species is missing. Also shown is the sargassum habitat for loggerhead turtles, which is described in more detail in §III.4.2.

Leatherback turtles are sometimes taken as bycatch by net and longline fishing in the MAB (Wallace et al., 2013). USGS analysis of the ~13,500 usable global sitings in the OBIS database showed that 316 individuals were identified in the survey area of the Proposed Action during any month and 76 during the July through September period. The locations of these sitings relative to the survey area are shown in Fig. 8. Fig. 9 shows the density map for leatherbacks from DiMatteo et al. (2017). Leatherback turtles are expected to be encountered in the area of the Proposed Action, particularly between the shelf-break and 1500 m water depth.
III. Affected Environment

Figure 9.  Summer NODES density spatial model for the leatherback turtle from DiMatteo et al. (2017). Note that the diagram’s caption is mislabeled in the original, and that this figure should be for summer. It is bound in the original publication by distribution figures for spring and fall.

2. Loggerhead Turtle

Under the ESA, the Northeast Atlantic Ocean DPS (east of 40°W) of the loggerhead turtle is listed as *endangered*, and the Northwest Atlantic Ocean DPS (west of 40°W) is listed as *threatened*. Globally, the loggerhead turtle is listed as *vulnerable* on the IUCN Red List of Threatened Species, but the North East Atlantic subpopulation is listed as *endangered*, and the North West Atlantic subpopulation is listed as *least concern*. The loggerhead distribution is largely constrained by water temperature; it does not generally occur in waters with temperatures below 15°C (O’Boyle 2001; Brazner and McMillan 2008).

The major nesting areas in the North Atlantic occur along the U.S. coast (NOAA 2017b). The loggerhead turtle is the most common sea turtle in North American waters (Spotila 2004; NOAA 2017b). The adult female population in the western North Atlantic is estimated at 38,334 individuals (Richards et al. 2011). Post-hatchlings may reside for months in waters off the nesting beach or be transported by ocean currents within the Gulf of Mexico and North Atlantic (Witherington 2002; COSEWIC 2010). Between 7–12 years of age, juvenile loggerheads migrate from offshore regions to nearshore coastal areas until reaching adulthood (Bjorndal et al. 2000, 2003). Loggerheads migrate considerable distances between near-equatorial nesting areas and temperate foraging areas, and some move with the Gulf Stream into eastern Canadian waters during the summer (Hawkes et al. 2007). Loggerheads may be seen in the open seas during migration and foraging (e.g., Mansfield et al. 2009). According to the analysis by Wallace et al. (2013), loggerheads are the turtle species most frequently encountered as bycatch within the MAB. Bycatch occurs through all fishing methods (nets, longlines, and trawls).

The Sargasso Sea is considered critical habitat for loggerhead turtles. §3.2 describes this area and its importance. Of ~38,200 usable records in the OBIS database, 2859 were within the polygon enclosing the survey area, and 1618 of those were in July through September. These sightings are plotted in Fig. 8, along with the location of the Sargasso Sea critical habitat. Note that by far the highest density of sightings is on
the inner and mid-continental shelf. Figure 10 shows the NODES model summer density of loggerhead turtles from DiMatteo et al. (2017). Loggerhead turtles are expected to be encountered during the Proposed Action, even at profound water depths (> 2000 m).

Figure 10. NODES density for summer distribution of loggerhead turtles from DiMatteo et al. (2017). Note that, despite the far larger number of OBIS sitings in the survey area during the summer months, the density map indicates a lower number of loggerheads than leatherbacks (Figure 9) expected in the Survey Area during the summer.

3. Green Turtle

The North Atlantic DPS of the green turtle is listed as threatened under the ESA and as endangered on the IUCN Red List of Threatened Species. The green sea turtle is widely distributed in tropical and subtropical waters near continental coasts and around islands between 30°N and 30°S (NOAA 2016b), although it has been recorded 500–800 miles from shore in some regions (Eckert 1993 in NMFS 2002). The most important nesting beaches for the North Atlantic DPS are in the Caribbean, Gulf of Mexico, and Florida (Seminoff et al. 2015). The turtle nester abundance for this DPS has been estimated at 167,424 (Seminoff et al. 2015).

Green sea turtles typically migrate along coastal routes from rookeries to feeding grounds, although some populations conduct trans-oceanic migrations (e.g., Ascension Island - Brazil). Hatchlings swim to offshore areas where they are thought to live for several years, feeding near the surface on pelagic plants and animals (NOAA 2016b). Juvenile and sub-adult green sea turtles may travel thousands of kilometers before returning to their breeding and nesting grounds (Carr et al. 1978; NOAA 2016b).

On the U.S. Atlantic margin, green sea turtles are occasionally taken as bycatch by nets and trawls (Wallace et al., 2013). Of the ~4900 usable green turtle records in the OBIS database, 133 are within the polygon bounding the outer edges of the Survey Area, and 56 of these sightings were in the summer. However, as shown in Figure 8, only 6 of these sightings were deeper than the shelf-break and overlapped
the general area of the Proposed Action. The DiMatteo et al. (2017) map for summer hardshell (green plus hawksbill) turtle density shows the highest concentration in the MAB to be on the shelf (Figure 11), where seismic operations will not occur. While green turtles may be encountered during the seismic activities, their occurrence is likely to be rare.

Figure 11. NODES model density distribution of hardshell turtles, which combines green and hawksbill turtles, from DiMatteo et al. (2017). These turtle species are combined because definitively identifying them at sea is challenging.

4. Hawksbill Turtle

The hawksbill turtle is listed as endangered under the ESA and critically endangered on the IUCN Red List of Threatened Species. Hawksbill turtles are the most tropical of all sea turtles, generally occurring between 30ºN and 30ºS in the Atlantic, Pacific, and Indian oceans (NOAA 2014a); nesting is confined to areas where water temperature is 25º–35ºC. The most important nesting beaches in the northern-hemisphere Atlantic are along the Yucatan Peninsula, southern Cuba, and a few Caribbean islands. Lutz et al. (2003 in NOAA 2014a) estimated that 27,000 adult hawksbills live in the Caribbean. Mature females return to their natal beaches to nest every two to three years between April and November (NOAA 2014a). Hawksbill turtles are typically observed in shallow waters with seagrass or algal meadows and are most common where healthy reef formations are present (NOAA 2014a). In the Atlantic, post-hatchling juveniles are thought to occupy the pelagic environment of the ocean, sheltering in floating algal mats and drift lines of flotsam and jetsam (NOAA 2014a). Hawksbill turtles most commonly perform short-distance movements between nesting beaches and offshore feeding banks, although long-distance movements are also known (e.g., Spotila 2004).

Of the ~8125 usable OBIS records for hawksbill turtles, only 5 (~0.06%) occurred within the large polygon that encloses the entire area. None of these occurrences were in the July through October period, and therefore no sightings are plotted for this species in Figure 8. The density map in Figure 11 includes
hawksbill turtles. It would be a rare occurrence for the Proposed Action to encounter a hawksbill turtle during seismic operations.

5. Kemp’s Ridley Turtle

The Kemp’s ridley turtle is listed as *endangered* under the ESA and *critically endangered* on the IUCN Red List of Threatened Species. Kemp’s ridley turtles have a more restricted distribution than most other sea turtles. Adult turtles usually only occur in the Gulf of Mexico, but juveniles and immature individuals range between the tropics and temperate coastal areas of the Northwest Atlantic, as far as New England (NOAA 2017c). Occasionally, individuals may be carried by the Gulf Stream as far as northern Europe, although those individuals are considered lost to the breeding population. Adult Kemp’s ridley turtles migrate along the coast between nesting beaches and feeding areas, nesting in arribadas on several beaches in Mexico from May to July (NOAA 2017c). Nesting also occurs on a smaller scale in North and South Carolina, Florida, Texas, and other locations in Mexico (NOAA 2017c). After nest emergence, some hatchlings remain within the Gulf of Mexico, while others may be swept out of the Gulf, around Florida and into the Atlantic Ocean (NOAA 2017c). Juveniles have been known to associate with floating Sargassum seaweed for a period of ~2 years; such sub-adults subsequently return to the neritic zones of the Gulf of Mexico or Northwest Atlantic to feed (NOAA 2017c).

Of over 900 usable records in the OBIS database, 32 were within the larger polygon enclosing the Survey Area. Twenty-four of these sightings occurred in July, August, or September (Figure 8), but only two of these occur deeper than the mid-shelf. The NODES density map (Figure 12) also shows a low density of these turtles in the Survey Area. While it is possible that a Kemp’s ridley turtle could be encountered in the area of the Proposed Action, it would be considered a rare occurrence.

![Figure 12. NODES density model for Kemp’s Ridley turtles during summer months from DiMatteo et al. (2017).](image-url)
Seabirds

Three seabird species that are listed under the ESA or under consideration for listing have ranges that overlap the area of the Proposed Action: the Bermuda petrel (*Pterodroma cahow*), the black capped petrel, and the roseate tern. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of seabird families is given in § 3.5.1 of the NSF-USGS PEIS.

1. Bermuda Petrel

The following is adopted verbatim from the Draft Scripps EA (LGL, 2017). The Bermuda petrel is listed as *endangered* under the ESA (USFWS 2007) and *endangered* on the 2017 IUCN Red List of Threatened Species (IUCN 2017). The Bermuda petrel was exploited for food and was thought to be extinct by the 17th century. It was only rediscovered in 1951, at which time the population consisted of 18 pairs (del Hoyo et al. 1992). The population has been the subject of an ongoing recovery effort, and by 2008 it was up to 85 breeding pairs (Madeiros et al. 2012). This population is now increasing slowly, but remains vulnerable to storm damage, erosion, and predation (BirdLife International 2017a; Madeiros et al. 2012).

Currently, all known breeding occurs on islets in Castle Harbour, Bermuda (Madeiros et al. 2012). Petrels return to the colony in mid-October and remain until June. During the non-breeding season (mid June–mid October), Bermuda petrels are strictly pelagic and likely follow the Gulf Stream. From 2009 to 2012, several birds were fitted with data-loggers to determine their pelagic range. These studies found that many Bermuda petrels spent the non-breeding season in the central North Atlantic, in the vicinity of the Azores, with some travelling as far as Ireland or Spain (Madeiros et al. 2014).

Based on the IUCN (2017) range map accessed by the USGS in March 2018, the entire Proposed Action occurs within the range of the Bermuda petrel. Thus, Bermuda petrels could be encountered in very small numbers during Proposed Action. As noted by the Draft Scripps EA (LGL, 2017), “based on satellite tracked birds, Bermuda petrels would be more likely to occur between 36.5º and 47.5ºN (Madeiros et al. 2014).” This confirms the possibility of encountering these birds within the area of the Proposed Action.

2. Black Capped Petrel

The black capped petrel (*Pterodroma hasitata*) is listed as *endangered* by the IUCN (2017) and is being considered for listing under ESA by the U.S. Fish and Wildlife Service. The following information is compiled from the IUCN (2017): The bird is primarily threatened by habitat loss in breeding areas in the Caribbean and has been entirely eliminated on some Caribbean islands. Currently, it is known to breed only on Hispanola, although it was thought to breed on Guadeloupe and Martinique (prior to 1900) and possibly Cuba in the past. The bird lays eggs and raises its young between mid-January and early July. Young birds depart for the feeding range after that time. Black capped petrels forage in the Gulf Stream and the Florida Current and their range as delineated by IUCN (2017) spatial data extends offshore North Carolina and far out to sea in the Mid-Atlantic region. The birds feed in flocks and mostly at dusk and nocturnally, targeting squid, fish, crustaceans, and Sargassum. Curtice et al. (2016) show very small abundance of these birds in the study area (Figure 13). Based on the range of these birds, it is possible that they could be encountered during the Proposed Action while acquiring data along the southernmost exemplary lines. If the Gulf Stream were to shift west during the Proposed Action, black capped petrels might also follow the current westward, thereby intersecting other parts of the survey area.
3. Roseate Tern

The U.S. Fish and Wildlife Service lists the Roseate tern (*Sterna dougalli*) is listed as *endangered* under the ESA on the Atlantic Coast from Massachusetts to North Carolina and threatened throughout the rest of the Western Hemisphere. The roseate tern is designated *Least Concern* on the 2017 IUCN Red List of Threatened Species (IUCN 2017). According to the IUCN, roseate terns on the U.S. Atlantic coast breed in the coastal areas and on offshore islands. No critical habitat has been established for the roseate tern. The area shown in Figure 13 marks the foraging area as obtained from IUCN (2017).

According to the information compiled by the IUCN (2017), the roseate tern is a plunge diving bird that feeds alone or in small groups. The primary prey is small pelagic fish and sometimes crustaceans. Birds generally forage within a few tens of kilometers of their coastal nesting sites, meaning that they are unlikely to be encountered in the survey area during the Proposed Action. The abundance map compiled by Curtice et al. (2016) shows effectively zero of these birds overlapping the survey area during the summer season.

![Figure 13. Compilation of information related to the black-capped petrel and the roseate tern. The yellow lines are the exemplary transects for the Proposed Action, with the pink lines nominal linking transits (interseismic lines). The purple area marks the foraging range of the roseate tern from the IUCN (2017). No critical habitat has yet been designated under ESA. The blue shows the area occupied by resident black-capped petrels as taken from the abundance maps of Curtice et al. (2016). Note that the abundance corresponding to this shading is $1.8 \times 10^7$ individuals. The range of the Bermuda petrel encompasses the entire area of the Proposed Action and is not depicted on the map.](image)
Fish

The area of the Proposed Action overlaps Essential Fish Habitat for numerous species listed in Table 4. These include species within the Mid-Atlantic and the northern part of the Southeast fisheries areas, as well as Atlantic highly-mobile species. This section describes in detail the ESA-listed species, essential fish habitat and habitats of particular concern, and commercial and recreational fisheries. Parts of the following sections are adopted verbatim from the Draft Scripps EA (LGL, 2017), with minor modifications to fit the circumstances of the Proposed Action.

