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* of the Puerto Rico Trench and Southern Slope of Puerto Rico, Northwest Atlantic Ocean

submitted by

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to

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SUMMARY

Researchers from Woods Hole Oceanographic Institution (WHOI), University of Texas Institute of Geophysics (UTIG), and University of Puerto Rico Mayagüez (UPRM), with funding from the U.S. National Science Foundation (NSF) and in collaboration with the United States Geological Survey (USGS) and researchers from the GEOMAR Helmholtz Centre for Ocean Research (GEOMAR) in Kiel, Germany, propose to conduct high-energy seismic surveys from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*) of the Puerto Rico Trench and southern slope of Puerto Rico in the North Atlantic Ocean. The USGS also proposes to conduct low-energy seismic surveys in the Caribbean Sea during the cruise. The seismic surveys would take place within the Exclusive Economic Zones (EEZ) and coastal zone of Puerto Rico, and the EEZs of the Dominican Republic, U.S. Virgin Islands, and British Virgin Islands. The surveys would use two different airgun configurations: (a) 36-airgun towed array with a total discharge volume of ~6600 in^3 in water depths ranging from ~100 m to 8400 m for the high-energy surveys, and (b) two 45/105-in^3 GI airguns with a total discharge volume of 90 in^3 off southern Puerto Rico in water depths ranging from ~100 m to 3000 m for the USGS low-energy surveys.

Numerous species of marine mammals inhabit the proposed marine project area in the North Atlantic Ocean. Under the U.S. Endangered Species Act (ESA), several of these species are listed as ***endangered***, including the sei, fin, blue, and sperm whales, which are managed by NMFS. Thus, 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).

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 areas, 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 high-energy seismic surveys with the 36-airgun array would seek to provide new constraints for examining earthquake and tsunami hazards associated with the Puerto Rico Trench region, and the low-energy surveys with the 2-GI guns would support USGS research to understand earth processes and the natural hazards they pose to Puerto Rico and the Virgin Islands. The proposed marine seismic surveys would occur within ~17–21°N, ~63.6–68.5°W; representative survey tracklines are shown in Figure 1. The surveys are proposed to occur within EEZ of Puerto Rico, U.S. Virgin Islands, British Virgin Islands, and the Dominican Republic, in water depths ranging from ~100–8400 m.

The main goal of the high-energy seismic program proposed by the Principal Investigators (PIs) Drs. J.P. Canales (WHOI), S. Han (UTIG), and E. Vanacore (UPRM) is to investigate the Puerto Rico Trench, its outer rise, and across the island of Puerto Rico, and provide data necessary to illuminate the depth, geometry, and physical properties of the seismogenic fault interface between the subducting Atlantic plate and the overlying accretionary wedge/Puerto Rico arc/Caribbean plate, as well as seismogenic structures in the accretionary wedge and submarine slopes of the island of Puerto Rico. To achieve project goals of the high-energy seismic surveys, the PIs propose to utilize the airgun capabilities of R/V *Langseth*. Dr. I. Grevemeyer (GEOMAR) would collaborate with the PIs of the Puerto Rico Trench project and would contribute ultra-deep sea Ocean Bottom Seismometers (OBSs) necessary for achieving the objectives. Land seismometers would also be used during the project. The low-energy seismic surveys proposed by PI U. ten Brink (USGS) would be located over the 2019–2020 area of seismic activity in the Caribbean Sea to define the geometry of the faults that ruptured and produced earthquakes of magnitude Mw≤6.4 and other potential seismogenic structures.

The high-energy surveys would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array at a depth of 12 m; the shot interval would be 50 m (~24 s) during multi-channel seismic (MCS) reflection surveys with the hydrophone streamer and 400 m (155 s) during OBS seismic refraction surveys. The receiving system would consist of a 15-km long solid state hydrophone streamer, 31 short-period OBSs, and 10 ultra-deep-water broadband OBSs. The surveys would occur in water ~100–8400 m. For the low-energy surveys, two 45/105-in^3 GI airguns with a total discharge volume of 90 in^3 would be used. The receiving system would consist of a 150-m long solid-state hydrophone streamer. The array would be towed at a depth of 3 m, and the shot interval would be 6.25 m (2.7 s). The low-energy surveys would occur in water depths ranging from ~100 m to 3000 m.

. Land seismometers would be deployed ~2 weeks prior to the start of marine seismic operations. The low-energy USGS surveys, consisting of ~3 days of seismic operations, would then take place. This would be followed by a 42-day cruise for the proposed high-energy surveys with the 36-airgun array, including ~21 days of seismic operations, 20 days for equipment deployment/recovery, and 2 days of transit/contingency time. R/V *Langseth* would likely leave out of and return to port in San Juan, Puerto Rico, during fall 2023.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys; acoustic pingers would also be used. 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.

