Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Low-Energy Marine Geophysical Surveys by R/V *Justo Sierra* in the Southeastern Gulf of Mexico, Summer 2020

Submitted by

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Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Low-Energy Marine Geophysical Surveys by R/V *Justo Sierra* in the Southeastern Gulf of Mexico, Summer 2020

**SUMMARY**

Scripps Institution of Oceanography (SIO) plans to support a research activity that would involve low-energy seismic surveys in the Gulf of Mexico (GoM) during summer 2020. The study would be conducted on R/V *Justo Sierra* (operated by Universidad Nacional Autónoma de México [UNAM]) using the portable multi-channel seismic (MCS) system operated by marine technicians from SIO. Researchers from the University of Texas Institute of Geophysics (UTIG), with funding from the U.S. National Science Foundation (NSF), propose to use a pair of low-energy Generator-Injector (GI) airguns with a total discharge volume of ~90 in$^3$ to conduct the surveys. The seismic surveys would take place within the Exclusive Economic Zones (EEZ) of Mexico and Cuba in the southeastern GoM. SIO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic surveys. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals inhabit the proposed survey area in the GoM. Under the U.S. Endangered Species Act (ESA), several of these species are listed as *endangered*, including the sperm whale and Gulf of Mexico Bryde’s whale. SIO is proposing a marine mammal monitoring and mitigation program to minimize the potential impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

Other ESA-listed species that could occur in the area that are listed as *endangered* include the leatherback, Kemp’s ridley, and hawksbill sea turtles, the giant manta ray, and smalltooth sawfish. *Threatened* species or Distinct Population Segments (DPSs) under the ESA that could occur in the proposed survey area include the Northwest Atlantic DPS of loggerhead sea turtle, North Atlantic DPS of green sea turtle, Nassau grouper, oceanic whitetip shark, and roseate tern.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, “Submission of Requests”, are set forth below. They include descriptions of the specific operations to be conducted, the marine mammals occurring in the project area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on those marine mammals.
I. Operations to be Conducted

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

Overview of the Activity

SIO plans to conduct low-energy seismic surveys in the GoM from ~30 July to 14 August 2020. The surveys would take place in the southeastern GoM between ~22°–25°N and 83.8°W–88°W (Fig. 1). Seismic acquisition would occur in two primary survey areas: the deep-water channel between the Campeche and Florida escarpments (Yucatán Channel survey area) and the northeastern flank of the Campeche escarpment (Campeche Bank survey area). The proposed seismic surveys in the Yucatán Channel survey area would occur within the EEZ of Cuba in water depths ranging from ~1500 to 3600 m. Surveys in the Campeche Bank survey area would occur within the EEZ of Mexico and Cuba in water ranging in depth from ~110 to 3000 m. No survey effort would occur in shallow water <100 m deep. Representative survey tracklines are shown in Figure 1; however, the actual survey effort could occur anywhere within the outlined study area as shown in Figure 1. Some deviation in actual tracklines and timing could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. In addition, if a permit cannot be obtained from Cuba to conduct surveys within its EEZ, all seismic effort would occur within the Campeche Bank survey area within the Mexican EEZ.

The proposed project consists of low-energy seismic surveys to image sediment drifts along Campeche Bank and in the deep water north of Yucatán Channel in order to reconstruct bottom water current changes through the Cenozoic era. Data collected would also be used to inform potential future site locations for an International Ocean Discovery Program (IODP). To achieve the program’s goals, Drs. C. Lowery and J. Austin (UTIG), propose to collect low-energy, high-resolution MCS profiles. Although not funded through NSF, international collaborators Drs. J. Urrutia Fucugauchi and L. Perez Cruz (UNAM) would work with the PIs to achieve the research goals, providing assistance, such as through logistical support and data acquisition, exchange, and interpretation. The procedures to be used for the seismic surveys would be similar to those used during previous seismic surveys by SIO and would use conventional seismic methodology.

The surveys would involve one source vessel, R/V Justo Sierra, using the portable MCS system operated by marine technicians from SIO. R/V Justo sierra (operated by UNAM) would deploy up to two 45-in³ GI airguns as an energy source with a maximum total volume of ~90 in³. The receiving system would consist of one hydrophone streamer, 1500 m in length. As the airguns are towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

In the Yucatán Channel survey area, a grid is proposed that consists of southwest-northeast trending strike profiles with crossing dip profiles to provide images of the deep water connection between the Straits of Florida and the basinal southeastern GoM (Fig. 1). Multibeam echosounder (MBES) data would provide information on modern seafloor morphology that may reveal seafloor features indicative of modern current flow, while Acoustic Doppler Current Profiler (ADCP) data would give a snapshot of present flow at depth in this area. In the Campeche Bank survey area, several long dip profiles would be acquired that are connected by several strike lines. The study area also includes three proposed sites for future IODP coring (all within the EEZ of Cuba). Around each site, an additional survey of a single 5 km by 5 km box would be conducted around the proposed site to better characterize the sediments and provide a number of options to choose the ideal location for proposed future drilling.
I. Operations to be Conducted

At the proposed survey areas, ~2171 km of seismic data would be collected. Although representative lines for the proposed GoM survey areas are depicted in Figure 1, the line locations for the survey areas are preliminary and could be refined in light of information from data collected during the study. All survey effort proposed for the Yucatán Channel survey area would occur in water >1000 m deep. In the Campeche Bank survey area, most effort would also occur in deep water (~80%); ~20% would occur in intermediate water. There could be additional seismic operations in the project area associated with equipment testing, re-acquisition due to reasons such as, but not limited to, equipment malfunction, data degradation during poor weather, or interruption due to shut-down or track deviation in compliance with IHA requirements. In our calculations [see § VII], 25% of effort has been added for those additional operations.

A hull-mounted MBES and an ADCP would also be operated from R/V Justo Sierra continuously throughout the seismic surveys, but not during transits to and from the survey area or when airguns are not operating. All planned data acquisition and sampling activities would be conducted by SIO and UNAM with on-board assistance by the scientists who have proposed the project. The vessel would be self-contained, and the crew would live aboard the vessel for the entire cruise.

FIGURE 1. Location of the proposed low-energy seismic surveys in the southeastern GoM, July–August 2020.
Source Vessel Specifications

*R/V Justo Sierra* has a length of 50 m, a beam of 10.3 m, and a maximum draft of 4.7 m. It has a diesel engine with 1680 hp at 800 rpm. An operation speed of ~7.4–9.3 km/h (~4–5 kt) would be used during seismic acquisition. When not towing seismic survey gear, *R/V Justo Sierra* cruises at 22 km/h (12 kt) and has a maximum speed of 23 km/h (12.5 kt). It has a normal operating range of ~10,000 n.mi. *R/V Justo Sierra* would also serve as the platform from which vessel-based protected species visual observers (PSVOs) would watch for marine species before and during airgun operations.

Other details of *R/V Justo Sierra* include the following:

**Owner:** Universidad Nacional Autónoma de México  
**Operator:** Universidad Nacional Autónoma de México  
**Flag:** Mexico  
**Built:** 1982  
**Gross tonnage:** 770 t  
**Accommodation capacity:** 36 including 21 scientists

Airgun Description

*R/V Justo Sierra* would tow two 45-in$^3$ GI airguns and a streamer containing hydrophones. The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, is 45 in$^3$. The larger (105 in$^3$) injector chamber injects air into the previously generated bubble to maintain its shape and does not introduce more sound into the water. The 45-in$^3$ GI airguns would be towed 25 m behind *R/V Justo Sierra*, at a depth of 2–4 m. Seismic pulses would be emitted at intervals of 8–10 s from the GI airguns.

**GI Airgun Specifications**

<table>
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<tr>
<th>Energy Source</th>
<th>Two GI guns of 45 in$^3$ each</th>
</tr>
</thead>
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<tr>
<td>Gun positions used</td>
<td>Two inline airguns 2- or 8-m apart</td>
</tr>
<tr>
<td>Towing depth of energy source</td>
<td>2–4 m</td>
</tr>
<tr>
<td>Source output (2-m gun separation)*</td>
<td>0-peak is 3.5 bar·m (230.9 dB re 1 μPa·m);</td>
</tr>
<tr>
<td></td>
<td>peak-peak 6.9 bar·m (236.7 dB re 1 μPa·m)</td>
</tr>
<tr>
<td>Air discharge volume</td>
<td>Approx. 90 in$^3$</td>
</tr>
<tr>
<td>Dominant frequency components</td>
<td>0–188 Hz</td>
</tr>
<tr>
<td>Gun volumes at each position (in$^3$):</td>
<td>45, 45</td>
</tr>
</tbody>
</table>

*Source output downward based on a conservative tow depth of 4 m.*

As the airguns are towed along the survey lines, the towed hydrophone array in the streamer would receive the reflected signals and transfer the data to the on-board processing system. The turning rate of the vessel with gear deployed would be ~5º. Thus, the maneuverability of the vessel would be limited during operations.

The source levels can be derived from the modeled farfield source signature, which is estimated using the PGS Nucleus software. The nominal downward-directed source levels indicated above do not represent actual sound levels that can be measured at any location in the water. Rather, they represent the level that would be found 1 m from a hypothetical point source emitting the same total amount of sound as is emitted by the combined GI airguns. The actual received level at any location in the water near the GI airguns...
would not exceed the source level of the strongest individual source. Actual levels experienced by any organism more than 1 m from either GI airgun would be significantly lower.

A further consideration is that the rms\(^1\) (root mean square) 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 \(\mu Pa_{rms}\) in the far field would typically correspond to ~170 dB re 1 \(\mu Pa_p\) or 176–178 dB re 1 \(\mu Pa_{pp}\), 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.

Mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the 160 dB re 1 \(\mu Pa_{rms}\) threshold for Level B takes. The background information and methodology for this are provided in Appendix A and briefly summarized here. The proposed surveys would acquire data with the 2-GI airgun array at a tow depth of ~2–4 m. L-DEO model results are used to determine the 160-dB\(_{rms}\) radius for the 2-GI airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. Table 1 shows the distances at which the 160-dB re 1 \(\mu Pa_{rms}\) sound level is expected to be received for the 2-GI airgun array at a 4-m tow depth.

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). Although Level A takes would not be anticipated, for other recent low-energy seismic surveys supported by SIO, NMFS required protected species observers (PSOs) to establish and monitor a 100-m exclusion zone (EZ) and a 200-m buffer zone beyond the EZ.

**Description of Operations**

The proposed surveys would involve one source vessel, R/V *Justo Sirra*. R/V *Justo Sierra* would tow a pair of 45-in\(^1\) GI airguns at a depth of 2–4 m and a streamer up to 1500-m in length containing hydrophones along predetermined lines. As the GI airguns are towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

The proposed cruise would acquire ~2171 km of seismic data in the southeastern GoM to reconstruct bottom water current changes through the Cenozoic era and to enable the selection and analysis of potential future IODP drill sites. All data acquisition in the Yucatán Channel survey area would occur in water >1000 m deep. In the Campeche Bank survey area, most effort would also occur in deep water (~80%); ~20% would occur in intermediate-depth water.

\(^1\) The rms (root mean square) pressure is an average over the pulse duration.
I. Operations to be Conducted

TABLE 1. Level B. Predicted distances to the 160 dB re 1 μPa<sub>rms</sub> sound level that could be received from two 45-in<sup>3</sup> GI guns (at a tow depth of 4 m) that would be used during the seismic surveys in the southeastern Gulf of Mexico during summer 2020 (model results provided by L-DEO).

<table>
<thead>
<tr>
<th>Airgun Configuration</th>
<th>Water Depth (m)</th>
<th>Predicted Distances (m) to a Received Sound Level of 160 dB re 1 μPa&lt;sub&gt;rms&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two 45-in&lt;sup&gt;3&lt;/sup&gt; GI guns</td>
<td>&gt;1000</td>
<td>539&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>100-1000</td>
<td>809&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Distance is based on L-DEO model results.
<sup>2</sup> Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.