1. ESA-listed Species

The term “species” under the ESA includes species, subspecies, and, for vertebrates only, Distinct Population Segments (DPSs) or “evolutionarily significant units (ESUs)”. ESA-listed species designated as endangered (NOAA 2017e) that could occur in the proposed project area include the Carolina, Chesapeake Bay, New York Bight DPSs of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) and the shortnose sturgeon (Acipenser brevirostrum). (The Gulf of Maine DPS of Atlantic sturgeon is an ESA-listed species designated as threatened and is not considered relevant to the Proposed Action). Species proposed for listing under the ESA as threatened and that may occur within the proposed project area include the giant manta ray (Manta birostris) and oceanic whitetip shark (Carcharhinus longimanus) (NOAA 2017f).

Atlantic Sturgeon

The Atlantic sturgeon is an anadromous, estuarine fish species that inhabits freshwater and brackish waters, as well as marine coastal waters. It is not believed to take extensive migrations beyond the coastal zone to the open ocean (NOAA 2017g). Sturgeon generally occur solitary or in small groups and are long-lived and late maturing (St. Pierre and Parauka 2006). This species is separated into four separate “Endangered” DPSs: New York Bight, Chesapeake Bay, Carolina, and South Atlantic; as well as one “Threatened” DPS in the Gulf of Maine (NOAA 2017g). All DPSs have designated several river systems that sturgeon are known to inhabit as critical habitat. The Atlantic sturgeon is not expected to occur in the offshore proposed project area.

Shortnose Sturgeon

The shortnose sturgeon is the smallest sturgeon species that is found in North America. Similar to the Atlantic sturgeon, it is both an anadromous and estuarine species that undertakes migrations in coastal waters throughout its adult life and is not known to make long offshore migrations (NOAA 2015b). The shortnose sturgeon occurs in many riverine systems along the east coast of North America, from the St. John River, New Brunswick to Florida (NOAA 2015b). It is not expected to occur in the area of the Proposed Action.

Giant Manta Ray

Giant manta rays are migratory and cold-water tolerant, with highly fragmented populations sparsely distributed in the tropical, subtropical, and temperate waters of the world (NOAA 2017h). Giant manta rays are the largest living ray in the world (NOAA 2017h) and tend to be solitary (DoW 2015a). This species filter-feeds virtually exclusively on plankton (DoW 2015a). Regional population sizes are small and have generally declined in known areas except where specifically protected (NOAA 2017h). It could occur within or near the proposed project area.

Oceanic Whitetip Shark

The oceanic white tip shark is an offshore pelagic species inhabiting surficial waters in the open ocean, occurring worldwide typically between 20°N and 20°S but also at higher latitudes during the
summer months (NOAA 2016e). Oceanic whitetip sharks are aggressive and persistent, and prey on bony fishes such as tunas, barracuda, white marlin, dolphinfish, lancetfish, oarfish, threadfish and swordfish), along with threadfins, stingrays, sea turtles, seabirds, gastropods, squid, crustaceans, mammalian carrion and garbage (NOAA 2016e). Oceanic whitetip shark populations have shown severe declines in the Atlantic Ocean (DoW 2015b). It could occur within or near the proposed project area.

2. Fish Habitats

Maps provided by the Marine-Life Data and Analysis Team (MDAT) at Duke University (Curtice et al., 2016) based on data from the Northeast Fisheries Science Center give compilations of biomass, diversity, and species richness based primarily on tow data acquired on the continental shelf. The maps do not extend beyond the shelf-break and thus do not overlap the area of the Proposed Action.

Essential Fish Habitat (EFH)

The following is taken verbatim or with slight modifications from the Final Environmental Assessment for the 2014 ENAM Project (RPS, 2014c). 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) covers nearly the entire survey area and the South Atlantic Fishery Management Council (SAFMC) has jurisdiction over the very southernmost parts of the surveys. The Highly Migratory Division of the National Marine Fisheries Service in Silver Spring, MD, manages highly migratory species (sharks, swordfish, billfish, and tunas).

Using ArcGIS, the exemplary seismic transects and tie-lines for the Proposed Action were intersected with the the polygons provided by NMFS for the Mid-Atlantic, South Atlantic, and Highly Mobile Species EFH. The result is a list of species EFH and species’ life stages that overlap with the USGS seismic surveys. Table 7 summarizes the results for the 41 species and the life stage that overlaps with the general area of the Proposed Action.

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) Restricted areas designated to minimize impacts on juvenile and adult tilefish EFH from bottom trawling activity (see further under next section); (2) 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 (3) Prohibitions on the possession of coral species and the use of 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.

Habitats of Particular Concern

As taken from the Final EA for the ENAM project (LGL, 2014), Habitat Areas of Particular Concern (HAPC) are subsets of EFH that provide important ecological functions and/or are especially vulnerable to degradation and that are designated by Fishery Management Councils. The exemplary survey lines for the Proposed Action do not directly intersect any HAPC in the Mid-Atlantic or South Atlantic region, nor HAPC or Atlantic highly mobile species.

One of the tie-lines (interseismic, linking lines) between primary exemplary survey lines may approach the seaward side of HAPC for juvenile and adult tilefish near the head of Norfolk Canyon. Tilefish inhabit
burrows in clay outcrops and in the walls of submarine canyons at water depths of 100-300 m (MAFMC and NMFS 2008) in this area. In addition, the southernmost exemplary dip-line for the Proposed Action lies ~3 nautical miles north of HAPC for snapper-grouper on a hardground called the Point, straddling the shelf-break offshore Cape Hatteras. This area is important for spawning.

TABLE 7. Marine species with Essential Fish Habitat (EFH) overlapping the proposed survey area. Table produced by combining exemplary seismic lines with the EFH polygons provided by NMFS. For life stage, E = embryo; L = larval/neonate; J=juvenile; A=adult; and SA = spawning adult.

<table>
<thead>
<tr>
<th>Species</th>
<th>Life Stage for Overlapping EFH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic herring Clupea harengus</td>
<td>E  L/N J A SA</td>
</tr>
<tr>
<td>Bluefish Pomatomus saltatrix</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Butterfish Peprilus triacanthus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Black sea bass Centropristis striata</td>
<td>o  o  o</td>
</tr>
<tr>
<td>Atlantic mackerel Scomber scombrus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Snapper-Grouper4</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Scup Stenotomus chrysops</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Golden tilefish Lopholatilus chamaeleonticeps</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Summer flounder Paralichthys dentatus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Albacore tuna Thunnus alalunga</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Bluefin tuna Thunnus thynnus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Bigeye tuna Thunnus obesus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Yellowfin tuna Thunnus albacres</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Skipjack tuna Katsuwonus pelamis</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Swordfish Xiphius gladius</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Blue marlin Makaira nigricans</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>White marlin Tetraparurus australis</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Sailfish Istiophorus platypterus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Longbill spearfish Tetraparurus pfluegeri</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Roundscale spearfish Tetraparurus georgii</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Angel shark Squatina dumeri</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Basking shark Cetorhinus maximus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Bigeye thresher shark Alopias superciliosus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Common thresher shark Alopias vulpinus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Blue shark Prionace glauca</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Longfin mako shark Isurus paucus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Shortfin mako shark Isurus oxyrinchus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Smooth (spiny) dogfish Squalus acanthias</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Tiger shark Galeocerdo cuvier</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Sand tiger shark Carcharias taurus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Dusky shark Carcharhinus obscurus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Night shark Carcharhinus isodon</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Oceanic whitetip shark Carcharhinus longimanus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Sandbar shark Carcharhinus plumbeus</td>
<td>o  o</td>
</tr>
<tr>
<td>Silky shark Carcharhinus falciformis</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Atlantic surfclam Spisula solidissima</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Ocean quahog Arctica islandica</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Spiny lobster Panulirus argus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Northern shortfin squid Illex illecebrosus</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Longfin inshore squid Loligo pealei</td>
<td>o  o  o  o  o</td>
</tr>
<tr>
<td>Coral, coral reefs and live/hard bottom17</td>
<td>o  o  o  o  o</td>
</tr>
</tbody>
</table>
3. Commercial Fisheries

Table 8 summarizes the catch data for commercial fisheries in the coastal states landward of the Proposed Survey area: New Jersey, Delaware, Maryland, Virginia, and North Carolina. Although the Proposed Action would not occur offshore New York or Pennsylvania, these states are also included. In 2015 and 2016, the value of commercial fishing in these states was over $1.25 billion for more than 1.37 billion pounds of fish landed. As noted in Table 8, most of the revenue was generated by estuarine and inner shelf species whose depth ranges do not overlap with that of the Proposed Action, which would only take place at greater than 100 m water depth. These high-value estuarine/inner shelf species include blue crab, various shellfish (oysters, clams, sea scallops), and menhaden. The following paragraphs touch only on the species that contribute the most to the overall revenue in the coastal states and that live at water depths beyond those characteristic of estuaries, the coastal zone, and the inner shelf.

Summer flounder, which is currently under fishing restrictions in the mid-Atlantic states for 2018 (with no landings permitted in Delaware), does occur on the uppermost continental slope (to 160 m water depth) according to the IUCN (accessed March 2018), which lists the species as “least threatened.” The Proposed Action occurs entirely within the Summer Flounder Management Area and occupies most of the Scup and Black Sea Bass Management areas (all extend eastward to the EEZ boundary) as defined by NOAA in 2014. The Proposed Action also overlaps the area where summer flounder trawl fisherman must use a turtle excluder device (TED).

Longfin squid occur at greater water depths (up to 400 m) from November through February than during the period of the Proposed Action (August), when they are expected only to ~180 m on the uppermost slope (NEFSC, 2005). The endangered golden tilefish, which occurs to 540 m water depth according to the IUCN (2018), was a high-value commercial species only in New York. The Norfolk Canyon HAPC for this species is discussed above.

On a per pound basis, the most economically-valuable fish for landings in the coastal states in 2015 and 2016 were nearly all estuarine/coastal shellfish. The major exceptions were bluefin and bigeye tuna, swordfish, golden tilefish (2016), and some sharks. None of these species constituted a large component of the commercial landings in the associated states.

Table 8. Compilation of commercial fish landings in the Mid-Atlantic Bight in 2015 and 2016.

<table>
<thead>
<tr>
<th>State</th>
<th>2015/2016 Catch Value ($, millions)</th>
<th>2015/2016 Catch (lbs. landed, millions)</th>
<th>Common name of primary species landed (% total value)</th>
<th>Depth range of primary species landed</th>
<th>Proposed Action (exclusively &gt; 100 m water depth) closest approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>99.3</td>
<td>56.3</td>
<td>Northern quahog, longfin squid, sea scallop (2016), golden tilefish, scup, summer flounder (56%)</td>
<td>Golden tilefish 80 to 540 m^;summer flounder to 160 m^; longfin squid adults up to 180 m March to October^; scup 10 to 200 m^; other species shelfal/estuarine</td>
<td>No lines offshore NY; ~100 nm (~185 km) to closest line</td>
</tr>
<tr>
<td>New Jersey</td>
<td>359.2</td>
<td>272.0</td>
<td>Scallops, clams, menhaden, blue crab, longfin squid, summer flounder (91%)</td>
<td>Summer flounder to 160 m^; Menhaden to 50 m^; longfin squid to 180 m March to October; other species shelfal/estuarine</td>
<td>~70 nm (~130 km)</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>0.24</td>
<td>0.14</td>
<td>Carp, minnows (77%)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Delaware</td>
<td>16.9</td>
<td>8.5</td>
<td>Blue crab (73%)</td>
<td>Estuarine/coastal</td>
<td>~65 nm (120 km)</td>
</tr>
<tr>
<td>Maryland</td>
<td>183.6</td>
<td>110.6</td>
<td>Blue crab (61%)</td>
<td>Estuarine/coastal</td>
<td>50 nm (~93 km)</td>
</tr>
</tbody>
</table>
III. Affected Environment

| Virginia          | 405.4 | 801.0 | Sea scallop, blue crab, menhaden, northern quahog, eastern oyster, summer flounder (87%) | Summer flounder up to 160 m²; menhaden to 50 m²; other species shelf/estuarine | 55 nm (102 km) |
| North Carolina    | 188.8 | 125.9 | Blue crab, white & brown shrimp, summer flounder (60%) | Summer flounder up to 160 m²; other species on shelf/estuarine | 38 nm (70 km) |

* https://www.nefsc.noaa.gov/publications/tm/tm193/tm193.pdf  ^ IUCN red list

4. Recreational Fisheries

The Mid-Atlantic area hosts several recreational fisheries that are managed by NOAA Fisheries. NOAA Fisheries collaborates with the Mid-Atlantic Regional Fishery Council, the coastal states, and the Atlantic States Marine Fisheries Commission to manage recreational fisheries in state and federal waters. As of March 2018, recreational fishing vessels operating in federal waters within the Greater Atlantic Regional fishing area must report on harvesting of Atlantic mackerel, squid, butterfish, summer flounder, scup, black sea bass, bluefish, and tilefish. In addition, these recreational activities come under the same management plan as that applied to commercial fisheries for summer flounder and black sea bass. Recreational fishers must already report bluefin tuna landings to NOAA. Maryland and North Carolina additionally require reporting on white and blue marlin, roundscale spearfish, and sailfish.

Some of the information in this section is taken from the MRIP/MRFSS catch estimates maintained by NOAA. About 9,000 individual saltwater fishing permits were held by recreational anglers in the coastal states landward of the Proposed Action in 2014 (NOAA, 2016f). All activities associated with recreational saltwater fishing in these states added value of approximately $3.1 billion to the economy. Highly migratory species (big game fish) are among those species whose habitats overlap with the Proposed Action, which occurs in deepwater areas. Pursuit of highly migratory species such as tuna, billfish, and sharks generated $17.7 million of added value to the economies the coastal states of Maine through North Carolina during a study period in 2011 (NOAA, 2014b). Maryland, Virginia, and North Carolina dominated the billfish recreational fishery, while New York and New Jersey constitute over 50% of the May through December 2011 trips focused on shark fishing. In the coastal states landward of the Proposed Action area, New Jersey recreational anglers conducted 45% of the tuna fishing trips during the reporting period.
IV. ENVIRONMENTAL CONSEQUENCES

Proposed Action

1. Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a brief summary of the anticipated potential effects (or lack thereof) of airgun sounds on marine mammals and sea turtles as provided in the NSF-USGS PEIS. It also includes updates from recent literature that has become available since the NSF-USGS 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, and § 3.8.4.3, and Appendix E of the NSF-USGS PEIS. Relevant background information on the hearing abilities of marine mammals and sea turtles can also be found in the NSF-USGS PEIS.

