Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V Marcus G. Langseth off Western Mexico, Eastern Tropical Pacific Ocean

submitted by

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to

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I. Operations to be Conducted

Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V Marcus G. Langseth off Western Mexico, Eastern Tropical Pacific Ocean

SUMMARY

Researchers from Columbia University’s Lamont-Doherty Earth Observatory (L-DEO), University of Texas Institute of Geophysics (UTIG), and Northern Arizona University (NAU), with funding from the U.S. National Science Foundation (NSF), and in collaboration with researchers from the National Autonomous University of Mexico (Universidad Nacional Autonoma de Mexico or UNAM) and Kyoto University, propose to conduct high-energy seismic surveys from the research vessel (R/V) Marcus G. Langseth (Langseth) in and around the Guerrero Gap off western Mexico, in the Eastern Tropical Pacific (ETP). The Langseth is owned and operated by L-DEO, and the surveys would use a 36-airgun towed array with a total discharge volume of ~6600 in³. The majority of the proposed 2-D seismic surveys would occur within Exclusive Economic Zone (EEZ) of Mexico, including territorial seas, and a small portion would occur in International Waters. The water depths in the survey area range from >100 m to 5560 m. 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 project area in the ETP. Under the U.S. ESA, several of these species are listed as endangered, including the sei, fin, blue, and sperm whale, and the Central America Distinct Population Segment (DPS) of the humpback whale. The threatened Mexico DPS of the humpback whale could also occur in the proposed project area, as well as the threatened Guadalupe fur seal. ESA-listed sea turtle species that could occur in the project area include the endangered leatherback, hawksbill turtle, and Mexico’s Pacific coast breeding population of olive ridley turtles, and the North Pacific Ocean DPS of loggerhead turtles, and the threatened East Pacific DPS of the green turtle. Marine mammals are subject to special protection under the Norma Oficial Mexicana (NOM), and sea turtles are considered in danger of extinction under the NOM. ESA-listed fish that could occur in the area include the endangered Eastern Pacific DPS of scalloped hammerhead shark, and the threatened oceanic whitetip shark and giant manta ray. ESA-listed seabirds that could be encountered in the area include the endangered California least 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 survey 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

The proposed study would use 2-D seismic surveying to quantify incoming plate hydration and examine the role of fluids on megathrust slip behavior in and around the Guerrero Gap of the Middle America Trench. This is one of the best-known examples in the world of along-strike variations in slip behavior of the plate boundary. The surveys would occur within ~14–18.5°N, ~99–105°W; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above. However, deviations in tracklines are expected to be limited and would not be expected to substantially affect the ensuing analysis. The surveys are proposed to occur within the EEZ of Mexico, including territorial seas, and a small portion would occur in International Waters; water depths in the survey area range from >100 m to 5560 m. The proposed surveys would be expected to last for 48 days, including ~20 days of seismic operations, ~3 days of transit to and from the survey area, 19 days for equipment deployment/recovery, and 6 days of contingency time. R/V Langseth would likely leave out of and return to port in Manzanillo during spring 2022.

To achieve the project goals, the Principal Investigators (PIs) Drs. A. Becel (L-DEO), B. Boston (L-DEO), A. Arnulf (UTIG), and D.J. Shillington (NAU) propose to utilize 2-D seismic reflection and refraction capabilities of R/V Langseth. Although not funded through NSF, collaborators Dr. M. Cruz-Atienza (UNAM) and Dr. Y. Ito (Kyoto University), would coordinate with the Principal Investigators (PIs) to complement an ongoing multi-year international project.

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, R/V Langseth, which would tow a 36-airgun array with a discharge volume of ~6600 in³ at a depth of 12 m. The receiving system would consist of a 15-km long solid-state hydrophone streamer and ~33 short-period OBSs. The airguns would fire at a shot interval of 50 m (~24 s) during multi-channel seismic (MCS) surveys with the hydrophone streamer and at a 400-m (155 s) interval during refraction surveys to OBSs.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), Acoustic Doppler Current Profiler (ADCP), and acoustic pingers would be operated from R/V Langseth continuously during the seismic surveys. All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

Vessel Specifications

R/V Marcus G. Langseth is described in § 2.2.2.1 of the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. The vessel speed during seismic operations would be ~4.1 kt (~7.6 km/h) during MCS reflection surveys and 5 kt (~9.3 km/h) during OBS
I. Operations to be Conducted

FIGURE 1. Location of the proposed seismic surveys and OBS deployments in the Eastern Tropical Pacific Ocean off the west coast of Mexico.

refraction surveys. When the Langseth is towing the airgun array and the hydrophone streamer, the turning rate of the vessel is limited to five degrees per minute. Thus, the maneuverability of the vessel is limited during operations with the streamer.

Airgun Description

During the surveys, R/V Langseth would tow four strings with 36 airguns (plus 4 spares). During the surveys, all four strings, totaling 36 active airguns with a total discharge volume of 6600 in³, would be used. The airgun array is described in § 2.2.3.1 of the PEIS, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. The array would be towed at a depth of 12 m, and the shot interval would be 50 m (~24 s) during MCS reflection surveys and 400 m (155 s) during refraction surveys.

Predicted Sound Levels

Mitigation zones for the proposed marine seismic survey were not derived from the farfield signature but calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and for the Level B (160 dB re 1μPa rms) threshold. The background information and methodology for this are provided in Appendix A.
I. Operations to be Conducted

L-DEO model results are used to determine the 160-dBrms radius for the 36-airgun array and 40-in³ airgun at a 12-m tow depth in deep water (>1000 m) down to a maximum 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. For shallow water (<100 m), radii are based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth. Table 1 shows the distances at which the 160-dB re 1µPa rms sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. Table 1 also shows the distances at which the 175-dB re 1µPa rms sound level is expected to be received for the 36-airgun array and a single airgun; this level is used by NMFS, as well as the US DoN (2017a), to determine behavioral disturbance for turtles.

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

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for shutdowns and to monitor an additional 500-m buffer zone beyond the EZ. A power down requires the reduction of the full array to a single 40-in³ airgun and implementation of a 100-m EZ for shut downs of the single airgun; shut downs would be implemented for sea turtles or diving ESA-listed seabirds. Enforcement of mitigation zones via power and shutdowns would be implemented as described in § XI.

OBS Description and Deployment

The seismometers would consist of ~33 4-comp short-period OBSs, which would be deployed at a total of 124 sites. The instruments would be deployed by R/V Langseth and spaced 10 or 12 km apart. Following refraction shooting of one line, short-period instruments on that line would be recovered, serviced, and redeployed on a subsequent refraction line while MCS data are acquired. The OBSs have a height and diameter of ~1 m and an anchor weighing ~80 kg. OBS sample rate would be set at 200 Hz. All OBSs would be recovered by the end of the survey.

To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor which is not retrieved.
I. Operations to be Conducted

Table 1. Level B. Predicted distances to which sound levels $\geq$160-dB re 1 $\mu$Pa$_{rms}$ could be received during the proposed survey off Mexico. The 160-dB criterion applies to all hearing groups of marine mammals, and the 175-dB criterion applies to sea turtles.

<table>
<thead>
<tr>
<th>Source and Volume</th>
<th>Tow Depth (m)</th>
<th>Water Depth (m)*</th>
<th>Predicted distances (in m) to the 160-dB Received Sound Level</th>
<th>Predicted distances (in m) to the 175-dB Received Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Bolt airgun, 40 in$^3$</td>
<td>12</td>
<td>&gt;1000 m</td>
<td>431$^1$</td>
<td>77$^{1,4}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>647$^2$</td>
<td>116$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;100 m</td>
<td>1041$^3$</td>
<td>170$^3$</td>
</tr>
<tr>
<td>4 strings, 36 airguns, 6600 in$^3$</td>
<td>12</td>
<td>&gt;1000 m</td>
<td>6,733$^1$</td>
<td>1,864$^1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>10,100$^2$</td>
<td>2,796$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;100 m</td>
<td>25,494$^3$</td>
<td>4,123$^3$</td>
</tr>
</tbody>
</table>

* Although no seismic acquisition would occur in shallow water <100 m deep, shallow water areas would be ensonified with sound levels >160 dB.
1 Distance is based on L-DEO model results.
2 Distance is based on L-DEO model results with a 1.5 $\times$ correction factor between deep and intermediate water depths.
3 Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
4 An EZ of 100 m would be used as the shut-down distance for sea turtles and ESA listed seabirds in all water depths.

Table 2. Level A threshold distances for different marine mammal hearing groups and sea turtles for the 36-airgun array and a shot interval of 50 m$^1$. Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances.

<table>
<thead>
<tr>
<th>Level A Threshold Distances (m) for Various Hearing Groups</th>
</tr>
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<tr>
<td>Low-Frequency Cetaceans</td>
</tr>
<tr>
<td>PTS SEL$_{cum}$</td>
</tr>
<tr>
<td>PTS Peak</td>
</tr>
</tbody>
</table>

$^1$ Using the 50-m shot interval provides more conservative distances than the 400-m shot interval.

Description of Operations

The procedures to be used for the proposed surveys would be similar to those used during previous seismic surveys by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V Langseth, which is owned and operated by L-DEO. R/V Langseth would deploy an array of 36 airguns as an energy source with a total volume of ~6600 in$^3$. The receiving system would consist of a 15-km long hydrophone streamer and ~33 short-period OBSs. As the airgun arrays are towed along the survey lines, the OBSs would receive and store the returning acoustic signals internally for later analysis, and the hydrophone streamer would transfer the data to the on-board processing system.
The proposed surveys consist of eight MCS lines, of which six are coincident OBS refraction lines that are located perpendicular to the margin; these six lines would therefore be acquired twice. Approximately ~3600 km of transect lines would be surveyed (~2230 km of 2-D MCS reflection data and 1370 km of OBS refraction data). There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations, 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. Most of the survey (94%) would occur in deep water (>1000 m), and 6% would occur in intermediate water (100–1000 m deep); no effort would occur in shallow water (<100 m deep). Approximately 6% of survey effort would occur in Mexican territorial waters. In addition to the operations of the airgun array, the ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of 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 proposed surveys would occur within ~14–18.5°N, ~99–105°W; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above. The majority of the proposed surveys would occur within the EEZ of Mexico, including territorial seas, and a small portion would occur in International Waters. The water depth in the survey area ranged from >100 m to 5560 m. The proposed cruise would be expected to last for 48 days, including ~20 days of seismic operations, ~3 days of transit to and from the survey area, 19 days for equipment deployment/recovery, and 6 days of contingency time for poor weather, etc. R/V Langseth would likely leave out of and return to port in Manzanillo, Mexico, during spring 2022.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Thirty marine mammal species could occur in or near the proposed survey area, including 6 mysticetes (baleen whales), 22 odontocetes (toothed whales, such as dolphins), and 2 pinnipeds (seals and sea lions) (Table 3). According to Muzquiz-Villalobos and Pompa-Mansilla (2018), species richness in Mexican waters is primarily influenced by sea surface temperature, dissolved oxygen, and salinity. Several species that could occur in the proposed survey area are listed under the U.S. ESA as endangered, including the sei, fin, blue, sperm, and Central America DPS of humpback whale. The threatened Mexico DPS of the humpback whale could also occur in the proposed project area. Although the threatened Guadalupe fur seal is unlikely to occur in the survey area, it is included in the species descriptions below.

Another 11 cetacean species that occur in the Northeast Pacific Ocean are unlikely to occur in the proposed survey area and are not discussed further, including the North Pacific right whale (Eubalaena japonica), gray whale (Eschrichtius robustus), Hubbs’ beaked whale (Mesoplodon carlhubbsi), Stejneger’s beaked whale (M. stejnegeri), Perrin’s beaked whale (M. perrini), Baird’s beaked whale (Berardius bairdii), vaquita (Phocoena sinus), harbor porpoise (Phocoena phocoena), Dall’s porpoise (Phocoenoides dalli), Pacific white-sided dolphin (Lagenorhynchus obliquidens), and northern right whale dolphin (Lissodelphis borealis). Two of the six species of pinnipeds – the California sea lion and Guadalupe fur seal –
TABLE 3. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area off the Pacific coast of Mexico.

<table>
<thead>
<tr>
<th>Species</th>
<th>Occurrence in Study Area during Survey</th>
<th>Habitat</th>
<th>Abundance</th>
<th>Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>North Pacific</td>
<td>ETP&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Mysticetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humpback whale</td>
<td>Uncommon</td>
<td>Mainly nearshore, banks</td>
<td>10,103&lt;sup&gt;8&lt;/sup&gt; 21,063&lt;sup&gt;9&lt;/sup&gt;</td>
<td>2566</td>
</tr>
<tr>
<td>Common minke whale</td>
<td>Uncommon</td>
<td>Coastal, pelagic</td>
<td>20,000&lt;sup&gt;11&lt;/sup&gt;</td>
<td>115</td>
</tr>
<tr>
<td>Bryde’s whale</td>
<td>Uncommon</td>
<td>Coastal, pelagic</td>
<td>-</td>
<td>10,411</td>
</tr>
<tr>
<td>Sei whale</td>
<td>Rare</td>
<td>Mostly pelagic</td>
<td>29,600&lt;sup&gt;12&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>Fin whale</td>
<td>Rare</td>
<td>Slope, pelagic</td>
<td>13,620-18,680&lt;sup&gt;13&lt;/sup&gt;</td>
<td>574</td>
</tr>
<tr>
<td>Blue whale</td>
<td>Uncommon</td>
<td>Coastal, pelagic</td>
<td>2500&lt;sup&gt;14&lt;/sup&gt;</td>
<td>1415</td>
</tr>
<tr>
<td><strong>Odontocetes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sperm whale</td>
<td>Uncommon</td>
<td>Pelagic, steep topography</td>
<td>-</td>
<td>4145</td>
</tr>
<tr>
<td>Pygmy sperm whale</td>
<td>Rare</td>
<td>Deeper waters off shelf</td>
<td>4111&lt;sup&gt;15&lt;/sup&gt;</td>
<td>-</td>
</tr>
<tr>
<td>Dwarf sperm whale</td>
<td>Uncommon</td>
<td>Deeper waters off shelf</td>
<td>-</td>
<td>11,200&lt;sup&gt;16&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cuvier’s beaked whale</td>
<td>Uncommon</td>
<td>Pelagic</td>
<td>90,725&lt;sup&gt;17&lt;/sup&gt;</td>
<td>20,000&lt;sup&gt;18&lt;/sup&gt;</td>
</tr>
<tr>
<td>Longman’s beaked whale</td>
<td>Rare</td>
<td>Pelagic</td>
<td>291&lt;sup&gt;17&lt;/sup&gt;</td>
<td>1007</td>
</tr>
<tr>
<td>Blaineville’s beaked whale</td>
<td>Rare</td>
<td>Pelagic</td>
<td>32,678&lt;sup&gt;20&lt;/sup&gt;</td>
<td>25,300&lt;sup&gt;21&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ginkgo-toothed beaked whale</td>
<td>Rare</td>
<td>Pelagic</td>
<td>32,678&lt;sup&gt;20&lt;/sup&gt;</td>
<td>25,300&lt;sup&gt;21&lt;/sup&gt;</td>
</tr>
<tr>
<td>Deraniyagala’s beaked whale</td>
<td>Rare</td>
<td>Pelagic</td>
<td>32,678&lt;sup&gt;20&lt;/sup&gt;</td>
<td>25,300&lt;sup&gt;21&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pygmy beaked whale</td>
<td>Uncommon</td>
<td>Pelagic</td>
<td>32,678&lt;sup&gt;20&lt;/sup&gt;</td>
<td>25,300&lt;sup&gt;21&lt;/sup&gt;</td>
</tr>
<tr>
<td>Risso’s dolphin</td>
<td>Uncommon</td>
<td>Shelf, slope, seamounts</td>
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<td>110,457</td>
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<td>Rough-toothed dolphin</td>
<td>Uncommon</td>
<td>Mainly pelagic</td>
<td>-</td>
<td>107,663</td>
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<tr>
<td>Common bottlenose dolphin</td>
<td>Common</td>
<td>Coastal, shelf, pelagic</td>
<td>-</td>
<td>335,834</td>
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<tr>
<td>Pantropical spotted dolphin</td>
<td>Common</td>
<td>Coastal and pelagic</td>
<td>-</td>
<td>1,297,092&lt;sup&gt;22&lt;/sup&gt;</td>
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<tr>
<td>Spinner dolphin</td>
<td>Common</td>
<td>Coastal and pelagic</td>
<td>-</td>
<td>2,075,871&lt;sup&gt;22&lt;/sup&gt;</td>
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<tr>
<td>Striped dolphin</td>
<td>Common</td>
<td>Off continental shelf</td>
<td>-</td>
<td>964,362</td>
</tr>
</tbody>
</table>
## IV. Environmental Consequences