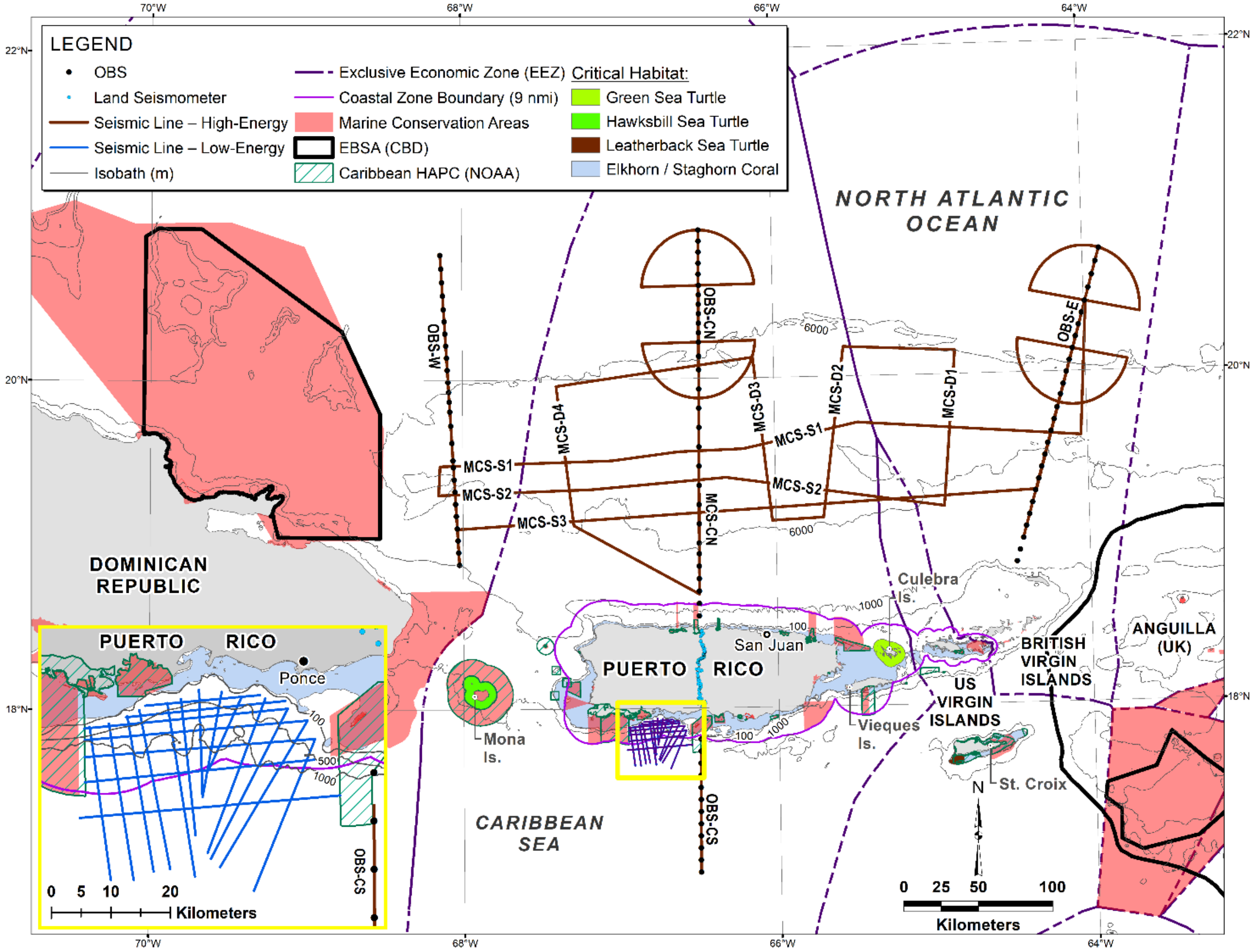

FIGURE 1. Location of the proposed seismic surveys (low-energy USGS surveys shown in inset), OBS deployments, land seismometer locations, marine conservation areas, and marine critical habitat. EBSA = ecologically and biologically significant marine areas (designated by the Convention of Biological Diversity or CBD). HAPC = habitat of particular concern.

Source 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 Records of Decision (NSF 2012; USGS 2013) referred to herein as the PEIS. The vessel speed during seismic operations with the 36-airgun array would be ~4.1 kt (~7.6 km/h) during MCS seismic reflection surveys and 5.0 kt (~9.3 km/h) during OBS seismic refraction surveys. During the low-energy surveys, the vessel speed would be ~4.5 kt (~8.3 km/h) during seismic acquisition. When R/V *Langseth* is towing the airgun array and 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 MCS seismic reflection and OBS seismic refraction surveys, R/V *Langseth* would tow four strings with 36 airguns (plus 4 spares); the strings are spaced 16 m apart, with the airguns and 1 spare airgun spaced 2–3.5 m along each string. The airgun array consists of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The four airgun strings would be distributed across an area of ~24x16 m behind the *Langseth* and would be towed ~140 m behind the vessel. During the high-energy surveys, all four strings, totaling 36 active airguns with a total discharge volume of 6600 in^3, would be used. The array would be towed at a depth of 12 m, and the shot interval would be 50 m (~24 s) during MCS seismic reflection surveys and 400 m (155 s) during OBS seismic refraction surveys. The airgun array and its source level and frequency components are described in § 2.2.3.1 of the PEIS and summarized below, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. During the USGS low-energy surveys, R/V *Langseth* would tow a 2 GI-airgun cluster in true GI (45/105 in^3) mode as the seismic source, with a total discharge volume of 90 in^3. The two inline GI airgun would be spaced 2.46 m apart. The array would be towed at a depth of 3 m, and the shot interval would be 6.25 m (~2.7 s). The firing pressure of the airguns is 1900 psi. During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns would be silent during the intervening periods.