This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys scheduled to occur during August 2018, along with a description of the rationale for USGS’s estimates of the numbers of individuals exposed to received sound levels $\geq 160$ dB re 1 µPa$_{rms}$. Acoustic modeling for the proposed action was conducted by L-DEO, consistent with past EAs submitted for USGS and NSF seismic surveys and as previously determined to be acceptable by NMFS for use in the calculation of estimated Level B takes under the MMPA. Take calculations were carried out by the USGS using methodology described below and in a teleconference/webinar with NMFS personnel on 8 March, 2018.

(a) Summary of Potential Effects of Airgun Sounds

The Draft Scripps EA (LGL, 2017) is hereby incorporated by reference. The section is taken verbatim from that document. Therefore, all material has simply been reproduced in Appendix D for convenience.

(b) Possible Effects of Other Acoustic Sources

The Simrad fisheries EK60/80 transceiver with a single (38 kHz) split-beam transducer would be operated from the source vessel at water depths less than $\sim 1800$ m. Such equipment was not commonly used when the NSF-USGS PEIS was completed, but is now installed and run routinely on many global class research ships (e.g., Okeanos Explorer) and NOAA fisheries vessels. The EK80 is the newer, broadband transceiver that is starting to replace the widely used EK60 transceiver on some federal fleet vessels.

The following is copied nearly verbatim from the NOAA Northeast Fisheries Science Center application for a Letter of Authorization (NEFSC, 2014) for small takes associated with their research operations. Minor modifications have been made to focus the text on the type of EK60/80 system the USGS will use during the Proposed Action. NMFS granted NEFSC a 5-year LOA in 2015.

“Category 2 active acoustic sources (as defined by NEFSC) have moderate to very high output frequencies (10 to 180 kHz), generally short ping durations, and are typically focused (highly directional) to serve their intended purpose of mapping specific objects, depths, or environmental features. A number of these sources, particularly those with relatively lower sound frequencies coupled with higher output levels can be operated in different output modes (e.g., energy can be distributed among multiple output beams) that may lessen the likelihood of perception by and potential impact on marine life.” The USGS Proposed Action would use only the 38 kHz transducer.
“Category 2 active acoustic sources are likely to be audible to some marine mammal species. Among the marine mammals, most of these sources are unlikely to be audible to whales and most pinnipeds, whereas they may be detected by odontocete cetaceans (and particularly high frequency specialists such as harbor porpoise). There is relatively little direct information about behavioral responses of marine mammals, including the odontocete cetaceans, but the responses that have been measured in a variety of species to audible sounds (see Nowacek et al. 2007; Southall et al. 2007 for reviews) suggest that the most likely behavioral responses (if any) would be short-term avoidance behavior of the active acoustic sources.

The potential for direct physical injury from these types of active sources is low, but there is a low probability of temporary changes in hearing (masking and even temporary threshold shift) from some of the more intense sources in this category. Recent measurements by Finneran and Schlundt (2010) of TTS in mid-frequency cetaceans from high frequency sound stimuli indicate a higher probability of TTS in marine mammals for sounds within their region of best sensitivity; the TTS onset values estimated by Southall et al. (2007) were calculated with values available at that time and were from lower frequency sources. Thus, there is a potential for TTS from some of the Category 2 active sources, particularly for mid- and high-frequency cetaceans. However, even given the more recent data, animals would have to be either very close (few hundreds of meters) and remain near sources for many repeated pings to receive overall exposures sufficient to cause TTS onset (Lucke et al. 2009; Finneran and Schlundt 2010). If behavioral responses typically include the temporary avoidance that might be expected (see above), the potential for auditory effects considered physiological damage (injury) is considered extremely low so as to be negligible in relation to realistic operations of these devices.” It should be noted that in 2015 the USGS experienced at least once instance of a large group of unidentified odontocetes (greater than 20) approaching the vessel and engaging with the vessel’s wake while the EK60 was running in active mode using the 38 kHz transducer in relatively low power mode at < 200 m water depth.

Additional information added by the USGS in formulating this EA: A recent study by Cholewiak et al. (2017) describes beaked whale detections and sightings on the shelf and upper slope while operating the EK60 in passive (listening for sounds) and active (transmitting a pulse from the transducer) mode off New England. The reduced number of sightings and vocalizations during EK60 surveys led the authors to conclude that beaked whales exhibit a behavioral response to EK60 surveys and that the whales may detect the signals at some distance. Cholewiak et al. (2017) also cite unpublished data showing that bottom recorders 1.3 km from the R/V Henry Bigelow could detect her EK60 transmissions at depths of 800 m. The results of a 2016 farfield sound source verification experiment conducted at ~100 m water depth with the USGS 38 kHz EK60 transducer are not yet available.

Clear data about the impact of EK60/80 fisheries sonars are still lacking. There is a possibility of a behavioral response to the EK60 transmissions from some odontocetes, despite the fact that the modeled radii to the 160 dB isopleths is small.

(c) Other Possible Effects of Seismic Surveys

The possible effects of seismic surveys are incorporated by reference to the Draft Scripps EA (2017). For convenience, this section is reproduced in Appendix E. Additional text related to the specifics of the Proposed Action is provided below.

Vessel noise from R/V Hugh R. Sharp could affect marine animals in the proposed project area. It should be noted that the ship was Navy-designed as a “quiet vessel” and produces underwater radiated noise at levels below the International Council on Exploration of the Seas (ICES) noise curve at 8 knots (cruising speed).

Note that the USGS Proposed Surveys will be carried out at ~4 knots, which requires the use of only one generator on the R/V Hugh R. Sharp. According to the ship’s radiated noise measurement report
IV. Environmental Consequences

(2009), this mode of operation produces two primary signals at less than 200 kHz: 83 kHz with SEL of 146 dB re 1 µPa at 1 yard and 163 kHz with SEL of 151 dB re 1 µPa at 1 yard.

2. Mitigation Measures

This section copies verbatim from the Draft Scripps EA (LGL, 2017), with modifications keyed to the USGS Proposed Action.

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activities. These measures include the following: power ramp ups of the airgun array during a 30 minute period, adding one gun at a time until the full array strength is reached; a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations, with two observers for 30 min before and during ramp ups during the day; use of mitigation gun to maintain sound input to the ocean during periods when a compressor is being refueled or a gun is being fixed; and shut downs when mammals or turtles are detected in or about to enter the designated EZ. The acoustic source would also be powered or shut down in the event an ESA-listed seabird were observed diving or foraging within the designated exclusion zone. Observers would also watch for any impacts the acoustic sources may have on fish. No airgun array start ups would occur during poor visibility or at night unless at least one airgun (mitigation gun) had been operating.

These mitigation measures are described in § 2.4.4.1 of the NSF-USGS PEIS and summarized earlier in this document, in § II(3). The fact that the GI airgun arrays, as a result of their design, direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure.

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 activities without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activities, and would be implemented under the Proposed Action or Alternative Action.

3. Potential Numbers of Marine Mammals Exposed to Various Received Sound Levels

All takes would be anticipated to be Level B “takes by harassment.” As described in § I, such takes involve temporary changes in behavior. As required by NMFS in past actions for research seismic surveys conducted by the USGS or NSF, Level A takes are being requested; given the small calculated EZs (0 to 40 m for LF and MF cetaceans and less than 81 m for HF cetaceans) and the proposed mitigation measures to be applied, injurious takes would not be expected. (However, as noted earlier and in the NSF-USGS 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 and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the USGS Proposed Action.

(a) Basis for Estimating Exposure

Parts of this section are taken verbatim from the Draft Scripps EA (LGL, 2017), while other components originate entirely with the USGS based on the circumstances of the Proposed Action.
IV. Environmental Consequences

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound $\geq 160$ dB re $1 \mu$Pa$_{rms}$ are predicted to occur (see Table 1). The estimated numbers are based on abundances (numbers) of marine mammals expected to occur in the area of the Proposed Action in the absence of a seismic survey. 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. Likewise, animals are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger $\geq 160$ dB (Level B) radius.

To estimate marine mammal exposures, the USGS used published, quantitative density models by Roberts et al. (2016) for the Survey Area, which is entirely within the U.S. EEZ. These models are provided at 10 km x 10 km resolution in ArcGIS compatible IMG grids on the Duke University cetacean density website (http://seamap.env.duke.edu/models/Duke-EC-GOM-2015/). When available, the cetacean density models for Month 8 (August) were used. Otherwise, the generic annual density model was employed. Only a single density model is provided for the Kogia guild (dwarf and sperm pygmy whales) and for the beaked whale guild (Blainville’s, Cuvier’s, Gervais’, Sowerby’s, and True’s beaked whales). There are no data for the pygmy killer whale, and results for the false killer whale were adopted.

Due to the heterogeneous species’ densities in the Survey Area and the USGS’s direct use of quantitative species density grids from Roberts et al. (2016) in estimating the impact of the surveys on cetaceans, it would be inappropriate to report the type of generic species density values commonly given in some Environmental Assessments produced for research seismic surveys. Instead, Table 9 gives calculated species density and standard deviation in the area containing the entire Proposed Action as calculated from the Roberts et al. (2016) density grid and summarizes group size, as taken primarily from the Draft Scripps EA (LGL, 2017).

To determine takes, the USGS combined the Duke density grids with buffer zones arrayed on either side of each exemplary seismic line and linking/interseismic line, with the buffer zone sizes determined based on the Level A EZ and Level B mitigation zones calculated from the acoustic modeling. The Level A and Level B takes for each species in each 10 km x 10 km block of the IMG density grids are calculated based on the fractional area of each block intersected by the buffer zones (EZ and MZ) for LF, MF, and HF cetaceans. Summing takes along all of the lines yields the total take for each species for the Proposed Action for the Base and Optimal (§ 1) surveys. The method also yields take for each survey line individually, allowing examination of those exemplary lines that will yield the largest or smallest take.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 $\mu$Pa$_{rms}$ criterion for all cetaceans. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered “taken by harassment”. Table 10 shows the estimates of the number of cetaceans that potentially could be exposed to $\geq 160$ dB re 1 $\mu$Pa$_{rms}$ during the Proposed Action for the Base Survey and the Optimal Survey if no animals moved away from the survey vessel. The Requested Take Authorization is given in the far right column of Table 10 and represents 25% more than the number of takes calculated using the ArcGIS-based quantitative method devised by the USGS. The requested takes are sometimes increased to account for the size of animal groups (Table 9), to capture the possibility that a rare species could be encountered and taken during the surveys, or to account for the fact that the species is particularly abundant and take up to 1% of population size should be considered.
IV. Environmental Consequences

The Base Survey would acquire data along the exemplary lines (solid) and 50% of the interseismic linking lines using the base configuration of the GI guns (4 guns at 105 in³ each). The Optimal Survey would acquire data on the exemplary lines using the GG gun configuration (4 guns at 210 in³ each for the portions of these lines at greater than 1000 m water depth). For the Optimal Survey, the portion of the exemplary lines between 100 and 1000 m (yellow shading; bathymetry from Andrews et al., 2016) plus 50% of the linking interseismic lines with the base configuration. Takes are calculated for the entire survey pattern shown here even though only 50% of the linking, interseismic lines would be acquired.

The calculated takes in Table 10 also assume that the proposed surveys would be completed. In fact, it is unlikely that the entire survey pattern (exemplary lines plus 50% of the interseismic, linking lines) would be completed given the limitations on ship time, likely logistical challenges (compressor and GI gun repairs), time spent on transits and refueling, and the historical problems with weather during August in the Northwest Atlantic. In fact, USGS calculated timelines indicate that 25 days, including contingency, could be required to complete the full survey pattern. In fact, 22 days or fewer would be scheduled for this survey with the ship operator. The lines that are actually acquired would be dependent on weather, strength of the Gulf Stream (affects ability to tow the streamer in the appropriate geometry), and other considerations. Thus, fewer takes would be expected than have been calculated or requested. Nonetheless, as is common practice, the requested takes have been increased by 25% (see below). Thus, the estimates of the numbers of marine mammals potentially exposed to Level B sounds ≥160 dB re 1 μPa rms are precautionary (conservative) and probably overestimate the actual numbers of marine mammals that could be involved.

In addition, it is possible that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the NSF-USGS PEIS and in this document. 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.
dB (NMFS 2013). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal’s initial response to the sound (NMFS 2013).

Table 9. Mean density and standard deviation of species’ population in a polygon enclosing the entire survey based on ArcGIS analysis of the Roberts et al. (2016) grids. Month 8 (August) is used when available. Otherwise, the generalized annual grid is used.