<table>
<thead>
<tr>
<th>Species</th>
<th>Occurrence in Study Area during Survey</th>
<th>Habitat</th>
<th>Abundance</th>
<th>Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>North Pacific</td>
<td>ETP</td>
</tr>
<tr>
<td>Short-beaked common dolphin</td>
<td>Common</td>
<td>Shelf, pelagic, seamounts</td>
<td>-</td>
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<td>Fraser’s dolphin</td>
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<td>Pelagic</td>
<td>-</td>
<td>289,300¹⁸</td>
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<tr>
<td>Short-finned pilot whale</td>
<td>Uncommon</td>
<td>Pelagic, high-relief</td>
<td>-</td>
<td>589,315²³</td>
</tr>
<tr>
<td>Killer whale</td>
<td>Uncommon</td>
<td>Widely distributed</td>
<td>-</td>
<td>8500¹⁸</td>
</tr>
<tr>
<td>False killer whale</td>
<td>Uncommon</td>
<td>Pelagic</td>
<td>-</td>
<td>39,800¹⁸</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td>Uncommon</td>
<td>Pelagic</td>
<td>-</td>
<td>38,900¹⁸</td>
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<tr>
<td>Melon-headed</td>
<td>Rare</td>
<td>Mainly coastal,</td>
<td>34,187²⁴</td>
<td>-</td>
</tr>
<tr>
<td>Guadalupe fur seal</td>
<td>Rare</td>
<td>Mainly coastal,</td>
<td>257,606¹⁵</td>
<td>105,000</td>
</tr>
<tr>
<td>California sea lion</td>
<td>Uncommon</td>
<td>Coastal</td>
<td>257,606¹⁵</td>
<td>105,000</td>
</tr>
</tbody>
</table>

¹ Occurrence in area at the time of the survey and in proposed water depths; based on professional opinion, and available data, including densities.

² Abundance for the ETP from NMFS (2015a) unless otherwise stated.

³ Pacific Mexico (excluding Gulf of California) from Gerrodette and Palacios (1996) unless otherwise indicated.

⁴ U.S. Endangered Species Act (ESA; NOAA 2021a): EN = Endangered; T = Threatened; DL = Delisted; NL = Not listed.

⁵ Norma Oficial Mexicana NOM-059-SEMARNAT-2010: P = En peligro de extinción (in danger of extinction); Pr = Sujetas a protección especial (subject to special protection).

⁶ Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2021); EN = Endangered; VU = Vulnerable; LC = Least Concern; NT = Near Threatened; DD = Data Deficient.

⁷ Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2021): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

⁸ Central North Pacific stock (Muto et al. 2021).

⁹ North Pacific (Barlow et al. 2011).

¹⁰ Central America DPS is endangered; Mexico DPS is most likely to occur in survey area and is listed as threatened.


¹² Central and Eastern North Pacific (IWC 2021).

¹³ North Pacific (Ohsumi and Wada 1974).

¹⁴ Eastern North Pacific (IWC 2021).

¹⁵ Abundance for U.S. West coast (Carretta et al. 2021).

¹⁶ Estimate for ETP is mostly for *K. sima* but may also include some *K. breviceps* (Wade and Gerrodette 1993).

¹⁷ Eastern North Pacific (Ferguson and Barlow 2001 in Barlow et al. 2006).

¹⁸ Wade and Gerrodette (1993).

¹⁹ All ziphiids.

²⁰ This estimate for the Eastern North Pacific includes all species of the genus *Mesoplodon* (Ferguson and Barlow 2001 in Barlow et al. 2006).

²¹ This estimate for the ETP includes all species of the genus *Mesoplodon* (Wade and Gerrodette 1993).

²² Includes several stocks added together.

²³ Based on surveys in 2000 (Gerrodette and Forcada 2002).

²⁴ Entire population from Mexico to California (Carretta et al. 2021).
known to occur in the ETP could potentially occur in the proposed project. The remaining five pinniped species known from the ETP – Galápagos sea lion (Zalophus wollebaeki), Galápagos fur seal (Arctocephalus galapagoensis), South American fur seal (Arctocephalus australis), South American sea lion (Otaria flavescens), and northern elephant seal (Mirounga angustirostris) – are not expected to occur in the survey area. 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.

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. 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. Two of the detailed analysis areas (DAAs) defined in the PEIS occur near the proposed survey area—Southern California is located north of the proposed survey area, and the Galapagos Ridge is located south of the survey area. The general distribution of mysticetes, odontocetes, and pinnipeds in these areas is discussed in § 3.6.2, § 3.7.2, and § 3.8.2 of the PEIS, respectively.

The most extensive regional distribution and abundance data that encompass the entire study area come primarily from multi-year vessel surveys conducted in the wider ETP by the NMFS Southwest Fisheries Science Center (SWFSC). Ferguson and Barlow (2001) reported on data collected from 1986–1996, and Forney et al. (2012) used SWFSC data collected during 1986–2006 to develop species-habitat models for the ETP. Initial systematic studies of cetaceans in the ETP were prompted by the incidental killing of dolphins in the purse-seine fishery for yellowfin tuna in the area (Smith 1983). Hundreds of thousands of dolphins used to be killed in the tuna fishery annually, the bycatch has been drastically reduced to <0.05% of the population size of each ETP dolphin stock (Bayliff 2004). The main cetacean species that were affected by the fishery are pantropical spotted and spinner dolphins (Smith 1983). Short-beaked common, striped, bottlenose, Fraser’s, and rough-toothed dolphins, as well as short-finned pilot whales, have also been killed in the fishery (e.g., Hall and Boyer 1989). Dolphin mortality was high at the onset of the fishery (Allen 1985), but has since dropped considerably (Hall 1998). During the 1960s, it was estimated that 200,000–500,000 dolphins per year were killed by the fishery (Wade 1995).

In 1992, the La Jolla Agreement provided a framework to reduce the mortality by setting dolphin mortality limits (DML) for fishing vessels (AIDCP 2020). The Agreement on the International Dolphin Conservation Program (AIDCP) formalized the provisions of the La Jolla Agreement and entered into force in 1999. The Parties to the AIDCP “committed to ensure the sustainability of tuna stocks in the eastern Pacific Ocean and to progressively reduce the incidental dolphin mortalities in the tuna fishery of the eastern Pacific Ocean to levels approaching zero and to avoid, reduce and minimize the incidental catch and the discard of juvenile tuna and the incidental catch of non-target species, taking into consideration the interrelationship among species in the ecosystem”.

The total DML was 5000 animals for 2019 and 2020 (AIDCP 2020). The bycatch was reported as 778 animals in 2019 and 819 animals in 2018, and has been <1000 since 2011 (AIDCP 2020). Populations of offshore spotted dolphins and eastern spinner dolphins had not recovered by the early 2000s (Gerrodette and Forcada 2005; Wade et al. 2007). It is currently unknown whether these populations have recovered, as current population estimates are unknown (Leslie and Morin 2016); no systematic surveys have taken place since 2006 (Scott et al. 2018). However, Oedekoven et al. (2021) conducted a trial survey for ETP
dolphins off the west coast of Mexico in November 2019, and a main survey is proposed for the future. The goal of a future main survey is to estimate the current abundance of dolphins in the ETP. The trial survey mainly tested the use of a drone to assess whether they can be used to detect dolphin schools ahead of the vessel, and whether they can be used to determine school size and species composition. Sighting information from the trial survey is included in the species accounts below.

**Mysticetes**

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

The humpback whale is found throughout all oceans of the World (Clapham 2018). Based on genetic data, there could be three subspecies, occurring in the North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). Nonetheless, genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Jackson et al. 2014; Bettridge et al. 2015). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Calambokidis et al. 2001; Garrigue et al. 2002, 2015; Zerbini et al. 2011). Humpbacks migrate between summer feeding grounds in high latitudes and winter calving and breeding grounds in tropical waters (Clapham and Mead 1999).

North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008; Bettridge et al. 2015). Humpbacks winter in four different breeding areas: (1) the coast of Mexico; (2) the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). In the Mexican Pacific, there are three main locations where humpbacks aggregate including the southern end of Baja California, the central portion of the mainland, and the Revillagigedo Archipelago; they also aggregate in the northern Gulf of California (Urbán and Aguayo 1987; Urbán et al. 2000). Humpbacks that winter off mainland Mexico and Baja California predominantly migrate to California, Oregon, Washington, and British Columbia during the summer (Urbán et al. 2000).

There is potential for mixing of the western and eastern North Pacific humpback populations on their summer feeding grounds, but this likely occurs to a limited extent (Muto et al. 2021). NMFS is reviewing the global humpback whale stock structure in light of the revisions to the ESA listing and identification of 14 DPSs (see NMFS 2016b; Carretta et al. 2021). Individuals encountered in the proposed survey area would most likely be from the Mexico DPS, but some individuals could also be from the Central America DPS as they move through the region en route to California (see Steiger et al. 1991; Calambokidis et al. 2008).

Most northeastern Pacific humpbacks spend the northern winter off the Baja California Peninsula and mainland Mexico, and summer off the western coast of North America from California to Alaska (Urbán and Aguayo 1987; Urbán et al. 2000). While on wintering grounds, humpbacks occur predominantly in coastal waters. The Northern Hemisphere humpbacks occur in the Mexican Pacific from as early as September through the winter to mid-May (Urbán and Aguayo 1987). However, they have been reported in the Gulf of California throughout the year (Bean et al. 1999 in Heckel et al. 2020), so it is likely that not all whales undergo the migration (Guerrero et al. 2006). Urbán et al. 1999 (in Heckel et al. 2020) provided an abundance estimate of 1813 individuals for the Gulf of California in 1992, and 914 whales for

During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 10 sightings of humpback whales were made (Gerrodette and Palacios 1996). Based on July–December 1986–1996 surveys, the density of humpback whales in the proposed project area was zero (Ferguson and Barlow 2001). However, 403 sightings were made near the proposed project area from 1981–1986, including in nearshore waters off Jalisco, Colima, Guerrero, and Oaxaca; most sightings were made from December through February (Urbán and Aguayo 1987). Jackson et al. (2004) did not encounter any humpbacks in the proposed study area or anywhere off the coast of Mexico during surveys in July–December 2003.

Nine sightings were made during surveys off the Pacific coast of Mexico in November 2019; the mean group size was one (Oedekoven et al. 2021). The central coast of Oaxaca is thought to be a migratory corridor during winter, with whales typically migrating up to 4 km from shore (Heckel et al. 2020). In 2012, 45 sightings were made off Oaxaca (Castillejos-Moguel and Villegas-Zurita 2014 in Heckel et al. 2020) including feeding behavior (Villegas-Zurita and Castillejos-Moguel 2013 in Heckel et al. 2020). Feeding has also been observed in Banderas Bay, which is known to be an aggregation area for humpbacks during the winter months (Frish-Jordán et al. 2019). There are nearly 1000 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; nearly all sightings were made from December through March (OBIS 2021). Although sightings are regularly made within the region during winter, sightings during the proposed late spring survey are likely to be uncommon, especially in the deep portions of the survey area.

**Common Minke Whale (Balaenoptera acutorostrata scammoni)**

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring and summer and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move south to within 2º of the Equator (Perrin et al. 2018). The International Whaling Commission (IWC) recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991).

Although the general distribution of minke whales includes Mexico, and they are known to occur off the Baja California Peninsula year-round (Heckel et al. 2020), minke whales are likely to be uncommon to rare in the survey area. Rankin and Barlow (2005) reported acoustic recordings of minke whale calls (boings) between 15º and 35ºN in the central and eastern North Pacific Ocean; eastern-type ‘boings’ were recorded off the coast of Mexico, including near the northern part of the proposed survey area. Arroyo (2017) reported the presence of this species Banderas Bay, just north of the proposed survey area, and González et al. (2008) also noted its presence off the Pacific coast of Mexico, south of 18ºN.

During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, eight sightings of minke whales were made (Gerrodette and Palacios 1996). However, all sightings were made off the Baja California Peninsula, and no minke whales were seen in the proposed project area over a 10-year period by Ferguson and Barlow (2001). Similarly, during July–December 2003 surveys by Jackson et al. (2004), no minke whales were encountered in the study area; a single minke whale sighting was made off Baja California. Thus, it seems unlikely that this species would be encountered during the proposed seismic survey. There are no sightings in or near the proposed study area in the OBIS database, but there are three records for the far offshore waters off
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Mexico; these sightings were made in November between 14.8°–17.2°N and 112.5°–115.5°W (OBIS 2021).

**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 (Kato and Perrin 2018). 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, although 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 whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2015).

In the Pacific U.S., a Hawaii and an ETP stock are recognized (Carretta et al. 2021). Bryde’s whales are known to occur along the entire coast of Mexico, including the Gulf of California (Heckel et al. 2020) and Banderas Bay (Arroyo 2017 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 12 sightings of *B. edeni* were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 649 *B. edeni* for the EEZ of Pacific Mexico. Based on July–December 1986–1996 surveys, the density of Bryde’s whales in the proposed project area ranged from 0.0001–0.0003/km² (Ferguson and Barlow (2001). Sightings were made north and south of the study area during surveys in 1998–2000 (Forney et al. 2012). One sighting was made near the northern part of the proposed survey area during July–December surveys in 2003; additional sightings were reported off the Baja California Peninsula, including the Gulf of California (Jackson et al. 2004). Four sightings of single sei/Bryde’s whales were made during surveys off the Pacific coast of Mexico during November 2019 (Oedekoven et al. 2021). Thus, Bryde’s whales could be encountered during the proposed seismic survey. There are seven sightings in the OBIS database for the waters in and adjacent to the proposed survey; the sightings were made during September and November (OBIS 2021).

**Sei Whale (Balaenoptera borealis)**

The sei whale occurs in all ocean basins (Horwood 2018), but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). On summer feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999). In the North Pacific during summer, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to the Baja California Peninsula, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N (Rice 1998). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001).

Sei whales may have been sighted during surveys in the greater ETP (Wade and Gerrodette 1993; Kinzy et al. 1999, 2000, 2001; Ferguson and Barlow 2001); however, it is difficult to distinguish sei whales from Bryde’s whales. Because sei whales generally have a more northerly and temperate distribution (Leatherwood et al. 1988), Wade and Gerrodette (1993) classified any tentative sei whale observations in the ETP as Bryde’s whale sightings. Sei whales are known to occasionally occur in the Gulf of California (Urbán et al. 2014 in Heckel et al. 2020), as well as off the west coast of the Baja California Peninsula.
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(Heckel et al. 2020). One sighting has been reported for waters off Nayarit (Urbán et al. 1997, Guerrero et al. 2006 in Heckel et al. 2020), and another sighting was made near the northern part of the proposed survey area, off Jalisco (Heckel et al. 2020). González et al. (2008) also reported the presence of sei whales off west coast of Mexico south of 23°N.

However, neither Ferguson and Barlow (2001) nor Jackson et al. (2004) positively identified any sei whales in Mexican waters during surveys conducted during July–December, although Jackson et al. (2004) reported a sighting of *B. borealis/edeni* near the northern part of the proposed survey area in 2003. Based on July–December 1986–1996 surveys, the density of Bryde’s/sei whales in the proposed project area ranged from zero to 0.0001/km² (Ferguson and Barlow 2001). Four sightings of single Bryde’s/sei whales were made during surveys off the coast of Mexico during November 2019 (Oedekoven et al. 2021). The sei whale is unlikely to occur in the proposed project region based on its generally more temperate distribution and the paucity of confirmed sightings in the region. There are no sightings in the OBIS database for the waters in and adjacent to the proposed survey (OBIS 2021).