Along with the airgun operations, two additional acoustical data acquisition systems would be operated during the seismic survey, but not during transits. The ocean floor would be mapped with the Kongsberg EM302 MBES and a Teledyne Ocean Observer ADCP. These sources, or similar, are described in § 2.2.3.1 of the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011), and Record of Decision (NSF 2012), referred to herein as the PEIS.

II. DATES, DURATION, AND REGION OF ACTIVITY

The date(s) and duration of such activity and the specific geographical region where it will occur.

The surveys would take place in the southeastern GoM between ~22°–25°N and 83.8°W–88°W (Fig. 1). Seismic acquisition would occur in two primary survey areas: the deep-water channel between the Campeche and Florida escarpments (Yucatán Channel survey area) and the northeastern flank of the Campeche escarpment (Campeche Bank survey area). The proposed seismic surveys in the Yucatán Channel survey area would occur within the EEZ of Cuba in water depths ranging from ~1500 to 3600 m. Surveys in the Campeche Bank survey area would occur within the EEZ of Mexico and Cuba in water ranging in depth from ~110 to 3000 m. R/V Justo Sierra would depart from Tampamochaco, Mexico, on ~30 July, and return to Progreso, Mexico, on ~14 August, after the program is completed. The cruise is expected to consist of 15 days at sea, including ~12 days of seismic operations (including 10 planned days and 2 contingency days) and ~3 days of transit. Some deviation in timing could also result from unforeseen events such as weather or logistical issues.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

The species and numbers of marine mammals likely to be found within the activity area

Twenty-eight species of cetaceans and one species of manatee are known to occur in the GoM (Jefferson and Schiro 1997; Würsig et al. 2000), but only 21 of the cetacean species occur there regularly (NOAA 2017). Most of these species occur in oceanic waters (>200 m deep), whereas the continental shelf waters (<200 m) are primarily inhabited by bottlenose and Atlantic spotted dolphins (Mullin and Fulling 2004; Mullin 2007). In the proposed study area in the southeastern GoM, 24 marine mammals species could occur, including four mysticetes (baleen whales) and 20 odontocetes (toothed whales) (Table 2). Pinnipeds and the West Indian manatee are not likely to be encountered in the proposed survey area in the GoM. 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.
### TABLE 2. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed survey area in the southeastern Gulf of Mexico.

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Occurrence in South-eastern GoM</th>
<th>Abundance</th>
<th>Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GoM2,3</td>
<td>GoM3,4</td>
<td>Western North Atlantic</td>
</tr>
<tr>
<td><strong>Mysticetes</strong></td>
<td></td>
<td>GoM4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fin whale</td>
<td>Coastal, pelagic</td>
<td>Rare</td>
<td>N.A.</td>
<td>7,418</td>
</tr>
<tr>
<td>Bryde’s whale</td>
<td>Pelagic and coastal</td>
<td>Rare</td>
<td>N.A.</td>
<td>33</td>
</tr>
<tr>
<td>(Gulf of Mexico subspecies)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minke whale</td>
<td>Coastal waters</td>
<td>Rare</td>
<td>N.A.</td>
<td>24,202 (^{11})</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>Mainly nearshore and banks</td>
<td>Rare</td>
<td>N.A.</td>
<td>11,570 (^{12})</td>
</tr>
<tr>
<td><strong>Odontocetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm whale</td>
<td>Usually pelagic and deep seas</td>
<td>Common</td>
<td>2,128</td>
<td>763</td>
</tr>
<tr>
<td>Pygmy sperm whale</td>
<td>Deeper waters off the shelf</td>
<td>Uncommon</td>
<td>2,234 (^{14})</td>
<td>186 (^{14})</td>
</tr>
<tr>
<td>Dwarf sperm whale</td>
<td>Deeper waters off the shelf</td>
<td>Uncommon</td>
<td>2,234 (^{14})</td>
<td>186 (^{14})</td>
</tr>
<tr>
<td>Cuvier's beaked whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>2,910 (^{15})</td>
<td>74</td>
</tr>
<tr>
<td>Gervais’ beaked whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>2,910 (^{15})</td>
<td>149 (^{16})</td>
</tr>
<tr>
<td>Blainville’s beaked whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>2,910 (^{15})</td>
<td>149 (^{16})</td>
</tr>
<tr>
<td>Rough-toothed dolphin</td>
<td>Mostly pelagic</td>
<td>Common</td>
<td>4,853</td>
<td>624</td>
</tr>
<tr>
<td>Bottlenose dolphin</td>
<td>Continental Shelf, coastal and offshore</td>
<td>Common</td>
<td>138,602</td>
<td>51,192 (^{17})</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td>Mainly pelagic</td>
<td>Common</td>
<td>84,014</td>
<td>50,880</td>
</tr>
<tr>
<td>Atlantic spotted waters</td>
<td>Mainly coastal waters</td>
<td>Common</td>
<td>47,488</td>
<td>N.A.</td>
</tr>
<tr>
<td>Spinner dolphin</td>
<td>Coastal, pelagic</td>
<td>Common</td>
<td>13,485</td>
<td>11,441</td>
</tr>
<tr>
<td>Clymene dolphin</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>11,000</td>
<td>129</td>
</tr>
<tr>
<td>Striped dolphin</td>
<td>Off the continental shelf</td>
<td>Common</td>
<td>4,914</td>
<td>1,849</td>
</tr>
<tr>
<td>Fraser's dolphin</td>
<td>Water &gt;1000 m</td>
<td>Uncommon</td>
<td>1,665</td>
<td>N.A.</td>
</tr>
<tr>
<td>Risso’s dolphin</td>
<td>Waters 400-1000 m</td>
<td>Common</td>
<td>3,137</td>
<td>2,442</td>
</tr>
<tr>
<td>Melon-headed whale</td>
<td>Oceanic</td>
<td>Common</td>
<td>6,733</td>
<td>2,235</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td>Oceanic</td>
<td>Uncommon</td>
<td>2,126</td>
<td>152</td>
</tr>
<tr>
<td>False killer whale</td>
<td>Pelagic</td>
<td>Uncommon</td>
<td>3,204</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
### Species, Habitat, Occurrence in Southeastern GoM, Abundance, Conservation Status

<table>
<thead>
<tr>
<th>Species</th>
<th>Habitat</th>
<th>Occurrence in Southeastern GoM</th>
<th>Abundance</th>
<th>Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Killer whale</td>
<td>Widely distributed</td>
<td>Uncommon</td>
<td>185</td>
<td>NL II Pr DD II</td>
</tr>
<tr>
<td>Short-finned pilot whale</td>
<td>Mostly pelagic</td>
<td>Common</td>
<td>1,981^{22}</td>
<td>2,415^{22}</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28,924</td>
<td>NL II Pr LC II</td>
</tr>
</tbody>
</table>

1. Occurrence in area at the time of the survey; based on professional opinion and available data.
2. Roberts et al. (2016).
3. N.A. = not applicable.
5. Libro Rojo de los Vertebrados de Cuba does not list any cetacean species as threatened (González Alonso 2012).
10. Convention on International Trade in Endangered Species of Wild Fauna and Flora: Appendix I = Threatened with extinction; Appendix II = not necessarily threatened with extinction but may become so unless trade is closely controlled.
14. Estimate includes dwarf and pygmy sperm whales.
15. Estimate includes all beaked whales.
16. Estimate includes GoM stocks for Gervais’ and Blainville’s beaked whales, and undifferentiated beaked whales in the Atlantic.
20. Offshore stock.
22. Estimate includes all Globicephala sp., although only short-finned pilot whales are present in the GoM.

### IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities

Sections III and IV are integrated here to minimize repetition. Two of the 24 marine mammal species that could occur in the proposed survey area in the southeastern GoM are listed under the ESA as endangered, including the sperm whale ad Gulf of Mexico Bryde’s whale. 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 PEIS. The rest of this section deals specifically with species distribution in the proposed project area in the GoM.

**Mysticetes**

**Fin Whale (Balaenoptera physalus)**

The fin whale is widely distributed in all the world’s oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution is not well known (Jefferson et al. 2015). The northern and southern fin whale populations...
likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018).

Most populations migrate seasonally between temperate waters, where mating and calving occur in winter, and polar waters where feeding occurs in the summer (Evans 1987). Although they are known to use the shelf edge as a migration route (Evans 1987), fin whales most commonly occur offshore but can also be found in coastal areas (Jefferson et al. 2015). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex and not all populations follow this simple pattern (Jefferson et al. 2015). Fin whales are only rarely seen in the GoM (Würsig et al. 2000; Würsig 2017). Würsig et al. (2000) reported five strandings in the GoM and up to seven sightings. No sightings have been reported since 1998 (Roberts et al. 2016). There are 12 records in the OBIS database, including six in the southern GoM (OBIS 2020). Ortega-Ortiz (2002) reported a fin whale at the Campeche escarpment. There is one record for southwestern Cuba (Whitt et al. 2011; OBIS 2020).

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

Bryde’s whale occurs in all tropical and warm temperate waters in the Pacific, Atlantic, and Indian oceans, between 40°N and 40°S (Jefferson et al. 2015). It is one of the least known large baleen whales, and it remains uncertain how many species are represented in this complex (Kato and Perrin 2018). *B. brydei* is commonly used to refer to the larger form or “true” Bryde’s whale and *B. edeni* to the smaller form; however, some authors apply the name *B. edeni* to both forms (Kato and Perrin 2018). Bryde’s whale remains in warm (>16°C) water year-round (Kato and Perrin 2018). Seasonal movements have been recorded towards the Equator in winter and offshore in summer (Kato and Perrin 2018). However, Debrot (1998) noted that this species is sedentary in the tropics.

Bryde’s whale is the most common mysticete in the tropics (Debrot 1998) and the only baleen whale to occur in the GoM on a regular basis throughout the year (Würsig et al. 2000). However, it is uncertain whether it occurs in the southern GoM in Mexican and Cuban waters (NOAA 2020a); according to Ortega-Ortiz (2002), it does not appear to occur in that region. Bryde’s whale calls were not detected via passive acoustic recorders at the Dry Tortugas or in the north-central GoM (south of Alabama) at Main Pass (Širović et al. 2014).

Bryde’s whale can be pelagic as well as coastal. In the northern GoM, Bryde’s whales often occur in relatively shallow water ~100 m deep (Davis et al. 1998, 2002). However, sightings have also been reported in northeast slope waters where depths range from 200 to 2000 m (Mullin and Fulling 2004; Mullin 2007); the density for the northern GoM was 0.01 animals/100 km² (Mullin and Fulling 2004). Bryde’s whale is frequently observed in biologically productive areas such as continental shelf breaks (Davis et al. 2002) and regions subjected to coastal upwelling (Gallardo et al. 1983; Siciliano et al. 2004). LaBrecque et al. (2015) have indicated a Biologically Important Area for Bryde’s whale off Florida to the north of the survey area. The OBIS database has 30 records for the northern GoM, but no records for the southern GoM (OBIS 2020). There is one record in the OBIS database for the eastern Yucatán Peninsula (OBIS 2020). It is possible, although unlikely, that Bryde’s whales would be encountered in the proposed project area at the time of the surveys.

Common Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2015). Minke whales migrate northward during spring
and summer and can be seen in pelagic water at this time; however, they also occur in coastal areas (Stewart and Leatherwood 1985). Although widespread and common overall, they are rare in the GoM (Würsig et al. 2000). Würsig et al. (2000) reported 10 strandings for the GoM including the Florida Keys; the strandings occurred in the winter and spring and may have been northbound whales from the open ocean or Caribbean Sea. Based on Ortega-Ortiz (2002), the only record of a minke whale in the southern GoM is a single whale recorded as stranded at Celestún, on the northwestern coast of the Yucatán Peninsula. It is possible, although unlikely, that minke whales would be encountered in the proposed project area at the time of the surveys. However, OBIS (2020) reports eight records for the southern GoM, and 16 additional records in the northern GoM. There is also a record for northern Cuba, in the Straits of Florida (OBIS 2020); Whitt et al. (2011) did not report any records for Cuba.