36-Airgun Array Specifications

Energy Source	Thirty-six 1900 psi Bolt airguns of 40–360 in^3, in four strings each containing nine operating airguns
Source output (downward)	0-pk is 84 bar-m (259 dB re 1 μPa · m); pk-pk is 177 bar · m (265 dB)
Air discharge volume	~6600 in^3
Dominant frequency components	2–188 Hz

2 GI Airgun Array Specifications

Energy Source	Two 45/105 in^3 GI airguns
Source output (downward)	0-pk is 3.6 bar-m (231.1 dB re 1 μPa · m); pk-pk is 7.1 bar · m (237 dB re 1 μPa · m)
Air discharge volume	~90 in^3
Gun positions used	Two inline GI guns 2.46 m apart
Dominant frequency components	2–188 Hz

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

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

Mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the exclusion zones (EZ) for Level A takes (for the 36-airgun array, only) and for the Level B (160 dB re 1μPa_{rms}) threshold (for the 36-airgun and 2-GI airgun arrays). The background information and methodology for this are provided in Appendix A. L-DEO model results are used to determine the 160-dB_{rms} radius for the various airgun sources down to a maximum depth of 2000 m (see Appendix A), as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5.

Table 1 shows the distances at which the 160-dB re 1μPa_{rms} sound levels are expected to be received for the 36-airgun array, a single 40 in^3 (mitigation) airgun, and a 2-GI airgun cluster. 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 various airgun sources; this level is used by NMFS, based on US DoN (2017), to determine behavioral disturbance for sea turtles.

The NSF and USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤180 dB re 1 μPa_{rms} (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤250 in^3. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-m EZ for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach is used here for the pair of 45/105 in^3 GI airguns in all water depths. A fixed 160-dB “Safety Zone” was not defined for the same suite of low-energy sources in the NSF and USGS PEIS.

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

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[1] The rms (root mean square) pressure is an average over the pulse duration.

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

Source and Volume	**Tow Depth (m)**	**Water Depth (m)**	**Predicted distances (in m) to the 160-dB Received Sound Level**	**Predicted distances (in m) to the 175-dB Received Sound Level**
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]	77[1,3]
		100–1000 m	647[2]	116[2]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]	1,864[1]
		100–1000 m	10,100[2]	2,796[2]
Two 45/105 in^3 GI airguns	3	>1000 m	438[1]	78[1,3]
		100–1000 m	657[2]	117[2]

[1] Distance is based on L-DEO model results. [2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths. [3] An EZ of 150 m would be used as the shut-down distance for ESA-listed sea turtles and 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 based on a shot interval of 50 m[1]. Consistent with NMFS (2016, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
PTS SEL_{cum}	**320.2**	0	1.0	10.4	0	**15.4**
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	10.6

[1] Using the 50-m shot interval provides more conservative distances than the 400-m shot interval.

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). We have proposed monitoring and mitigation measures that have been required by NMFS for other similar recent high- and low-energy seismic surveys. Enforcement of mitigation zones via power and shut downs would be implemented as described in § XI or as otherwise required by regulators.

OBS Description and Deployment

Four refraction lines would be acquired using OBSs: East, West, and Central-North, and Central-South. Refraction data would be acquired using 31 short-period OBSs from the Ocean Bottom Seismometer Instrument Center (OBSIC) at WHOI. Short-period OBSs would be deployed at a total of 69 sites in water depths <6000 m by R/V *Langseth*. Fifteen ultra-deep-water OBSs provided by GEOMAR would be deployed at a total of 25 sites in water depths of ~6000–8400 m. Following refraction shooting of one line, OBSs on that line would be recovered, serviced, and redeployed on a subsequent refraction line. The OBSIC OBSs have a height of ~1 m, a diameter of ~0.5 m, and a weight ~22 kg; the steel anchor is 30.5 cm x 38 cm x 2.5 cm high and weighs ~24 kg. The GEOMAR OBSs have a height of ~0.5 m, a diameter of ~1 m, and a weight ~60 kg, including the steel anchor. All OBSs would be recovered by the end of the survey. To retrieve the OBSs, the instrument is released via an acoustic release system to float to the surface from the anchor, which is not retrieved.

Description of Operations

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 high-energy surveys would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume of ~6600 in^3 at a depth of 12 m. The receiving system would consist of a 15-km long solid-state hydrophone streamer, 31 short-period OBSs, and 10 GEOMAR ultra-deep-water broadband OBSs. For the low-energy surveys, two 45/105-in^3 GI airguns with a total discharge volume of 90 in^3 would be towed at a depth of 3 m from R/V *Langseth* The receiving system would consist of a 150-m long solid-state hydrophone streamer. As the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis.

The following generally describes the proposed data collection plan::

(1) Acquisition of wide-angle reflection/refraction seismic data using OBSs would occur along four major transects: Central-North (OBS-CN), Central-South (OBS-CS), East (OBS-E), and West (OBS-W).

(2) MCS data would be acquired along transects MCS-D1, D2, D3, and D4 and along transects MCS-S1, S2, and S3. MCS-CN, -W, and -E coinciding with the OBS profiles north of the island; thus, those transects would be acquired twice (once with OBS and once with MCS). The Central South line (OBS-CS) would only be acquired once during OBS refraction surveys.

(3) Low-energy MCS surveys would occur on the southwestern flank of Puerto Rico over the location of recent seismic activity.

(4) An array of short-period nodal land seismometers would be deployed on Puerto Rico on properties along PR-149 to connect the Central and Central South OBS marine profiles.

Approximately 4630 km of seismic acquisition are proposed. During the high-energy surveys, ~4070 km of transect lines would be surveyed (~2565 km of 2-D MCS seismic reflection data and 1505 km of OBS refraction data); the low-energy USGS surveys would consist of ~560 line km. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations (see § 4.1.1.5), 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. All of the high-energy surveys with the 36-airgun array would occur in deep water >1000 m deep. For the low-energy USGS surveys conducted with the 2-GI airguns, 43% would occur in intermediate-depth water 100–1000 m deep, and 57% would take place in deep water >1000 m; no effort would occur in shallow water (<100 m deep).