**Fin Whale (Balaenoptera physalus)**

The fin whale is widely distributed in all the World’s oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). A review of fin whale distribution in the North Pacific noted the lack of sightings across pelagic waters between eastern and western winter areas (Mizroch et al. 2009). Fin whales most commonly occur offshore, but can also be found in coastal areas (Jefferson et al. 2015).

Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar and García-Vernet 2018). Some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The northern and southern fin whale populations likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985). Information about the seasonal distribution of fin whales in the North Pacific has been obtained from the detection of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are recorded in the North Pacific year-round (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). However, fin whales are considered rare in the proposed survey area.

Although Gerrodette and Palacios (1996) reported an abundance of 145 fin whales for the EEZ of Pacific Mexico, this abundance is based on sightings off the west coast of the Baja California Peninsula (see Ferguson and Barlow 2001). No sightings were made in the proposed survey area during July–December surveys during 1986–1996, 2003, or 2019 (Ferguson and Barlow 2001; Jackson et al. 2004; Oedekoven et al. 2021). Similarly, Edwards et al. (2015) reported no sightings or acoustic detections for the proposed survey area, although sightings have been reported for the Gulf of California and a few sightings exist for offshore waters far west of Mexico. However, González et al. (2008) reported the
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presence of this species off west coast of Mexico south of 23°N, and a sighting has been reported for Banderas Bay (Arroyo 2017). There are no sightings in the OBIS database for the waters in and adjacent to the proposed survey, but there are four records for the far offshore waters of Mexico; the sightings were made between 15.8°–21.0°N and 116.1°–119.6°W during September and November (OBIS 2021). It seems unlikely that this species would be encountered during the proposed seismic survey.

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Blue whales are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: the eastern and central (formerly western) stocks (Carretta et al. 2021). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016). Blue whales from the eastern stock winter in Mexico and Central America (Stafford et al. 1999, 2001) and feed off the U.S. West Coast, as well as the Gulf of Alaska, during summer (Sears and Perrin 2018; Carretta et al. 2021). However, Busquets-Vass et al. (2021) suggested that most blue whales from the North Pacific feed in the California Current System, whereas some individuals occur in the Gulf of California or CRD for most of the year. The central North Pacific stock feeds off Kamchatka, south of the Aleutians and in the Gulf of Alaska during summer (Stafford 2003; Watkins et al. 2000b) and migrates to the western and central Pacific (including Hawaii) to breed in winter (Stafford et al. 2001; Carretta et al. 2021).

In the Northeast Pacific Ocean, including the ETP, blue whale calls are detected year-round (Stafford et al. 1999, 2001, 2009; Monnahan et al. 2014). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections. In the ETP, blue whales have been sighted mainly off the Baja California Peninsula, near Costa Rica particularly the CRD, at and near the Galápagos Islands, and along the coasts of Ecuador and northern Peru (Clarke 1980; Donovan 1984; Reilly and Thayer 1990; Mate et al. 1999; Palacios 1999; Palacios et al. 2005; Branch et al. 2006). However, sightings have also been made off the mainland coast of Mexico (Fiedler 2002), including Banderas Bay (Arroyo 2017). In Mexican waters, blue whales generally occur from December–April (Rice 1974; Yochem and Leatherwood 1985; Gendron 2002 in Heckel et al. 2020), after which time they migrate northward; a large proportion occurs off California during the summer (Sears and Perrin 2018).

During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 30 sightings of blue whales were made (Gerrodette and Palacios 1996). Based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 773 blue whales for the EEZ of Pacific Mexico. Based on surveys in 1997 and 1998, Gendron (2002 in Heckel et al. 2002) estimated the abundance off the western coast of the Baja California Peninsula at 576 individuals. The density of blue whales in the proposed project area was zero based on July–December surveys during 1986–1996 (Ferguson and Barlow 2001). Sightings were made in and near the proposed survey area during surveys in 1998–2000 (Forney et al. 2012). One sighting was made near the proposed survey area during July–December surveys in 2003; additional sightings were made off the west coast of Baja California Peninsula (Jackson et al. 2004). Two sightings each of two blue whales were made during surveys off the Pacific coast of Mexico during November 2019 (Oedekoven et al. 2021). There are ~60 sightings of blue
whales in the OBIS database for the waters in and adjacent to the proposed survey; sightings were made during November, December, March, and May (OBIS 2021). Blue whales are likely to be uncommon to rare in the proposed survey area during late spring.

**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 (Whitehead 2018).

Sperm whales are distributed widely across the North Pacific (Rice 1989). Males migrate north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita 1988). During summer and fall, sperm whales are widely distributed in the ETP, although they are generally more abundant in deep “nearshore” waters than far offshore (e.g., Polacheck 1987; Wade and Gerrodette 1993). It is not clear whether sperm whales seen in the ETP are part of the Northern or Southern Hemisphere stocks, or whether they should be considered a separate stock (Berzin 1978). More than 180 sightings have been reported for the ETP, with the highest concentrations at 10°N–10°S, 80°–100°W (Guerrero et al. 2006).

Sightings for Pacific Mexico include records off the Baja California Peninsula and in the Gulf of California (Guerrero et al. 2006; Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 46 sightings of sperm whales were made (Gerrodette and Palacios 1996). Based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 2810 sperm whales for the Pacific EEZ of Mexico, excluding the Gulf of California. In the proposed study area, sperm whale densities ranged from 0–0.0004/km² according to surveys conducted in July–December 1986–1996 (Ferguson and Barlow 2001). No sightings were made along the mainland coast of Mexico during July–December surveys in 2003, although one sighting was made off the west coast of Baja California Sur (Jackson et al. 2004). Records also exist for Banderas Bay (Arroyo 2017) and Oaxaca (Pérez and Gordillo 2002 in Heckel et al. 2020). There are 22 non-whaling records in the OBIS database for the waters in and adjacent to the proposed survey area; all sightings were made from August through November (OBIS 2021).

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

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

Vocalizations of *Kogia* spp. have been recorded in the North Pacific Ocean (Merkens et al. 2016). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, eight sightings of pygmy sperm whales were made (Gerrodette and Palacios 1996). Pygmy sperm whale strandings have been reported for the Gulf of California (Guerrero et al. 2006; Heckel et al. 2020) and Banderas Bay (Arroyo 2017), and sightings of pygmy sperm whales have been made just north of the proposed survey area off Jalisco (Salinas 2005, Godínez et al. 2015 in Heckel et al. 2020). According to Heckel et al. (2020), pygmy sperm whale distribution in Mexico does not extend farther south than Jalisco.

Dwarf sperm whales are known to occur along most of the Mexican coast; in the Gulf of California, they occur year-round (Urbán et al. 2012 in Heckel et al. 2020). They also occur off the west coast of the Baja California Peninsula, and there appears to be a resident population in Banderas Bay (Arroyo 2017). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 29 sightings of dwarf sperm whales were made (Gerrodette and Palacios 1996). The densities of dwarf sperm whales in the proposed study area ranged from 0.0171–0.021/km² during July–December 1986–1996 (Ferguson and Barlow 2001). Dwarf sperm whales were seen in the proposed survey area during 1998–2000 (Forney et al. 2012). Several sightings of dwarf sperm whales were made along the mainland coast of Mexico during July–December surveys in 2003, including within the proposed survey area (Jackson et al. 2004). Three sightings of single dwarf sperm whales were made during surveys off the coast of Mexico during November 2019 (Oedekoven et al. 2021). There are nearly 200 sightings of dwarf sperm whales in the OBIS database for the waters in and adjacent to the proposed survey; sightings were made from August through November; there are no confirmed sightings of pygmy sperm whales (OBIS 2021).

**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 and near the continental slope (Gannier and Epinat 2008; Baird 2018a). Ferguson et al. (2006) noted that in the ETP, the mean water depth where Cuvier’s beaked whales were sighted was ~3.4 km. Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006).

Cuvier’s beaked whales are widely distributed in the ETP, and MacLeod and Mitchell (2006) identified this region as a key area for beaked whales. Ferguson et al. (2006) reported 90 sightings in the ETP. There are numerous records for the Gulf of California and off the Baja California Peninsula (Heckel et al. 2020), and it also occurs in Banderas Bay (Arroyo 2017). The Guadalupe Islands appear to be an important area for this species, possibly for breeding and foraging (Cárdenas-Hinojosa et al. 2015 in Heckel et al. 2020), as numerous sightings have been made there, including 33 sightings of one to six individuals in 2016 (Cárdenas-Hinojosa et al. 2017 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Pacific during July–December 1986–1990, 1992 and 1993, 18 sightings of Cuvier’s beaked whales were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 68,828 ziphiids for the EEZ of Pacific Mexico. During surveys conducted during July–December 1986–1996, densities of Cuvier’s beaked whales within the proposed study area ranged from 0.0025–0.003/km² (Ferguson and Barlow 2001). Sightings were also made in the proposed survey.
area during 1998 surveys (Forney et al. 2012). In addition, several sightings were made along the mainland coast of Mexico during July–December surveys in 2003, including within the proposed survey area (Jackson et al. 2004). One sighting of two Cuvier’s beaked whales was reported during surveys off the Pacific coast of Mexico during November 2019 (Oedekoven et al. 2021). There are ~70 sightings of Cuvier’s beaked whales in the OBIS database for the waters in and adjacent to the proposed survey; sightings were made from August through November (OBIS 2021).

**Longman’s Beaked Whale (Indopacetus pacificus)**

Longman’s beaked whale, also known Indo-Pacific beaked whale or tropical bottlenose whale, occurs in tropical waters throughout the Indo-Pacific (Pitman 2018a). Longman’s beaked whale is most often sighted in waters with temperatures ≥21°C and over or adjacent to continental slopes (Anderson et al. 2006; Jefferson et al. 2015). Longman’s beaked whale is rare in the eastern Pacific (Pitman 2018a; Heckel et al. 2020). In the ETP, most tropical bottlenose whale sightings have been made between 3°N and 10°N (Pitman et al. 1999). Kinzey et al. (2001) noted one sighting of *I. pacificus* in the ETP at ~6.9°N, 135.5°W. Pitman et al. (1999) suggested that several sightings of *Hyperoodon* spp. in the ETP were actually misidentifications (e.g., Wade and Gerrodette 1993) and were, in fact, sightings of tropical bottlenose whales.

Both Ferguson and Barlow (2001) and Jackson et al. (2004) reported *I. pacificus* in the ETP. However, the density of tropical bottlenose whales in the proposed project area was zero based on 10 years of surveys during July–December (Ferguson and Barlow 2001). There are, however, other records for the Mexican Pacific as well as the Gulf of California (Rosales-Nanduca et al. 2011, Arellano-Peralta and Medrano-González 2015, Urbán et al. 2012 in Heckel et al. 2020). There is one sighting in the OBIS database for the proposed survey area; the sighting was made during September 1987 at 14.7°N, 101.6°W (OBIS 2021).

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

Blainville’s beaked whale is found in tropical and warm temperate waters of all oceans; it has the widest distribution throughout the world of any *Mesoplodon* species (Pitman 2018b). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Like other beaked whales, Blainville’s beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). In the ETP, Blainville’s beaked whale has been sighted in offshore as well as nearshore areas of Central and South America (Pitman et al. 1987; Ferguson and Barlow 2001; Pitman and Lynn 2001). MacLeod et al. (2006) reported stranding and sighting records in the eastern Pacific ranging from 37.3°N to 41.5°S. MacLeod and Mitchell (2006) identified the ETP as a key area for beaked whales.

There have been very few sightings off the west coast of Mexico (Heckel et al. 2020), but sightings have been reported off the Baja California Peninsula, an unconfirmed sighting was made in the Gulf of California, and there were sightings in Banderas Bay (Esquivel et al. 1993 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, one sighting of Blainville’s beaked whale was made (Gerrodette and Palacios 1996). However, no sightings were made within the proposed survey area during July–December 1986–1996 surveys (Ferguson and Barlow 2001). There are no sightings in the OBIS database for the waters in and adjacent to the proposed survey (OBIS 2021).

**Ginkgo-toothed Beaked Whale (Mesoplodon ginkgodens)**

The ginkgo-toothed beaked whale is only known from stranding and capture records (Mead 1989; Jefferson et al. 2015). It is hypothesized to occupy tropical and warm temperate waters of the Indian and
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Pacific oceans (Pitman 2018b). Its distributional range in the North Pacific extends from Japan to the Galapagos Islands, and there are also records for the South Pacific as far south as Australia and New Zealand (Jefferson et al. 2015). The species is thought to occupy relatively cool areas in the temperate and tropical Pacific, where upwelling is known to occur, such as in the California and Peru currents and the equatorial front (Palacios 1996a). For Mexico, there is a single record for the west coast of the Baja California Peninsula, and a skull was found in the Gulf of California (Heckel et al. 2020). Densities of unidentified *Mesoplodon* sp. in the proposed study area ranged from 0.0027–0.0028/km² (Ferguson and Barlow 2001); some of these sightings could have potentially been gingko-toothed beaked whales. There are no records for ginkgo-toothed beaked whales in the OBIS database for Mexican waters (OBIS 2021).

**Deraniyagala’s Beaked Whale (Mesoplodon hotaula)**

Deraniyagala’s beaked whale is a newly recognized species of whale that recently has been described for the tropical Indo-Pacific, where it is thought to occur between ~15°N and ~10°S (Dalebout et al. 2014). Strandings have been reported for the Maldives, Sri Lanka, Seychelles, Kiribati, and Palmyra Atoll (Dalebout et al. 2014), and acoustic detections have been made at Palmyra Atoll and Kingman Reef in the Line Islands (Baumann-Pickering et al. 2014). It is closely related to ginkgo-toothed beaked whale, but DNA and morphological data have shown that the two are separate species (Dalebout et al. 2014). It is possible that this species may occur off the coast of Mexico. There are no sightings in the OBIS database for Mexican waters (OBIS 2021).

**Pygmy Beaked Whale (Mesoplodon peruvianus)**

The pygmy beaked whale is the smallest mesoplodont (Reyes et al. 1991). This eastern-Pacific species is thought to occur between 25°N and 15°S, from the Baja California Peninsula to Peru, foraging in mid-to-deep waters (Urbán-Ramírez and Aurioles-Gamboa 1992). However, Pitman and Lynn (2001) noted a stranding record for the species in Chile, at 29.25°S. Pitman and Lynn (2001) noted that the species may have been known previously as *M*. sp. “A”. The pygmy beaked whale is believed to be widespread in the ETP and is the most frequently sighted *Mesoplodon* sp. there (Pitman 2018b); it appears to be concentrated off central Mexico (Pitman and Lynn 2001). Wade and Gerrodette (1993) reported several sightings for *M. peruvianus* as well as *M*. sp. “A” in the ETP.

During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 13 sightings of *Mesoplodon* sp. A were made (Gerrodette and Palacios 1996). Densities of *Mesoplodon* sp. A based on July–December 1986–1996 surveys were zero for the proposed survey area (Ferguson and Barlow 2001). There are several sighting and stranding records for the pygmy beaked whale for the Pacific coast of Mexico, including records for Banderas Bay and Oaxaca (Heckel et al. 2020). No sightings of pygmy beaked whales were made off Mexico during July–December surveys in 2003; however, several sightings of *Mesoplodon* sp. A were made off the mainland coast of Mexico, including near the proposed survey area (Jackson et al. 2004). Two sightings of pygmy beaked whales were made off Central America during July–December surveys in 2003 (Jackson et al. 2004). Three sightings of pygmy beaked whale were reported during surveys off the coast of Mexico during November 2019 (Oedekoven et al. 2021); the mean group size was three. There are 53 sightings in the OBIS database for the proposed survey area; sightings were made from September through December (OBIS 2021).