**Humpback Whale (Megaptera novaeangliae)**

The humpback whale is found in all ocean basins (Clapham 2018). It is highly migratory, undertaking one of the world’s longest mammalian migrations by traveling between mid- to high-latitude waters where it feeds during spring to fall and low-latitude wintering grounds over shallow banks, where it mates and calves (Winn and Reichley 1985; Bettridge et al. 2015). Although considered to be mainly a coastal species, it often traverses deep pelagic areas while migrating (Baker et al. 1998; Garrigue et al. 2002; Zerbini et al. 2011). In the western North Atlantic, it occurs from Greenland to Venezuela (Würsig et al. 2000). For most North Atlantic humpbacks, the summer feeding grounds range from the northeast coast of the U.S. to the Barents Sea (Katona and Beard 1990; Smith et al. 1999). In the winter, the majority of humpback whales migrate to wintering areas in the West Indies (Smith et al. 1999); this is known as the West Indies Distinct Population Segment (DPS) (Bettridge et al. 2015).

Although humpbacks only occur rarely in the GoM, several sightings have been made off the west coast of Florida, near Alabama, and off Texas (Würsig et al. 2000); these may have been individuals from the West Indian winter grounds that strayed into the GoM during migration (Weller et al. 1996; Jefferson and Schiro 1997). In addition, Würsig et al. (2000) reported that humpback songs have also been recorded with hydrophones in the northwestern GoM, and there are two stranding records. Humpbacks have also been sighted off the northwest coast of Cuba (Whitt et al. 2011). There are 35 records in the OBIS database for the GoM, including records for the Campeche Bank survey area, Straits of Florida, and northwestern Cuba. Ortega-Ortiz (2002) only report one record for the southwestern GoM, on the lower slope off Tuxpan, but there are four records for the southwestern GoM in the OBIS database (OBIS 2020). It is possible, although unlikely, that humpback would be encountered in the proposed project area at the time of the surveys.

**Odontocetes**

**Sperm Whale (Physeter macrocephalus)**

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

Sperm whales generally occur in deep waters, along continental slopes (Rice 1989; Davis et al. 1998, 2002; Ortega-Ortiz 2002). Baumgartner et al. (2001) and Davis et al. (2002) noted that in the GoM, sperm
Pygmy Sperm Whale (*Kogia breviceps*)

The pygmy sperm whale is distributed throughout tropical and temperate waters of the Atlantic, Pacific, and Indian oceans, but its precise distribution is unknown because much of what we know of the species comes from strandings (McAlpine 2018). It is difficult to sight at sea, because of its dive behavior and perhaps because of avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). It is seen primarily along the continental shelf edge, slope, and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015; McAlpine 2018). Baumgartner et al. (2001) noted that *Kogia* spp. are sighted more frequently in areas with high zooplankton biomass.

In the western North Atlantic, pygmy sperm whales are known to occur from Nova Scotia to Cuba, and as far west as Texas in the GoM (Würsig et al. 2000; Würsig 2017). These whales are considered common in the GoM and occur there year-round (Würsig et al. 2000; Mullin et al. 2004). They strand frequently along the coast of the GoM, especially in autumn and winter; this may be associated with calving (Würsig et al. 2000). In the northern GoM, pygmy sperm whales are typically sighted in waters 100–2000 m deep (Würsig et al. 2000). Würsig et al. (2000) noted that densities of pygmy sperm whales were highest...
in the spring and summer and lower in the fall and winter. Mullin and Fulling (2004) reported a spring density of 0.20 Kogia spp./100 km$^2$ for oceanic waters of the northern GoM.

Kogia spp. sightings have been made throughout the northern GoM, including in deep water beyond the 1000-m isobath just to the north of the Yucatán Channel survey area during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). The OBIS database includes one pygmy sperm whale record in the Campeche Bank survey area, as well as several other records on Campeche Bank and in the Straits of Florida (OBIS 2020). Ortega-Ortiz (2002) reported 10 strandings of pygmy sperm whales in the southern GoM and east coast of the Yucatán Peninsula, including at Tecolutla, Veracruz; Alvarado, Veracruz; Progreso and El Cuyo, Yucatán; Chitales, Cozumel; Bahía de la Ascensión; and Cancún, Quintana Roo. There are also stranding records for the northwestern coast of Cuba (Whitt et al. 2011).

**Dwarf Sperm Whale (K. sima)**

The dwarf sperm whale is distributed widely in the world’s oceans, but it is poorly known (Caldwell and Caldwell 1989). Although there are few useful estimates of abundance anywhere in its range, the dwarf sperm whale is thought to be fairly common in some areas. These whales are primarily sighted along the shelf edge and slope (Rice 1998; Wang et al. 2002; MacLeod et al. 2004; McAlpine 2018). Barros et al. (1998) suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales.

In the western North Atlantic, dwarf sperm whales are known to occur from Virginia to the Caribbean and the GoM, where they are thought to be common (Würsig et al. 2000; Würsig 2017). These whales strand frequently along the coast of the GoM, but not as frequently as pygmy sperm whales (Würsig et al. 2000). Mullin et al. (2004) reported year-round sightings in the GoM. Kogia spp. sightings have been made throughout the northern GoM, including in deep water beyond the 1000-m isobath just to the north of the Yucatán Channel survey area during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). The OBIS database includes one dwarf sperm whale record in the Campeche Bank survey area, as well as several other records on Campeche Bank, Florida Bank, and in the Straits of Florida (OBIS 2020). Ortega-Ortiz (2002) reported five strandings of dwarf sperm whales in the southern GoM, including at Antón Lizardo, Veracruz; Las Colorados and El Cuyo, Yucatán; and Tulúm, Quintana Roo. Strandings have also been reported for the northwestern coast of Cuba (Whitt et al. 2011).

**Cuvier’s Beaked Whale (Ziphius cavirostris)**

Cuvier’s beaked whale is probably the most widespread and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 2018a). It is rarely observed at sea and is known mostly from strandings; it strands more commonly than any other beaked whale (Heyning 1989). Cuvier’s beaked whale is found in deep water in the open-ocean and over or near the continental slope (Gannier and Epinat 2008; Baird 2018a). It is rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep (Carwardine 1995).

In the western North Atlantic, these whales occur from Massachusetts to Florida, the West Indies, and the GoM (Würsig et al. 2000). In the GoM, they have been sighted on the lower continental slope, where depths are ~2000 m (Davis and Fargion 1996; Mullin and Hoggard 2000). Beaked whale sightings (undetermined species) have been made throughout the northern GoM, including in deep water beyond the 1000-m isobath just to the north of the Yucatán Channel survey area during systematic surveys of the northern GoM during 1996–2001 (Würsig 2017). Mullin and Fulling (2004) and Mullin (2007) reported a spring density of 0.02 Cuvier’s beaked whales/100 km$^2$ for oceanic waters of the northern GoM. During a survey of the GoM and Caribbean Sea during summer 1991, one sighting of four Cuvier’s beaked whales
was made on 7 June to the east of the Yucatán Channel survey area in the Straits of Florida at 23.8°N, 81.5°W in water 1280 m deep (Jefferson and Lynn 1994). The OBIS database includes records along the outer Florida Bank and the Straits of Florida for spring through fall (OBIS 2020).

Most strandings in the GoM are from the eastern area, especially from Florida (Würsig et al. 2000). Mass strandings are rare (although individual strandings are quite common), with only seven documented cases of more than four individuals stranding between 1963 and 1995 (Frantzis 1998). Ortega-Ortiz (2002) reported three strandings in the southern GoM at Campeche, and Holbox and Puerto Morelos, Quintana Roo. Strandings have also been reported for the northwestern coast of Cuba (Whitt et al. 2011).

**Blainville’s Beaked Whale (Mesoplodon densirostris)**

Blainville’s beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2018). It has the widest distribution throughout the world of all Mesoplodon species (Pitman 2018). It is rarely sighted, and most of the knowledge on the distribution of this species is derived from stranding data. There is no evidence that Blainville’s beaked whales undergo seasonal migrations, although movements into higher latitudes are likely related to warm currents, such as the Gulf Stream in the North Atlantic. This species is pelagic, and like other beaked whales, is generally found in deep slope waters (Davis et al. 1998; Jefferson et al. 2015). However, it may also occur in coastal areas, particularly where deep water gullies come close to shore.

In the western North Atlantic, it is found from Nova Scotia to Florida, the Bahamas, and the GoM (Würsig et al. 2000). In the OBIS database, there are ~32 records for the northern and southwestern GoM, but there are no records near the proposed survey areas (OBIS 2020). Stranding records exist for Louisiana, Texas, Mississippi/Alabama, and Florida (Würsig et al. 2000), as well as for the Yucatán (Ortega-Ortiz 2002). Most strandings involve single individuals, although groups of 3 to 7 have been reported in tropical waters (Jefferson et al. 1993). Blainville’s beaked whale has also been sighted in the northern GoM (Würsig et al. 2000).

**Gervais’ Beaked Whale (Mesoplodon europaeus)**

Although Gervais’ beaked whale is generally considered to be a North Atlantic species, it likely occurs in deep waters of the temperate and tropical Atlantic Ocean in both the northern and southern hemispheres (Jefferson et al. 2015). Its distribution is primarily known from stranding records. Strandings may be associated with calving, which takes place in shallow water (Würsig et al. 2000). Gervais’ beaked whale usually inhabits deep waters (Davis et al. 1998). It is more frequent in the western than the eastern Atlantic (Mead 1989) and occurs from New York to Florida and the GoM (Rice 1998). In the OBIS database, there are ~50 records throughout the GoM, including one just northeast of the Yucatán Channel survey area, one in the Campeche Bank survey area, as well as other records for Campeche Bank, Straits of Florida, and off northwestern Cuba (OBIS 2020). Strandings were reported in the GoM for Florida and Texas (Würsig et al. 2000). Ortega-Ortiz (2002) reported strandings at Isla Aguada and Celestún, Campeche; and Chelum, Yucatán. Strandings have also been reported for the northwestern coast of Cuba (Whitt et al. 2011).

**Risso’s Dolphin (Grampus griseus)**

Risso’s dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999). although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014; Hartman 2018). In the western Atlantic, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999). It has been sighted off Florida and in the western GoM off the coast of Texas, and stranding records also exist for Texas and Florida (Würsig et al. 2000). Mullin et al.
(2004) reported sightings for this species during all seasons in the northern GoM; spring density was reported as 0.57 dolphins/100 km² by Mullin and Fulling (2004). Sightings have been made throughout the northern GoM, including just to the north of the Yucatán Channel survey area, during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). In addition, a sighting has been made in the Straits of Florida, and sightings and strandings have been reported along the northwestern coast of Cuba (Whitt et al. 2011). The OBIS database includes numerous records northeast of the Yucatán Channel survey area along the edge of the Florida Bank, one in the Campeche survey area, as well as other records for Campeche Bank, and off northwestern Cuba (OBIS 2020).

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

The rough-toothed dolphin is distributed worldwide in tropical and subtropical waters (Jefferson et al. 2015). In the western Atlantic, this species occurs between the southeastern U.S. and southern Brazil, including the GoM (Jefferson 2015). Although it is generally seen in deep, oceanic water (Davis et al. 1998; Jefferson et al. 2015), it also occurs in continental shelf waters of the GoM (Ortega-Ortiz 2002; Fulling et al. 2003). The fall density for the outer continental shelf waters (20–200 m deep) of the northern GoM was estimated at 0.5 dolphins/100 km² (Fulling et al. 2003), whereas that for oceanic waters in spring was estimated at 0.26 dolphins/100 km² (Mullin and Fulling 2004). Rough-toothed dolphins are thought to occur year-round in the GoM (Würsig et al. 2000; Mullin et al. 2004).