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, and acoustic pingers would be used to retrieve OBSs. These sources are described in § 2.2.3.1 of the PEIS and Section 2.1.2.7 of the associated Draft EA.

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 marine seismic surveys would occur within ~17–21°N, ~63.6–68.2°W; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, for the surveys, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within the EEZ of Puerto Rico, U.S. Virgin Islands, British Virgin Islands, and the Dominican Republic, in water depths ranging from ~100–8400 m. The closest approach of the proposed low-energy survey lines to land on the south side of Puerto Rico is ~2.5 km from Isla de Ratones (Isla Piñero), ~3.4 km from Cayo Maria Langa, and ~3 km from Cayo Aurora. The closest approach of the high-energy survey lines to the coast of Puerto Rico is ~22 km, 28 km to the British Virgin Islands, 42 km to Dominican Republic, and 77 km to the U.S. Virgin Islands.

The proposed high-energy surveys with the 36-airgun array would be expected to last for 42 days, including ~21 days of seismic operations, 20 days for equipment deployment/recovery, and 2 days transit/contingency time. The low-energy USGS surveys would consist of ~3 days of seismic operations. Land seismometers would be deployed ~2 weeks prior to the start of marine seismic operations. R/V *Langseth* would likely leave out of and return to port in San Juan, Puerto Rico, during fall 2023.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

According to Debrot et al. (2013), at least 33 marine mammal species have been documented in the Wider Caribbean Region (WCR). Mignucci-Gianonni (1998) reported 17 species of cetaceans for Puerto Rico and the Virgin Islands. The distribution and abundance of marine mammals in the northern Caribbean Sea are poorly known (Roden and Mullin 2000; Mignucci-Giannoni 1998). Twenty-eight species of cetaceans could occur within the proposed survey areas in the Northwest Atlantic Ocean, including six mysticetes (baleen whales) and 22 odontocetes (toothed whales) (Table 3); four of these marine mammals are listed as ***endangered*** under the ESA, including the sperm, blue, sei, and fin whales.

TABLE 3. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed project area off Puerto Rico, Northwest Atlantic Ocean.

Species	**Habitat**	**Occurrence in study area off Puerto Rico at time of surveys[1]**	**Abundance for Western North Atlantic / GoM[2]**	**Abundance for Western North Atlantic / GoM[3]**	**Conservation Status**				
					US ESA[4]	**SPAW[5]**	**DR Red List[6]**	**IUCN[7]**	**CITES[8]**
Mysticetes									
Fin whale	Coastal, pelagic	Rare	6,802	5,746	E	II	-	VU	I
Blue whale	Pelagic	Rare	402[10]	11	E	II	-	EN	
Sei whale	Pelagic	Rare	6,292[11]	1,519	E	II	-	EN	
Bryde's whale	Pelagic & coastal	Rare	-	7	E	II	-	LC	I
Minke whale	Coastal waters	Uncommon	21,968[12]	2,420	NL	II	-	LC	I
Humpback whale *West Indies DPS*	Mainly nearshore & banks	Uncommon	1,396[13]	1,897	NL	II	-	LC[9]	I
Odontocetes									
Sperm whale	Usually pelagic & deep seas	Common	4,349[14] / 1,180	5,353 / 2,128	E	II	-	VU	I
Pygmy sperm whale	Deeper waters off the shelf	Uncommon	7,750[15] / 336	678[15] / 2,234	NL	II	-	DD	II
Dwarf sperm whale	Deeper waters off the shelf	Uncommon	7,750[15] / 336	678[15] / 2,234	NL	II	-	DD	II
Cuvier's beaked whale	Pelagic	Uncommon	5,744 / 18	14,491[17] / 2,910	NL	II	-	LC	II
Gervais' beaked whale	Pelagic	Uncommon	10,107[16] / 20	14,491[17] / 2,910	NL	II	-	DD	II
Blainville's beaked whale	Pelagic	Uncommon	10,107[16] / 98	14,491[17] / 2,910	NL	II	-	DD	II
True's beaked whale	Pelagic	Rare	10,107[16]	14,491[17] / 2,910	NL	II	-	LC	II
Rough-toothed dolphin	Mostly pelagic	Common	136	532 / 4,853	NL	II	-	LC	II
Bottlenose dolphin	Continental Shelf, coastal & offshore	Common	62,851[18] / 7,462[19]	97,476 / 138,602	NL	II	VU	LC	II
Pantropical spotted dolphin	Mainly pelagic	Common	6,593 / 37,195	4,436 / 84,014	NL	II	-	LC	II
Atlantic spotted dolphin	Mainly coastal waters	Common	39,921 / 21,506	55,436 / 47,488	NL	II	-	LC	II
Spinner dolphin	Coastal, pelagic	Common	4,102 / 2,991	262 / 13,485	NL	II	-	LC	II
Clymene dolphin	Pelagic	Uncommon	4,237 / 513	12,515 / 11,000	NL	II	-	LC	II
Striped dolphin	Off the continental shelf	Common	67,036 / 1,817	75,657 / 4,914	NL	II	-	LC	II
Fraser's dolphin	Water >1000 m	Uncommon	-. / 213	492 / 1,665	NL	II	-	LC	II
Common dolphin	Shelf, pelagic	Common	172,974	86,098	NL	II	-	LC	II
Risso's dolphin	Waters 400-1000 m	Common	35,215 / 1,974	7,732 / 3,173	NL	II	-	LC	II