**Risso’s Dolphin (Grampus griseus)**

Risso’s dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999), although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a
strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018).

Polacheck (1987) noted that the highest encounter rates of Risso’s dolphin in the ETP were in (relatively) nearshore areas. Risso’s dolphins occur along the entire Pacific coast of Mexico (Heckel et al. 2020), including Banderas Bay (Arroyo 2017). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 73 sightings of Risso’s dolphins were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 24,084 Risso’s dolphins for the Pacific EEZ of Mexico. Sightings of Risso’s dolphins were made in and near the survey area during surveys in 1998–2000 (Forney et al. 2012) and between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). One sighting of 33 Risso’s dolphins was made during surveys off the coast of Mexico during November 2019 (Oedekoven et al. 2021). The densities of Risso’s dolphins in the project area was reported as 0.0172–0.0761/km² by Ferguson and Barlow (2001). There are ~170 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; the sightings were made from September through December (OBIS 2021).

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

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994). In the Pacific, it occurs from central Japan and northern Australia to the Baja California Peninsula, Mexico, and southern Peru (Jefferson et al. 2015). It generally occurs in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2015). In the ETP, sightings of rough-toothed dolphins have been reported by Perrin and Walker (1975), Pitman and Ballance (1992), Wade and Gerrodette (1993), Kinzey et al. (1999, 2000, 2001), Ferguson and Barlow (2001), Jackson et al. (2004), and May-Collado et al. (2005). In Mexico, rough-toothed dolphins occur from the southern Baja California Peninsula and the Gulf of California, southward along the entire coast (Urbán 2008 in Heckel et al. 2020). This species is common although not abundant in Banderas Bay (Arroyo et al. 2016) and may be resident off Oaxaca (Ramírez-Barragán et al. 2014 in Heckel et al. 2020).

Gerrodette and Palacios (1996) reported an abundance of 37,511 rough-toothed dolphins for the EEZ of Pacific Mexico, excluding the Gulf of California, based on surveys during July–December 1986–1990, 1992 and 1993. Densities of rough-toothed dolphins in the region encompassing the proposed project area ranged from 0.0226–0.0362/km² based on surveys conducted during July–December 1986–1996 (Ferguson and Barlow 2001). Sightings of rough-toothed dolphins were made in and near the proposed survey area during surveys conducted in 1998–2000 and 2006 (Gerrodette et al. 2008; Forney et al. 2012) and during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). Ten sightings were made during surveys off the Pacific coast of Mexico during November 2019; the mean group size was seven (Oedekoven et al. 2021). There are ~260 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; sightings were made from September through November (OBIS 2021).

**Common Bottlenose Dolphin (Tursiops truncatus)**

The bottlenose dolphin is distributed worldwide in coastal and shelf waters of tropical and temperate oceans (Jefferson et al. 2015). There are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). Coastal common bottlenose dolphins exhibit a range of movement patterns including seasonal migration, year-round residency, and a combination of long-range movements and repeated local residency (Wells and Scott 2018). In the ETP, bottlenose dolphins tend to be more
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abundant close to the coasts and islands (Scott and Chivers 1990); they also seem to occur more inshore than other dolphin species (Wade and Gerrodette 1993).

Common bottlenose dolphins occur in all Pacific waters of Mexico (Urbán 2008 in Heckel et al. 2020), including Banderas Bay, Nayarit, and off Oaxaca (Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 163 sightings of bottlenose dolphins were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 61,536 bottlenose dolphins for the Pacific EEZ of Pacific. Densities of bottlenose dolphins in the project area ranged from 0.0083–0.0025/km² based on surveys conducted during July–December 1986–1996 (Ferguson and Barlow 2001). Sightings of bottlenose dolphins were made in and near the proposed survey area during surveys in 1998–2000 and 2006 (Gerrodette et al. 2008; Forney et al. 2012) and during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). Ten sightings were reported during surveys off the Pacific coast of Mexico during November 2019; the mean group size was eight (Oedekoven et al. 2021). Acoustic detections were reported to the northwest and southeast of the proposed survey area during summer/fall of 1998 and 1999 (Oswald et al. 2003). There are ~260 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; sightings were made from September through December (OBIS 2021).

**Pantropical Spotted Dolphin (Stenella attenuata)**

The pantropical spotted dolphin is one of the most abundant cetaceans and is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). In the ETP, this species ranges from 25ºN off the Baja California Peninsula to 17ºS, off southern Peru (Perrin and Hohn 1994). Au and Perryman (1985) noted that the pantropical spotted dolphin occurs primarily north of the Equator, off southern Mexico, and westward along 10°N. There are two forms of pantropical spotted dolphin (Perrin 2018a): coastal (S. a. graffmani) and offshore (S. a. attenuata), both of which could occur within the proposed survey area. Along the coast of Latin America, the coastal form typically occurs within 20 km from shore (Urbán 2008 in Heckel et al. 2020). There are currently three recognized stocks of spotted dolphins in the ETP: the coastal stock and two offshore stocks – the northeast and the west/south stocks (Wade and Gerrodette 1993; Leslie et al. 2019). However, based on more recent data, there are at least nine genetically distinct stocks of this species in coastal areas from the Baja California Peninsula south to Ecuador (Rosales and Escorza-Treviño 2005; Escorza-Treviño et al. 2005).

Much of what is known about the pantropical spotted dolphin in the ETP is related to the tuna purse-seine fishery in that area (Perrin and Hohn 1994). There was an overall stock decline of spotted dolphins from 1960–1980 because of the fishery (Allen 1985). In 1979, the population size of spotted dolphins in the ETP was estimated at 2.9–3.3 million (Allen 1985). For 1986–1990, Wade and Gerrodette (1993) reported an estimate of 2.1 million. Gerrodette and Forcada (2005) noted that the population of offshore northeastern spotted dolphins had not yet recovered from the earlier population declines; possible reasons for the lack of growth were attributed to unreported bycatch, effects of fishing activity on survival and reproduction, and long-term changes in the ecosystem. The abundance estimate for 2006 was ~857,884 northeastern offshore spotted dolphins, and 439,208 western-southern offshore spotted dolphins; the coastal subspecies was estimated at 278,155 and was less affected by fishing activities (Gerrodette et al. 2008). In 2004, the mortality rate in the tuna fishery was estimated at 0.03% (Bayliff 2004). Perrin (2018a) noted that for the last few years, hundreds of spotted dolphins have been taken in the fishery. Currently, there are ~640,000 northeastern offshore spotted dolphins inhabiting the ETP (Perrin 2018a). This stock is still considered depleted and may be slow to recover due to continued chase and encirclement by the tuna fishery, which may in turn affect reproductive rates (Cramer et al. 2008; Kellar et al. 2013).
The spotted dolphin is widely distributed in Mexican waters (Heckel et al. 2020) and is expected to be the most common delphinid in the area. Approximately 500 coastal spotted dolphins inhabit the waters off Colima and southern Jalisco, but only 3% are considered resident, so the area appears to be used for transit (González-Salgueiro et al. 2016 in Heckel et al. 2020). The Pantropical spotted dolphin is resident off Oaxaca and the most abundant marine mammal in the region (Pérez and Gordillo 2002 in Heckel et al. 2020). It is also the most common species in Banderas Bay (Arroyo 2017). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 251 sightings of offshore and eight sightings of coastal spotted dolphins were made (Gerrodette and Palacios 1996). Based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 146,296 spotted dolphins for the Pacific EEZ of Mexico. Densities of spotted dolphins in the region encompassing the proposed project area ranged from zero for the coastal stock and 0.27–0.42/km² for the offshore stock (Ferguson and Barlow 2001). Sightings of spotted dolphins were made in and near the proposed survey area during surveys in 1998–2000 and 2006 (Gerrodette et al. 2008; Forney et al. 2012) and during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). Twenty-six sightings of offshore spotted dolphins were made during surveys off the coast of Mexico during November 2019, with a mean group size was 30; three sightings of the coastal form were also made, with a mean group size of 21 (Oedekoven et al. 2021). In addition, 32 sightings of unspecified S. attenuata were made off the coast of Mexico during those surveys, for which the group size was 26 (Oedekoven et al. 2021). There are ~900 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; sightings were made from September through November (OBIS 2021).

**Spinner Dolphin (Stenella longirostris)**

The spinner dolphin is pantropical in distribution, including oceanic tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2015). It is generally considered a pelagic species, but it can also be found in coastal waters (Perrin 2018b). In the Pacific, Au and Perryman (1985) noted that the spinner dolphin occurs primarily north of the Equator, off southern Mexico, and westward along 10ºN; they also noted its occurrence in seasonal tropical waters south of the Galápagos Islands. In the ETP, three types of spinner dolphins have been identified and two of those are recognized as subspecies: the eastern spinner dolphin (S.l. orientalis), considered an offshore species, the Central American spinner (S.l. centroamericana; also known as the Costa Rican spinner), considered a coastal species occurring from southern Mexico to Costa Rica (Perrin 1990; Dizon et al. 1991), and the ‘whitebelly’ spinner is thought to be a hybrid of the eastern spinner and Gray’s spinner (S.l. longirostris). Gray’s spinner dolphin is not expected to occur within the proposed study area. The whitebelly spinner dolphin is common in oceanic waters of the ETP (Heckel et al. 2020).

Although there is a great deal of overlap between the ranges of eastern and whitebelly spinner dolphins, the eastern form generally occurs in the northeastern portion of the ETP, whereas the whitebelly spinner occurs in the southern portion of the ETP, ranging farther offshore (Wade and Gerrodette 1993; Reilly and Fiedler 1994). Reilly and Fiedler (1994) noted that eastern spinners are associated with waters that have high surface temperatures and chlorophyll and shallow thermoclines, whereas whitebelly spinners are associated with cooler surface temperatures, lower chlorophyll levels, and deeper thermoclines. The eastern spinner dolphins are the most likely to occur in the proposed survey area (see Ferguson and Barlow 2001; Heckel et al. 2020), as this subspecies occurs in the ETP, east of 145ºW, between 24ºN off the Baja California Peninsula and 10ºS off Peru (Perrin 1990).

Wade and Gerrodette (1993) reported an abundance estimate of 1.7 million, and Gerrodette et al. (2005) estimated the abundance at 1.1 million for 2003. Gerrodette and Forcada (2005) noted that the
population of eastern spinner dolphins had not yet recovered from the earlier population declines due to the
tuna fishery. The population estimate for eastern spinner dolphins in 2003 was 612,662 (Gerrodette et al. 2005). In 2000, the whitebelly dolphin was estimated to number 801,000 in the ETP (Gerrodette et al. 2005). Bayliff (2004) noted a spinner dolphin mortality rate in the tuna fishery of 0.03% for 2004. Possible reasons why the population has not recovered include under-reported bycatch, effects of fishing activity on survival and reproduction, and long-term changes in the ecosystem (Gerrodette and Forcada 2005). The continued chase and encirclement by the tuna fishery may be affecting the reproductive rates of the eastern spinner dolphin (Cramer et al. 2008).

The spinner dolphin is expected to be one of the most abundant cetacean species in the project area. Sightings have also been made in Nayarit, including Banderas Bay (Arroyo 2017) and off Oaxaca (Meraz and Sánchez-Diaz 2008; Perez and Gordillo 2002 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 163 sightings of eastern spinner dolphin were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 186,906 spinner dolphins for the Pacific EEZ of Pacific. Data from Ferguson and Barlow (2001) showed that the density of eastern spinner dolphin ranged from 0.21–0.27/km² in the proposed survey area; the whitebelly spinner dolphin had densities of zero. Sightings of eastern spinner dolphins were made in and near the proposed survey area 1998–2000 and 2006 (Gerrodette et al. 2008; Forney et al. 2012) and during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). One hundred eight sightings of eastern spinner dolphins were made during surveys off the coast of Mexico during November 2019; the mean group size was 140 (Oedekoven et al. 2021). Acoustic detections were reported to the northwest and southeast of the proposed survey area during summer/fall of 1998 and 1999 (Oswald et al. 2003). There are ~500 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; sightings were made from September through December (OBIS 2021).

**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. 1994a; Jefferson et al. 2015). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). It is common in the ETP up to 25°N (Perrin et al. 1985). In the ETP, striped dolphin distribution is associated with cool, upwelling areas along the equator (Au and Perryman 1985).

In Mexico, striped dolphins occur from the Baja California Peninsula along the entire coast, but they do not occur in the northern Gulf of California (Perez-Cortés et al. 2000). The striped dolphin is expected to be one of the most abundant cetaceans in the offshore waters of the proposed project area, but has been reported in Banderas Bay and off Matanchén Beach, San Blas, Nayarit (Videl et al. 1993, Urbán 2008 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 160 sightings of striped dolphins were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 128,867 striped dolphins for the Pacific EEZ of Pacific Mexico. Polacheck (1987) noted that the highest encounter rates in the ETP were off western Mexico. Ferguson and Barlow (2001) reported densities of striped dolphins in the survey area from 0.016–0.045826/km². Sightings of striped dolphins were made in and near the proposed survey area during survey in 1998–2000 and 2006 (Gerrodette et al. 2008; Forney et al. 2012) and during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). There are ~180 sightings in the OBIS database for the
waters in and adjacent to the proposed survey area; sightings were made from September through December (OBIS 2021).

**Common Dolphin (Delphinus delphis)**

The common dolphin is found in oceanic and nearshore waters of tropical and warm temperate oceans around the world, ranging from ~60°N to ~50°S (Jefferson et al. 2015). Based on Perrin (2018c), here we assume that there are currently three recognized subspecies, including *D. delphis delphis* (the short-beaked form), *D. delphis bairdii* (the long-beaked form, formerly known as *D. capensis*), and *D. delphis tropicalis* (Indian Ocean subspecies). The long-beaked form generally prefers shallower water (Perrin 2018c), typically occurring within 180 km from shore (Jefferson et al. 2015). The common dolphin is very abundant in the ETP (Perrin 2018c), and its distribution there is associated with cool, upwelling areas along the Equator and off the Baja California Peninsula, Central America, and Peru (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994; Ballance et al. 2006). Reilly (1990) noted no seasonal changes in common dolphin distribution, although Reilly and Fiedler (1994) observed interannual changes in distribution that were likely attributable to El Niño events.

The short-beaked form occurs along the entire coast of Mexico and has been sighted near the proposed survey area off Nayarit, Michoacán, and Guerrero; the long-beaked form occurs off the Baja California Peninsula and the Gulf of California (Heckel et al. 2020). The southern limit of the long-beaked form appears to be 22°N (Urbán 2008), and no sightings in Mexican waters have been made to the south of that. Thus, only the short-beaked form is expected to occur within the study area. During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 92 sightings of short-beaked and 74 sightings of long-beaked common dolphins were made. Gerrodette and Palacios (1996) reported an abundance of 283,196 short-beaked common dolphins and 55,112 long-beaked common dolphins for the Pacific EEZ of Mexico. The density of short-beaked common dolphins in the proposed survey area ranged from zero to 0.02375/km² based on July–December 1986–1996 surveys; the density for long-beaked common dolphins was zero (Ferguson and Barlow 2001). Several sightings of short-beaked common dolphins were made along the mainland coast of Mexico during July–December surveys in 2003, including within the proposed survey area; sightings of the long-beaked form were made off the Baja California Peninsula (Jackson et al. 2004). Sightings of common dolphins were also made in coastal waters of the proposed survey area during surveys in 1998–2000 and 2006 (Gerrodette et al. 2008; Forney et al. 2012) and during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). Nine sightings were made during surveys off the coast of Mexico during November 2019; the mean group size was 126 dolphins (Oedekoven et al. 2021). There are ~75 sightings of short-beaked common dolphins in the OBIS database for the waters in and adjacent to the proposed survey area, with sightings from September through November; there are no records for the long-beaked form (OBIS 2021).