<table>
<thead>
<tr>
<th></th>
<th>Mean Density Per 100 km² in Polygon Enclosing Total Survey</th>
<th>Std Deviation on Mean Density Per 100 km²</th>
<th>Group Size</th>
<th>Source¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mysticetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Atlantic Right Whale (Eubalaena glacialis)</td>
<td>0.00002</td>
<td>0.00013</td>
<td>1</td>
<td>J</td>
</tr>
<tr>
<td>Humpback Whale (Megaptera novaeangliae)</td>
<td>0.002</td>
<td>0.007</td>
<td>2</td>
<td>W</td>
</tr>
<tr>
<td>Minke Whale (Balaenoptera acutorostrata)</td>
<td>0.002</td>
<td>0.004</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td>Bryde’s Whale (Balaenoptera edeni/brydei)</td>
<td>&lt;0.001</td>
<td>NA</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td>Sei Whale (Balaenoptera borealis)</td>
<td>0.005</td>
<td>0.02</td>
<td>1.42</td>
<td>W</td>
</tr>
<tr>
<td>Fin Whale (Balaenoptera physalus)</td>
<td>0.041</td>
<td>0.077</td>
<td>1.71</td>
<td>W</td>
</tr>
<tr>
<td>Blue Whale (Balaenoptera musculus)</td>
<td>&lt;0.001</td>
<td>NA</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td><strong>Odontocetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm Whale (Physeter macrocephalus)</td>
<td>2.18</td>
<td>0.909</td>
<td>1.6</td>
<td>W</td>
</tr>
<tr>
<td>Cuvier’s Beaked Whale (Ziphias cavirostris)</td>
<td>0.062</td>
<td>0.006</td>
<td>10</td>
<td>J</td>
</tr>
<tr>
<td>True’s Beaked Whale (Mesoplodon mitus)</td>
<td>4.46</td>
<td>7.143</td>
<td>19</td>
<td>P</td>
</tr>
<tr>
<td>Gervais’ Beaked Whale (Mesoplodon europaeus)</td>
<td>20.17</td>
<td>14.514</td>
<td>26.3</td>
<td>P</td>
</tr>
<tr>
<td>Sowerby’s Beaked Whale (Mesoplodon bidens)</td>
<td>0.035</td>
<td>0.014</td>
<td>4-10</td>
<td>NOAA²</td>
</tr>
<tr>
<td>Blainville’s Beaked Whale (Mesoplodon densirostris)</td>
<td>0.064</td>
<td>0.083</td>
<td>14.71</td>
<td>W</td>
</tr>
<tr>
<td>Northern Bottlenose Whale (Hyperoodon ampullatus)</td>
<td>0.094</td>
<td>0.012</td>
<td>4-10</td>
<td>NOAA²</td>
</tr>
<tr>
<td>Rough-toothed Dolphin (Steno bredanensis)</td>
<td>0.062</td>
<td>0.006</td>
<td>10</td>
<td>J</td>
</tr>
<tr>
<td>Common Bottlenose Dolphin (Tursiops truncatus)</td>
<td>0.55</td>
<td>1.262</td>
<td>60-80</td>
<td>NOAA²</td>
</tr>
<tr>
<td>Pantropical Spotted Dolphin (Stenella attenuata)</td>
<td>0.005</td>
<td>0.02</td>
<td>1.42</td>
<td>W</td>
</tr>
<tr>
<td>Atlantic Spotted Dolphin (Stenella longirostris)</td>
<td>20.17</td>
<td>14.514</td>
<td>26.3</td>
<td>P</td>
</tr>
<tr>
<td>Striped Dolphin (Stenella coeruleoalba)</td>
<td>0.005</td>
<td>0.02</td>
<td>1.42</td>
<td>W</td>
</tr>
<tr>
<td>Atlantic White-sided Dolphin (Lagenorhynchus acutus)</td>
<td>0.064</td>
<td>0.083</td>
<td>14.71</td>
<td>W</td>
</tr>
<tr>
<td>White-beaked Dolphin (Lagenorhynchus albirostris)</td>
<td>&lt;0.001</td>
<td>0.003</td>
<td>3</td>
<td>W</td>
</tr>
<tr>
<td>Short-beaked Common Dolphin (Delphinus delphis)</td>
<td>20.17</td>
<td>45.57</td>
<td>9.15</td>
<td>W</td>
</tr>
<tr>
<td>Risso’s Dolphin (Grampus griseus)</td>
<td>2.653</td>
<td>5.01</td>
<td>11.5</td>
<td>P</td>
</tr>
<tr>
<td>Pygmy Killer Whale (Feresa attenuata)</td>
<td>No data</td>
<td>No data</td>
<td>12</td>
<td>J</td>
</tr>
<tr>
<td>False Killer Whale (Pseudorca crassidens)</td>
<td>0.005</td>
<td>NA</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td>Killer Whale (Orcinus Orca)</td>
<td>&lt;0.001</td>
<td>NA</td>
<td>5</td>
<td>W</td>
</tr>
<tr>
<td>Short-finned Pilot Whale (Globicephala macrorhynchus)</td>
<td>4.153</td>
<td>2.738</td>
<td>25.76</td>
<td>W</td>
</tr>
<tr>
<td>Long-finned Pilot Whale (Globicephala melas)</td>
<td>0.042</td>
<td>0.042</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td>Clymene’s dolphin (Stenella clymene)</td>
<td>1.365</td>
<td>1.262</td>
<td>60-80</td>
<td>NOAA²</td>
</tr>
<tr>
<td>Spinner dolphin (Stenella longirostris)</td>
<td>0.042</td>
<td>0.042</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td>Fraser’s dolphin (Lagenodelphis hosei)</td>
<td>0.005</td>
<td>0.02</td>
<td>1.42</td>
<td>W</td>
</tr>
<tr>
<td>Melon-headed whale (Peponocephala electra)</td>
<td>0.109</td>
<td>0.12</td>
<td>&gt;100</td>
<td>NOAA²</td>
</tr>
<tr>
<td><strong>High Frequency Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harbor Porpoise (Phocoena phocoena)</td>
<td>0.009</td>
<td>0.019</td>
<td>3.6</td>
<td>P</td>
</tr>
<tr>
<td>Pygmy Sperm Whales (Kogia breviceps)</td>
<td>0.093</td>
<td>0.008</td>
<td>1.8</td>
<td>P</td>
</tr>
</tbody>
</table>

TABLE 10. Densities and estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the Northwest Atlantic Ocean in August 2018. As detailed in §1, the base survey corresponds to 4 GI guns producing a total of 420 in$^3$ of air. The optimal survey acquires the exemplary seismic lines with 4 GI guns operated in GG mode (840 in$^3$ of air) and interseismic linking lines collected with 4 GI guns operated at 105 in$^3$ each. Species in italics are listed under the ESA as endangered. Requested takes in bold have been increased over the calculations to reflect group size or other issues, as explained in the text.

<table>
<thead>
<tr>
<th>Species</th>
<th>Base Survey$^2$</th>
<th>Optimal Survey$^2$</th>
<th>Max Level A Take</th>
<th>Max Level B Take for Optimal or Base Surveys +25%</th>
<th>Popula-tion used from Table 6</th>
<th>Level A + (Level B+25%) as % of Pop.$^5$</th>
<th>Requested Take Authorization$^6$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level A$^3$</td>
<td>Level B$^4$</td>
<td>Level A$^3$</td>
<td>Level B$^4$</td>
<td>Max Level B Take</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LOW FREQUENCY CETACEANS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Atlantic right whale</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>440</td>
<td>0</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11,570</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Minke whale</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>157,000</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Bryde’s whale</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Sei whale</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>10,300</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Fin whale</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>24,887</td>
<td>0.02</td>
</tr>
<tr>
<td>Blue whale</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>855</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td><strong>MID-FREQUENCY CETACEANS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm whale</td>
<td>0</td>
<td>119</td>
<td>0</td>
<td>127</td>
<td>0</td>
<td>159</td>
<td>13,190</td>
</tr>
<tr>
<td>Cuvier’s beaked whale</td>
<td>0</td>
<td>947</td>
<td>0</td>
<td>102</td>
<td>0</td>
<td>127</td>
<td>3,532</td>
</tr>
<tr>
<td>True’s beaked whale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gervais beaked whale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sowerby’s beaked whale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blainville’s beaked whale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern bottlenose whale</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>40,000</td>
</tr>
<tr>
<td>Rough-toothed dolphin</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>6</td>
<td>NA</td>
</tr>
<tr>
<td>Common bottlenose dolphin</td>
<td>0</td>
<td>572</td>
<td>0</td>
<td>584</td>
<td>0</td>
<td>730</td>
<td>77,532</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td>0</td>
<td>38</td>
<td>0</td>
<td>39</td>
<td>0</td>
<td>49</td>
<td>3,333</td>
</tr>
<tr>
<td>Atlantic spotted dolphin</td>
<td>0</td>
<td>1191</td>
<td>0</td>
<td>1276</td>
<td>0</td>
<td>1595</td>
<td>44,715</td>
</tr>
<tr>
<td>Striped dolphin</td>
<td>0</td>
<td>1086</td>
<td>0</td>
<td>1158</td>
<td>0</td>
<td>1447</td>
<td>54,807</td>
</tr>
<tr>
<td>Atlantic white-sided dolphin</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>6</td>
<td>48,819</td>
</tr>
<tr>
<td>White-beaked dolphin</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2003</td>
</tr>
<tr>
<td>Short-beaked common</td>
<td>0</td>
<td>1253</td>
<td>0</td>
<td>1151</td>
<td>0</td>
<td>1566</td>
<td>70,184</td>
</tr>
<tr>
<td>Risso’s dolphin</td>
<td>0</td>
<td>181</td>
<td>0</td>
<td>163</td>
<td>0</td>
<td>226</td>
<td>18,250</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>False killer whale</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>442</td>
</tr>
<tr>
<td>Killer whale</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>15,014</td>
</tr>
<tr>
<td>Long-finned pilot whale</td>
<td>0</td>
<td>215</td>
<td>0</td>
<td>222</td>
<td>0</td>
<td>278</td>
<td>5,636-16,058</td>
</tr>
<tr>
<td>Short-finned pilot whale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
<td>21,515</td>
</tr>
<tr>
<td>Clymene’s dolphin</td>
<td>0</td>
<td>91</td>
<td>0</td>
<td>97</td>
<td>0</td>
<td>121</td>
<td>6,068</td>
</tr>
<tr>
<td>Spinner dolphin</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>ND</td>
</tr>
<tr>
<td>Fraser’s dolphin</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>492</td>
</tr>
<tr>
<td>Melon-headed whale</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>10</td>
<td>3451</td>
</tr>
<tr>
<td><strong>HIGH-FREQUENCY CETACEANS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pygmy/dwarf sperm whale</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>8</td>
<td>3,785</td>
</tr>
<tr>
<td>Harbor porpoise</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>79,833</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

1 See text for density sources. N.A. = population size not available (see Table 6).
2 Take calculated using method described in text and discussed with NMFS on USGS-managed webinar on March 8, 2018.
**IV. Environmental Consequences**

(b) Potential Number of Marine Mammals Exposed to ≥160 dB

As noted above, the number of cetaceans that could be exposed to airgun sounds with received levels \( \geq 160 \text{ dB re } 1 \mu \text{Pa rms} \) (Level B) for marine mammals on one or more occasions has been estimated by combining the gridded animal abundances available from the Duke University cetacean density website [http://seamap.env.duke.edu/models/Duke-EC-GOM-2015/](http://seamap.env.duke.edu/models/Duke-EC-GOM-2015/) with the exemplary track lines/linking lines and Level B PTS threshold buffers calculated by LDEO. The method intersects the ensonified area along each track line for the appropriate Level B threshold buffer with the gridded animal abundances. For each block of the underlying abundance grid intersected by the trackline and associated ensonified area, the take is calculated as the percentage of that block that is ensonified multiplied by the abundance of animals in the block. The takes are summed along each trackline and linking line and added to determine the total take for the surveys. 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 *Sharp* approaches. The amount of overlap of the ensonified area is minimal and confined to areas of turns at the ends of exemplary survey lines or where linking lines join exemplary lines. The small amount of overlap reflects in part the fact that most exemplary dip lines are spaced at more than 20 km.

Total estimated takes for the entire survey are reported in Table 10 for the Optimal and Base surveys. The table also reports the maximum take of each species for the two survey configurations (see below) with 25% added as a buffer and the requested take authorization. The Optimal Survey includes most dip lines and one strike line acquired with the GG configuration (840 in\(^3\) of air), with the remaining lines and linking lines acquired using the base (4x105 in\(^3\) or 420 in\(^3\) of air) configuration (Figure 14). Note that this is an overestimate since it assumes that all of the interseismic linking lines would have data acquisition, even though at most only half of the lines will be acquired. Some of the linking lines would not even be surveyed with seismic methods since transit between exemplary lines is faster with no streamer in the water, and such transits provide an opportunity to fix gear, refuel compressors, and address other issues. The take calculations for the Base Survey assume all of the exemplary lines and linking lines are acquired with the base (420 in\(^3\) of air) configuration and, again, that all of the interseismic linking lines are acquired.

The maximum estimate of the number of cetaceans that could be exposed to seismic sounds with received levels \( \geq 160 \text{ dB re } 1 \mu \text{Pa rms} \) in the survey area is 4965 (Table 10). This number was calculated assuming that seismic data would be acquired along all the shelf-break and deepwater interseismic connecting lines shown in the red dashed pattern in Figure 1 and assuming the maximum source levels are used for the major exemplary seismic lines (Optimal Survey). At most, only about half of the interseismic connecting lines will be acquired at either the shelf-break or deepwater. The maximum Level B take estimate of 4965 cetaceans includes ~131 cetacean individuals listed under the ESA: 1 sei whale, 4 fin whales, 127 sperm whales, and no blue or North Atlantic right whales. Adding the nominal 25% extra take to these values, the sperm whale figure represents 1.21% of the estimated population, fin whale take is ~0.02%, and sei whale take is 0.01%. In addition, 102 beaked whales could be exposed. Most Level B exposures would accrue to mid-frequency cetaceans. The largest potential takes would be for species that are plentiful and widespread, such as Atlantic spotted dolphin, striped dolphin, short-beaked common dolphin, and common bottlenose dolphin.

The take authorizations requested in the last column of Table 10 are precautionary and assume that certain extralimital mysticetes could be encountered during the Proposed Survey. Note also that the basis of the Take Authorization Request is the maximum A + B takes +25% for the Base and Optimal surveys.
IV. Environmental Consequences

so the requested takes are very conservative. Were an equipment failure to force the Proposed Action to be
carried out with the Base Configuration, takes would be far smaller based on the much smaller MZ given
in Appendix A.