Species	Habitat	Occurrence in study area off Puerto Rico at time of surveys[1]	Abundance for Western North Atlantic / GoM[2]	Abundance for Western North Atlantic / GoM[3]	Conservation Status				
					US ESA[4]	SPAW[5]	DR Red List[6]	IUCN[7]	CITES[8]
Melon-headed whale	Oceanic	Common	- / 1,749	1,175 / 6,733	NL	II	-	LC	II
Pygmy killer whale	Oceanic	Uncommon	- / 613	- / 2,126	NL	II	-	LC	II
False killer whale	Pelagic	Uncommon	1,791 / 494	95 / 3,204	NL	II	-	NT	II
Killer whale	Widely distributed	Uncommon	- / 267	11 / 185	NL	II	-	DD	II
Short-finned pilot whale	Mostly pelagic	Common	28,924 / 1,321	18,977[20] / 1,981	NL	II	-	LC	II

- not available. DR = Dominican Republic.

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

[2] Abundance estimates from U.S. Atlantic and Gulf of Mexico Draft Marine Mammal Stock Assessment (Hayes et al. 2022; NMFS 2022) unless otherwise indicated; if only one values is given, it is for the Atlantic. No abundance estimates are available for the Puerto Rico/U.S. Virgin Islands stock.

[3] Abundance estimates for Western Atlantic and Gulf of Mexico from Roberts et al. (2016); if only one values is given, it is for the Atlantic.

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

[5] Specially Protected Areas and Wildlife Protocol of the Cartagena Convention: Annex II, strictly protected fauna. Accessed at https://www.unep.org/cep/what-we-do/specially-protected-areas-and-wildlife-spaw.

[6] Lista de Especies en Peligro de Extinción, Amenzadaso Protegidas de la República Dominicana, List Roja (Ministro de Medio Ambiente y Recursos Naturales 2011): VU = Vulnerable (risk of extinction in the médium term).

[7] International Union for the Conservation of Nature Red List of Threatened Species version 2021-1: VU = vulnerable; NT = near threatened; LC = least concern; DD = data deficient.

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

[9] Global status.

[10] Minimum population size.

[11] Nova Scotia.

[12] Canadian East Coast.

[13] Gulf of Maine.

[14] North Atlantic.

[15] Estimate includes dwarf and pygmy sperm whales.

[16] Estimate includes all Mesoplodont whales in the North Atlantic, including Sowerby's beaked whale.

[17] Beaked whale guild

[18] Offshore stock.

[19] Oceanic stock.

[20] Pilot whale guild.

It is unlikely that Sowerby's beaked whales (*Mesoplodon bidens*), northern bottlenose whale (*Hyperoodon ampullatus*), North Atlantic right whales (*Eubalaena glacialis*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), white-beaked dolphins (*Lagenorhynchus albirostris*), and harbor porpoise (*Phocoena phocoena*) would be encountered. Additionally, pinniped occurrence in the Caribbean is extralimital and is not discussed further. 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. The Caribbean Sea detailed analysis area (DAA), as defined in the PEIS, is located just south of the proposed survey areas; The Northwestern Atlantic DAA is located northeast of the proposed survey areas. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of baleen whales and toothed whales are given in § 3.6.1 and § 3.7.1, respectively, of the PEIS. The rest of this section deals specifically with the distribution of cetaceans within the proposed survey areas off Puerto Rico.

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). It is highly migratory, undertaking one of the world's longest mammalian migrations by traveling between mid- to high-latitude waters where it feeds during spring to fall and low-latitude wintering grounds over shallow banks, where it mates and calves (Winn and Reichley 1985; Bettridge et al. 2015). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Calambokidis et al. 2001; Garrigue et al. 2002, 2015; Zerbini et al. 2011).

In the western North Atlantic, the humpback whale occurs from Greenland to Venezuela (Würsig et al. 2000). For most North Atlantic humpbacks, the summer feeding grounds range from the northeast coast of the U.S. to the Barents Sea (Katona and Beard 1990; Smith et al. 1999). In the winter, the majority of humpback whales migrate to wintering areas in the West Indies (Smith et al. 1999); this is known as the West Indies Distinct Population Segment (DPS) (Bettridge et al. 2015). Feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016a). According to Hayes et al. (2020), NMFS is currently reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (e.g., NMFS 2016b). The West Indies DPS population is estimated at 10,852 individuals (Stevick et al. 2003a).

Stevick et al. (2018) found that the timing and migration destinations of humpback whales in the northwestern and southeastern Caribbean are different and suggested that there could be two different breeding populations in the West Indies. Stevick et al. (2003b) reported that males were often seen on breeding grounds earlier than females. Some individuals from the North Atlantic are known to migrate to Cape Verde to breed (e.g., Wenzel et al. 2009). A small proportion of the Atlantic humpback whale population remains in high latitudes in the eastern North Atlantic during winter (e.g., Christensen et al. 1992).