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

Fraser’s dolphin is a tropical oceanic species distributed between 30°N and 30°S that generally inhabits deep oceanic water (Dolar 2018). It occurs rarely in temperate regions and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). The species occurs throughout the ETP (Perrin et al. 1973, 1994b) and has been sighted there at least 15 km from shore in waters 1500–2500 m deep (Dolar 2018). Wade and Gerrodette (1993) showed a mainly equatorial distribution in the ETP and estimated its abundance in the area at 289,300 individuals. Pitman and Ballance (1992) also noted its occurrence in the ETP. Pérez-Cortés et al. (2000) reported sightings off northwestern Mexico, and two sightings have been reported near the Revillagigedo Archipelago (Heckel et al. 2020).
González et al. (2008) also reported the presence of Fraser’s dolphin off the west coast of Mexico between 18° and 23°N, as well as the possible presence south of 18°N. The density of Fraser’s dolphin in the region encompassing the proposed project area ranged from 0–0.0056/km² based on 1986–1996 surveys (Ferguson and Barlow 2001). Thus, Fraser’s dolphin may occasionally occur in low numbers in the proposed project area. There are no sightings for Pacific waters of Mexico in the OBIS database (OBIS 2021).

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

The short-finned pilot whale is found in tropical and warm temperate waters (Olson 2018); it is seen as far south as ~40ºS and as far north as ~50ºN (Jefferson et al. 2015). Pilot whales are generally nomadic, but may be resident in certain locations, such as California and Hawaii (Olson 2018). Pilot whales occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson 2018). Based on genetic data, Van Cise et al. (2017) suggested that two types of short-finned pilot whales occur in the Pacific – one in the western and central Pacific, and one in the Eastern Pacific; they hypothesized that prey distribution rather than sea surface temperature determine their latitudinal ranges.

Pilot whales have a wide distribution throughout the ETP, but are most abundant in colder waters where upwelling occurs (Wade and Gerrodette 1993). Polacheck (1987) noted that encounter rates for pilot whales in the ETP were highest inshore, and that offshore concentrations may also occur, but at lower densities (Polacheck 1987). In Pacific waters of Mexico, sightings and strandings have been reported for the Gulf of California and off the west coast of the Baja California Peninsula, but Heckel et al. (2020) did not report any records in the Pacific waters off Mexico south of 20°N. However, González et al. (2008) reported the presence of this species off the entire west coast of Mexico. During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 15 sightings of short-finned pilot whales were made; based on those surveys, Gerrodette and Palacios (1996) reported an abundance of 3348 short-finned pilot whales for the Pacific EEZ of Mexico. No sightings were made along the mainland coast of Mexico during July–December surveys in 1998–2000, 2003, or 2006 (Jackson et al. 2004; Gerrodette et al. 2008; Forney et al. 2012). There are no sightings in the OBIS database for the waters in and adjacent to the proposed survey area (OBIS 2021).

**Killer Whale (Orcinus orca)**

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales tend to be more common in nearshore areas and at higher latitudes (Jefferson et al. 2015). Nonetheless, they can be found throughout the ETP (Pitman and Ballance 1992; Wade and Gerrodette 1993), but are most densely distributed near the coast from 35ºN to 5ºS (Dahlheim et al. 1982). Dahlheim et al. (1982) noted the occurrence of a cluster of sightings at two offshore locations in the ETP. One location was bounded by 7– 14ºN and 127–139ºW, and the other was within a band between the equator and 5ºN and from the Galápagos Islands to 115ºW.

In Mexico, killer whales are most often reported off the west coast of the Baja California Peninsula, Revillagigedo Archipelago, and the Gulf of California (Guerrero 2013 in Heckel et al. 2020). Sightings have also been made in Banderas Bay (Arroyo 2017), and off Jalisco, Colima, Michoacán (Vargas-Bravo et al. 2014 in Heckel et al. 2020), and off Oaxaca (Meraz and Sánchez-Díaz 2008; Pérez and Gordillo 2002, Ponce-Quezada et al. 2014 in Heckel et al. 2020). In the Pacific waters of Mexico, killer whales most often occur along the continental shelf edge and nearshore (Guerrero 1997, Guerrero et al. 2005 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 15 sightings of killer whales were made (Gerrodette and Palacios 1996). The density of killer whales in the proposed project area based on 1986–1996 surveys...
ranged from 0.0001–0.0003/km² (Ferguson and Barlow 2001). One sighting was made near the proposed survey area during July–December surveys in 2003; additional sightings were made off the Baja California Peninsula (Jackson et al. 2004). One sighting of 16 killer whales was made during surveys off the coast of Mexico during November 2019 (Oedekoven et al. 2021). There are ~24 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; the sightings were made from August through November (OBIS 2021).

**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 rare to uncommon throughout its range (Baird 2018b). The false killer whale generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2015). In the North Pacific, it occurs from Japan and southern California, southward and across the Pacific, including Hawaii.

Wade and Gerrodette (1993) noted the occurrence of false killer whales especially along the Equator. False killer whales in the ETP are usually seen far offshore (Wade and Gerrodette 1983). They are thought to occur along the entire Pacific coast of Mexico (Heckel et al. 2020), including Banderas Bay (Arroyo 2017) and off Nayarit, Jalisco, Colima, and Oaxaca (Castillo-Sánchez et al. 2014 in Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, three sightings of false killer whales were made (Gerrodette and Palacios 1996). The density of this species in the proposed project area based on 1986–1996 surveys was zero, although adjacent areas had densities up to 0.0025/km² (Ferguson and Barlow 2001). One sighting was made within the proposed survey area during July–December surveys in 2003 (Jackson et al. 2004). Five sightings were made during surveys off the coast of Mexico during November 2019; the mean group size was 19 (Oedekoven et al. 2021). There are ~20 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; the sightings were made from August through November (OBIS 2021).

**Pygmy Killer Whale (Feresa attenuata)**

The pygmy killer whale has a worldwide distribution in tropical waters (Baird 2018c), generally not ranging south of 35°S (Jefferson et al. 2015). In the North Pacific, it occurs from Japan and to the Baja California Peninsula, southward and across the Pacific Ocean, including Hawaii. In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters.

Pygmy killer whales are known to occur in the ETP (e.g., Van Waerebeek and Reyes 1988; Pitman and Ballance 1992; Wade and Gerrodette 1993; Gerrodette and Palacios 1996). The pygmy killer whale may occasionally occur in small numbers in the proposed project area; sightings and stranding records exist for the Baja California Peninsula, Gulf of California, and offshore waters off Mexico (Heckel et al. 2020). During 25,356 km of surveys (excluding the Gulf of California) within the EEZ of Pacific Mexico, during July–December 1986–1990, 1992 and 1993, 13 sightings of pygmy killer whales were made (Gerrodette and Palacios 1996). The density of this species in the proposed project area, based on 1986–1996 surveys, ranged up to 0.0124–0.0154/km² (Ferguson and Barlow 2001). Records have also been reported for Banderas Bay (Arroyo 2017) and Jalisco (Godínez-Domi and Franco-Gordo 2013 in Heckel et al. 2020). Sightings were also made during surveys between 12°–17°N and 104°–108°W, southwest of Manzanilla, from late August–November 2007 (Schwarz et al. 2010). Four sightings were reported during surveys off the coast of Mexico during November 2019; the mean group size was 42 (Oedekoven et al. 2021). There are ~60 sightings in the OBIS database for the waters in and adjacent to the proposed survey area; the sightings were made from August through November (OBIS 2021).
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 is commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997). It occurs most often in deep offshore waters and occasionally in nearshore areas where deep oceanic waters occur near the coast (Perryman and Danil 2018). In the North Pacific, it is distributed south of central Japan and southern California, as well as across the Pacific, including Hawaii.

Au and Perryman (1985) and Perryman et al. (1994) reported that the melon-headed whale occurs primarily in equatorial waters, although Wade and Gerrodette (1993) noted its occurrence in non-equatorial waters. The melon-headed whale likely occurs in small numbers in the proposed project area; there are only a few records for Pacific waters of Mexico, in the Gulf of California (Urbán 2008; Pérez-Cortés et al. 2000; Heckel et al. 2020). However, based on surveys conducted during 1986–1996, the density of this species in the proposed project area was zero (Ferguson and Barlow 2001). There are three sightings in the OBIS database to the west of the proposed survey area; the sightings were made during September and October between 11.3°–12.8°N and 102.9°–103.0°W from August through November (OBIS 2021).

Pinnipeds

**Guadalupe Fur Seal (*Arctocephalus townsendi*)**

During the summer breeding season, most Guadalupe fur seal adults occur at rookeries in Mexico (Carretta et al. 2021). Most breeding and births occur at Isla Guadalupe, off the west coast of Baja California Peninsula; a secondary rookery exists at Isla Benito del Este (Maravilla-Chavez and Lowry 1999; Aurioles-Gamboa et al. 2010). A few Guadalupe fur seals are known to occur at California sea lion rookeries in the Channel Islands, primarily at San Miguel Island (Carretta et al. 2021), but sightings have also been made at Santa Barbara, San Nicolas, and San Clemente islands (Stewart et al. 1987). Following the breeding season, adult males tend to move north to forage. Fur seals younger than two years old are more likely to travel to more northerly, offshore areas than older fur seals (Norris 2017 in DoN 2019). Females have been observed feeding south of Guadalupe Island, making an average round trip of 2375 km (Ronald and Gots 2003).

While at sea, this species usually is solitary but typically gathers in the hundreds to thousands at breeding sites. Guadalupe fur seals prefer rocky habitat for breeding and hauling out. They generally haul out at the base of towering cliffs on shores characterized by solid rock and large lava blocks (Peterson et al. 1968), although they can also inhabit caves and recesses (Belcher and Lee 2002). In 2015–2021, 714 Guadalupe fur seals stranded on the coast of west coast of the U.S.; this has been declared an unusual mortality event (NOAA 2021b). Guadalupe fur seals are unlikely to be encountered during the proposed seismic survey, as they typically occur farther north. Heckel et al. (2020) reported occasional records for Guerrero and Oaxaca. There are no sightings in or near the proposed study area in the OBIS database (OBIS 2021).

**California Sea Lion (*Zalophus californianus californianus*)**

The primary range of the California sea lion includes the coastal areas and offshore islands of the eastern North Pacific Ocean from British Columbia to central Mexico, including the Gulf of California (Jefferson et al. 2015). However, its distribution is expanding (Jefferson et al. 2015), and its secondary range extends into the Gulf of Alaska (Maniscalco et al. 2004) and southern Mexico (Gallo-Reynoso and Solórzano-Velasco 1991; Meraz and Sánchez-Díaz 2008), where it is occasionally recorded. The California sea lion has been documented as far south as Costa Rica on several occasions (e.g., Acevedo-Gutierrez 1996; Rodriguez-Herrera et al. 2002). The California sea lion is considered as the subspecies *Z.c.*
californianus (other subspecies are found on the Galápagos Islands and in Japan, although the latter is likely extinct).

California sea lion rookeries are located on islands located in southern California, the western Baja California Peninsula, and the Gulf of California (Carretta et al. 2021). A single stock is recognized in U.S. waters, but there are five genetically distinct geographic populations (1) Pacific Temperate (includes rookeries in U.S. waters and the Coronados Islands to the south), (2) Pacific Subtropical, (3) Southern Gulf of California, (4) Central Gulf of California, and (5) Northern Gulf of California (Schramm et al. 2009). In California and the Baja California Peninsula, births occur on land from mid-May to late-June. During August and September, after the mating season, the adult males migrate northward to feeding areas as far north as Washington (Puget Sound) and British Columbia (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature California sea lions is less well known but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). However, most immature seals are presumed to remain near the rookeries for most of the year, as are females and pups (Lowry et al. 1992).

During 25,356 km of surveys (excluding the Gulf of California) within the Pacific EEZ of Mexico, during July–December 1986–1990, 1992 and 1993, 43 sightings of California sea lions were made (Gerrodette and Palacios 1996); however, these sightings were made north of the proposed survey area, off the Baja California Peninsula. However, occasional sightings have been reported off Nayarit, Guerrero, Oaxaca, and Chiapas (Meraz and Sánchez-Díaz 2008; Arroyo 2017). There are no sightings in or near the proposed survey area in the OBIS database (OBIS 2021).

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.

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys off the Pacific coast of Mexico, in the ETP, during spring 2022. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. “Takes” by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the 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 is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. Consistent with past similar proposed actions, NSF has followed the NOAA Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes would be unlikely.
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. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the ETP. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment “takes” during the planned surveys, as well Level A “takes”.

Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, but TTS is not considered an 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). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine
mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

**Tolerance**

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

**Masking**

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

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). 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.
**IV. Environmental Consequences**

**Disturbance Reactions**

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). 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. 2017).

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 boat; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs (McCauley et al. 1998, 2000). However, some individual humpback whales, especially males, approached within distances of 100–400 m.
Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 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(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in³) within 3 km and received levels of at least 140 dB re 1 μPa²·s (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in³ array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 μPa²·s (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000).

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

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 \(\mu\)Pa\(^2\)·s, decreased at CSEL\textsubscript{10-min} \(>127\) dB re 1 \(\mu\)Pa\(^2\)·s, and whales were nearly silent at CSEL\textsubscript{10-min} \(>160\) dB re 1 \(\mu\)Pa\(^2\)·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 \textit{western gray whales} exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above \(~163\) dB re 1 \(\mu\)Pa\(_{\text{rms}}\) (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to \(~170\) dB re 1 \(\mu\)Pa 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 \textit{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). Sightings 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 \(\sim 1.5\) km) during seismic operations compared with non-seismic periods (median CPA \(\sim 1.0\) km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity
(Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

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

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

**Toothed Whales.**— Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.
Observations from seismic vessels using large arrays off the U.K. from 1994 to 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). Winsor et al. (2017) outfitted sperm whales in the Gulf of Mexico with satellite tags to examine their spatial distribution in relation to seismic surveys. They found no evidence of avoidance or changes in orientation by sperm whales to active seismic vessels. Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2017), could have significant consequences on individual fitness. Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

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

The limited available data suggest that harbor porpoises show stronger avoidance of seismic operations than do Dall’s porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013b) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB µPa²·s). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 µPa₀·peak. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in³ airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB µPa²·s. One porpoise moved away from the sound source but returned to natural movement patterns within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

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

**Pinnipeds.**—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for grey seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during
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seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in³ airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Hearing Impairment and Other Physical Effects

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

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

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

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a $SEL_{cum}$ of 188 and 191 $\mu$Pa²·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, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (cf. Southall et al. 2007). Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012a) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB (Kastelein et al. 2012a). Kastelein et al. (2013b) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 µPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

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

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level
of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018).

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or harbor porpoises when using single airguns in shallow water. Similarly, it is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. However, Gedamke et al. (2011), based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, suggested that some baleen whales whose CPA to a seismic vessel is 1 km or more could experience TTS.

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

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a, 2018) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans, MF cetaceans, HF cetaceans, phocids, and otariids.

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially...
susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland’s coast increased with seismic surveys operating offshore (McGeady et al. 2106). 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 (UME) in the U.S. (NOAA 2019e). In a hearing to examine the Bureau of Ocean Energy Management’s 2017–2022 OCS Oil and Gas Leasing Program (https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program), it was Dr. Knapp’s (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

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

Possible Effects of Other Acoustic Sources

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

There has been some recent 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 like that used on R/V Langseth. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, “all ranges are multiplied by a factor of 4” (Lurton 2016:209).

There is nearly no available information on marine mammal behavioral responses 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 (GVP) 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 GVP 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 grey 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).
Despite the aforementioned information that has recently become available, and in agreement with § 3.6.7, 3.7.7, and 3.8.7 of the PEIS, the operation of MBESs, SBPs, and pingers 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 *Langseth* could affect marine animals in the proposed survey areas. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20 to 300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018); Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

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

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

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey area during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there
IV. Environmental Consequences

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).

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). Pirotta et al. (2015) noted that the physical presence of vessels, not just ship noise, disturbed the foraging activity of bottlenose dolphins. 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.

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. 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. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but 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. There has been no history of marine mammal vessel strikes with R/V Langseth, or its predecessor, R/V Maurice Ewing over the last two decades.