All of the calculated takes fall well within the typical definition of “small takes” as implemented
under the MMPA. Some of the requested takes, but not all, have been increased to account for the average
group size (Table 9). In other cases, group size was not taken into consideration. For example, melon-
headed whales often occur in very large groups, but the requested take has been kept at the calculated value
of 10 individuals. Harbor porpoise take is requested due to the sheer abundance of these animals and the
remote possibility that they could occur extralimitally in the Proposed Survey Area. In some cases, the take
request was increased to 1% of the population for particularly abundant species that are likely to be
encountered in the Survey Area (e.g., common bottlenose dolphin).

(c) Level A Takes

Level A takes were determined to be zero for all species and both survey configurations. The highest
Level A take calculated was 0.375 individuals for the *Kogia* guild (not separated into pygmy and dwarf
sperm whales in the Roberts et al., 2016 data) for the entire Optimal survey. Even increasing this by 25%
still yields a take less than 1 for Level A for this guild.

4. Conclusions for Marine Mammals and Sea Turtles

The Proposed Action would involve towing an array of two to four GI airguns that introduce 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”.

(a) Cetaceans

This section incorporates by reference and adopts nearly verbatim the Draft Scripps EA (2017), with
minor changes to reflect the particular circumstances applicable to the Proposed Action.

In § 3.6.2, 3.7.2, and 3.8.2, the NSF-USGS 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 cetaceans in the Northwest Atlantic DAA, that Level A effects were
highly unlikely, and that operations were unlikely to adversely affect ESA-listed species. Nonetheless,
NMFS requires the calculation and request of potential Level A takes for the Proposed Action. For five
past NSF-funded seismic surveys and the 2014/15 USGS ECS survey (RPS, 2014a), 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 (NMFS 2015b, 2016b,c, NMFS 2017a,b).

In this Draft EA, 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 appreciable
disturbance are very low percentages of the regional population sizes (Table 10).

The take calculations are likely to yield significant overestimates of the actual number of animals
that would be exposed to and would react to the seismic sounds, particularly because most mammals, except
some delphinids, tend to move away from sound sources. The relatively short-term exposures are unlikely
to result in any long-term negative consequences for the individuals or their populations. Therefore, no
significant impacts on marine mammals would be anticipated from the proposed activities.
In decades of seismic surveys carried out by the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., to be 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 the 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 the 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 160-dB zone, which is based on predicted sound levels, is thought to be conservative given the type of acoustic modeling used to calculate the distance from the source to this isopleth; thus, not all animals detected within this zone would be expected to have been exposed to actual sound levels >160 dB.

(b) Sea Turtles

In § 3.4.7, the NSF-USGS 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. Only foraging or migrating individuals are likely to occur in the area of the Proposed Action. Given the proposed activities, no significant impacts on sea turtles would be anticipated. In decades of seismic surveys carried out by the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related turtle injuries or mortality.

5. Direct Effects on Marine Invertebrates, Fish, Fisheries, and Their Significance

§ IV.4 of the Draft Scripps EA (2017) is hereby incorporated by reference. This information is provided nearly verbatim, with small changes to reflect the particular Proposed Action, in Appendix F, as part of an effort to comply with streamlining directives for NEPA documentation.

(a) Effects of Sound on Marine Invertebrates

(b) Effects of Sound on Fish

(c) Effects of Sound on Fisheries

(d) Conclusions for Invertebrates, Fish, and Fisheries

This section is mostly verbatim from the Draft Scripps EA (LGL, 2017), with changes to reflect the specifics of the USGS’s Proposed Action.

The newly available information does not affect the outcome of the effects assessment as presented in the NSF-USGS PEIS. The NSF-USGS 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 NSF-USGS PEIS also concluded that seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on commercial and recreation fisheries would not be significant.
Interactions between the proposed survey and fishing operations in the proposed project area are expected to be limited. Two possible conflicts in general are streamer entangling with fishing gear and the temporary displacement of fishers from the proposed project area. Fishing activities could occur within the proposed project area; however, a safe distance would need to be kept from R/V *Sharp* and the towed seismic equipment. During the survey, the towed seismic streamer is relatively short, so this distance would be relatively small. Conflicts would be avoided through communication with the fishing community during the surveys. In particular, USGS experience on the R/V *Sharp* in 2015, 2016, and 2017 (including during times that partially overlap the month of the Proposed Action for 2018) indicates that the vessel’s crew has good relationships with fishers and a good understanding of how they arrange their gear, where fishing is most likely, and how to negotiate in real-time to ensure that both the scientific and fishing operations can continue. Based on past experience by the USGS investigators participating in six cruises in the Survey Area since 2014, the most likely overlap between fishing activities and the Proposed Action would be on the uppermost continental slope, between the shallowest extent of the surveys (100 m water depth) and ~500 m water depth, particularly near canyons. Particular diligence will be exercised to communicate with fishers in these areas 6 to 12 hours before commencing acquisition of data on these parts of the exemplary survey lines.

Given the proposed activity, no significant impacts on marine invertebrates, marine fish, and their fisheries would be expected. In decades of seismic surveys carried out by vessels in the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related fish or invertebrate injuries or mortality.

6. **Direct Effects on Seabirds and Their Significance**

§ IV.5 of the Draft Scripps EA (2017) is hereby incorporated by reference. The section is reproduced in Appendix G for the sake of convenience.

7. **Indirect Effects on Marine Mammals, Sea Turtles, Seabirds, Fish, and Their Significance**

§ IV.6 of the Draft Scripps EA (LGL, 2017) is hereby incorporated by reference. The section is reproduced in Appendix G for the sake of convenience.

8. **Cumulative Effects**

Taking text verbatim from the Draft Scripps EA (LGL, 2017) and making small changes to reflect the particulars of the Proposed USGS Action for this leading paragraph: The results of the cumulative impacts analysis in the NSF-USGS PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed USGS marine seismic research. However, the NSF-USGS 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 area of the proposed seismic surveys that may result in cumulative impacts to environmental resources. Here we focus on activities that could impact animals specifically in the proposed project area (academic and industry research activities, vessel traffic, and fisheries).”

**(a) Past and future research activities in the area**

Industry has not acquired any airgun seismic data on the U.S Atlantic margin between Cape Hatteras and Hudson Canyon for at least 30 years (Figure 15), except for work under contract to the academic community for acquisition of the EDGE line in 1990 (see below). The legacy industry data released by BOEM through the USGS NAMSS portal over the past few years show that the industry lines acquired between ~1975 and 1985 do not extend beyond 1500 m or occasionally 2000 m water depth in most cases.
IV. Environmental Consequences

Several IHAA for industry seismic activities have been considered by BOEM and NMFS over the past few years, and more could be anticipated with implementation of Executive Order 13795 of April 28, 2017.

Figure 15. Industry seismic lines acquired primarily from 1975 to 1982 (some as late as 1985) are shown in black relative to the MATRIX seismic survey (Proposed Action). The industry data were released by BOEM through the USGS NAMSS portal over the past few years. The blue polygons were identified by BOEM as moderately to highly prospective for gas hydrates (BOEM, 2012a). White circles indicate research boreholes (e.g., Ocean Drilling Program and other), and blue wells were drilled by industry, including some COST wells.

In 2015, NSF funded a 540 km² airgun survey (700 in³ air volume) that was carried out by the R/V Langseth on the New Jersey shelf between 27 and 64 m water depth (Crone et al., 2017), about 25 nm landward of the shelf-break end of the northernmost exemplary dip line (Figure 16). This survey covered an area where IODP Expedition 313 had drilled to investigate a long-term sea level rise record in 2009 (Expedition 313 Scientists, 2010).

In 2014, the USGS acquired seismic data with the 36-gun R/V Langseth seismic array between the northernmost exemplary line for this Proposed Action and Hudson Canyon as part of the Extended Continental Shelf (ECS) project (RPS, 2014a) in support of the U.S. Law of the Sea effort (Figure 16). The ECS line is 30 nm NNW of the landward side of the northernmost dip line for the Proposed Action and 15 nm NNW at the distal end of that dip line. The ECS cruise traveled far seaward of the EEZ and went much farther out to sea than data will be acquired in the Proposed Action.

The last extensive airgun seismic research program on the Mid-Atlantic part of the margin was carried out by the USGS in 1979 (gray lines; Figure 16). Working with partner organizations such as the BGR (Bundesanstalt fur Geowissenschaften und Rohstoffe; Hannover, Germany), the USGS acquired a grid of seismic lines within the Proposed Action area. These data have been used, and in some cases, reprocessed by BOEM to delineate some aspects of deepwater areas where gas hydrates may be present (blue polygons in Figure 16), but the data are considered too incomplete to be definitive. Navigation on these lines was before the Global Positioning System and did not even use the LORAN standard.
In 1990, NSF funded the acquisition of the EDGE seismic survey (Figure 16), which comprised one long dip line and two shorter, mostly shelf, lines shot as part of an onshore-offshore experiment (e.g., Holbrook et al., 1994). Acquisition was conducted by an industry operator (Geco). The landward end of the primary dip line is just south of Chesapeake Bay. The data along this line are of much higher quality than legacy industry data released by BOEM and significantly improved relative to the older USGS data described above. The Proposed Action has exemplary dip lines that bound the 1990 EDGE line, but do not overlap it since the EDGE data are considered good enough to contribute to better constraints on gas hydrate distributions, particularly if the data can eventually be commercially reprocessed.

In 2014, the NSF-funded ENAM project (LGL, 2014) used the R/V Langseth to acquire MCS data between the Currituck and Cape Fear slides, north and south of Cape Hatteras (purple lines in Fig. 16). The southernmost exemplary dip line for the Proposed Action is ~10 nm north of one of the ENAM dip lines. No other MATRIX dip lines are planned by the USGS near the ENAM survey since the area has already been well-described by the 2014 seismic data, which are openly available to the marine community. The USGS plans a strike line through a deepwater hydrate feature identified by BOEM and not surveyed by ENAM in the area of the ENAM surveys and at water depths of ~2000-3000 m. This strike line will also cross an important fracture zone that played a key role in opening of this part of the Atlantic Ocean during the Mesozoic rifting event that created the ocean basin.

In June and July 2018, Scripps Institute of Oceanography (LGL, 2017) would collect MCS data with two 45 in³ GI-guns aboard the R/V Atlantis on a NSF-funded cruise in the northwest Atlantic, outside the US EEZ. None of the area ensonified by that survey will also be ensonified by the USGS’s Proposed Action.

**Figure 16.** Past airgun seismic surveys conducted by the research community on the northern part of the U.S. Atlantic margin, along with some high-resolution (non-airgun) surveys. The gray lines show legacy USGS data, mostly from the late 1970s. Purple lines are the 2014 NSF ENAM cruise (RPS, 2014c), and navy blue lines denote the USGS-led ECS acquisition in 2014 and 2015 (RPS, 2014a, b). Light blue lines are data acquired for the NSF EDGE program by an industry operator in 1990. Also shown are the the positions of high-resolution seismic data (red, orange) acquired by the USGS with towed sparker sources on the upper slope over the past decade.
In April 2015, the USGS Gas Hydrates Project used a mini-sparker operated at less than 2.9 kJ and a \(~500\) m streamer to collect \(~550\) line-km of high-resolution seismic data in the Proposed Action Area between Wilmington and Washington Canyons, from the shelf-break to \(~1500\) m water depth, using the \textit{R/V Endeavor} as the platform (Ruppel et al., 2015; red lines Figure 16). These data cannot directly image the base of the gas hydrate stability zone without analysis of the seismic attributes, nor do they penetrate the sediments deeply enough to capture all the relevant shallow gas features. They provide a good complement to the lines to be acquired during the Proposed Action in some places, but cover less than a third of the along-margin sector and only a fraction of the water depth range to be imaged during the Proposed Action. Since the late 2000s, the USGS has also acquired other low-energy (e.g., mini-sparker source), high-resolution (not very deep penetration) MCS data from the \textit{R/V Oceanus} and the contract vessel \textit{Tiki}. These lines (orange on Figure 16) are on the upper slope or at the shelf-break near the Currituck slide and just to the south and across the outer shelf in the area near the landward end of the northernmost exemplary dip line, just seaward of the 2015 New Jersey shelf MCS survey. None of these USGS data are useful for constraining the distribution of continuous deepwater gas hydrates.

Because the cruise tracks for academic surveys are not always public knowledge, this subsection details only those activities about which the USGS has direct knowledge over the past few years. Activities whose primary focus was the shelf (e.g., NSF-funded project on the New Jersey margin in 2015), and thus landward of the Proposed Action, are not considered. Between 2011 and 2013, the NOAA vessel \textit{Okeanos Explorer} mapped large swathes of the Proposed Area from the shelf-break to 1500 or 2000 m water depth using hull-mounted instrumentation. Most of the data were acquired with a Kongsberg EM302 hull-mounted multibeam (30 kHz), with additional information sometimes acquired using a Knudsen hull-mounted Chirp. An EK60 system with multiple transducers was operational during many of the activities, but did not yield useful data for most of them due to a calibration problem (T. Weber, pers. comm.). NOAA’s Deep Discoverer ROV also conducted a few dives in the Survey Area during this period. The \textit{Okeanos Explorer} will conduct expeditions that include MBES, EK60, and Knudsen mapping and D2 dives on the U.S. Atlantic margin starting in mid-2018, with some activities focused on the mid-Atlantic part of the margin, particularly if dives or additional MBES mapping are requested there by the larger marine community. The USGS participates in planning activities for the \textit{Okeanos Explorer} program, and the only potential overlap in time is for the northernmost dip line in the Survey Area during August 2018. The USGS has already provided NOAA’s Ocean Exploration and Research Program with the GIS file containing survey lines for the Proposed Action.