The largest winter concentration of humpbacks occurs at Silver and Navidad Banks off northeastern Dominican Republic (Mattila et al. 1989; Whitehead and Moore 1992). Hundreds of humpbacks aggregate there from January through March to calve (Mattila et al. 1989). Mona Passage (Puerto Rico), Virgin Bank, and Anguilla Bank are also considered to be major calving grounds (Mattila and Clapham 1989). Humpback whales are commonly sighted in Puerto Rico and the Virgin Islands during the winter

(Mignucci-Giannoni 1998). Hotspots for humpback whales off the west coast of Puerto Rico are related to bathymetry, with groups of two or more primarily occurring in deeper water, singing males occur near the shelf edge, whereas non-singing individuals occur farther from the shelf edge; mother-calf pairs primarily occur in shallow water, unless they are with an escort, in which case they were seen farther from shore (MacKay et al. 2016). Similarly, Sanders et al. (2005) reported that mother-calf pairs sighted off northwestern Puerto Rico from January–March were most frequently reported in shallow water <100 m deep.

Samaná Bay, on the northeastern coast of the Dominican Republic, is also recognized as an important winter ground for western North Atlantic humpback whales (Mattila et al. 1994; Betancourt et al. 2012). Photo identification has shown that whales that occurred in the Dominican Republic were seen at high-latitude feeding areas, such as the Gulf of Maine, Newfoundland, Gulf of St. Lawrence, and Greenland), as well as at other regions in the West Indies, such as Silver Bank and Navidad Bank off Dominican Republic, Puerto Rico, Guadeloupe, Virgin Bank, and Anguilla Bank (Mattila et al. 1989, 1994; MacKay et al. 2019), even within the same season (e.g., MacKay et al. 2019). Two humpbacks outfitted with satellite transmitters near the Dominican Republic during winter and spring of 2008–2012 were later reported off the east coast of Canada (Kennedy et al. 2014). Humpback whale vocalizations were recorded off the northern Dominican Republic during each month from December 2016 through May 2017 (Heenehan et al. 2019). Humpback whales were sighted within the proposed survey areas during winter 1995 (Roden and Mullin 2000), winter 2000 (Swartz et al. 2001), and winter 2001 (Swartz et al. 2002); they were also detected there acoustically during winter 2001 (Swartz et al. 2002). Although most sightings of humpbacks occur off the northern Dominican Republic, four sightings were made during March 2005 off the southern coast (Whaley et al. 2006). There are numerous records of humpbacks throughout the proposed study area, including sightings in offshore waters to the north of Puerto Rico, nearshore sightings off western Puerto Rico and around the Virgin Islands, and numerous sightings on Silver and Navidad banks north of the Dominican Republic; all sightings were reported for January–March (OBIS 2021). However, some sightings have been reported in nearshore waters of northern Puerto Rico and the U.S. Virgin Islands during fall (DoN 2002).

Common Minke Whale (*Balaenoptera acutorostrata*)

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

Minke whales occur in the southeastern U.S. and Caribbean during the winter; however, a lack of acoustic detection in the region during summer indicates either absence of minke whales at that time of year, or a change in vocal behavior at different times of the year (Risch et al. 2014). Risch et al. (2014) deployed acoustic detectors throughout the North Atlantic to detect minke whale occurrence; one recorder was deployed in the Caribbean, at Saba Bank. There, minke whales were acoustically detected during winter and spring (Risch et al. 2014). Minke whale vocalizations were also recorded 200–350 km off northeastern Puerto Rico, March 1994 (Mellinger et al. 2000). Mignucci-Giannoni (1998) reported three sightings for Puerto Rico and the Virgin Islands up to 1989. One minke whale was sighted in the proposed survey area north of Puerto Rico during winter 1995 (Roden and Mullin 2000). Another sighting of a minke was made in offshore waters of the proposed survey area north of Puerto Rico on 20 January 2014 (Rodriguez-Ferrer et al. 2018). In the OBIS database, there are 16 records of minke whales for the northeastern portion of the proposed survey area; all sightings were reported during March 1994 (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). It does not undertake long north/south migrations, although local seasonal movements toward the Equator in winter and to higher latitudes in summer take place in some areas (Evans 1987; Jefferson et al. 2015). One stranding has also been reported for the U.S. Virgin Islands (Mignucci-Giannoni 1996; Mignucci-Giannoni et al. 1999a). Erdman (1970 *in* Ward et al. 2001) reported sightings for Puerto Rico and the Virgin Islands. There are no sightings in the OBIS database for the proposed survey areas or in the Caribbean Sea (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). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985). A small number of individuals have been sighted in the eastern North Atlantic between October and December, indicating that some animals may remain at higher latitudes during winter (Evans 1992). Sei whales have been seen from South Carolina south into the Gulf of Mexico and the Caribbean during winter (Rice 1998); however, the location of sei whale wintering grounds in the North Atlantic is unknown (Víkingsson et al. 2010). There are three sei whale stocks in the North Atlantic: Nova Scotia, Iceland-Denmark Strait, and Eastern (Donovan 1991). Mignucci-Giannoni (1998) reported two sightings for Puerto Rico and the Virgin Islands. There has also been a stranding in the Dominican Republic (Whitt et al. 2011). There are no sightings in the OBIS database for the proposed survey areas or in the Caribbean Sea (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).

In the North Atlantic, fin whales are found in summer from Baffin Bay, Spitsbergen, and the Barents Sea, south to North Carolina and the coast of Portugal (Rice 1998). In winter, they have been sighted from Newfoundland to the Gulf of Mexico and the Caribbean, and from the Faroes and Norway south to the Canary Islands (Rice 1998). Based on geographic differences in fin whale calls, Delarue et al. (2014) suggested that there are four distinct stocks in the Northwest Atlantic, including a central North Atlantic stock that and extends south along the Mid-Atlantic Ridge. Similarly, the four stocks in the Northwest Atlantic currently recognized by the North Atlantic Marine Mammal Commission (NAMMCO 2016) are located off West Iceland (in the Central Atlantic), Eastern Greenland, Western Greenland, and Eastern Canada. Mignucci-Giannoni (1998) reported three sightings for Puerto Rico and the Virgin Islands. Edwards et al. (2015) reported no detections for fin whales in the Caribbean Sea or north of Puerto Rico. There is one record of a fin whale in the OBIS database in the northern portion of the survey area; the sighting was made in February 1978; there are no other records for the Caribbean Sea (OBIS 2021).