**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. Consistent with past similar proposed actions, NSF has followed the NOAA Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing for estimating and requesting Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals...
of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A “takes” would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys (additional details are provided in Appendix B). The estimates are based on consideration of the number of marine mammals that could be harassed by sound (Level B takes) produced by the seismic surveys in the ETP outside of Mexican territorial waters. Numbers of animals potentially exposed to Level B and Level A sounds in Mexican territorial waters are provided in Appendix C.

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, SBP, 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 MBES and SBP given their characteristics (e.g., narrow downward-directed beam) 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 “Takes”**

The numbers of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 µPa rms (Level B) on one or more occasions have been estimated using a method recommended by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day (~222 km for OBS lines; 182 km for MCS lines) that is roughly similar to that of the entire survey. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by “drawing” the applicable Level B and PTS threshold buffers) around each line. The ensonified areas, increased by 25%, were then multiplied by the number of survey days (7 OBS days; 13 MCS days). This is equivalent to adding an additional 25% to the proposed line km (Appendix B). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V Langseth approaches.

To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

We used habitat-based stratified marine mammal densities for summer for the ETP when available (Barlow et al. 2009), and densities for the ETP from NMFS (2015b) for all other species (Table 4). For the sei whale, for which NMFS (2015b) reported a density of zero, we used the spring density for Baja from U.S. DoN (2017b). The habitat-based density models consisted of 100 km x 100 km grid cells. Densities in the grid cells that overlapped the survey area were averaged for each of the three water depth categories (shallow, intermediate, deep). The density for olive ridley sea turtles was obtained from Eguchi et al.
TABLE 4. Densities of marine mammals in the Pacific waters of Mexico (Barlow et al. 2009) and the wider ETP (NMFS 2015b), as well as sea turtle densities. Densities in bold were used to estimate Level B and Level A takes.

<table>
<thead>
<tr>
<th>Density (#/km²) in Survey Area [Barlow et al. 2009]</th>
<th>Density (#/km²) in wider ETP [NMFS 2015b]</th>
<th>Density (#/km²) Sea Turtles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow Water &lt;100 m</td>
<td>Intermediate Water 100-1000 m</td>
<td>Deep Water &gt;1000 m</td>
</tr>
<tr>
<td>LF Cetaceans</td>
<td></td>
<td></td>
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<tr>
<td>Humpback whale</td>
<td></td>
<td></td>
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<tr>
<td>Minke whale</td>
<td>0.00001</td>
<td></td>
</tr>
<tr>
<td>Bryde's whale</td>
<td>0.000486</td>
<td>0.000489</td>
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<tr>
<td>Fin whale</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sei whale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue whale</td>
<td>0.00010</td>
<td>0.00009</td>
</tr>
<tr>
<td>MF Cetaceans</td>
<td></td>
<td></td>
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<tr>
<td>Sperm whale</td>
<td>0.00019</td>
<td></td>
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<tr>
<td>Cuvier's beaked whale</td>
<td>0.00105</td>
<td>0.00106</td>
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<tr>
<td>Longman's beaked whale</td>
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<td></td>
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<tr>
<td>Mesoplodon spp.</td>
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<td>0.00033</td>
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<td>Blaineville's beaked whale¹</td>
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<tr>
<td>Ginkgo-toothed beaked whale¹</td>
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<td></td>
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<tr>
<td>Deraniyagala's beaked whale¹</td>
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<td></td>
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<tr>
<td>Pygmy beaked whale¹</td>
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<tr>
<td>Risso's dolphin</td>
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<tr>
<td>Rough-toothed dolphin</td>
<td>0.00880</td>
<td>0.00891</td>
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<td>Common bottlenose dolphin</td>
<td>0.04809</td>
<td>0.04502</td>
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<tr>
<td>Pantropical spotted dolphin</td>
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<tr>
<td>Spinner dolphin (whitebelly)</td>
<td>0.00148</td>
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<tr>
<td>Spinner dolphin (eastern)</td>
<td>0.13182</td>
<td>0.12989</td>
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<td>Striped dolphin</td>
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<td>Short-beaked common dolphin</td>
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<td>Fraser's dolphin</td>
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<td>Short-finned pilot whale²</td>
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<td>False killer whale</td>
<td>0.00186</td>
<td></td>
</tr>
<tr>
<td>Pgymy killer whale</td>
<td>0.00183</td>
<td></td>
</tr>
<tr>
<td>Melon-headed whale</td>
<td>0.00213</td>
<td></td>
</tr>
<tr>
<td>HF Cetaceans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pygmy sperm whale³</td>
<td>0.00005</td>
<td>0.00005</td>
</tr>
<tr>
<td>Dwarf sperm whale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kogia spp.</td>
<td>0.00005</td>
<td>0.00005</td>
</tr>
<tr>
<td>Otariid Seals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guadalupe fur seal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>California sea lion¹</td>
<td>0.16262</td>
<td></td>
</tr>
<tr>
<td>Sea Turtle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive Ridley Sea Turtle⁵</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leatherback Sea Turtle⁶</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0000114</td>
<td></td>
</tr>
</tbody>
</table>

¹ Densities not available.
² Bold densities are for Globicephala spp.
³ No densities available for pygmy sperm whale; densities for Kogia spp. shown.
⁴ Density was assumed to be zero in deep water >1000 m.
⁵ Density for 2003 from Eguchi et al. (2007).
⁶ Density for California Current Ecosystem (DoN 2019).
Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Ferrero et al. 2002; Philbrick et al. 2003; Escorza-Treviño 2009). Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_rms criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered “taken by harassment”. Table 5 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_rms during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details), along with the *Requested Take Authorization*. It should be noted that the exposure estimates assume that the proposed surveys would be completed; in fact, the calculated takes for cetaceans, pinnipeds, and sea turtles *have been increased by 25%* (see below). Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_rms are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF/USGS PEIS. The 160-dB_rms criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of “takes by harassment” of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as “taken” to sound levels <160 dB (NMFS 2016c). 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 2016c).

The number of cetaceans and pinnipeds that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_rms (Level B) on one or more occasions have been estimated using a method recommended by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day; in this case, a representative 182-km MCS line and a 222-km long OBS line were chosen. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by “drawing” the applicable 160-dB (Table 1) and PTS threshold buffers (Table 2) around each line. The ensonified areas were then multiplied by the number of survey days (7 days for OBS survey effort; 13 days for MCS survey effort) increased by 25%; this is equivalent to adding an additional 25% to the proposed line kilometers (see Appendix B for more details). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches.

Estimates of the numbers of marine mammals and sea turtles that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs observe animals approaching or inside the EZs), are also
TABLE 5. Estimates of the possible numbers of individual marine mammals and sea turtles that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the Pacific waters of Mexico. Takes for Mexican Territorial Waters are not included here, but are provided separately in Appendix C.

<table>
<thead>
<tr>
<th>Species</th>
<th>LF Cetaceans</th>
<th>MF Cetaceans</th>
<th>HF Cetaceans</th>
<th>Otariid Seals</th>
<th>Sea Turtle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level B¹</td>
<td>Level A¹</td>
<td>Regional Population Size³</td>
<td>Level B + Level A as % of Pop.⁴</td>
<td>Requested Take Authorization⁵</td>
</tr>
<tr>
<td>Species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humpback whale</td>
<td>8</td>
<td>0</td>
<td>2,566</td>
<td>0.32</td>
<td>8</td>
</tr>
<tr>
<td>Minke whale</td>
<td>1</td>
<td>0</td>
<td>115</td>
<td>0.55</td>
<td>2</td>
</tr>
<tr>
<td>Bryde’s whale</td>
<td>27</td>
<td>1</td>
<td>649</td>
<td>4.41</td>
<td>29</td>
</tr>
<tr>
<td>Fin whale</td>
<td>2</td>
<td>0</td>
<td>145</td>
<td>1.31</td>
<td>2</td>
</tr>
<tr>
<td>Sei whale</td>
<td>3</td>
<td>0</td>
<td>29,600</td>
<td>0.00</td>
<td>3</td>
</tr>
<tr>
<td>Blue whale</td>
<td>5</td>
<td>0</td>
<td>773</td>
<td>0.65</td>
<td>5</td>
</tr>
<tr>
<td>Sperm whale</td>
<td>12</td>
<td>0</td>
<td>2,810</td>
<td>0.43</td>
<td>12</td>
</tr>
<tr>
<td>Cuvier’s beaked whale</td>
<td>69</td>
<td>0</td>
<td>20,000</td>
<td>0.34</td>
<td>68</td>
</tr>
<tr>
<td>Longman’s beaked whale</td>
<td>3</td>
<td>0</td>
<td>1,007</td>
<td>0.25</td>
<td>3</td>
</tr>
<tr>
<td>Mesoplodon spp.</td>
<td>23</td>
<td>0</td>
<td>25,300</td>
<td>0.09</td>
<td>N.A.</td>
</tr>
<tr>
<td>Blainville’s beaked whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>25,300</td>
<td>&lt;0.01</td>
<td>7</td>
</tr>
<tr>
<td>Ginkgo-toothed beaked whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>25,300</td>
<td>&lt;0.01</td>
<td>3</td>
</tr>
<tr>
<td>Dermanyagala’s beaked whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>25,300</td>
<td>&lt;0.01</td>
<td>3</td>
</tr>
<tr>
<td>Pygmy beaked whale</td>
<td>N.A.</td>
<td>N.A.</td>
<td>25,300</td>
<td>&lt;0.01</td>
<td>10</td>
</tr>
<tr>
<td>Risso’s dolphin</td>
<td>327</td>
<td>1</td>
<td>24,084</td>
<td>1.36</td>
<td>327</td>
</tr>
<tr>
<td>Rough-toothed dolphin</td>
<td>596</td>
<td>1</td>
<td>37,511</td>
<td>1.59</td>
<td>597</td>
</tr>
<tr>
<td>Common bottlenose dolphin</td>
<td>2,268</td>
<td>6</td>
<td>61,536</td>
<td>3.69</td>
<td>2,274</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td>7,973</td>
<td>15</td>
<td>146,296</td>
<td>5.46</td>
<td>8,069</td>
</tr>
<tr>
<td>Spinner dolphin (whitebelly)</td>
<td>121</td>
<td>0</td>
<td>186,906</td>
<td>0.06</td>
<td>121</td>
</tr>
<tr>
<td>Spinner dolphin (eastern)</td>
<td>8,173</td>
<td>16</td>
<td>186,906</td>
<td>4.34</td>
<td>8,103</td>
</tr>
<tr>
<td>Striped dolphin</td>
<td>2,209</td>
<td>3</td>
<td>128,867</td>
<td>1.72</td>
<td>2,212</td>
</tr>
<tr>
<td>Short-beaked common dolphin</td>
<td>2,812</td>
<td>6</td>
<td>283,196</td>
<td>1.00</td>
<td>2,818</td>
</tr>
<tr>
<td>Fraser’s dolphin</td>
<td>856</td>
<td>2</td>
<td>289,300</td>
<td>0.30</td>
<td>858</td>
</tr>
<tr>
<td>Short-finned pilot whale</td>
<td>244</td>
<td>0</td>
<td>3,348</td>
<td>7.21</td>
<td>241</td>
</tr>
<tr>
<td>Killer whale</td>
<td>25</td>
<td>0</td>
<td>852</td>
<td>2.97</td>
<td>25</td>
</tr>
<tr>
<td>False killer whale</td>
<td>118</td>
<td>0</td>
<td>39,600</td>
<td>0.30</td>
<td>118</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td>116</td>
<td>0</td>
<td>38,900</td>
<td>0.30</td>
<td>116</td>
</tr>
<tr>
<td>Melon-headed whale</td>
<td>135</td>
<td>0</td>
<td>45,400</td>
<td>0.30</td>
<td>135</td>
</tr>
<tr>
<td>Pygmy sperm whale</td>
<td>3</td>
<td>0</td>
<td>N.A.</td>
<td>N.A.</td>
<td>3</td>
</tr>
<tr>
<td>Dwarf sperm whale</td>
<td>32</td>
<td>1</td>
<td>11,200</td>
<td>N.A.</td>
<td>34</td>
</tr>
<tr>
<td>Kogia spp.</td>
<td>3</td>
<td>0</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Guadalupe fur seal</td>
<td>468</td>
<td>1</td>
<td>34,107</td>
<td>1.37</td>
<td>469</td>
</tr>
<tr>
<td>California sea lion</td>
<td>349</td>
<td>16</td>
<td>105,000</td>
<td>0.35</td>
<td>365</td>
</tr>
<tr>
<td>Olive Ridley Sea Turtle</td>
<td>6,901</td>
<td>56</td>
<td>1,390,000</td>
<td>0.50</td>
<td>6,957</td>
</tr>
<tr>
<td>Leatherback Sea Turtle</td>
<td>2</td>
<td>0</td>
<td>N.A.</td>
<td>N.A.</td>
<td>2</td>
</tr>
</tbody>
</table>

N.A. means not applicable or not available.
1 Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.
2 Level A takes if there were no mitigation measures.
3 Population sizes are for Pacific waters of Mexico, except those in italics are for the ETP or wider Pacific (see Table 3).
4 Requested take authorization expressed as % of population (see Table 3).
5 Requested take authorization is Level A plus Level B calculated takes; numbers in bold are maximum group sizes (see text for details).
6 Most if not all takes are expected to be from the threatened Mexico DPS.
given in Table 5. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

Conclusions

The proposed seismic surveys would involve towing a 36-airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute “taking”. In §3.6.7, §3.7.7, §3.8.7, and §3.9.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticetes, odontocetes, and pinnipeds, and that Level A effects were highly unlikely. Consistent with past similar proposed actions, NSF has followed the Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing for estimating Level A takes for the Proposed Action, however, following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys. For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species (and recently not for MF species) for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g., NMFS 2019b,c).

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested “take authorization”. The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes. However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by R/V *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by R/V *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B ‘takes’ whether or not a behavioral response occurred. The Level B estimates are thought to be conservative; thus, not all animals detected within this threshold distance would be expected to have been exposed to actual sound levels >160 dB.

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.

There is no subsistence hunting near the proposed survey area, so the proposed activity would not
have any impact on the availability of the species or stocks for subsistence users.

**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.

**X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals**

| 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 activities.

**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 are known to occur in the proposed survey area. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental ‘take’ of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS).

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 L-DEO 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. (2013a), 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 activities begins during the planning phase of the proposed activity. Several factors were considered during the planning phase of the proposed activity, including

1. **Energy Source**—Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. However, the scientific objectives for the proposed surveys could not be met using a smaller source. A large airgun source is required to penetrate the crustal depths that would address the project goals and to image the plate boundary fault zone from 0–25 km depth, and the crust-mantle boundary (Moho) of the down-going Cocos oceanic plate (~12 km depth, including water column).

2. **Survey Location and Timing**—The PIs worked with L-DEO and NSF to consider potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using R/V Langseth. Although most marine mammals are expected to occur in the proposed survey area throughout the year, the humpback whale is common in the region seasonally from December through March. Thus, late spring is the most practical season for the proposed surveys based on the occurrence of marine mammals, weather conditions, and other operational requirements. If the surveys would be conducted in April/May most of the humpback whales would have migrated northward by that time.

3. **Mitigation Zones**—The proposed surveys would acquire data with the 36-airgun array at a tow depth of 12 m. L-DEO model results are used to determine the 160-dB$_{1\mu Pa_{rms}}$ radius for the 36-airgun array and 40-in$^3$ airgun in deep water (>1000 m) down to a maximum water depth of 2000 m. Table 1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound levels are expected to be received for the airgun arrays and the 40-in$^3$ airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

The thresholds for PTS onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including LF cetaceans, MF cetaceans, HF, phocids, and otariids. Per the Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (NMFS 2016a, 2018), the largest distance of the dual criteria was used to calculate takes and Level A threshold distances. Here, SEL$_{cum}$ is used for LF cetaceans, and Peak SPL is used for all other hearing groups (Table 2). Enforcement of mitigation zones via power and shut downs would be implemented during operations, as noted below.