Sightings have been made throughout the northern GoM, including in deep water just to the north of the Yucatán Channel survey area, during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). Sightings have also been made in the southern GoM (Jefferson and Schiro 1997; Ortega-Ortiz 2002). During a survey of the GoM and Caribbean Sea during summer 1991, one sighting of 20 individuals was made on 24 July to the northwest of the Campeche Bank survey area at 25.5°N, 87.7°W in water 3290 m deep (Jefferson and Lynn 1994). The OBIS database includes one record to the northeast of the Yucatán Channel survey area, one for the Campeche Bank survey area, as well as other records for Campeche Bank and off northwestern Cuba (OBIS 2020).

Strandings are known for Texas and Florida (Würsig et al. 2000), as well as in the southern GoM at San Benito and Telchac, Yucatán; and Celestún and Punta Cam Balam, Campeche (Ortega-Ortiz 2002). There is one capture record off northwestern Cuba (Whitt et al. 2011).

**Common Bottlenose Dolphin (*Tursiops truncatus*)**

The bottlenose dolphin occurs in tropical, subtropical, and temperate waters throughout the world (Wells and Scott 2018). Although it is more commonly found in coastal and shelf waters, it can also occur in deep offshore waters (Jefferson et al. 2015). In the Northwest Atlantic, these dolphins occur from Nova Scotia to Florida, the GoM, and the Caribbean and southward to Brazil (Würsig et al. 2000). There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998, 2002). Klatsky (2004) noted that offshore dolphins show a preference for water <2186 m deep. As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995).

Both types of bottlenose dolphins are known to occur in the GoM (Walker et al. 1999); the inshore type inhabits shallow lagoons, bays, and inlets, and the oceanic population occurs in deeper, offshore waters over the continental shelf (Würsig et al. 2000). The bottlenose dolphin is the most widespread and common cetacean in coastal waters of the GoM (Würsig et al. 2000; Würsig 2017). During surveys by Griffin and Griffin (2003), it was the most common species in waters <20 m deep. Fulling et al. (2003) reported a
density of 10.3 dolphins/100 km$^2$ for waters 20–200 m deep. For oceanic waters (>200 m) of the northern GoM, Mullin and Fulling (2004) reported a spring density of 0.59 dolphins/100 km$^2$. Although bottlenose dolphins occur in the GoM year-round, seasonal variation in abundance have been reported for this species (e.g., Hubard et al. 2004). Shane (2004) reported that dolphin sightings were highest during spring in southwestern Florida. Sight fidelity has also been noted for this species (Irwin and Würsig 2004; Hubard et al. 2004).

During systematic surveys of the northern GoM, fall sightings were made throughout the region, but primarily on the shelf, including on the Florida Bank; during spring and summer surveys, sightings were made between the 100- and 1000-m isobaths, including just north of the Yucatán Channel survey area (Würsig 2017). Bottlenose dolphins comprise most (71%) of the existing cetacean records in the southern Gulf of Mexico, mainly because they are common in coastal waters, including Campeche Bank, where most survey effort has been concentrated (Ortega-Ortiz 2002). During L-DEO’s Chicxulub cruise off the northern Yucatán Peninsula in winter 2005, several sightings were made within the 50-m isobath (Holst et al. 2005). During a survey of the GoM and Caribbean Sea during summer 1991, one sighting of 15 individuals was made on 24 July to the west of the Campeche Bank survey area at 23.9°N, 87.8°W in water 85 m deep (Jefferson and Lynn 1994). The OBIS database includes one record in the Campeche Bank survey area, as well as numerous other records on Campeche Bank, on Florida Bank, the Straits of Florida, and northwestern Cuba (OBIS 2020).

**Pantropical Spotted Dolphin (Stenella attenuata)**

The pantropical spotted dolphin is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). It is one of the most abundant cetaceans and is found in coastal, shelf, slope, and deep waters (Perrin 2018a). In the Northwest Atlantic, it occurs from North Carolina to the West Indies and down to the equator (Würsig et al. 2000). In the GoM, it is the most common species of cetacean in the deeper water (Davis and Fargion 1996; Würsig et al. 2000), but only rarely occurs over the continental shelf or continental shelf edge (Davis et al. 1998; Waring et al. 2004). It was the most abundant species during spring surveys in oceanic waters (>200 m) in the northern GoM, with a density of 24 dolphins/100 km$^2$ (Mullin and Fulling 2004). Fairfield-Walsh et al. (2005) also reported this as the most frequently sighted cetacean in the eastern GoM in waters >200 m deep. It occurs in the GoM year-round (Mullin et al. 2004).

Sightings have been made throughout the northern GoM, including just to the north of the Yucatán Channel survey area, during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). Several sightings have also been reported for the southern GoM, on the continental slope as well as on the Yucatán continental shelf, including Campeche Bank west of the proposed survey area, and in Yucatán Channel, including near the survey area off northwestern Cuba (Ortega-Ortiz 2002; Whitt et al. 2011). The OBIS database includes one sighting in the Campeche Bank survey area, and several other sightings on Campeche Bank, northeast of the Yucatán Channel survey area, Yucatán Channel, and Straits of Florida (OBIS 2020). The presence of this species on the Yucatán shelf may be due to upwelling in the area (Ortega-Ortiz 2002).

**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
Atlantic spotted dolphins are common in the GoM (Würsig et al. 2000). They do not appear to occur in deep water of the northern or southern GoM, but typically inhabit shallow waters on the continental shelf inshore of the 250-m isobath (Davis et al. 1998, 2002; Fulling et al. 2003; Würsig 2017). Mullin and Fulling (2004) reported a density of 0.05 dolphins/100 km² in water >200 m deep for the northern GoM. Although Atlantic spotted dolphins prefer shallow-water habitats, they are not common in nearshore waters (Davis et al. 1996). In the eastern GoM, this is the predominant species in waters 20–180 m deep (Griffin and Griffin 2003). Similarly, Fulling et al. (2003) noted that the Atlantic spotted dolphin was the most abundant species sighted during a survey in waters 20–200 m deep, with densities ~8x higher in the northeast (20.1 dolphins/100 km²) than in the northwestern (2.6 dolphins/100 km²) GoM. Although spotted dolphins occur in the GoM year-round, Griffin and Griffin (2004) noted significant seasonal variations in densities of spotted dolphins along the continental shelf. Griffin and Griffin (2004) and Griffin et al. (2005) noted that abundance was lower in nearshore waters during the summer, and densities were higher during the winter. Würsig et al. (2000) noted these dolphins move inshore in the spring and summer, perhaps associated with the arrival of carangid fishes.

During systematic surveys of the northern GoM during 1996–2001 and 2003–2004, sightings were made throughout the region, but primarily on the shelf, including on the Florida Bank north of the Yucatán Channel survey area (Würsig 2017). Atlantic spotted dolphins occur extensively off Campeche Bank to the north and west of the Yucatán Peninsula (Ortega-Ortiz 2002; Würsig et al. 2000) including west of the Campeche Bank survey area. There have also been a number of sightings in the offshore waters over the outer continental shelf in the southern GoM, along with some sightings and strandings along the eastern Yucatán Peninsula (Ortega-Ortiz 2002). During L-DEO’s Chicxulub cruise off the northern Yucatán Peninsula in winter 2005, several sightings were made within the 50-m isobath (Holst et al. 2005). Sightings have also been made off northwestern Cuba near the Yucatán Channel survey area (Whitt et al. 2011). The OBIS database includes one record in the Campeche Bank survey area, and several other records on Campeche Bank, Florida Bank northeast of the Yucatán Channel survey area, Yucatán Channel, and Straits of Florida (OBIS 2020).

**Spinner Dolphin (Stenella longirostris)**

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 40ºN and 40ºS (Jefferson et al. 2015). It is generally considered a pelagic species (Perrin 2018b), but can also be found in coastal waters and around oceanic islands (Rice 1998). In the western North Atlantic, it occurs from South Carolina to Florida, the Caribbean, GoM, and southward to Venezuela (Würsig et al. 2000). Almost all sightings in the GoM have been made east and southeast of the Mississippi Delta, in areas deeper than 100 m (Würsig et al. 2000; Würsig 2017). Mullin and Fulling (2004) reported a density of 3.15 dolphins/100 km² in oceanic waters of the northern GoM. During systematic surveys of the northern GoM during 1996–2001 and 2003–2004, sightings were made throughout the northeastern GoM, including just to the north of the Yucatán Channel survey area (Würsig 2017). There are also records in the Straits of Florida and off northwestern Cuba (Whitt et al. 2011). The OBIS database includes two records in the southern portion of the Yucatán Channel survey area, and several other records in Yucatán Channel and Straits of Florida (OBIS 2020).
Clymene Dolphin (Stenella clymene)
The Clymene dolphin only occurs in tropical and subtropical waters of the Atlantic Ocean (Jefferson et al. 2015). It inhabits areas where water depths are 700–4500 m or deeper (Fertl et al. 2003). However, there are a few records in water as shallow as 44 m (Fertl et al. 2003). In the western Atlantic, it occurs from New Jersey to Florida, the Caribbean Sea, the GoM, and south to Venezuela and Brazil (Würsig et al. 2000; Fertl et al. 2003). In the GoM, it is widely distributed in the west during spring and the northeast during summer and winter (Würsig et al. 2000). Mullin and Fulling (2004) also noted that this dolphin is primarily sighted in the western GoM in the spring, with an estimated density of 4.56 dolphins/100 km² for the northern GoM. During systematic surveys of the northern GoM during 1996–2001 and 2003–2004, sightings were made throughout the northwestern GoM, primarily in deep water beyond the 1000-m isobath (Würsig 2017), but no sightings were reported near the proposed survey areas. Ortega-Ortiz (2002) reported two records for the northeastern Yucatán Peninsula, but no other records in the southern GoM. The OBIS database includes one record off the east coast of the Yucatán Peninsula, and one record just northeast of the Yucatán Channel survey area; most other records are for the northern and southwestern GoM (OBIS 2020).

Striped Dolphin (Stenella coeruleoalba)
The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994b; Jefferson et al. 2015). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). In the Northwest Atlantic, it occurs from Nova Scotia to the GoM and south to Brazil (Würsig et al. 2000). A concentration of striped dolphins is thought to exist in the eastern part of the northern GoM, near the DeSoto Canyon just east of the Mississippi Delta (Würsig et al. 2000). Nonetheless, sightings have been made throughout the northern GoM including just to the north of the Yucatán Channel survey area, during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). Mullin and Fulling (2004) reported a mean density of 1.71 dolphins/100 km² for oceanic waters of the northern GoM. The OBIS database includes two records just northeast of the Yucatán Channel survey area; most other records are for the northern and southwestern GoM (OBIS 2020). Ortega-Ortiz (2002) reported two strandings in the southern GoM in Veracruz and El Cuyo, Yucatán.

Fraser’s Dolphin (Lagenodelphis hosei)
Fraser’s dolphin is a tropical oceanic species generally distributed between 30°N and 30°S that generally inhabits deeper, offshore water (Dolar 2018). It ranges from the GoM to Uruguay in the western Atlantic (Rice 1998). Fraser’s dolphin has been sighted on occasion in the northern GoM (Jefferson and Schiro 1997), including in water deeper than 100 m during systematic surveys (Würsig 2017). A density of 0.19 dolphins/100 km² was estimated for oceanic waters of the northern GoM (Mullin and Fulling 2004). However, there are no sighting records within or near the proposed survey areas (Ortega-Ortiz 2002; Würsig 2017; OBIS 2020). Although Ortega-Ortiz (2002) did not report any records for the southern GoM, there are 10 records for the southwestern GoM in the OBIS database (OBIS 2020). Strandings have been reported for Florida and Texas (Würsig et al. 2000).