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Blue whales are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). Generally, blue whales are seasonal migrants between high latitudes in summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Their summer range in the North Atlantic extends from Davis Strait, Denmark Strait, and the waters north of Svalbard and the Barents Sea, south to the Gulf of St. Lawrence and the Bay of Biscay (Rice 1998). Although the winter range is mostly unknown, some occur near Cape Verde at that time of year (Rice 1998). Mignucci-Giannoni (1998) noted that blue whales may not occur regularly in the Caribbean, as there is a single record for Panama. There are no sightings in the OBIS database for the proposed survey areas or in the Caribbean Sea (OBIS 2021).

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 <40º where sea surface temperatures are <15ºC; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds (Whitehead 2018). Sperm whales are the second most frequently sighted large cetacean in the northeastern Caribbean (Roden and Mullin 2000). Mignucci-Giannoni (1998) reported 43 sightings for Puerto Rico and the Virgin Islands up to 1989; most occurred near the shelf edge. Some sightings have been reported during the fall (DoN 2002). Rodriguez-Ferrer et al. (2018) reported several other sightings along the shelf edge off western Puerto Rico between 1995 and 2018. Sperm whales were also seen south of the U.S. Virgin Islands during winter 1995 (Roden and Mullin 2000), and they were detected visually and acoustically in the EEZs of Puerto Rico, and the U.S. and British Virgin Islands during winter 2001 (Swartz et al. 2002). Opportunistic sightings of sperm whales have also been reported for the Dominican Republic (Whaley et al. 2006). There are 11 records in the OBIS database within or near the proposed survey areas (OBIS 2021).

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

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

In the western North Atlantic, pygmy sperm whales are known to occur from Nova Scotia to Cuba, and dwarf sperm whales are distributed from Virginia to the Caribbean (Würsig et al. 2000; Würsig 2017). Records for the Caribbean are uncommon, but several strandings have been reported for the Dominican Republic, Puerto Rico, and the Virgin Islands (Cardona-Maldonado and Mignucci-Giannoni 1999). Several strandings of both *Kogia* spp. have been recorded in Puerto Rico, only pygmy sperm whale strandings have reported for the U.S. Virgin Islands, and strandings of undetermined *Kogia* sp. have been recorded for the Dominican Republic (Mignucci-Giannoni 1996, 1998; Mignucci-Giannoni et al. 1999a; Cardona-Maldonado and Mignucci-Giannoni 1999). There is one record of a dwarf sperm whale and one of an unidentified *Kogia* sp. in the OBIS database within the proposed survey areas, just off the northern coast of Puerto Rico; there are several other records of unidentified *Kogia* sp. for the Virgin Islands and one record of a pygmy sperm whale off Anguilla (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). It is rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep (Carwardine 1995). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006).

In the western North Atlantic, these whales occur from Massachusetts to Florida, the West Indies, and the Gulf of Mexico (Würsig et al. 2000). Strandings are common in Puerto Rico and the Virgin Islands, with most records in winter and spring (Mignucci-Giannoni 1996, 1998; Mignucci-Giannoni et al. 1999a). Several sightings have also been made, including north and south of Puerto Rico (DoN 2002). There is one record southwest of Anguilla in the OBIS database (OBIS 2021).

Gervais' Beaked Whale (*Mesoplodon europaeus*)

Although Gervais' beaked whale is generally considered to be a North Atlantic species, it likely occurs in deep waters of the temperate and tropical Atlantic Ocean in both the northern and southern hemispheres (Jefferson et al. 2015). Its distribution is primarily known from stranding records. Strandings may be associated with calving, which takes place in shallow water (Würsig et al. 2000). Gervais' beaked whale usually inhabits deep waters (Davis et al. 1998). It is more frequent in the western than the eastern Atlantic (Mead 1989) and occurs from New York to Florida and the GoM (Rice 1998). Numerous sightings and strandings have been reported for the Caribbean, including in the Dominican Republic and the U.S. Virgin Islands (Mignucci-Giannoni 1996; Mignucci-Giannoni et al. 1999a; Rosario-Delestre et al. 1999). There is one record just off the southeastern Puerto Rico shoreline in the OBIS database (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 2018). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). It is rarely sighted, and most of the knowledge on the distribution of this species is derived from stranding data. There is no evidence that Blainville's beaked whales undergo seasonal migrations, although movements into higher latitudes are likely related to warm currents, such as the Gulf Stream in the North Atlantic. Like other beaked whales, Blainville's beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). However, it may also occur in coastal areas, particularly where deep-water gullies come close to shore.

In the western North Atlantic, it is found from Nova Scotia to Florida, the Bahamas, and the GoM (Würsig et al. 2000). Two sightings have been made in the Caribbean – one each at Grand Cayman Island and Puerto Rico (Rosario-Delestre et al. 1999). One stranding has been reported for Puerto Rico (Mignucci-Giannoni 1996; Mignucci-Giannoni et al. 1999a). There is one record between the U.S. and British Virgin Islands in the OBIS database (OBIS 2021).