Mitigation During Operations

Mitigation measures that would be adopted during the proposed surveys include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures. Although these measures are proposed by L-DEO based on past experience and for consistency with the PEIS, L-DEO would ultimately follow monitoring and mitigation measures required by the IHA and ITS.
XI. Mitigation Measures

Shut-down Procedures

The operating airgun(s) would be shut down if a marine mammal is seen within or approaching the EZ. Special shut downs at any distance would also be implemented for large whales with a calf, and aggregations (6 or more individuals) of large whales. However, shut downs would not be required for small dolphins that are most likely to approach the vessel.

Following a shut down, airgun activity would not resume until the marine mammal has cleared the EZ. The animal would be considered to have cleared the EZ 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, or
- 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.

The airgun array would be ramped up gradually after a shut down. Ramp-up procedures are described below.

Ramp-up Procedures

A ramp-up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that, for the present survey, this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal has not cleared the EZ as described earlier.

Ramp up would begin with the smallest airgun in the array (40 in³). Ramp-up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals are sighted, a shut down or power down would be implemented, respectively, as though the full array were operational. Ramp up would only commence at night or during poor visibility if the EZ has been monitored acoustically monitored with PAM for 30 min prior to the start of operations without any marine mammal detections during that period.

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.
The proposed activity would take place in the ETP, and no activities would take place in traditional Arctic subsistence hunting area. The proposed activities would not preclude or hinder subsistence activities from occurring within the survey 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.

L-DEO 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 expected monitoring requirements of the IHA. L-DEO’s proposed Monitoring Plan is described below. L-DEO 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. L-DEO 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**

Observations by PSOs would take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations would be shut down when marine mammals 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 near the seismic vessel for at least 30 min prior to the planned start of airgun operations. Observations would also be made during daytime periods when R/V *Langseth* is underway without seismic operations, such as during transits. PSOs would also watch for any potential impacts of the acoustic sources on fish.

During seismic operations, five PSOs would be based aboard R/V *Langseth*. All PSOs would be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals around the seismic vessel; these observers may be referred to as the visual PSOs or “PSVOs”. Use of two simultaneous observers would increase the effectiveness of detecting animals around the source vessel. PSVO(s) would be on duty in shifts of duration no longer than 4 h, or per the IHA. Other crew would also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew would be given additional instruction regarding how to do so.

R/V *Langseth* is a suitable platform for marine mammal observations. When stationed on the observation platform, the eye level would be ~21.5 m above sea level, and the observer would have a good view around the entire vessel. During daytime, the PSVO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.
Passive Acoustic Monitoring

Passive acoustic monitoring (PAM) would take place to complement the visual monitoring program. Visual monitoring typically is not effective during periods of poor visibility or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical monitoring can be used in addition to visual observations to improve detection, identification, and localization of cetaceans. The acoustic monitoring would serve to alert PSVOs (if on duty) when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or by night, and does not depend on good visibility. It would be monitored in real time so that the visual observers can be advised when cetaceans are detected.

The PAM system consists of hardware (i.e., hydrophones) and software. The “wet end” of the system consists of a towed hydrophone array that is connected to the vessel by a tow cable. The tow cable is 250 m long, and the hydrophones are fitted in the last 10 m of cable. A depth gauge is attached to the free end of the cable, and the cable is typically towed at depths <20 m. The array would be deployed from a winch located on the back deck; however, at times, deployment and connection to the vessel may deviate depending upon conditions such as severe weather or airgun configuration. A deck cable would connect the tow cable to the electronics unit in the main computer lab where the acoustic station, signal conditioning, and processing system would be located. The acoustic signals received by the hydrophones are amplified, digitized, and then processed by the Pamguard software. The system can detect marine mammal vocalizations at frequencies up to 250 kHz.

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when R/V Langseth is underway while the airguns are not operating. PAM may not be possible if damage occurs to the array or back-up systems during operations; in that event, the PAM system would be repaired and re-deployed as quickly as possible. One PSO would monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSO monitoring the acoustical data referred to as the PSAO, would be on shift for no longer than 6 h at a time, or per the IHA. All observers would be expected to rotate through the PAM position, although the most experienced with acoustics would be on PAM duty more frequently.

When a vocalization is detected while visual observations are in progress, the PSAO would contact the PSVO immediately, to alert him/her to the presence of cetaceans (if they have not already been seen), and to allow a power or shut down to be initiated, if required. The information regarding the call would be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified dolphin, sperm whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection could also be recorded for further analysis.

PSO Data and Documentation

PSOs would record data to estimate the numbers of marine mammals 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 animals potentially ‘taken’ by harassment (as defined in the MMPA). They would also provide information needed to order a shut down of the airguns when a marine mammal is within or near the EZ.

When a sighting is made, the following information about the sighting would be recorded:
XIII. Monitoring and Reporting Plan

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 power or 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 (airgun power down or 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 in the area where the seismic study is conducted;
4. information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity;
5. data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity; and
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, turtles, and diving ESA-listed seabirds 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.

L-DEO and NSF would coordinate with applicable U.S. agencies (e.g., NMFS, USFWS) and Mexican agencies, and would comply with their requirements.


Ferguson, M.C., J. Barlow, S.B. Reilly, and T. Gerrodette. 2006. Predicting Cuvier’s (Ziphius cavirostris) and Mesoplodon beaked whale population density from habitat characteristics in the Eastern Tropical Pacific Ocean. J. Cetacean Res. Manage. 7(3): 287-299


XV. Literature Cited


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NSF and USGS (National Science Foundation and U.S. Geological Survey). 2011. Final programmatic environmental impact statement/Overseas environmental impact statement for marine seismic research funded by the National Science Foundation or conducted by the U.S. Geological Survey.


LIST OF APPENDICES

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APPENDIX A: DETERMINATION OF MITIGATION ZONES
APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1µPa rms) for Level B takes. Received sound levels have been predicted by L-DEO’s model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the 36-airgun array and for a single 1900LL 40-in³ airgun, which would be used during power downs; all models used a 12-m tow depth. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

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

In deep and intermediate-water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the 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 the 36-airgun array at a maximum tow depth of 12 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. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS). The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey...
to account for the differences in tow depth between the calibration survey (6 m) and the proposed survey (12 m); whereas the shallow water in the GoM may not exactly replicate the shallow water environment at the proposed survey site, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths determined by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array.

For the 36-airgun array, the 150-dB Sound Exposure Level (SEL)\(^1\) corresponds to deep-water maximum radii of 10,553 m for 12-m tow depth (Fig. A-1) and 7244 m for a 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4568 to be applied to the shallow-water 6-m tow depth results. Similarly, the 165 dB SEL corresponds to deep-water maximum radii of 1864 m for 12-m tow depth (Fig. A-1) and 1284 m for 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4517. The 185 SEL corresponds to deep-water maximum radii of 181 m for 12-m tow depth (Fig. A-1) and 126 m for 6-m tow depth (Fig. A-2), yielding a scaling factor of 1.4331. Measured 160-, 175-, and 195-dB re \(1 \mu \text{Pa}_{\text{rms}}\) distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 2.84 km, and 0.24 km, respectively, based on a 95\(^{th}\) percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth difference between 6 and 12 m yields distances of 25,494 m, 4123 m, and 344 m for the 160-, 175-, and 195-dB sound levels, respectively.

Measurements have not been reported for the single 40-in\(^3\) airgun. L-DEO model results are used to determine the 160-dB\(_{\text{rms}}\) radius for the 40-in\(^3\) airgun at a 12-m tow depth in deep water (Fig. A-3). For intermediate-water depths, a correction factor of 1.5 was applied to the deep-water model results. For shallow water, a scaling of the field measurements obtained for the 36-airgun array was used. The 150-dB SEL level corresponds to a deep-water radius of 431 m for the 40-in\(^3\) airgun at 12-m tow depth (Fig. A-3) and 7244 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.0595. Similarly, the 165-dB SEL level corresponds to a deep-water radius of 77 m for the 40-in\(^3\) airgun at 12-m tow depth (Fig. A-3) and 1284 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.060. The 185-dB SEL level corresponds to a deep-water radius of 7.5 m for the 40-in\(^3\) airgun at 12-m tow depth (Fig. A-3) and 126.3 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.0594. Measured 160-, 175-, and 195-dB re \(1 \mu \text{Pa}_{\text{rms}}\) distances in shallow water for the 36-airgun array towed at 6-m depth were 17.5 km, 2.8 km, and 240 m, respectively, based on a 95\(^{th}\) percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the difference in array sizes and tow depths yields distances of 1041 m, 170 m, and 14 m, respectively.

\(^1\) SEL (measured in dB re \(1 \mu \text{Pa}^2 \cdot \text{s}\)) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO’s model.
FIGURE A-1. Modeled deep-water received sound exposure levels (SELS) from the 36-airgun array at a 12-m tow depth planned for use during the proposed survey off the Pacific coast of Mexico. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.
Figure A-2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.
FIGURE A-3. Modeled deep-water received SELs from a single 40-in³ airgun towed at a 12-m depth, which is planned for use during power downs during the proposed survey off the Pacific coast of Mexico. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.
Table A-1 shows the distances at which the 160-dB and 175-dB re 1µPa_{rms} sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criteria (Level B) that is used by NMFS to estimate anticipated takes for marine mammal. The 175-dB level is used by NMFS, based on data from the DoN (2017a), to determine behavioral disturbance for turtles. A recent retrospective analysis of acoustic propagation of R/V *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that in situ measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with in situ received levels² have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat}, respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-4) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). The largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances. The dual criteria for sea turtles (DoN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re 1µPa_{rms}, for Level B harassment (behavior). Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups.

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

² L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).
Table A-3. Level B. Predicted distances to which sound levels $\geq 160$-dB and $\geq 175$-dB re $1 \mu Pa_{rms}$ could be received during the proposed survey off the Pacific coast of Mexico. The 160-dB criterion applies to all hearing groups of marine mammals; the 175-dB criterion applies to sea turtles.

<table>
<thead>
<tr>
<th>Source and Volume</th>
<th>Tow Depth (m)</th>
<th>Water Depth (m)*</th>
<th>Predicted distances (in m) to the 160-dB Received Sound Level</th>
<th>Predicted distances (in m) to the 175-dB Received Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Bolt airgun, 40 in$^3$</td>
<td>12</td>
<td>&gt;1000 m</td>
<td>431$^1$</td>
<td>77$^{1,4}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>647$^2$</td>
<td>116$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;100 m</td>
<td>1041$^3$</td>
<td>170$^3$</td>
</tr>
<tr>
<td>4 strings, 36 airguns, 6600 in$^3$</td>
<td>12</td>
<td>&gt;1000 m</td>
<td>6,733$^1$</td>
<td>1,864$^1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100–1000 m</td>
<td>10,100$^2$</td>
<td>2,796$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;100 m</td>
<td>25,494$^3$</td>
<td>4,123$^3$</td>
</tr>
</tbody>
</table>

* Although no seismic acquisition would occur in shallow water <100 m deep, shallow water areas would be ensonified with sound levels $>160$ dB. $^1$ Distance is based on L-DEO model results. $^2$ Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths. $^3$ Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth. $^4$ An EZ of 100 m would be used as the shut-down distance for sea turtles in all water depths.

**FIGURE A-4.** Auditory weighting functions for the 5 marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.
The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SELcum isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.16067 m/s and a 1/Repetition rate of 23.1 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SELcum PTS thresholds (Level A) for the 36-airgun array and the single 40-in³ mitigation airgun.

For the LF cetaceans during operations with the 36-airgun array, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SELcum isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -12.91 dB assuming a propagation of 20 log₁₀(Radial distance) (Table A-2).

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

For the 36-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SELcum, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-5 shows the impact of weighting functions by hearing group. Figures A-5–A-7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

The thresholds for Peak SPLflat for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-10–A-12 show the modeled received sound levels to the Peak SPLflat thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.
TABLE A-2. Results for modified farfield SEL source level modeling for the 36-airgun array with and without applying weighting functions to various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of $20 \log_{10} (\text{Radial distance})$ is used to estimate the modified farfield SEL.

<table>
<thead>
<tr>
<th>SEL_{cum} Threshold</th>
<th>183</th>
<th>185</th>
<th>155</th>
<th>185</th>
<th>203</th>
<th>204*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial Distance (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no weighting)</td>
<td>315.5691</td>
<td>246.4678</td>
<td>8033.2</td>
<td>246.4678</td>
<td>28.4413</td>
<td>25.1030</td>
</tr>
<tr>
<td>Modified Farfield SEL</td>
<td>232.9819</td>
<td>232.8352</td>
<td>233.0978</td>
<td>232.8352</td>
<td>232.0790</td>
<td>231.9945</td>
</tr>
<tr>
<td>Radial Distance (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(with weighting function)</td>
<td>71.3752</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Adjustment (dB)</td>
<td>-12.91</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

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

FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

For the single 40 in³ mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-6. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 40 in³ airgun are shown in Table A-7. Figure A-13 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-14–A-15 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-16 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 40 in³ airgun, as well as the distances to the PTS thresholds, are
shown in Table A-8. Figures A-17–A-18 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

**TABLE A-3.** Results for single shot SEL source level modeling for the 36-airgun array with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20log_{10} (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-5).
FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}(\text{radial distance})$.

FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).
FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (28.4 m).

FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The
difference in radial distances between Fig. A-7 and this figure (71.4 m) allows us to estimate the adjustment in dB.

**TABLE A-4.** NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and sea turtles and predicted distances to Level A thresholds for various hearing groups that could be received from the 36-airgun array during the proposed surveys off the Pacific coast of Mexico.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds/Sea Turtles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radial Distance to Threshold (m)</td>
<td>45.00</td>
<td>13.57</td>
<td>364.67</td>
<td>51.59</td>
<td>10.62</td>
</tr>
<tr>
<td>Modified Farfield Peak SPL</td>
<td>252.06</td>
<td>252.65</td>
<td>253.24</td>
<td>252.25</td>
<td>252.52</td>
</tr>
<tr>
<td>PTS Peak Isopleth (Radius) to Threshold (m)</td>
<td>38.9</td>
<td>13.6</td>
<td>268.3</td>
<td>43.7</td>
<td>10.6</td>
</tr>
</tbody>
</table>

N.A. means not applicable or not available.

**TABLE A-5.** Level A threshold distances for different marine mammal hearing groups and sea turtles for the 36-airgun array. Following the guidance by NMFS (2016, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances.

<table>
<thead>
<tr>
<th>Level A Threshold Distances (m) for Various Hearing Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Frequency Cetaceans</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>PTS SEL_{cum}</td>
</tr>
<tr>
<td>PTS Peak</td>
</tr>
</tbody>
</table>

2 Using the 50-m shot interval provides more conservative distances than the 400-m shot interval.
FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.
FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-6. Results for single shot SEL source level modeling for the 40 in³ airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL\(_{\text{cum}}\) threshold is the largest. A propagation of 20 log\(_{10}\) (Radial distance) is used to estimate the modified farfield SEL.

<table>
<thead>
<tr>
<th>SEL(_{\text{cum}}) Threshold</th>
<th>183</th>
<th>185</th>
<th>155</th>
<th>185</th>
<th>203</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (m)</td>
<td>9.9893</td>
<td>7.8477</td>
<td>294.0371</td>
<td>7.8477</td>
<td>0.9278</td>
</tr>
<tr>
<td>(no weighting function)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance (m) (with weighting function)</td>
<td>2.3852</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Adjustment (dB)</td>
<td>-12.44</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

*Propagation of 20 \log R.  N.A. means not applicable or not available.

Amplitude spectral density from Farfield signature and effect of auditory weighting for the 5 hearing groups, one 40 cu.in 1900 LL airgun @ 12 m low depth.

FIGURE A-13. Modeled amplitude spectral density of the 40-in³ airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.
TABLE A-7. Results for single shot SEL source level modeling for the single 40-in³ airgun with weighting function calculations for the SELcum criteria, as well as resulting isopleths to thresholds for various hearing groups.