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

Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). In the GoM, killer whales are occasionally seen, with most sightings occurring in waters 200–2000 m deep southwest of the Mississippi Delta (Würsig et al. 2000; Würsig 2017). Mullin and Fulling (2004) reported five sightings in the northwestern GoM during the spring, and a density of 0.03 animals/100 km² for oceanic waters of the northern GoM. There have also been summer reports of killer whales off Texas near the 200-m isobath (Würsig et al. 2000). No sightings were reported near the proposed Yucatán Channel survey area during systematic surveys of the northern GoM during 1996–2001 and 1996–2001 (Würsig 2017). The OBIS database includes records throughout the northern and southern GoM, including one record in the Campeche Bank survey area, along with several other records on Campeche Bank and in the Straits of Florida (OBIS 2020). Ortega-Ortiz (2002) reported three stranding events along the northern Yucatán Peninsula and one sighting beyond the continental shelf in Campeche Bay. Killer whales have also been sighted off northwestern Cuba, to the east of the proposed survey area (Whitt et al. 2011; Bolaños-Jiménez et al. 2014).

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

The short-finned pilot whale is found in tropical and warm temperate waters, and the long-finned pilot whale (G. melas) is distributed antitropically in cold temperate waters (Olson 2018). The ranges of the two species show little overlap, and only the short-finned pilot whale is expected to occur in the GoM (Olson 2018). Short-finned pilot whale distribution does not generally range south of 40°S (Jefferson et al. 2015). The short-finned pilot whale occurs in deep water at the edge of the continental shelf and over deep submarine canyons (Carwardine 1995; Davis et al. 1998).

In the western North Atlantic, short-finned pilot whales occur from Virginia to northern South America, including the Caribbean and GoM (Würsig et al. 2000). They are known to strand frequently in the GoM and are likely to occur there year-round (Würsig et al. 2000). In the northern GoM, it is most commonly seen in the central and western areas in waters 200–1000 m deep, i.e., along the continental slope (Würsig et al. 2000; Würsig 2017). Mullin and Fulling (2004) noted that during a spring survey in the northern GoM, short-finned pilot whales were primarily seen west of Mobile Bay, AL (~88°W); they reported a mean density of 0.63 Globicephala spp./100 km² for oceanic waters >200 m deep. During systematic surveys of the northern GoM during 1996–2001 and 2003–2004, sightings were made just to the north of the Yucatán Channel survey area (Würsig 2017). In the southern GoM, sightings mainly occur on the continental slope, and strandings are most frequently reported for the northern Yucatán Peninsula and surrounding islands (Ortega-Ortiz 2002). There is one fall sighting on Campeche Bank, and a spring sighting on the slope off Campeche Bank, to the west of the proposed survey area (Ortega-Ortiz 2002). The OBIS database includes one record in the Campeche Bank survey area, along with other records on Campeche Bank, northeast of the Yucatán Channel survey area, and in the Straits of Florida (OBIS 2020). In addition, there are strandings records for northwestern Cuba (Whitt et al. 2011).

**False Killer Whale (Pseudorca crassidens)**

The false killer whale is found worldwide in tropical and temperate waters, generally between 50°N and 50°S (Odell and McClune 1999). It is widely distributed, but is not abundant anywhere (Carwardine 1995). It generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2015; Baird 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). In the Northwest Atlantic, it occurs from Maryland to the GoM and the Caribbean (Würsig et al. 2000).
In the GoM, most false killer whales have been seen in the northeastern region (Mullin and Hoggard 2000; Würsig 2017) in water 200–2000 m deep (Würsig et al. 2000). Mullin and Fulling (2004) reported a spring density of 0.27 whales/100 km² in the oceanic waters of the northern GoM. During systematic surveys of the northern GoM during 1996–2001 and 2003–2004, sightings were primarily beyond the 1000-m isobath, including just north of the Yucatán Channel survey area (Würsig 2017). Ortega-Ortiz (2002) also reported sightings in the Yucatán Channel. The OBIS database includes records throughout the GoM, including one in the Campeche Bank survey area, along with other records on Campeche Bank, northeast of the Yucatán Channel survey area, and in the Straits of Florida (OBIS 2020). Strandings have also been reported for the GoM, with records for Cuba, Florida, Louisiana, Texas, and southern Mexico (Würsig et al. 2000). In the southern Gulf of Mexico, strandings of up to 79 individuals have been reported at Alacranes Reef; Cancún, Campeche; El Cuyo, Yucatán; and Veracruz (Ortega-Ortiz 2002). In addition, there are stranding records and a capture record off northwestern Cuba (Whitt et al. 2011).

**Pygmy Killer Whale (Feresa attenuata)**

The pygmy killer whale has a worldwide distribution in tropical and subtropical waters, generally not ranging south of 35°S (Jefferson et al. 2015). It is known to inhabit the warm waters of the Indian, Pacific, and Atlantic oceans (Jefferson et al. 2015). In the Northwest Atlantic, it occurs from the Carolinas to Texas and the West Indies, and the GoM (Würsig et al. 2000). It is found in nearshore areas where the water is deep and in offshore waters (Jefferson et al. 2015). Sightings have been made throughout the northern region of the GoM, primarily between the 100- and 1000-m isobaths, including just to the north of the Yucatán Channel survey area, during systematic surveys during 1996–2001 and 2003–2004 (Würsig 2017). A spring density of 0.11 whales/100 km² has been reported for oceanic waters (>200 m) of the northern GoM (Mullin and Fulling 2004). The OBIS database includes records throughout the GoM, including on Campeche Bank, northeast of the Yucatán Channel survey area, and in the Straits of Florida (OBIS 2020). Strandings have been reported from Florida to Texas, with most strandings occurring in the winter (Würsig et al. 2000). Ortega-Ortiz (2002) reported two strandings for the southern GoM at Tampico in Tamaulipas and Punta Villa Rica in Veracruz. Pygmy killer whales are thought to occur in the GoM year-round (Würsig et al. 2000).

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

The melon-headed whale is an oceanic species found worldwide in tropical and subtropical waters from ~40°N to 35°S (Jefferson et al. 2015). It occurs most often in deep offshore waters and occasionally in nearshore areas where the water is deep (Jefferson et al. 2015). In the western Atlantic, its range extends from the GoM to southern Brazil (Rice 1998). In the GoM, melon-headed whales have been sighted in the northwest from Texas to Mississippi (Würsig et al. 2000; Würsig 2017), typically in waters >200 m deep and away from the continental shelf (Mullin et al. 1994; Würsig et al. 2000; Würsig 2017). Mullin and Fulling (2004) reported three sightings primarily west of Mobile Bay, AL, during spring surveys, and a density of 0.91 whales/100 km² for the northern GoM. No sightings were made near the proposed survey areas during systematic surveys of the northern GoM during 1996–2001 and 2003–2004 (Würsig 2017). Strandings have been reported for Texas and Louisiana (Würsig et al. 2000). Ortega-Ortiz (2002) reported one record of this species in the southern GoM—an individual that was entangled in fishing line off Tuxpan, Veracruz, in water ~200 m deep. The OBIS database includes 10 records for the southwestern GoM, but none near the proposed study area (OBIS 2020).
V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.

SIO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys in the southeastern GoM during July–August 2020. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the GI airguns used during the surveys, by echosounders, and by general vessel operations. “Takes” by harassment would potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the GI airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of “Level B Harassment” for those species managed by NMFS. No take by serious injury or lethal takes (Level A) is expected, given the nature of the planned operations, the mitigation measures that are planned (see § XI, MITIGATION MEASURES), in addition to the general avoidance by marine mammals of loud sound.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section V], and the number of times such takings by each type of taking are likely to occur.

The material for § VI and § VII has been combined and presented in reverse order to minimize duplication between sections.

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

The anticipated impact of the activity upon the species or stock of marine mammal.

The material for § VI and § VII has been combined and presented in reverse order to minimize duplication between sections.

• First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII, and refer to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the PEIS.

• Then we summarize the potential impacts of operations by the echosounder. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the PEIS.

• Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the southeastern GoM during July–August 2020. This section includes a description of the rationale for the estimates of the potential numbers of harassment “takes” during the planned surveys, as called for in § VI.
Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (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; Weilgart 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 (permanent threshold shift [PTS]), in the unlikely event that it occurred, would constitute injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal’s hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source (Hastie et al. 2019). Temporary threshold shift (TTS) is not considered an injury by some authors (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 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. Nieukirk 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., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). 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. 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".

Behavioural reactions of marine mammals to sound are difficult to predict in the absence of site- and context-specific data (Ellison et al. 2018). Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). 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; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2018). 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.

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). 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. 2017a). 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). Humpbacks reduced their southbound migration, or deviated from their path thereby avoiding the active array, when they were within 4 km of the active large airgun source, where received levels were >135 dB re 1 μPa²·s (Dunlop et al. 2017b). These results are consistent with earlier studies (e.g., McCauley et al. 2000). However, some individuals did not show avoidance behaviors even at levels as high as 160 to 170 dB re 1 μPa²·s (Dunlop et al. 2018).

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

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

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 µPa; at SPLs <108 dB re 1 µPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received CSEL\textsubscript{10-min} (cumulative SEL over a 10-min period) of ~94 dB re 1 µPa\textsuperscript{2}·s, decreased at CSEL\textsubscript{10-min} >127 dB re 1 µPa\textsuperscript{2}·s, and whales were nearly silent at CSEL\textsubscript{10-min} >160 dB re 1 µPa\textsuperscript{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 rms (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in 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.

Pirotta et al. (2018) used a dynamic state model of behavior and physiology to assess the consequences of disturbance (e.g., seismic surveys) on whales (in this case, blue whales). They found that the impact of localized, acute disturbance (e.g., seismic surveys) depended on the whale’s behavioral response, with whales that remained in the affected area having a greater risk of reduced reproductive success than whales that avoided the disturbance. Chronic, but weaker disturbance (e.g., vessel traffic) appeared to have less effect on reproductive success.

**Toothed Whales.**—Little systematic information is available about reactions of toothed whales to sound pulses. However, there are 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. (2018), 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).

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 $\geq 170$ dB disturbance criterion (rather than $\geq 160$ 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; Tyack and Thomas 2019).

**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, 2019; 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. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b; Supin et al. 2016).

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

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL of 188 and 191 µPa²·s, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

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

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga (see § 3.7.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans (cf. Southall et al. 2007; NMFS 2016, 2018). Some cetaceans could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin.

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 marine 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 noise exposure criteria for marine mammals that were released by NMFS (2016b, 2018c) account for the newly available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL<sub>cum</sub> over 24 hours) and peak SPL<sub>flat</sub>. Onset of PTS is assumed to be 15 dB higher when considering SEL<sub>cum</sub> and 6 dB higher when considering SPL<sub>flat</sub>. 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 <i>Kogia</i> 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 (see § XI and § XIII). 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 stranding 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 70 marine mammal Unusual Mortality Events (UMEs) in the U.S., including three bottlenose dolphin UMEs in the GoM, with the most recent one occurring in 2019 (NOAA 2020b). 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 GoM, and the greater activity of oil and gas exploration in the GoM.

Non-auditory physical effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales and some odontocetes, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal, the large proportion of survey effort in deeper water, 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.

Possible Effects of Other Acoustic Sources

The Kongsberg EM300 MBES and a Knudsen 3260 SBP would be operated from the source vessel during the proposed surveys, but not during transits. Information about this equipment, or similar, was provided in § 2.2.3.1 of the PEIS. A review of the anticipated potential effects (or lack thereof) of MBESs and SBPs on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

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

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

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system similar to that used on R/V Justo Sierra. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m.

There is no available information on marine mammal behavioral response to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response
to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

During a recent study, group vocal periods (GVPs) were used as proxies to assess foraging behavior of Cuvier’s beaked whales during multibeam mapping in southern California (Varghese et al. 2019). The study found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, but the number of GVPs was significantly greater after MBES exposure than before MBES exposure. During an analogous study assessing Naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2019).

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

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

This new information presented here is in agreement with the assessment presented in § 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs and ADCPs is not likely to impact marine mammals, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal given the movement and speed of the vessel.

Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear. Vessel noise from R/V Justo Sierra could affect marine animals in the proposed project area. 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; Kyhn et al. 2019); 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 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 Branstetter 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; Tuack 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).

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 whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance (Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986). Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016). 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).

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.

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 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, 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 (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels (McKenna et al. 2015). The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals 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 ~9 km/h, and ~30% is expected to occur at 15 km/h; typical cruise speed when not operating airguns would be ~22 km/h. The number of seismic survey km and cruise speed are low relative to other fast-moving vessels in the area. There has been no history of marine mammal vessel strikes with any of the vessels in the U.S. academic research fleet in the last two decades.

Numbers of Marine Mammals that could be “Taken by Harassment”

All takes would be anticipated to be Level B “takes by harassment” as described in § I, involving temporary changes in behavior. No injurious takes (Level A) would be expected. In the sections below, we describe methods to estimate the number of potential exposures to Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be harassed or disturbed appreciably by Level B sound levels by the seismic surveys in the southeastern GoM. The main sources of distributional and numerical data used in deriving the estimates are summarized below.

It is assumed that, during simultaneous operations of the airgun array and the other sources, any marine mammals close enough to be affected by the MBES and ADCP would already be affected by the airguns. However, whether or not the airguns are operating simultaneously with the other sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the ADCP and MBES, given their characteristics (e.g., narrow downward-directed beam of the MBES) and other considerations described in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS. Such reactions are not considered to constitute “taking” (NMFS 2001). Therefore, no additional allowance is included for animals that could be affected by sound sources other than airguns.

Basis for Estimating “Take by Harassment”

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 ≥160 dB re 1 µPa rms are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of seismic surveys. 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 best available marine mammal density data for this region are
available from habitat-based density modeling conducted by Roberts et al. (2016). The Roberts et al. (2016) data provide abundance estimates for species or species guilds within 10 km x 10 km grid cells (100 km²) within the U.S. EEZ in the GoM and Atlantic Ocean on a monthly or annual basis, depending on the species and location. In the GoM, marine mammals do not migrate seasonally, so a single estimate for each grid cell is provided and represents the predicted abundance of that species in that 100 km² location at any time of year.

As the planned survey lines are outside of the U.S. EEZ, they do not directly overlap the available spatial density data. However, some of the survey lines occur near the U.S. EEZ, and the distribution and abundance of species in U.S. EEZ waters are likely representative of those in the nearby survey area. To select a representative sample of grid cells for the calculation of densities in three different water depth categories (>100 m, 100-1000 m, and >1000 m), a 200-km perimeter around the survey lines was created in GIS. The areas within this perimeter within the three depth categories was then used to select grid cells containing the estimates for each species in the Roberts et al. (2016) data (i.e., >100 m, n = 157 grid cells; 100–1000, n = 169 grid cells; >1000 m, n = 410 grid cells). The average abundance for each species in each water depth category was calculated as the mean value of the grid cells within each category and then converted to density (individuals/1 km²) by dividing by 100 km².

Table 3 shows estimated densities for cetacean species that could occur in the proposed project area. There is uncertainty about the representativeness of the data and the assumptions used to estimate exposures below. Thus, for some species, the densities derived from the abundance models described above may not precisely represent the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data. The calculated exposures that are based on these densities are best estimates for the proposed surveys.

Potential Number of Marine Mammals Exposed

The numbers of animals that could be exposed to airgun sounds with received levels ≥160 dB re 1 µPa rms (Level B) for marine mammals on one or more occasions were estimated by calculating the area that would be within the Level B threshold around the operating seismic source and the expected density of animals in the area. This involves determining the area potentially ensonified above threshold levels within each depth category on a single day during the surveys. The daily ensonified area within each depth category is then multiplied by the densities in each depth category to estimate the daily number of exposures. Multiplication of the daily number of exposures for each species by the number of survey days results in the total take estimate for each species. Due to uncertainties with respect to permitting for surveys in Cuban waters, this was done separately for transect lines in Mexican and Cuban waters, for which 4.2 and 5.5 survey days were estimated, respectively. An alternative take estimate is also presented assuming all 9.7 survey days would occur in Mexican waters.

The area expected to be ensonified was determined by entering the planned survey lines into ArcGIS and then using GIS to identify the relevant ensonified areas by “drawing” the 160-dB threshold buffer around each seismic line according to the depth category in which the lines occurred. The total ensonified area within each depth category was then divided by the total number of survey days to provide the proportional daily ensonified area within each depth category. The daily ensonified area in each depth class was then increased by 25% to allow for additional airgun operations such as testing of the source or re-surveying lines with poor data quality. This approach assumes that no animals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V Justo Sierra approaches.
TABLE 3. Marine mammal and sea turtle densities (individuals per km$^2$) estimated for three water depth categories within the survey area in the southeastern Gulf of Mexico. Species in italics are listed as endangered or threatened under the ESA.

<table>
<thead>
<tr>
<th></th>
<th>Shallow Water &lt;100 m</th>
<th>Intermediate Water 100–1000 m</th>
<th>Deep Water &gt;1000 m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bryde’s whale</em></td>
<td>5.45x10^{-8}</td>
<td>0.00002</td>
<td>1.75x10^{-14}</td>
</tr>
<tr>
<td><em>Fin whale</em></td>
<td>0.00001</td>
<td>0.00001</td>
<td>0.00001</td>
</tr>
<tr>
<td><em>Minke whale</em></td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td><em>Humpback whale</em></td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td><strong>MF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sperm whale</em></td>
<td>1.02x10^{-8}</td>
<td>0.00384</td>
<td>0.00579</td>
</tr>
<tr>
<td>Beaked spotted dolphin</td>
<td>0.24369</td>
<td>0.07022</td>
<td>5.9x10^{-6}</td>
</tr>
<tr>
<td><em>Common bottlenose dolphin</em></td>
<td>6.64x10^{-9}</td>
<td>0.00498</td>
<td>0.00882</td>
</tr>
<tr>
<td><em>Clymene dolphin</em></td>
<td>3.47x10^{-10}</td>
<td>0.00325</td>
<td>0.00403</td>
</tr>
<tr>
<td><em>False killer whale</em></td>
<td>0.00005</td>
<td>0.00744</td>
<td>0.00748</td>
</tr>
<tr>
<td><em>Fraser’s dolphin</em></td>
<td>0.00002</td>
<td>0.00386</td>
<td>0.00389</td>
</tr>
<tr>
<td><em>Killer whale</em></td>
<td>3.56x10^{-6}</td>
<td>0.00007</td>
<td>0.00082</td>
</tr>
<tr>
<td><em>Melon-headed whale</em></td>
<td>3.17x10^{-7}</td>
<td>0.00624</td>
<td>0.01186</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td>5.01x10^{-6}</td>
<td>0.14764</td>
<td>0.31353</td>
</tr>
<tr>
<td><em>Pilot whales</em></td>
<td>7.15x10^{-9}</td>
<td>0.00636</td>
<td>0.00128</td>
</tr>
<tr>
<td><em>Pygmy killer whale</em></td>
<td>1.46x10^{-7}</td>
<td>0.00201</td>
<td>0.00648</td>
</tr>
<tr>
<td><em>Risso’s dolphin</em></td>
<td>1.16x10^{-6}</td>
<td>0.02315</td>
<td>0.00748</td>
</tr>
<tr>
<td>Rough-toothed dolphin</td>
<td>0.00420</td>
<td>0.00890</td>
<td>0.00768</td>
</tr>
<tr>
<td><em>Spinner dolphin</em></td>
<td>6.95x10^{-9}</td>
<td>0.15723</td>
<td>0.00412</td>
</tr>
<tr>
<td><em>Striped dolphin</em></td>
<td>2.73x10^{-8}</td>
<td>0.00212</td>
<td>0.01268</td>
</tr>
<tr>
<td><strong>HF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Kogi spp.</em></td>
<td>1.85x10^{-6}</td>
<td>0.01052</td>
<td>0.00490</td>
</tr>
<tr>
<td><strong>Sea Turtles</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Green sea turtle</em></td>
<td>0.14287</td>
<td>1.67822</td>
<td>1.17112</td>
</tr>
<tr>
<td><em>Kemp’s Ridley sea turtle</em></td>
<td>0.00052</td>
<td>0.01968</td>
<td>0.11003</td>
</tr>
<tr>
<td><em>Loggerhead sea turtle</em></td>
<td>0.02956</td>
<td>0.18343</td>
<td>0.09654</td>
</tr>
</tbody>
</table>

N.A. means not available. Very small numbers (<0.00001) are shown in scientific notation.
VII. Anticipated Impact on Species or Stocks

Table 4 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa rms during the planned Campeche Bank seismic survey (Mexican waters) and Yucatán Channel seismic survey (Cuban waters) if no animals moved away from the survey vessel. Table 5 shows the corresponding estimates if the seismic surveys occur only in the Campeche Bank area in Mexican waters. The *Requested Take Authorization* is given in the far-right column of Table 4. Except for species for which densities were not available (minke and humpback whales), we have included a *Requested Take Authorization* for marine mammals based on the calculations shown in Appendix B and the ensonified areas shown in Appendix C. For species for which the estimated takes were smaller than the mean group size, *Requested Take Authorizations* were increased to mean group size (see footnote in Table 4). For the fin whale, one take is being requested (Table 4).

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa rms in the Campeche Bank and Yucatán Channel survey areas is 1478 (Table 4). That total includes 17 cetaceans listed under the ESA, all of which would be sperm whales, representing 0.8% of their regional population. A total of 25 beaked whales could be exposed. Most (96%) of the cetaceans potentially exposed would be mid-frequency cetaceans, including estimates of 864 pantropical spotted dolphins. Estimates of cetacean exposures for an alternative scenario where all survey effort would occur in the Campeche Bank survey area in Mexican waters are higher, with an estimate of 1880 exposures (Table 5).

It should be noted that the estimates of exposures assume that the proposed surveys would be fully completed; in fact, the calculated takes have been increased by 25%. Thus, estimates of the numbers of marine mammals potentially exposed to Level B sounds ≥160 dB re 1 μPa rms are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the PEIS and §4.1.1.1 of 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 (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).

**Conclusions**

The proposed seismic project would involve towing a very small source, a pair of 45-in³ GI airguns, that introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute “taking”. In §3.6.7, 3.7.7, and 3.8.7, the PEIS concluded that outside the Gulf of Alaska, 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 and pinnipeds, that Level A effects were unlikely, and that operations were unlikely to adversely affect ESA-listed species. Level A takes are considered highly unlikely. The brief duration of exposure of any given animal, the large proportion of survey effort in deeper water, 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.
TABLE 4. Marine mammal and sea turtle take estimates for surveys in the proposed Campeche Bank and Yucatán Channel survey areas. Species in italics are listed as endangered or threatened under the ESA.