A pre-2015 NOPP activity that involved BOEM, NOAA, and the USGS conducted other ROV dives and AUV operations in localized areas to study corals, canyon habitats, and chemosynthetic communities at seep sites. The NOPP cruises typically used NOAA vessels (e.g., \textit{R/V Nancy Foster}) or other available vessels. The full range of activities carried out by NMFS itself is unknown, but is believed to be often confined to the shelf and uppermost continental slope, with the exception of some specialized surveys (e.g., beaked whale surveys out of NEFSC; Cholewiak, 2017). A newly funded NOPP collaboration commenced in 2017 and conducted brief mapping offshore Cape Hatteras in 2017. The 2018 program will include \textit{DSV Alvin} dives and more multibeam mapping in the southern part of the Survey Area during the summer. The Alvin expedition is co-led by a USGS investigator, with whom the lead MATRIX lead PI often collaborates and with whom the MATRIX program is coordinating.

Due to its involvement in the discovery of more than 570 seep sites on the US Atlantic margin as published in a 2014 paper and database (Skarke et al., 2014), the USGS has led or been a part of 6 cruises in the landward side of the Proposed Action area (shelf-break to upper slope depths of \(~1500\) m) since 2014. In July 2014, a NSF-sponsored cruise conducted CTDs, EK60 water column imaging, and Knudsen imaging in Hudson Canyon and at an adjacent control site on the upper continental slope as part of a methane flux and oxidation rate study aboard the \textit{R/V Endeavor}. In April 2015, the USGS collected high-resolution
(mini-sparker source) MCS data between Wilmington and Washington Canyons, as mentioned above. In September 2015, the USGS led a piston coring, multicoring, and EK60 survey that sampled sites from Washington Canyon to the New England margin. In March 2016, the USGS participated in a R/V Neil Armstrong science verification cruise that acquired multibeam and EK60 data along isolated tracklines from Cape Hatteras to Baltimore Canyon. In May 2017, the USGS conducted a ROV cruise sponsored primarily by NOAA OER, diving on sites from just south of Norfolk Canyon to Baltimore Canyon and collecting authigenic carbonates, benthic community samples, water, and sediments. In August/September 2017, the USGS co-led a CTD, large volume water sampling, and EK60 cruise from Cape Hatteras to Baltimore Canyon. We are also aware of a DSV Alvin cruise led by Cindy Van Dover in 2015. In the area from north of Cape Hatteras and stretching nearly to Georges Bank, this cruise conducted about a dozen dives on seep sites originally described by Skarke et al. (2014).

The northernmost exemplary dip lines for MATRIX purposely intersect or come close to industry/research wells (e.g., COST B-3, completed in 1979) and some ODP upper continental slope boreholes (e.g., for ODP Leg 150 in 1993, ODP Leg 174A in 1997). Acquiring modern MCS data along these lines will enhance the utility of stratigraphic and timing data from these wells and advance the interpretation of the existing borehole logs.

(b) Vessel traffic

Several major ports are located between Cape Hatteras and Hudson Canyon, and traffic to Norfolk, Baltimore, and New York City and into Delaware Bay all crosses parts of the Proposed Action area. Vessel traffic in the project area would consist mainly of cargo vessels, commercial fishing vessels, and tankers, as well as U.S. Navy vessels (near Norfolk especially), and an occasional cruise ship and long-distance sailboat. As of 22 February, the Automated Mutual-Assistance Vessel Rescue (AMVER) site was unavailable (last attempted access on 3 March, 2018). This system, managed by the U.S. Coast Guard (USCG), provides information about all identified ship traffic. Live vessel traffic information is available from MarineTraffic, including vessel names, types, flags, positions, and destinations, but legacy information requires payment. Various types of vessels were within the total area of the Proposed Action when marinetrack.com was accessed on March 3, 2018, including cargo vessels (16), tankers (4), and a passenger vessel. In August 2018, commercial fishing vessels are also expected to be in the area, and the USGS has frequently encountered Navy vessels and operations in the part of the Survey Area between Delaware Bay and Cape Hatteras on previous cruises. The R/V Sharp expects to spend 1-2 days acquiring data on each of the exemplary seismic lines, meaning that it will add only negligible additional traffic. Analysis of the 2012 USCG Automatic Identification System (AIS) shipping density grid for the area north of the Maryland-Virginia border as provided by the Mid-Atlantic Ocean Data Portal from MARCO shows that the exemplary seismic lines for the Proposed Action intersect locations with up to 6 shiptracks per year on an annualized basis. Thus, the combination of the USGS operations with the existing shipping operations is expected to produce only a negligible increase in overall ship disturbance effects on marine mammals.

(c) Fisheries

This section is partially excerpted from the Draft Scripps EA (LGL, 2017). The commercial fisheries in the general area of the proposed survey are described in § III. The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve direct and indirect removal of prey items, sound produced during fishing activities, and potential entanglement (Reeves et al. 2003). There may be some localized avoidance or attraction by marine mammals of fishing vessels near the
IV. Environmental Consequences

proposed project area. Fishing operations in the proposed project area are likely to be limited to the upper continental slope and locations near canyons.

The USGS operations in the Proposed Action are of limited duration (<1 month), with only 1-2 days operating on a specific line. The combination of the USGS operations with the existing commercial fishing operations is expected to produce only a negligible increase in overall disturbance effects on marine mammals and sea turtles. Proposed survey operations should not impede fishing operations, and R/V Sharp would avoid fishing vessels when towing seismic equipment. Operation of R/V Sharp, therefore, would not be expected to significantly impact commercial fishing operations in the area.

(d) Summary of Cumulative Impacts to Marine Mammals, Sea Turtles, Seabirds, and Fish

This section is taken verbatim from the Draft Scripps EA (LGL, 2017), with changes to reflect the specifics of USGS activities. The impacts of the USGS’s proposed seismic surveys are expected to be no more than a minor (and short-term) increment when viewed in light of other human activities within the proposed project area. Unlike some other ongoing and routine activities in the area (e.g., commercial fishing), the USGS activities are not expected to result in injuries or deaths of sea turtles or marine mammals. Although the airgun sounds from the seismic surveys will have higher source levels than do the sounds from most other human activities in the area, airgun operations during the surveys would last only 1-3 days at each location, in contrast to those from many other sources that have lower peak pressures but occur continuously over extended periods. Thus, the combination of the USGS operations with the existing shipping and fishing activities would be expected to produce only a negligible increase in overall disturbance effects on marine mammals and turtles.

9. Unavoidable Impacts

This section is taken verbatim from the Draft Scripps EA (LGL, 2017). Unavoidable impacts to the species of marine mammals and turtles occurring in the proposed project area would be limited to short-term, localized changes in behavior of individuals. For cetaceans, some of the changes in behavior may be sufficient 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 turtles, or on the populations to which they belong. Effects on recruitment or survival would be expected to be (at most) negligible.

10. Coordination with Other Agencies and Processes

This Draft EA incorporates by reference large components of the Scripps EA (2017), recently prepared by LGL on behalf of SIO, NSF, OSU, and Rutgers. Potential impacts to endangered species and critical habitat have also been assessed in the document; it will be used to support the ESA Section 7 consultation process with NMFS and USFWS. This document will also be used as supporting documentation for an IHA application submitted to NMFS, under the U.S. MMPA, for “taking by harassment” (disturbance) of small numbers of marine mammals, for this proposed seismic project. The USGS will comply with any additional applicable federal regulations and will continue to coordinate with federal regulatory agencies and their requirements.

Alternative Action: Another Time

Adopting the language of the Draft Scripps EA (LGL, 2017) for usage here: An alternative to issuing the IHA for the period requested, and to conducting the Project then, is to issue the IHA for another time, and to conduct the project at that alternative time. The proposed dates for the cruise (August 2018) are the dates when the personnel and equipment essential to meet the overall project objectives are available.
Marine mammals and sea turtles are expected to be found throughout the proposed project area and throughout the time period during which the project would occur. Except for some baleen whales, most marine mammal species probably occur in the project area year-round, so altering the timing of the proposed project likely would result in no net benefits for most species (see § III, above).

**No Action Alternative**

This section is taken verbatim from the Draft Scripps EA (LGL, 2017): “An alternative to conducting the proposed activities 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 mammals or sea turtles attributable to the proposed activities; however, valuable data about the marine environment would be lost.” Data collection to provide information about the distribution of marine gas hydrates and shallow methane offshore the US and within its EEZ would not be acquired. The No Action Alternative would not meet the purpose and need for the proposed activities.

**DISCLAIMER:** Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.
V. LIST OF PREPARERS


Patrick Hart, Seismologist, U.S. Geological Survey, Pacific Coastal and Marine Science Center, Santa Cruz, CA


Anne Bécel, Ph.D., Lamont Assistant Research Professor, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY.

VI. LITERATURE CITED

Many of the biological references are taken directly from the Draft Scripps EA (LGL, 2017), as incorporated in this Draft EA by reference. Updates have been made where necessary to reflect additional or alternate information used by or accessed by the U.S. Geological Survey. All access dates for online information refer to LGL’s activities in preparation of the Draft Scripps EA (LGL, 2017) when these dates are in 2017.


Christensen, I., T. Haug, and N. Øien. 1992. Seasonal distribution, exploitation and present abundance of stocks of


DoW. 2015b. A petition to list the oceanic whitetip shark (*Carcharhinus longimanus*) as an endangered, or alternatively as a threatened, species pursuant to the *Endangered Species Act* and for the concurrent designation of critical habitat. Defenders of Wildlife, Denver, CO. Submitted to the U.S. Secretary of Commerce and


submitted to the Scientific Committee of the International Whaling Commission, Anchorage, AK.


Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton, and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109 In: W.J. Richardson (ed.), *Marine mammal and acoustical monitoring of Western Geophysical’s open-water seismic


NMFS. 2017b. Environmental assessment: proposed issuance of an incidental authorization to the Scripps Institution...
of Oceanography to take marine mammals by harassment incidental to a low-energy geophysical survey in the northeastern Pacific Ocean, fall 2017. U.S. Department of Commerce, 73 p.


NSF (National Science Foundation). 2012. Record of Decision for marine seismic research funded by the National Science Foundation. June 2012. 41 p.


APPENDICES

In accordance with deliberations underway at the Council on Environmental Quality and the order of the Secretary of the Interior dated August 31, 2017 (Secretary’s Order 3355) on “Streamlining National Environmental Policy Reviews and Implementation of Executive Order 13807, “Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects,” this Draft EA has incorporated by reference and taken verbatim from existing Draft EAs (particularly the Draft Scripps EA (LGL, 2017)) whenever possible. In addition, material not necessary in the core of this Draft EA document has been shifted to the appendices. In some cases, these appendices provide material nearly verbatim from the Draft Scripps EA (LGL, 2017). This text is provided here for the convenience of reviewers, even though it is considered fully incorporated by reference within this Draft EA.

Appendix A: Backup Configuration Information and Calculations

In the case of compressor failure or other equipment problems, the airguns could be operated in the backup, 2 GI gun, configuration. The exclusion/mitigation zones for this configuration are significantly smaller than those for the configurations (Base and GG) targeted for the Optimal and Base Surveys. Thus, takes calculated for the other configurations are larger and therefore more conservative than applicable to the Backup Configuration. For the sake of completeness, information about the backup configuration is provided here and calculations of the sound source levels are given in Appendix C.

Backup Configuration (Configuration 3) is 2 GI guns producing 210 m$^3$ total volume, as shown in Figure 4. If a compressor were offline, this lowest-energy configuration would be used to sustain data acquisition. Guns will be towed at 3 m water depth of the port towpoint on the stern, with 2 m front-to-back separation between the guns.
Figure A1. **Backup configuration** (Source configuration 3): 210 in³ total volume consisting of 2x105/105 in³ GI guns firing in standard GI mode. Guns are labelled as S#G*, where # is the side and * is the gun number.
FIGURE 8. Modeled deep-water received sound exposure levels (SELs) from the backup configuration (Configuration 3; two 105 in$^3$ GI-guns) at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths, respectively. The upper plot is a blow-up of the lower plot.
Appendix B: Sound Exposure Levels (SEL): Scaling Analyses and All Results

SEL (dB) associated with airgun arrays tested in the Gulf of Mexico as part of Tolstoy et al. (2009). These values are used to scale calculations conducted by L-DEO for the Proposed Action.

**FIGURE B1.** Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. These values are used along with a scaling factor to determine SELs for shallow-water deployments with the three proposed configurations. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

For the **Base Configuration** (Configuration 1):
- the 150-decibel (dB) Sound Exposure Level (SEL)$^3$ corresponds to deep-water maximum radii of 1090.6 m for the four 105 in$^3$ airguns at 3 m tow depth (Fig. 5), and 7,244 m for the 6600 in$^3$ at 6-m tow depth, yielding scaling factors of 0.151 to be applied to the shallow-water 6-m tow depth results.

- the 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 193.94 m for the four 105 in$^3$ airguns at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.151 to be applied to the shallow-water 6-m tow depth results.

- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 109.72 for the four 105 in$^3$ airguns at 3 m tow depth (Fig. 2) and 719 m for the 6600 in$^3$ at 6-m tow depth (Fig. 4), yielding the same 0.152 scaling factor.

- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 19.89 m for the four 105 in$^3$ at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.157 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re $1 \mu$Pa rms distances in shallow water for the 36-airgun R/V Langseth array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the USGS Proposed Action Base Configuration, the 420 cu.in airgun array at 3 m tow depth yields distances of 2.642 km, 429 m, 243 m, 71 m and 38 m, respectively.

For the **GG Configuration** (Configuration 2):

- the 150-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 1,244 m for the four 210 in$^3$ airguns at 3 m tow depth (Fig. 6), and 7,244 m for the L-DEO 6600 in$^3$ at 6-m tow depth (Fig. 8), yielding scaling factors of 0.172 to be applied to the shallow-water 6-m tow depth results.

- the 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 219.54 m for the four 210 in$^3$ airguns at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.171 to be applied to the shallow-water 6-m tow depth results.

- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 124.72 for the four 210 in$^3$ airguns at 3 m tow depth (Fig. 2) and 719 m for the 6600 in$^3$ at 6-m tow depth (Fig. 4), yielding the same 0.173 scaling factor.

- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 22.69 m for the four 210 in$^3$ at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.179 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re $1 \mu$Pa rms distances in shallow water for the 36-airgun R/V Langseth array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 840 cu.in airgun array at 3 m tow depth yields distances of 3.01 km, 485 m, 277 m, 80 m and 43 m, respectively.

For the **Backup Configuration** (Configuration 3):

---

$^3$ SEL (measured in dB re $1 \mu$Pa$^2$ · s) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO’s model.
- the 150-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 578.152 m for the two 105 in³ airguns at 3 m tow depth (Fig. 7), and 7,244 m for the 6600 in³ at 6-m tow depth (Fig. 8), yielding scaling factors of 0.080 to be applied to the shallow-water 6-m tow depth results.

- the 165-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 102.37 m for the two 105 in³ airguns at 3 m tow depth, and 1,284 m for a 6-m tow depth, yielding a scaling factor of 0.080 to be applied to the shallow-water 6-m tow depth results.

- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 58.395 for the two 105 in³ airguns at 3 m tow depth (Fig. 2) and 719 m for the 6600 in³ at 6-m tow depth (Fig. 4), yielding the same 0.081 scaling factor.

- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 11.343 m for the two 105 in³ at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.089 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1μPa$_{\text{rms}}$ distances in shallow water for the 36-airgun R/V *Langseth* array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95$^{th}$ percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 110 cu.in airgun array at 3 m tow depth yields distances of 1.4 km, 227 m, 130 m, 38 m and 21 m, respectively.
Table B1. Predicted distances to which sound levels ≥ 195, 190-, 180-, 175-, and 160-dB re 1 μPa$_{rms}$ are expected to be received during the proposed surveys in the Northwest Atlantic Ocean. The Proposed Action will not involve ensonifying the seafloor at water depths shallower than 100 m.

<table>
<thead>
<tr>
<th>Source and Volume</th>
<th>Tow Depth (m)</th>
<th>Water Depth (m)</th>
<th>Predicted rms Radii (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>195 dB</td>
<td>190 dB</td>
</tr>
<tr>
<td>Base Configuration (Configuration 1) Four 105 in$^3$ G-guns</td>
<td>3</td>
<td>&gt;1000 m</td>
<td>100$^4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>100$^4$</td>
</tr>
<tr>
<td>GG Configuration (Configuration 2) Four 210 in$^3$ G-guns</td>
<td>3</td>
<td>&gt;1000 m</td>
<td>100$^4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>100$^4$</td>
</tr>
<tr>
<td>Backup Configuration (Configuration 3) Two 105 in$^3$ G-guns</td>
<td>3</td>
<td>&gt;1000 m</td>
<td>100$^4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>100$^4$</td>
</tr>
</tbody>
</table>

$^1$ Distance is based on L-DEO model results.

$^2$ Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.

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

$^4$ Modeled distances based on empirically derived measurements in the GoM are smaller than 100 m. Therefore, we use 100 m for these mitigation zone according to accepted practice.
Appendix C. Supporting Documentation for Level A Acoustic Modeling

The following information was provided by Dr. Anne Bécel at Lamont-Doherty Earth Observatory based on modeling methodology previously applied in EAs for NSF-funded programs. The documentation is provided verbatim, with modifications only to eliminate redundancies, to clarify how the different components relate to the Proposed Action, and to ensure consistency in terminology across this Draft EA.

BASE CONFIGURATION:

4 x 105 cu.in – 2 m separation aft-fore direction and 8.6 m separation in the port-starboard direction @ a 3 m tow depth

SELcum methodology (spreadsheet – Sivle et al., 2014)

<table>
<thead>
<tr>
<th>Source Velocity (meters/second)</th>
<th>2.05778*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/Repetition rate^ (seconds)</td>
<td>12.149**</td>
</tr>
</tbody>
</table>

† Methodology assumes propagation of 20 log R; Activity duration (time) independent
^ Time between onset of successive pulses.
* 4 kts

Table C1: Table showing the results for one single SEL SL modeling without and with applying weighting function to the 5 hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SELcum threshold is the largest. A propagation is of 20 log10 (Radial distance) is used to estimate the modified farfield SEL.

<table>
<thead>
<tr>
<th>SELcum Threshold</th>
<th>183 dB</th>
<th>185 dB</th>
<th>155 dB</th>
<th>185 dB</th>
<th>203 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance(m) (no weighting function)</td>
<td>34.3541</td>
<td>28.0537</td>
<td>907.6353</td>
<td>28.0537</td>
<td>N/A (&lt;1m)</td>
</tr>
<tr>
<td>Modified Farfield SEL*</td>
<td>213.7196</td>
<td>213.9598</td>
<td>214.1582</td>
<td>213.9598</td>
<td>203</td>
</tr>
<tr>
<td>Distance (m) (with weighting function)</td>
<td>15.6980</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Adjustment (dB)</td>
<td>-6.80</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* Propagation of 20 log R

For the Low Frequency Cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 34.35 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL cum isopleth is located at 15.69 m from the source. Difference between 34.35 m and 15.69 m gives an adjustment factor of -6.80 dB assuming a propagation of 20log10(R).
TABLE C2. Results for single shot SEL source level modeling for the four 105 in³ airguns with weighting function calculations for SEL$_{cum}$ criteria.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL$_{cum}$ Threshold</td>
<td>183</td>
<td>185</td>
<td>155</td>
<td>185</td>
<td>203</td>
</tr>
<tr>
<td>PTS SEL$_{cum}$ Isopleth to threshold (meters)</td>
<td>31.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
</tr>
</tbody>
</table>
FIGURE C1: Auditory weighting functions for the 5 marine mammal hearing groups defined by NOAA’s Acoustic Guidelines.

FIGURE C2: Modeled amplitude spectral density of the four 105 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, High Frequency Cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and...
weighted source level at each frequency and to derive the adjustment factors for the Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, and High Frequency Cetaceans as inputs into the NMFS user spreadsheet.

FIGURE C3: Modeled received sound levels (SEls) in deep water from the four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (907.6 m).
FIGURE C4: Modeled received sound levels (SELs) in deep water from the four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183 and 185 dB SEL isopleths.
FIGURE C5: Modeled received sound exposure levels (SELs) from the four 105 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 4 (34.35 m) and this figure (15.69 m) allows us to estimate the adjustment in dB.

**Peak Sound Pressure Level:**

TABLE C3. LEVEL A. NMFS Level A acoustic thresholds (Peak SPLflat) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the four 105 cu.in airguns at a 3 m tow depth during the proposed seismic survey in the northwestern Atlantic Ocean.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radius to threshold (m)</td>
<td>10.03</td>
<td>N/A (0)</td>
<td>70.426</td>
<td>11.35</td>
<td>N/A (0)</td>
</tr>
</tbody>
</table>
FIGURE C6: Modeled deep-water received Peak SPL from the four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (70.43 m).
FIGURE C7: Modeled deep-water received Peak SPL from four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the radius of the 218 and 219 dB isopleths.
GG CONFIGURATION

4 x 210 cu.in – 2 m separation aft-fore direction and 8.6 m separation in the port-starboard direction @ a 3 m tow depth

Table C4: Table showing the results for one single SEL SL modeling without and with applying weighting function to the 5 hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SELcum threshold is the largest. A propagation is of $20 \log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

<table>
<thead>
<tr>
<th>SELcum Threshold</th>
<th>183</th>
<th>185</th>
<th>155</th>
<th>185</th>
<th>203</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance(m) (no weighting function)</td>
<td>39.4216</td>
<td>30.8975</td>
<td>1029.1</td>
<td>30.8975</td>
<td>1.8439</td>
</tr>
<tr>
<td>Modified Farfield SEL*</td>
<td>214.9147</td>
<td>214.7985</td>
<td>215.2492</td>
<td>214.7985</td>
<td>208.3147</td>
</tr>
<tr>
<td>Distance (m) (with weighting function)</td>
<td>17.7149</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Adjustment (dB)</td>
<td>-6.9479</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* Propagation of $20 \log R$

For the Low Frequency Cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 39.42 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL cum isopleth is located at 17.71 m from the source. Difference between 17.71 m and 39.42 m gives an adjustment factor of -6.95 dB assuming a propagation of $20\log_{10}(R)$.

TABLE C5. Results for single shot SEL source level modeling for the four 210 in$^3$ airguns with weighting function calculations for SELcum criteria.
### Appendix C: Modeling of Airgun Noise Effects

#### Source Velocity (meters/second)

| Source Velocity (meters/second) | 2.0578 |

#### Resultant Isosepths

<table>
<thead>
<tr>
<th>Source Factor</th>
<th>Modified Source SEL *</th>
<th>SEL Cum Threshold</th>
<th>PTS SEL Cum Isopleth to threshold (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0522057</td>
<td>264.9147</td>
<td>183</td>
<td>39.5</td>
</tr>
<tr>
<td>2.0009072</td>
<td>264.9183</td>
<td>185</td>
<td>0.0</td>
</tr>
<tr>
<td>2.7058211</td>
<td>264.9242</td>
<td>155</td>
<td>0.1</td>
</tr>
<tr>
<td>2.4999125</td>
<td>264.9584</td>
<td>185</td>
<td>0.5</td>
</tr>
<tr>
<td>3.5068195</td>
<td>268.3147</td>
<td>203</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### Weighting Function Calculations

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL Cum Threshold</td>
<td>183</td>
<td>185</td>
<td>155</td>
<td>185</td>
<td>203</td>
</tr>
<tr>
<td>PTS SEL Cum Isopleth to threshold (meters)</td>
<td>39.5</td>
<td>0.0</td>
<td>0.1</td>
<td>0.5</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Figure C8: Modeled Amplitude Spectral Density

Amplitude spectral density from Farfield signature and effect of auditory weighting for the 5 hearing groups. Four 210 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, High Frequency Cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted results.
weighted source level at each frequency and to derive the adjustment factors for the Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, and High Frequency Cetaceans as inputs into the NMFS user spreadsheet.

FIGURE C9: Modeled received sound levels (SEls) in deep water from the four 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (1029.1 m).
FIGURE C10: Modeled received sound levels (SELS) in deep water from the four 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185 and 203 dB SEL isopleths.
FIGURE C11: Modeled received sound exposure levels (SELs) from the four 210 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 4 (39.42 m) and this figure (17.71 m) allows us to estimate the adjustment in dB.

**Peak Sound Pressure Level:**

**TABLE C6.** LEVEL A. NMFS Level A acoustic thresholds (Peak SPL_{peak}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the four 210 cu.in airguns at a 3 m tow depth during the proposed seismic survey in the north western Atlantic Ocean.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radius to threshold (meters)</td>
<td>11.56</td>
<td>N/A (0)</td>
<td>80.50</td>
<td>13.04</td>
<td>N/A (0)</td>
</tr>
</tbody>
</table>
FIGURE C12: Modeled deep-water received Peak SPL from four 210 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (80.50 m).
FIGURE C13: Modeled deep-water received Peak SPL from two 210 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 218 and 219 dB peak isopleths.

**BACKUP CONFIGURATION**

2 x 105 cu.in – 2 m separation aft-fore direction @ 3 m depth

**SELcum methodology (spreadsheet – Sivle et al., 2014)**

Table C7: Table showing the results for one single SEL SL modeling without and with applying weighting function to the 5 hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SELcum threshold is the largest. A propagation of 20 log_{10} (Radial distance) is used to estimate the modified farfield SEL.

<table>
<thead>
<tr>
<th>SELcum Threshold</th>
<th>183</th>
<th>185</th>
<th>155</th>
<th>185</th>
<th>203</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance(m) (no weighting function)</td>
<td>17.9821</td>
<td>14.5253</td>
<td>459.5354</td>
<td>14.5352</td>
<td>2.2227</td>
</tr>
<tr>
<td>Modified Farfield SEL*</td>
<td>208.0968</td>
<td>208.2425</td>
<td>208.2464</td>
<td>208.2425</td>
<td>209.9376</td>
</tr>
<tr>
<td>Distance (m) (with weighting function)</td>
<td>9.1754</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Adjustment (dB)</td>
<td>- 5.84</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
For the Low Frequency Cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 17.98 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL cum isopleth is located at 9.17 m from the source. Difference between 17.98 m and 9.17 m gives an adjustment factor of -5.84 dB assuming a propagation of 20log(R).

TABLE C8. Results for single shot SEL source level modeling for the two 105 in³ airguns with weighting function calculations for SEL_{cum} criteria.
### FIGURE C14: Modeled amplitude spectral density of the two 105 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, High Frequency Cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted source level at each frequency and to derive the adjustment factors for the Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, and High Frequency Cetaceans as inputs into the NMFS user spreadsheet.
FIGURE C15: Modeled received sound levels (SEls) in deep water from the two 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (459.5 m).
FIGURE C16: Modeled received sound levels (SELs) in deep water from the two 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183 and 185 dB SEL isopleths.
FIGURE C17: Modeled received sound exposure levels (SEls) from the two 105 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 4 (17.98 m) and this figure (9.17 m) allows us to estimate the adjustment in dB.

**Peak Sound Pressure Level:**

TABLE C9. LEVEL A. NMFS Level A acoustic thresholds (Peak SPL_{fla}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the two 105 cu.in airguns at a 3 m tow depth during the proposed seismic survey in the northwestern Atlantic Ocean.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radius to threshold</td>
<td>6.52</td>
<td>1.58</td>
<td>42.32</td>
<td>7.31</td>
<td>1.08</td>
</tr>
</tbody>
</table>
FIGURE C18: Modeled deep-water received Peak SPL from two 105 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (44.14 m).
FIGURE C19: Modeled deep-water received Peak SPL from two 105 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

Summary Tables for PTS SEL$_{cum}$ and Peak SPL$_{flat}$.