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log10 (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-13).
FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).
FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in$^3$ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in$^3$ mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL$_{cum}$ isopleth for one shot. The difference in radial distances between Fig. A-15 and this figure allows us to estimate the adjustment in dB.

TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL$_{peak}$) for impulsive sources for marine mammals and sea turtles and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 40-in$^3$ airgun during the proposed seismic surveys off the Pacific coast of Mexico.

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Low-Frequency Cetaceans</th>
<th>Mid-Frequency Cetaceans</th>
<th>High-Frequency Cetaceans</th>
<th>Phocid Pinnipeds</th>
<th>Otariid Pinnipeds/Sea Turtles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Threshold</td>
<td>219</td>
<td>230</td>
<td>202</td>
<td>218</td>
<td>232</td>
</tr>
<tr>
<td>Radial Distance to Threshold (m)</td>
<td>1.76</td>
<td>N.A.</td>
<td>12.47</td>
<td>1.98</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
Modified Farfield Peak  |  223.93  |  224.09  |  223.92  |  223.95  |  223.95  
PTS Peak Isopleth (Radius) to Threshold (m)  |  1.76  |  N.A.  |  12.5  |  1.98  |  N.A.  

N.A. means not applicable or not available.

**FIGURE A-17.** Modeled deep-water received Peak SPL from one 40 in$^3$ airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.
FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in³ airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

Literature Cited


Appendix B: Marine Mammal Take Calculations for Non-Territorial Waters
APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS FOR NON-TERRITORIAL WATERS

The ensonified areas that were used to calculate Level A and B takes are detailed in Table B-1 below, and the detailed take calculations are shown in Table B-2.

**TABLE B-1. Areas expected to ensonified (excluding Mexican territorial waters) during the proposed survey in the ETP.**

<table>
<thead>
<tr>
<th>Survey Type</th>
<th>Survey Zone</th>
<th>Criterion</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>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Mammals</td>
<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>0</td>
<td>7</td>
<td>1.25</td>
<td>0</td>
<td>25,494</td>
</tr>
<tr>
<td>OBS</td>
<td>Intermediate 100-1000 m</td>
<td>160 dB</td>
<td>89.7</td>
<td>7</td>
<td>1.25</td>
<td>784.6</td>
<td>9,468</td>
</tr>
<tr>
<td>OBS</td>
<td>Deep &gt;1000 m</td>
<td>160 dB</td>
<td>2793.1</td>
<td>7</td>
<td>1.25</td>
<td>24439.6</td>
<td>6,733</td>
</tr>
<tr>
<td>MCS</td>
<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>0</td>
<td>13</td>
<td>1.25</td>
<td>0</td>
<td>25,494</td>
</tr>
<tr>
<td>MCS</td>
<td>Intermediate 100-1000 m</td>
<td>160 dB</td>
<td>89.7</td>
<td>13</td>
<td>1.25</td>
<td>1457.2</td>
<td>9,468</td>
</tr>
<tr>
<td>MCS</td>
<td>Deep &gt;1000 m</td>
<td>160 dB</td>
<td>2254.5</td>
<td>13</td>
<td>1.25</td>
<td>36635.0</td>
<td>6,733</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>160 dB</td>
<td>5226.9</td>
<td>19</td>
<td>1.25</td>
<td>63316.4</td>
<td></td>
</tr>
<tr>
<td>Sea Turtles</td>
<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>0</td>
<td>7</td>
<td>1.25</td>
<td>0</td>
<td>25,494</td>
</tr>
<tr>
<td>OBS</td>
<td>Intermediate 100-1000 m</td>
<td>160 dB</td>
<td>38.7</td>
<td>7</td>
<td>1.25</td>
<td>338.7</td>
<td>9,468</td>
</tr>
<tr>
<td>OBS</td>
<td>Deep &gt;1000 m</td>
<td>160 dB</td>
<td>753.9</td>
<td>7</td>
<td>1.25</td>
<td>6596.9</td>
<td>6,733</td>
</tr>
<tr>
<td>MCS</td>
<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>0</td>
<td>13</td>
<td>1.25</td>
<td>0</td>
<td>25,494</td>
</tr>
<tr>
<td>MCS</td>
<td>Intermediate 100-1000 m</td>
<td>160 dB</td>
<td>38.7</td>
<td>13</td>
<td>1.25</td>
<td>629.0</td>
<td>9,468</td>
</tr>
<tr>
<td>MCS</td>
<td>Deep &gt;1000 m</td>
<td>160 dB</td>
<td>604.8</td>
<td>13</td>
<td>1.25</td>
<td>9828.2</td>
<td>6,733</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>160 dB</td>
<td>1436.2</td>
<td>19</td>
<td>1.25</td>
<td>17392.8</td>
<td></td>
</tr>
<tr>
<td>Hearing Groups</td>
<td>All zones</td>
<td>LF Cetacean</td>
<td>133.4</td>
<td>7</td>
<td>1.25</td>
<td>1,167.5</td>
<td>320.2</td>
</tr>
<tr>
<td>OBS</td>
<td>All zones</td>
<td>MF Cetacean</td>
<td>5.7</td>
<td>7</td>
<td>1.25</td>
<td>49.5</td>
<td>13.6</td>
</tr>
<tr>
<td>OBS</td>
<td>All zones</td>
<td>HF Cetacean</td>
<td>111.8</td>
<td>7</td>
<td>1.25</td>
<td>978.1</td>
<td>268.3</td>
</tr>
<tr>
<td>OBS</td>
<td>All zones</td>
<td>Otariid</td>
<td>4.4</td>
<td>7</td>
<td>1.25</td>
<td>38.6</td>
<td>10.6</td>
</tr>
<tr>
<td>OBS</td>
<td>All zones</td>
<td>Phocid</td>
<td>18.2</td>
<td>7</td>
<td>1.25</td>
<td>159.2</td>
<td>43.7</td>
</tr>
<tr>
<td>OBS</td>
<td>All zones</td>
<td>Sea Turtle</td>
<td>6.4</td>
<td>7</td>
<td>1.25</td>
<td>56.1</td>
<td>15.4</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>LF Cetacean</td>
<td>107.8</td>
<td>13</td>
<td>1.25</td>
<td>1,752.0</td>
<td>320.2</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>MF Cetacean</td>
<td>4.6</td>
<td>13</td>
<td>1.25</td>
<td>74.3</td>
<td>13.6</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>HF Cetacean</td>
<td>90.3</td>
<td>13</td>
<td>1.25</td>
<td>1,467.7</td>
<td>268.3</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>Otariid</td>
<td>3.6</td>
<td>13</td>
<td>1.25</td>
<td>57.9</td>
<td>10.6</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>Phocid</td>
<td>14.7</td>
<td>13</td>
<td>1.25</td>
<td>238.8</td>
<td>43.7</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>Sea Turtle</td>
<td>5.2</td>
<td>13</td>
<td>1.25</td>
<td>84.1</td>
<td>15.4</td>
</tr>
</tbody>
</table>
### TABLE B-2. Take estimates (excluding takes in Mexican territorial waters) for the proposed survey area off the Pacific coast of Mexico.

<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated Density (#/km²)</th>
<th>Regional Population Size</th>
<th>Level B Ensonified Area (km²)</th>
<th>Population Level A</th>
<th>Level B Ensonified Area (km²)</th>
<th>Population Level B</th>
<th>Level B Takes (All)</th>
<th>Only Level B Takes</th>
<th>Level A Takes</th>
<th>% of Pop. (Total Takes)</th>
<th>Requested Level A/B Take Authorization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humpback whale</td>
<td>0.00013</td>
<td>0.00013</td>
<td>0.00013</td>
<td>2,566</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Minke whale</td>
<td>0.00001</td>
<td>0.00001</td>
<td>0.00001</td>
<td>115</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bryde's whale</td>
<td>0.00049</td>
<td>0.00049</td>
<td>0.00045</td>
<td>649</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>Fin whale</td>
<td>0.00003</td>
<td>0.00003</td>
<td>0.00003</td>
<td>145</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Sei whale</td>
<td>0.00005</td>
<td>0.00005</td>
<td>0.00005</td>
<td>29,600</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Blue whale</td>
<td>0.00010</td>
<td>0.00009</td>
<td>0.00008</td>
<td>773</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td><strong>MF Cetaceans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotted dolphin (oriental)</td>
<td>0.00019</td>
<td>0.00019</td>
<td>0.00019</td>
<td>2,810</td>
<td>MF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Common bottlenose dolphin</td>
<td>0.00032</td>
<td>0.00033</td>
<td>0.00036</td>
<td>25,300</td>
<td>MF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>124</td>
<td>0</td>
</tr>
<tr>
<td>Longman's beaked whale</td>
<td>0.00004</td>
<td>0.00004</td>
<td>0.00004</td>
<td>1,007</td>
<td>MF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>124</td>
<td>0</td>
</tr>
<tr>
<td>Risso's dolphin</td>
<td>0.00017</td>
<td>0.00017</td>
<td>0.00017</td>
<td>24,084</td>
<td>MF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>124</td>
<td>0</td>
</tr>
<tr>
<td>Short-beaked common dolphin</td>
<td>0.04839</td>
<td>0.04502</td>
<td>0.03957</td>
<td>61,536</td>
<td>MF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>124</td>
<td>0</td>
</tr>
<tr>
<td>Bottlenose dolphin</td>
<td>0.00001</td>
<td>0.00001</td>
<td>0.00001</td>
<td>2,566</td>
<td>LF</td>
<td>0</td>
<td>2,242</td>
<td>61,075</td>
<td>0</td>
<td>2,920</td>
<td>0</td>
</tr>
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<td>0.00001</td>
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<td>LF</td>
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<td>2,920</td>
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<td>0.00049</td>
<td>0.00045</td>
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<td>LF</td>
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<td>2,242</td>
<td>61,075</td>
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<td>0.00001</td>
<td>0.00001</td>
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<td>LF</td>
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<td>2,242</td>
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<td>0.03957</td>
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<td>61,075</td>
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<td><strong>Deep &gt;1000 m</strong></td>
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<tr>
<td><strong>Level B + A Takes</strong></td>
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</tr>
<tr>
<td><strong>N.A. means not available or not applicable.</strong></td>
<td></td>
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</tr>
</tbody>
</table>

1. Population size in italics is for larger Pacific or ETP, not just Pacific waters of Mexico.
APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS FOR MEXICAN TERRITORIAL WATERS
APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS FOR MEXICAN TERRITORIAL WATERS

The ensonified areas that were used to calculate Level A and B takes are detailed in Table C-1 below, and detailed take calculations are shown in Table C-2. Based on the proposed line configuration (see Fig. 1), here we have assumed that the vessel would be acquiring refraction (OBS) seismic data in territorial seas on 3 days and MCS data on 5 days.

TABLE C-1. Areas expected to ensonified in Mexican territorial waters during the proposed survey off Mexico.

<table>
<thead>
<tr>
<th>Survey Type</th>
<th>Survey Zone</th>
<th>Criterion</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>
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<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>119</td>
<td>3</td>
<td>1.25</td>
<td>448</td>
<td>25,494</td>
</tr>
<tr>
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<td>Intermediate 100-1000 m</td>
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<td>3</td>
<td>1.25</td>
<td>1151.6</td>
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<td>3</td>
<td>1.25</td>
<td>1.6</td>
<td>6,733</td>
</tr>
<tr>
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<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>119</td>
<td>5</td>
<td>1.25</td>
<td>746</td>
<td>25,494</td>
</tr>
<tr>
<td>MCS</td>
<td>Intermediate 100-1000 m</td>
<td>160 dB</td>
<td>307.1</td>
<td>5</td>
<td>1.25</td>
<td>1919.4</td>
<td>9,468</td>
</tr>
<tr>
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<td>Deep &gt;1000 m</td>
<td>160 dB</td>
<td>0.4</td>
<td>5</td>
<td>1.25</td>
<td>2.7</td>
<td>6,733</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td></td>
<td></td>
<td>160 dB</td>
<td>20</td>
<td>1.25</td>
<td>4269.4</td>
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<td><strong>Sea Turtles</strong></td>
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<tr>
<td>OBS</td>
<td>Shallow &lt;100 m</td>
<td>160 dB</td>
<td>0</td>
<td>3</td>
<td>1.25</td>
<td>1</td>
<td>25,494</td>
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<tr>
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<td>1.25</td>
<td>336.3</td>
<td>9,468</td>
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<tr>
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<td>Deep &gt;1000 m</td>
<td>160 dB</td>
<td>0.1</td>
<td>3</td>
<td>1.25</td>
<td>0.3</td>
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<tr>
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<td>160 dB</td>
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<td>1.25</td>
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<td>6,733</td>
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<tr>
<td><strong>Overall</strong></td>
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<td></td>
<td>160 dB</td>
<td>20</td>
<td>1.25</td>
<td>900.5</td>
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<td>1.25</td>
<td>34.0</td>
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<tr>
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<td>3</td>
<td>1.25</td>
<td>1.4</td>
<td>13.6</td>
</tr>
<tr>
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<td>All zones</td>
<td>HF Cetacean</td>
<td>7.6</td>
<td>3</td>
<td>1.25</td>
<td>28.4</td>
<td>268.3</td>
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<td>All zones</td>
<td>Otariid</td>
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<td>1.25</td>
<td>1.1</td>
<td>10.6</td>
</tr>
<tr>
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<td>Phocid</td>
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<td>3</td>
<td>1.25</td>
<td>4.6</td>
<td>43.7</td>
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<td>Sea Turtle</td>
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<td>1.25</td>
<td>1.6</td>
<td>15.4</td>
</tr>
<tr>
<td>MCS</td>
<td>All zones</td>
<td>LF Cetacean</td>
<td>9.1</td>
<td>5</td>
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<td>56.6</td>
<td>320.2</td>
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<tr>
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<td>All zones</td>
<td>MF Cetacean</td>
<td>0.4</td>
<td>5</td>
<td>1.25</td>
<td>2.4</td>
<td>13.6</td>
</tr>
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<td>1.25</td>
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<td>Phocid</td>
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<td>5</td>
<td>1.25</td>
<td>7.6</td>
<td>43.7</td>
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<tr>
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<td>All zones</td>
<td>Sea Turtle</td>
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<td>5</td>
<td>1.25</td>
<td>2.7</td>
<td>15.4</td>
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### TABLE C-2. Take estimates for Mexican territorial waters for the proposed survey area off the Pacific coast of Mexico.

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<tr>
<th>Species</th>
<th>Estimated Density (#/km²)</th>
<th>Regional Population Size¹</th>
<th>Hearing Group</th>
<th>Level A Ensonified Area (km²)</th>
<th>Level A Takes</th>
<th>Level B Ensonified Area (km²)</th>
<th>Level B Takes</th>
<th>Level B Takes (All)</th>
<th>Level A Takes</th>
<th>% of Pop.</th>
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</thead>
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<tr>
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<td>Shallow &lt;100 m</td>
<td>Intermediate 100-1000 m</td>
<td>Deep &gt;1000 m</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>LF Cetaceans</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
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<td>0.00013</td>
<td>0.00013</td>
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<td>3,071</td>
<td>4</td>
<td>91</td>
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<td>0.00001</td>
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<td>3,071</td>
<td>4</td>
<td>91</td>
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<td>3,071</td>
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<td>LF</td>
<td>1,194</td>
<td>3,071</td>
<td>4</td>
<td>91</td>
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<td>LF</td>
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<td>0.00107</td>
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<td>3,071</td>
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<td>1,007</td>
<td>MF</td>
<td>1,194</td>
<td>3,071</td>
<td>4</td>
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<td>0</td>
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<td>0.00036</td>
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<td>MF</td>
<td>1,194</td>
<td>3,071</td>
<td>4</td>
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<td>3,071</td>
<td>4</td>
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<td>3,071</td>
<td>4</td>
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<td>3,071</td>
<td>4</td>
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<td>N.A.</td>
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<td>0.00183</td>
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<td>3,071</td>
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N.A. means not available or not applicable.

¹ Population size in italics is for larger Pacific or ETP, not just Pacific waters of Mexico.