<table>
<thead>
<tr>
<th>Species</th>
<th>Calculated Level B Take</th>
<th>Regional Population Size $^1$</th>
<th>Level B Take as % of Population</th>
<th>Requested Take $^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-Frequency Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bryde’s whale</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Fin whale</td>
<td>0</td>
<td>7,418</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Minke whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>0</td>
</tr>
<tr>
<td>Humpback whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mid-Frequency Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm whale</td>
<td>17</td>
<td>2,128</td>
<td>0.8</td>
<td>17</td>
</tr>
<tr>
<td>Atlantic spotted dolphin</td>
<td>56</td>
<td>47,488</td>
<td>0.1</td>
<td>56</td>
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<tr>
<td>Beaked whale guild$^3$</td>
<td>25</td>
<td>2,910</td>
<td>0.9</td>
<td>25</td>
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<tr>
<td>Common bottlenose dolphin</td>
<td>158</td>
<td>138,602</td>
<td>0.1</td>
<td>158</td>
</tr>
<tr>
<td>Clymene dolphin</td>
<td>12</td>
<td>11,000</td>
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<td>24</td>
<td>3,204</td>
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<td>65</td>
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<tr>
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<td>1,665</td>
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<td>Killer whale</td>
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<td>185</td>
<td>1.1</td>
<td>6</td>
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<td>Melon-headed whale</td>
<td>33</td>
<td>6,733</td>
<td>0.5</td>
<td>250</td>
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<tr>
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<td>84,014</td>
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<td>864</td>
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<tr>
<td>Pilot whale spp.$^4$</td>
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<td>1,981</td>
<td>0.4</td>
<td>34</td>
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<tr>
<td>Pygmy killer whale</td>
<td>17</td>
<td>2,126</td>
<td>0.8</td>
<td>17</td>
</tr>
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<td>36</td>
<td>3,137</td>
<td>1.2</td>
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<td>4,853</td>
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<td></td>
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<td>20</td>
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<td><strong>Sea Turtles</strong></td>
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<td>Green sea turtle</td>
<td>725</td>
<td>N.A.</td>
<td>N.A.</td>
<td>725</td>
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<tr>
<td>Kemp’s Ridley sea turtle</td>
<td>49</td>
<td>N.A.</td>
<td>N.A.</td>
<td>49</td>
</tr>
<tr>
<td>Loggerhead sea turtle</td>
<td>66</td>
<td>N.A.</td>
<td>N.A.</td>
<td>66</td>
</tr>
</tbody>
</table>

N.A. means not available.

$^1$ Population size for the GoM from Roberts et al. (2016), except for Bryde’s whale (GoM stock; NMFS 2020a) and fin whale (Western North Atlantic population size; NMFS 2020a).

$^2$ Requested takes in bold have been increased to the maximum mean group size as presented by Mullin and Fulling (2004) or Mullin (2007), except for the fin whale for which an arbitrary take of one is requested.

$^3$ Requested takes for beaked whales have been proportioned in roughly equal numbers to each of the three species that occur there, including 9 Cuvier’s, 8 Blainville’s, and 8 Gervais’ beaked whales.

$^4$ All pilot whales are expected to be short-finned pilot whales.

$^5$ As pygmy sperm whales are likely to be more common than dwarf sperm whales in the GoM, 40% of takes (8) are requested for K. sima and 60% (12) for K. breviceps.
TABLE 5. Marine mammal and sea turtle take estimates for proposed surveys in the southeastern Gulf of Mexico if all survey effort were to take place in the Mexican EEZ. Species in italics are listed as endangered or threatened under the ESA.

<table>
<thead>
<tr>
<th>Species</th>
<th>Calculated Level B Take</th>
<th>Regional Population Size 1</th>
<th>Level B Take as % of Population</th>
<th>Requested Take 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-Frequency Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bryde's Whale</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Fin whale</td>
<td>0</td>
<td>7,418</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minke Whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>0</td>
</tr>
<tr>
<td>Humpback Whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mid-Frequency Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm whale</td>
<td>17</td>
<td>2,128</td>
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<td>17</td>
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<td>0.3</td>
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<td>Beaked whale guild 3</td>
<td>25</td>
<td>2,910</td>
<td>0.8</td>
<td>25</td>
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<tr>
<td>Common bottlenose dolphin</td>
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<td>138,602</td>
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<td>343</td>
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<td>Clymene dolphin</td>
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<td>0.8</td>
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<td>Melon-headed whale</td>
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<td>Striped dolphin</td>
<td>26</td>
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<td><strong>High-Frequency Cetaceans</strong></td>
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<tr>
<td>Kogia spp. 5</td>
<td>28</td>
<td>2,234</td>
<td>1.3</td>
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<tr>
<td><strong>Sea Turtles</strong></td>
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<tr>
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<td>N.A.</td>
<td>N.A.</td>
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<td>Loggerhead Turtle</td>
<td>66</td>
<td>N.A.</td>
<td>N.A.</td>
<td>66</td>
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</table>

N.A. means not available.

1 Population size for the GoM from Roberts et al. (2016), except for Bryde’s whale (GoM stock; NMFS 2020a) and fin whale (Western North Atlantic population size; NMFS 2020a).

2 Requested takes in bold have been increased to the maximum mean group size as presented by Mullin and Fulling (2004) or Mullin (2007), except for the fin whale for which an arbitrary take of one is requested.

3 Requested takes for beaked whales have been proportioned in roughly equal numbers to each of the three species that occur there, including 9 Cuvier’s, 8 Blainville’s, and 8 Gervais’ beaked whales.

4 All pilot whales are expected to be short-finned pilot whales.

5 As pygmy sperm whales are likely to be more common than dwarf sperm whales in the GoM, 40% of takes (11) are requested for K. sima and 60% (17) for K. breviceps.
VII. Anticipated Impact on Species or Stocks

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested “take authorization”. The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are low percentages of the regional population sizes (Table 4). The calculated take estimates are likely over-estimates of the actual number of animals that would be exposed to and would react to the seismic sounds. 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 NSF-funded 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 marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by 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 three 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; thus, not all animals detected within this zone would be expected to have been exposed to actual sound levels >160 dB.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses. (This issue is only applicable in Alaska.)

The proposed action would not occur in the Alaska region or have the potential to impact the ability of Alaska Natives to conduct subsistence hunts. Therefore, the proposed action would not constitute an unmitigable adverse impact on the availability of marine mammals for subsistence uses.

IX. ANTICIPATED IMPACT ON HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

The proposed seismic surveys would not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations.
XI. Mitigation Measures

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

The proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, because operations would be limited in duration. However, a small minority of the marine mammals that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned activity.

XI. Mitigation Measures

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

Marine mammals and sea turtles are known to occur in the proposed project area. To minimize the likelihood that impacts would occur to the species and stocks, GI airgun operations would be conducted in accordance with regulations by NMFS under the MMPA and the ESA, including obtaining permission for incidental harassment or incidental ‘take’ of marine mammals and other endangered species.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity. The procedures described here are based on protocols used during previous NSF-funded seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017).

Planning Phase

As discussed in § 2.4.1.1 of the PEIS, mitigation of potential impacts from the proposed activity begins during the planning phase. Several factors were considered during the planning phase of the proposed activity, including

Energy Source.—Part of the considerations for the proposed surveys was to evaluate what source level was necessary to meet the research objectives. It was decided that the scientific objectives could be met using a low-energy source consisting of two 45-in³ GI guns (total volume of 90 in³) at a tow depth of ~2–4 m. Although mini GI airguns were considered for the entire survey, the imaging would not be as effective as with the 45-in³ GI airguns in the deeper water of the study area where the higher-energy GI airguns would provide greater depth of penetration. The SIO portable MCS system’s energy source level is one of the smallest source levels used by the science community for conducting seismic research.

Survey Timing.—The PIs worked with SIO, UTIG, UNAM, and NSF to identify potential times to carry out the survey, taking into consideration key factors such as environmental conditions (e.g., seasonal presence of marine mammals), weather conditions, equipment, and optimal timing for other proposed research cruises. Most 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 seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the Level B (160 dB re 1μPa rms) threshold. The background information and methodology for this are provided in
Appendix A. The proposed surveys would acquire data with the 2-GI airgun array at a tow depth of ~2–4 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 2-GI airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5.

The NSF and USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤180 dB re 1 µPa_{rms} (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤250 in³. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-EZ for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach is used here for the pair of 45-in³ GI airguns in all water depths. The 100-m EZ would also be used as the EZ for sea turtles and diving ESA-listed seabirds. If marine mammals, diving ESA-listed seabirds, or sea turtles are detected in or about to enter the appropriate 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. A fixed 160-dB “Safety Zone” was not defined for the same suite of low-energy sources in the NSF and USGS PEIS.

Mitigation During Operations

Mitigation measures that would be adopted include (1) vessel speed or course alteration, provided that doing so would not compromise operational safety requirements, (2) GI-airgun shut down within EZs, and (3) ramp-up procedures. Although power-down procedures are often standard operating practice for seismic surveys, they would not be used here because powering down from two airguns to one airgun would make only a small difference in the EZs—probably not enough to allow continued one-airgun operations if a mammal or turtle came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal or sea turtle is detected outside the EZ, based on its position and the relative motion, is likely to enter the EZ, the vessel’s speed and/or direct course could be changed. This would be done if operationally practicable while minimizing the effect on the planned science objectives. The activities and movements of the marine mammal or sea turtle (relative to the seismic vessel) would then be closely monitored to determine whether the animal is approaching the applicable EZ. If the animal appears likely to enter the EZ, further mitigative actions would be taken, i.e., either further course alterations or a shut down of the seismic source. Typically, during seismic operations, the source vessel is unable to change speed or course and one or more alternative mitigation measures (see below) would need to be implemented.

Shut-down Procedures

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, and if the vessel’s speed and/or course cannot be changed to avoid having the animal enter the EZ, the GI airguns would be shut down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the GI airguns would be shut down immediately. The operating airguns would also be shut down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ. Following a shut down, seismic activity would not resume until the marine mammal or turtle has cleared the EZ, or until the PSO is confident that the animal has left the vicinity of the vessel. The animal would be considered to have cleared the EZ zone if

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes and sea turtles,
XI. Mitigation Measures

- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

**Ramp-up Procedures**

A ramp-up procedure would be followed when the pair of GI airguns begins operating after a specified period without GI airgun operations. It is proposed that, for the present survey, this period would be 15 min. Ramp up would not occur if a marine mammal or sea turtle has not cleared the EZ as described earlier. Ramp up would begin with one GI airgun 45 in³, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals or turtles are sighted, a shut down would be implemented as though the full array were operational.

If the EZ has not been monitored by PSOs for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up would not commence. A ramp up from a shut down may occur at night or in poor visibility as long as the EZ has been continually monitored by PSOs for 30 minutes prior to ramp-up with no marine mammal or sea turtle detections. Ramp up of the GI airguns would not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZ.

XII. PLAN OF COOPERATION

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:

- (i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;
- (ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;
- (iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and
- (iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activity would take place in the GoM, and no activities would take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding...

SIO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring, and to satisfy the anticipated monitoring requirements of the IHA. SIO’s proposed Monitoring Plan is described below. SIO
XIII. Monitoring and Reporting Plan

The SIO IHA Application for the Gulf of Mexico, 2020 understands that this Monitoring Plan would be subject to review by NMFS, and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. SIO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

**Vessel-based Visual Monitoring**

PSO observations would take place during daytime GI airgun operations and nighttime start ups of the airguns. GI airgun operations would be suspended when marine mammals, turtles, or diving ESA-listed seabirds are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals and turtles near the seismic vessel for at least 30 min prior to the planned start of airgun operations. When feasible, PSOs would also make observations during daytime periods when the seismic system is not operating for comparison of animal abundance and behavior. PSOs would also watch for any potential impacts of the acoustic sources on fish.

Three PSOs would be appointed by SIO, with NMFS Office of Protected Resources concurrence. One dedicated PSO would monitor the EZ during all daytime seismic operations. PSOs would normally work in shifts of 4-hour duration or less. The vessel crew would also be instructed to assist in detecting marine mammals and turtles.

*R/V Justo Sierra* is a suitable platform from which PSOs would watch for marine mammals, ESA-listed seabirds, and turtles. Standard equipment for marine mammal observers would be 7 x 50 reticle binoculars and optical range finders. At night, night-vision equipment would be available. The observers would be in communication with ship’s officers on the bridge and scientists in the vessel’s operations laboratory, so they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

**PSO Data and Documentation**

PSOs would record data to estimate the numbers of marine mammals, turtles, and diving ESA-listed seabirds exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. They would also record any observations of fish potentially affected by the sound sources. Data would be used to estimate numbers of marine mammals potentially ‘taken’ by harassment (as defined in the MMPA). They would also provide information needed to order a power down or shut down of the airguns when a marine mammal, sea turtle, or diving ESA-listed seabird is within or near the EZ.