Table C10. PTS SEL$_{cum}$ isopleth to threshold in meters (*italics*) for each source configuration and hearing group, as calculated using the NMFS spreadsheet.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL$_{cum}$ Threshold</td>
<td>183 dB</td>
<td>185 dB</td>
<td>155 dB</td>
</tr>
<tr>
<td>Base Configuration</td>
<td>31.0 m</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GG Configuration</td>
<td>39.5 m</td>
<td>0.0</td>
<td>0.1 m</td>
</tr>
<tr>
<td>Backup Configuration</td>
<td>10.6 m</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
TABLE C11. SUMMARY LEVEL A. NMFS Level A acoustic thresholds (Peak SPL\textsubscript{na}) for impulsive sources and predicted radial distances to Level A thresholds in meters for the three source configurations.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
</tr>
</thead>
<tbody>
<tr>
<td>PK Threshold</td>
<td>219 dB</td>
<td>230 dB</td>
<td>202 dB</td>
</tr>
<tr>
<td>Base configuration</td>
<td>10.03 m</td>
<td>N/A (0)</td>
<td>70.426 m</td>
</tr>
<tr>
<td>GG configuration</td>
<td>11.56 m</td>
<td>N/A (0)</td>
<td>80.50 m</td>
</tr>
<tr>
<td>Backup configuration</td>
<td>6.52 m</td>
<td>1.58 m</td>
<td>42.32 m</td>
</tr>
</tbody>
</table>
Appendix D: Affected Environment Text

As noted above, this section is taken verbatim from the Draft Scripps EA (2017) and has been incorporated by reference. It is reproduced here only for the sake of completeness.

Summary Effects of Airguns on Marine Mammals and Turtles (Section IV.1.a)

As noted in the NSF-USGS 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 (e.g., 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). 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, but temporary threshold shift (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 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). Although the possibility cannot be entirely excluded, it is 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 encounter a survey while it is underway, 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 at a distance of 2000 km from the seismic source. Nieuwirk et al. (2012) and Blackwell et al. (2013) 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., Nieuwirk 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). 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. Sills et al. (2017) reported that recorded airguns sounds masked the detection of low-frequency sounds by ringed and spotted seals, especially at the onset of the airgun pulse when signal amplitude was variable. We are not aware of any information concerning masking of hearing in sea turtles.

**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; Elliston et al. 2012). 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). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Elliston et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017). Various authors have noted that some marine mammals that show no obvious avoidance or behavioral changes may still be adversely affected by sound (e.g., Weilgart 2007; Wright et al. 2011; Gomez et al. 2016).

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.

**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).

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 vessel; 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.

More recent studies examining the behavioral responses of humpback whales to airguns have also been conducted off eastern Australia (Cato et al. 2011, 2012, 2013, 2016), although results are not yet available for all studies. Dunlop et al. (2015) reported that humpback whales responded to a vessel operating a 20 in³ 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 in³, although an increase in distance from the airgun array 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). Responses to ramp up and use of a 3130 in³ array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Overall, the results showed that humpbacks were more likely to avoid active airgun arrays (of 20 and 140 in³) within 3 km and at levels of at least 140 dB re 1 μPa²·s (Dunlop et al. 2017). These results are consistent with earlier studies (e.g., McCauley et al. 2000). Although there was no clear evidence of avoidance by humpbacks on their summer feeding grounds in southeast Alaska, there were subtle behavioral effects at distance up to 3.2 km and received levels of 150 to 172 re 1 μPa on an approximate rms basis (Malme et al. 1985).

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). 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).
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), Bain et al. (2015), Houser et al. (2016), and Lyamin et al. (2016) also reported that sound could be a potential source of stress for marine mammals.

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

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 µPa; at SPLs <108 dB re 1 µPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received CSEL_{10-min} (cumulative SEL over a 10-min period) of ~94 dB re 1 µPa^{2·s}, decreased at CSEL_{10-min} >127 dB re 1 µPa^{2·s}, and whales were nearly silent at CSEL_{10-min} >160 dB re 1 µPa^{2·s}. 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) or 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 seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong
responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa (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 British Columbia 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 to 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. 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.

**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 protected species 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 short-beaked 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.

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). However, foraging behavior can 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. 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). Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity during 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 is 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. 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). 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. (2012a) 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. 2013a). 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).

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 (in particular mid-frequency cetaceans), which tend to be less responsive than the more responsive cetaceans. NMFS is currently 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).

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 NSF-USGS 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 in³) 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; however, concentration areas are not known to occur within the proposed project area. 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; Finneran 2012, 2015; Kastelein et al. 2012b,c; 2013b,c, 2014, 2015a, 2016a,b; Ketten 2012; Supin et al. 2016).

Recent data 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).
Recent 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) 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.

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).

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 NSF-USGS 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; NMFS 2016a). 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. 2012c, 2013b,c, 2014, 2015a) have indicated that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012c) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB. Kastelein et al. (2013b) exposed a harbor porpoise to a long, continuous 1.5-kHz tone, which induced a 14-dB TTS with a total SEL of 190 dB. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

For the harbor porpoise, Tougaard et al. (2015) suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{eq\text{-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). According to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. Mulsow et al. (2015) suggested that basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals. Houser et al. (2017) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

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. (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. 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). 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.

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. Similarly, 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).

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a) 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 airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL$_{\text{cum}}$ over 24 hours) and Peak SPL$_{\text{flat}}$. Onset of PTS is assumed to be 15 dB higher when considering SEL$_{\text{cum}}$ and 6 dB higher when considering SPL$_{\text{flat}}$. 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).

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 62 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2015a). In a hearing to examine the Bureau of Ocean Energy Management’s 2017–2022 OCS Oil and Gas Leasing Program (http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=110E5E8F-3A65-4BEC-9D25-5D843A0284D3), 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.

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, the deep water in the majority of the study area, 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. Given the high source levels of airgun pulses and the substantial received levels even at distances many km away from the source, it is probable that sea turtles can also hear the sound source output from distant seismic vessels. 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 NSF-USGS 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 μPa²·s SELcum (weighted) for PTS; and 226 dB peak and 189 dB weighted SEL for TTS (USN 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 highly 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 dBpeak 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 Hugh R. Sharp would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.
Appendix E. Impact of Ship Noise

(Additional material for §IV.1c, adopted nearly verbatim from the Draft Scripps EA (LGL, 2017).

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. The Proposed Action lies entirely within the Atlantic Large Whale Take Reduction Plan Regulated Waters (GARFO, 2015; 50CFR 229), which manages the use of certain fishing equipment to prevent entanglement of particularly North American right, humpback, minke, and fin whales. Seismic streamers are inherently simpler than longlines, gill nets, trawls, or vertical lines that mark or support various fishing gear. These streamers also move through the water behind a sound source and do not extend more than a few meters below the water’s surface. For all of these reasons, the risk of entanglement with seismic gear is considered lower than that for fishing gear for marine mammals.

Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels. 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); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by harbor porpoise (Teilmann et al. 2015) and humpback whales (Blair et al. 2016).

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). 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 Brandt 2013; Sills et al. 2017). 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). 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 project area 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...
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). Fin whale sightings in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

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

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

The NSF-USGS 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 NSF-USGS PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. 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 NSF-USGS PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but is 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. During the proposed cruise, most (70%) of the seismic survey effort is expected to occur at a speed of ~15 km/h, and 30% is expected to occur at 9 km/h. However, the number of seismic survey km are low relative to other fast-moving vessels in the area (see Cumulative Effects section). There has been no history of marine mammal vessel strikes by vessels in the U.S. marine academic research fleet in the past two decades.
Appendices

Appendix F. Direct Effects

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 NSF-USGS PEIS. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the NSF-USGS PEIS are summarized below. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015; Carroll et al. 2016).

(a) Effects of Sound on Marine Invertebrates

Noise effects on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses, injuries, or mortalities (Aguilar de Soto 2016; Carroll et al. 2016; Edmonds et al. 2016). Unknowns that remain include how particle motion, rather than sound pressure levels, affect invertebrates exposed to sound (Hawkins and Popper 2017). The small amount of available information suggests that invertebrates, particularly crustaceans, may be relatively resilient to airgun sounds (Day et al. 2016a,b). Fewtrell and McCauley (2012) exposed captive squid (Sepioteuthis australis) to pulses from a single airgun, with received sound levels ranging from 120 to 184 dB re 1 μPa²·s SEL. Increases in alarm responses (ink discharge, change in swim pattern or vertical position in water column) were seen at SELs >147–151 dB re 1 μPa²·s. Solé et al. (2013) exposed four caged cephalopod species 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 showed stressed behavior, decreased activity, and loss of muscle tone.

When New Zealand scallop (Pecten novaezelandiae) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (Aguilar de Soto et al. 2013). The 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.

Day et al. (2016a,b, 2017) exposed scallops (Pecten fumatus) and egg-bearing female spiny 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 in³, 150 in³ (low pressure), and 150 in³ (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 μPa²·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, and haemolymph chemistry (Day et al. 2016b, 2017). 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). However, there were non-lethal effects, including changes in reflex behavior time and haemolymph chemistry, as well as apparent damage to statocysts; no mortalities were reported for control or exposed lobsters (Day et al. 2016a,b).
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 larvae or snow crab embryos to seismic sounds (Pearson et al. 1994; DFO 2004; Morris et al. 2017).

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 airgun 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\text{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 hepatopancreas. 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 to 200 dB re 1 μPa and 148 to 172 dB re 1 μPa\text{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.

Celi et al. (2013) exposed captive red swamp crayfish (Procambarus clarkia) to linear sweeps with a frequency range of 0.1–25 kHz and a peak amplitude of 148 dB re 1 μPa\text{rms} at 12 kHz for 30 min. They found that the noise exposure caused changes in the haemato-immunological parameters (indicating stress) and reduced agonistic behaviors. Wale et al. (2013a,b) showed increased oxygen consumption and effects on feeding and righting behavior of shore crabs when exposed to ship sound playbacks.

McCauley et al. (2017) conducted a 2-day study to examine the potential effects of sound exposure of a 150 in\text{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.

Leite et al. (2016) reported observing a dead giant squid (Architeuthis dux) while undertaking marine mammal observation work aboard a vessel conducting a seismic survey offshore from Brazil. The seismic vessel was operating a 48-airgun array with a total volume of 5085 in³. 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.

(b) Effects of Sound on Fish

Potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), and Fay and Popper (2012); they include pathological, physiological, and behavioral effects. Radford et al. (2014) suggested that masking of key environmental sounds or social signals could also be a potential negative effect from sound. 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) cautioned that particle motion as well as sound pressure should be considered when assessing the effects of underwater sound on fishes.

Bui et al. (2013) examined the behavioral responses of Atlantic salmon (Salmo salar L.) to light, sound, and surface disturbance events. They reported that the fish showed short-term avoidance responses to the three stimuli. Salmon that were exposed to 12 Hz sounds and/or surface disturbances increased their swimming speeds.

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 μPa²⋅s). 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 to 184 dB re 1 dB re 1 μPa²⋅s SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 μPa²⋅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.

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 postlarval seabass to playback recordings of seismic survey sound (single strike SEL 144 dB re 1 µPa^2 · s) in large indoor tanks containing underwater speakers. Their findings indicated that short-term exposure of seismic sound increased the ventilation rate (i.e., opercular beat rate [OBR]) of seabass that were not previously exposed to seismic relative to seabass in controlled, ambient sound conditions. Fish that were reared in tanks that were repeatedly exposed to seismic sound over a 12-week period exhibited a reduced OBR response to that sound type, but fish exposed over the same time period to pile-driving noise displayed a reduced response to both seismic and pile-driving noise. An increased ventilation rate is indicative of greater stress in seabass; however, there was no evidence of mortality or effects on growth of the seabass throughout the 12-week study period.

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

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

Sierra-Flores (2015) examined sound as a short-term stressor in Atlantic cod (Gadus morhua) using cortisol as a biomarker. An underwater loudspeaker emitted SPLs ranging from 104 to 110 dB re 1 µPa. Plasma cortisol levels of fish increased rapidly with noise exposure, returning to baseline levels 20-40 min post-exposure. A second experiment examined the effects of long-term noise 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 noise 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.

(c) 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 Before-After/Control-Impact (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 airgun arrays used in the geophysical survey had sound pressure levels of 237 dB re 1μPa0-p, 243 dB re 1μPa p-p, and 218 dB re 1μPa rms. Received SPLmax ranged from 107 to 144 dB re 1 μPa, and received SELcum ranged from 111 to 141 dB re 1μPa2-s for airgun pulses measured by sound recorders at four fyke net locations. They determined that fyke nets closest to airgun activities showed decreases in catch per unit effort (CPUE) while nets further away from the airgun source showed increases in CPUE.

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 to 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, it contributes evidence that normal fish use of reef ecosystems is reduced when they are impacted by seismic sounds.

Morris et al. (2017) conducted a two-year (2015–2016) BACI study examining the effects of 2-D seismic exploration on catch rates of snow crab (Chionoecetes opilio) 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 in³, horizontal zero-to-peak SPL of 251 dB re 1 μPa, and SEL of 229 dB re 1 μPa2·s. The seismic source came 100 m of the sound recorders in 2016. Overall, the findings indicated that the sound from the commercial seismic survey did not significantly reduce snow crab catch rates in the short-term (i.e., days) or longer term (i.e., weeks) in which the study took place. Morris et al. (2017) 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.
Appendix G. Other Effects

Sections adopted nearly verbatim from the Draft Scripps EA (LGL, 2017).

Direct Effects on Seabirds and Their Significance

The underwater hearing of seabirds (including loons, scaups, gannets, and ducks) has recently been investigated, and the peak hearing sensitivity was found to be between 1500 and 3000 Hz (Crowell 2016). Great cormorants were also found to respond to underwater sounds and may have special adaptations for hearing underwater (Hansen et al. 2016; Johansen et al. 2016). Effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the NSF-USGS PEIS. The NSF-USGS 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. Given the proposed activities and the mitigation measures, no significant impacts on seabirds would be anticipated. In decades of seismic surveys carried out by the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related seabird injuries or mortality.

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

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

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates, if any, 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.