When a sighting is made, the following information about the sighting would be recorded:

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to the airguns or vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.

2. Time, location, heading, speed, activity of the vessel, sea state, visibility, and sun glare.

The data listed under (2) would also be recorded at the start and end of each observation watch, and during a watch whenever there is a change in one or more of the variables.

All observations and shut downs would be recorded in a standardized format. Data would be entered into an electronic database. The accuracy of the data entry would be verified by computerized data validity checks as the data are entered and by subsequent manual checking of the database. These procedures would...
allow initial summaries of data to be prepared during and shortly after the field program, and would facilitate transfer of the data to statistical, graphical, and other programs for further processing and archiving.

Results from the vessel-based observations would provide

1. The basis for real-time mitigation (GI airgun shut down).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals, turtles, and diving ESA-listed seabirds in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals, turtles, and diving ESA-listed seabirds relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals and turtles seen at times with and without seismic activity.
6. any observations of fish potentially affected by the sound sources.

A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals, ESA-listed seabirds, and turtles near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations, all marine mammal, turtle, and diving ESA-listed seabird sightings (dates, times, locations, activities, associated seismic survey activities), and any observations of fish potentially affected by the sound sources. The report would also include estimates of the number and nature of exposures that could result in “takes” of marine mammals by harassment or in other ways.

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

| Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects. |

SIO and NSF would coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. NMFS’s interactive map (accessed during preparation of this IHA application) did not identify any other authorized activities in the proposed action area. SIO and NSF would coordinate with applicable U.S. agencies (e.g., NMFS and USFWS) and would comply with their requirements, as well as any requirements from Mexican and Cuban agencies.

XV. LITERATURE CITED


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


LIST OF APPENDICES

APPENDIX A: DETERMINATION OF MITIGATION ZONES
APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS
APPENDIX C: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS
APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for the Level B (160 dB re 1µPa_{rms}) threshold. Received sound levels have been predicted by L-DEO’s model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the airguns, for the two 45-in³ GI airguns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). 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 GoM in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth (~2000 m) for marine mammals (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The results are summarized below.

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

The proposed surveys would acquire data with two 45-in³ GI guns at a tow depth of 2–4 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 (Fig. A-1). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS).
FIGURE A-1. Modeled deep-water received sound exposure levels (SEls) from the two 45-in³ GI guns, with a 2-m gun separation, planned for use during the proposed surveys in the Gulf of Mexico at a 4-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.
Shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in source volume and tow depth between the calibration survey (6000 in$^3$; 6-m tow depth) and the proposed survey (90 in$^3$; 4-m tow depth). A simple scaling factor is calculated from the ratios of the isopleths determined by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array.

For the 150-dB Sound Exposure Level (SEL)$^2$, the corresponding deep-water maximum radii are 539 m for the 2-GI airgun array at 4 m tow depth (Fig. A-1), and 7244 m for the 6000 in$^3$ array at a 6-m tow depth (Fig. A-2), resulting in a scaling factor of 0.074. Similarly, the 165 dB SEL corresponds to deep-water maximum radii of 95 m for the 2-GI airgun array (Fig. A-1), and 1284 m for the 6000 in$^3$ array (Fig. A-2), also resulting in a scaling factor of 0.074. Measured 160- and 175-dB re 1μPa$_{rms}$ distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km and 2.84 km, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth difference between the arrays yields distances of 1295 m for the 160-dB sound level for the 2-GI gun array, and 210 m for the 175-dB sound level.

Table A-1 shows the distances at which the 160- and 175-dB re 1μPa$_{rms}$ sound exposure levels (SEL)$^3$ are expected to be received for the 2-GI airgun array at the maximum 4-m tow depth at various depth categories. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS, as well as the U.S. Navy (USN 2017), to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of R/V Langseth sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V Langseth sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that in situ measurements and estimates of the 160- and 180-dB distances collected by R/V Langseth hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with in situ received level$^4$ have confirmed that the L-DEO model generated conservative mitigation zones, resulting in significantly larger zones than required by NMFS.

---

2 SEL (measured in dB re 1 μPa$^2$·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.

3 SEL (measured in dB re 1 μPa$^2$·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.

4 L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).
FIGURE A-2. Modeled deep-water received sound exposure levels (SELS) from the 36-airgun array at a 6-m tow depth used during the Gulf of Mexico calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

TABLE A-1. Level B. Predicted distances to the 160 dB re 1 μPa$_{\text{rms}}$ sound levels that could be received from two 45-in$^3$ GI guns (at a tow depth of 4 m) that would be used during the seismic surveys in the Gulf of Mexico during summer 2020 (model results provided by L-DEO).

<table>
<thead>
<tr>
<th>Airgun Configuration</th>
<th>Water Depth (m)</th>
<th>Predicted Distances (m) to Various Received Sound Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>160 dB re 1 μPa$_{\text{rms}}$</td>
</tr>
<tr>
<td>Two 45-in$^3$ GI guns / 2-m gun separation</td>
<td>&gt;1000</td>
<td>539$^1$</td>
</tr>
<tr>
<td></td>
<td>100-1000</td>
<td>809$^2$</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 × correction factor between deep and intermediate water depths.
In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species, but did not establish new thresholds for Level B Harassment. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). The 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).

Literature Cited


# Appendix B: Marine Mammal Take Calculations

Table B-1. Densities of marine mammals and sea turtles and daily areas ensonified above threshold levels used to calculate potential takes for the proposed surveys in the Campeche Bank and Yucatán Channel survey areas in the Gulf of Mexico. Species listed as in italics are endangered or threatened under the ESA.

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated Density (#/km^2)</th>
<th>Level B (160 dB) Daily Ensonified Area (km^2)</th>
<th># of Survey Days</th>
<th>Level B Takes</th>
<th>% of Pop. (Level B Takes)</th>
<th>Requested Take Authorization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shallow &lt;100 m</td>
<td>Intermediate 100-1000 m</td>
<td>Deep &gt;1000 m</td>
<td>Regional Population Size</td>
<td>Shallow &lt;100 m</td>
<td>Intermediate 100-1000 m</td>
</tr>
<tr>
<td><strong>LF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bryde’s Whale</em></td>
<td>5.45E-08</td>
<td>1.74E-05</td>
<td>1.75E-14</td>
<td>33</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Fin whale</em></td>
<td>1.22E-05</td>
<td>1.22E-05</td>
<td>1.22E-05</td>
<td>7,418</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Minke Whale</em></td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Humpback Whale</em></td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><strong>MF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sperm whale</em></td>
<td>1.02E-08</td>
<td>3.84E-03</td>
<td>5.79E-03</td>
<td>2,128</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Atlantic spotted dolphin</em></td>
<td>2.44E-01</td>
<td>7.02E-02</td>
<td>5.90E-06</td>
<td>47,488</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Beaked whale guild</em></td>
<td>6.64E-09</td>
<td>4.98E-03</td>
<td>8.82E-03</td>
<td>2,910</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Common bottlenose dolphin</em></td>
<td>2.53E-01</td>
<td>1.80E-01</td>
<td>5.66E-03</td>
<td>138,602</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Clymene dolphin</em></td>
<td>3.47E-10</td>
<td>3.25E-03</td>
<td>4.03E-03</td>
<td>11,000</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>False killer whale</em></td>
<td>4.77E-05</td>
<td>7.44E-03</td>
<td>7.48E-03</td>
<td>3,204</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Frasers dolphin</em></td>
<td>2.48E-05</td>
<td>3.86E-03</td>
<td>3.89E-03</td>
<td>1,665</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Killer whale</em></td>
<td>3.56E-06</td>
<td>7.06E-05</td>
<td>8.20E-04</td>
<td>185</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Melon-headed whale</em></td>
<td>3.17E-07</td>
<td>6.24E-03</td>
<td>1.19E-02</td>
<td>6,733</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Pantropical spotted dolphin</em></td>
<td>5.01E-06</td>
<td>1.48E-01</td>
<td>3.14E-01</td>
<td>84,014</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Pilot whales</em></td>
<td>7.15E-09</td>
<td>6.36E-03</td>
<td>1.28E-03</td>
<td>1,981</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Pygmy killer whale</em></td>
<td>1.46E-07</td>
<td>2.01E-03</td>
<td>6.48E-03</td>
<td>2,126</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Risso’s dolphin</em></td>
<td>1.16E-06</td>
<td>2.32E-02</td>
<td>7.48E-03</td>
<td>3,137</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td><em>Rough-toothed dolphin</em></td>
<td>4.20E-03</td>
<td>8.90E-03</td>
<td>7.68E-03</td>
<td>4,853</td>
<td>0</td>
<td>83</td>
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<tr>
<td><em>Spinner dolphin</em></td>
<td>6.95E-09</td>
<td>1.57E-01</td>
<td>4.12E-03</td>
<td>13,485</td>
<td>0</td>
<td>83</td>
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<tr>
<td><em>Striped dolphin</em></td>
<td>2.73E-08</td>
<td>2.12E-03</td>
<td>1.27E-02</td>
<td>4,914</td>
<td>0</td>
<td>83</td>
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<tr>
<td><strong>HF Cetaceans</strong></td>
<td></td>
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<tr>
<td><em>Kogi spp.</em></td>
<td>1.85E-06</td>
<td>1.05E-02</td>
<td>4.90E-03</td>
<td>2,234</td>
<td>0</td>
<td>83</td>
</tr>
</tbody>
</table>
TABLE B-2. Densities of marine mammals and sea turtles and daily areas ensonified above threshold levels used to calculate potential takes for the proposed survey in the Gulf of Mexico if all effort were to occur in the Mexican EEZ. Species listed as in italics are endangered or threatened under the ESA.

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<td>0</td>
<td>191</td>
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<td>1.22E-05</td>
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<td>191</td>
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<td>7.48E-03</td>
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<td>13,485</td>
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<td>1.27E-02</td>
<td>4.914</td>
<td>0</td>
</tr>
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<td></td>
<td></td>
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<td>Kogi spp.</td>
<td>1.85E-06</td>
<td>1.05E-02</td>
<td>4.90E-03</td>
<td>2.234</td>
<td>0</td>
</tr>
</tbody>
</table>

SIO IHA Application for the Gulf of Mexico, 2020  Page B-2
APPENDIX C: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

TABLE C-1. Areas ensonified above threshold levels used to calculate potential takes for the proposed surveys in the Campeche Bank and Yucatán Channel survey areas in the Gulf of Mexico.

<table>
<thead>
<tr>
<th>Survey Zone</th>
<th>Criteria</th>
<th>Daily Ensonified Area (km²)</th>
<th>Total Survey Days</th>
<th>25% Increase</th>
<th>Total Ensonified Area (km²)</th>
<th>Relevant Isopleth (m)</th>
<th>Total Ensonified Area (km²)</th>
<th>Relevant Isopleth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow (&lt;100 m)</td>
<td>160 dB</td>
<td>0.0</td>
<td>9.7</td>
<td>1.25</td>
<td>0.0</td>
<td>1,295</td>
<td>0.0</td>
<td>1,295</td>
</tr>
<tr>
<td>Intermediate (100-1000 m)</td>
<td>160 dB</td>
<td>152.5</td>
<td>9.7</td>
<td>1.25</td>
<td>1,848.6</td>
<td>809</td>
<td>809</td>
<td>809</td>
</tr>
<tr>
<td>Deep (&gt;1000 m)</td>
<td>160 dB</td>
<td>144.1</td>
<td>9.7</td>
<td>1.25</td>
<td>1,747.0</td>
<td>539</td>
<td>2,379.0</td>
<td>539</td>
</tr>
<tr>
<td>Overall</td>
<td>160 dB</td>
<td>296.5</td>
<td>9.7</td>
<td>1.25</td>
<td>3,595.6</td>
<td>3,179.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE C-2. Areas ensonified above threshold levels used to calculate potential takes for the proposed survey in the Gulf of Mexico if all effort were to occur in the Mexican EEZ.