True's Beaked Whale (*Mesoplodon mirus*)

True's beaked whale is mainly oceanic and occurs in warm temperate waters of the North Atlantic and southern Indian oceans (Pitman 2018). In the western North Atlantic, strandings have been recorded from Nova Scotia (~46°N) to Florida (~27°N; MacLeod et al. 2005). There are no OBIS sightings of True's beaked whale near the proposed project area (OBIS 2021). True's beaked whale likely would be rare in the proposed project area, although Mignucci-Giannoni (1996, 1998) noted that it could occur in the Caribbean.

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994). It generally occurs in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2015). In the western Atlantic, this species occurs between the southeastern U.S. and southern Brazil (Jefferson et al. 2015). Mignucci-Giannoni (1998) reported nine sightings for Puerto Rico and the Virgin Islands up to 1989, and Mignucci-Giannoni (1996) and Mignucci-Giannoni et al. (1999a) reported several strandings for Puerto Rico and the U.S. Virgin Islands. Swartz et al. (2002) reported one sighting of three individuals northeast of Puerto Rico during winter 2001 surveys. Rodriguez-Ferrer et al. (2018) reported another four sightings along the shelf edge off southwestern Puerto Rico between 2010 and 2017. There is one record off the east coast of Puerto Rico in the OBIS database (OBIS 2021).

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin occurs in tropical, subtropical, and temperate waters throughout the world (Wells and Scott 2018). Although it is more commonly found in coastal and shelf waters, it can also occur in deep offshore waters (Jefferson et al. 2015). In the Northwest Atlantic, these dolphins occur from Nova Scotia to Florida, the GoM, and the Caribbean and southward to Brazil (Würsig et al. 2000). There are two distinct bottlenose dolphin types: a shallow water type mainly found in coastal waters and a deepwater type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999). The nearshore dolphins usually inhabit shallow waters along the continental shelf and upper slope, at depths <200 m (Davis et al. 1998, 2002). Klatsky (2004) noted that offshore dolphins show a preference for water <2186 m deep. As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). 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). It is the most frequently sighted dolphin in Puerto Rico and the Virgin Islands (Mignucci-Giannoni 1998). Two sightings of bottlenose dolphins were made during winter 2001 off southern Puerto Rico and north of the Virgin Islands (Swartz et al. 2002). Bottlenose dolphins have also been seen during surveys of eastern Dominican Republic (Mattila et al. 1994; Whaley et al. 2006). There are eight records within or near the proposed survey areas in the OBIS database (OBIS 2021).

Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). It is one of the most abundant cetaceans and is found in coastal, shelf, slope, and deep waters (Perrin 2018a). In the Northwest Atlantic, it occurs from North Carolina to the West Indies and down to the equator (Würsig et al. 2000). Pantropical spotted dolphins have been cited throughout the WCR, including off the Dominican Republic and off the northern and southern coasts of Puerto Rico (Jefferson and Lynn 1994; DoN 2002; Roden and Mullin 2000; Swartz et al. 2002; Mignucci-Giannoni et al. 2003; Whaley et al. 2006). There is one record off the southern coast of Puerto Rico in the OBIS database (OBIS 2021).

Atlantic Spotted Dolphin (*Stenella frontalis*)

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 North Atlantic, it occurs from Brazil to New England and to the coast of Africa (Jefferson et al. 2015). There are two forms of Atlantic spotted dolphin—a large, heavily spotted coastal form that is usually found in shelf waters, and a smaller and less-spotted offshore form that occurs in pelagic offshore waters and around oceanic islands (Jefferson et al. 2015). In the western Atlantic, the distribution extends from southern New England, south to the Gulf of Mexico, and the Caribbean to Venezuela (Leatherwood et al. 1976; Perrin et al. 1994a; Rice 1998). The Atlantic spotted dolphin is common on the shelf off Puerto Rico and the Virgin Islands (Mignucci-Giannoni 1998; Debrot et al. 2013), as well as in deeper water north and south of Puerto Rico (Swartz et al. 2002). Rodriguez-Ferrer et al. (2018) reported numerous sightings along the shelf edge of Puerto Rico, in particular along the southwestern coast. Atlantic spotted dolphins have been sighted in coast waters of the Dominican Republic (e.g., Mattila et al. 1994; Whaley et al. 2006) as well as in offshore waters north of the Dominican Republic (Jefferson and Lynn 1994). There are seven records within or near the proposed survey aresa in the OBIS database (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). It is generally considered a pelagic species (Perrin 2018b) but can also be found in coastal waters and around oceanic islands (Rice 1998). In the western North Atlantic, it occurs from South Carolina to Florida, the Caribbean, GoM, and southward to Venezuela (Würsig et al. 2000). Mignucci-Giannoni (1998) reported 41 sightings for Puerto Rico and the Virgin Islands up to 1989. Rodriguez-Ferrer et al. (2018) reported 18 sightings off western Puerto Rico between 1995 and 2014. During February–March 2001 surveys off Puerto Rico, one sighting was made off the west coast and another was made off the north coast. DoN (2002) reported concentrations of spinner dolphins within the 1000-m isobath surrounding Puerto Rico and the Virgin Islands. There is one record off the southwestern coast of Puerto Rico in the OBIS database (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. 1994b; Jefferson et al. 2015). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). In the Northwest Atlantic, it occurs from Nova Scotia to the Gulf of Mexico and south to Brazil (Würsig et al. 2000). Mignucci-Giannoni (1996, 1998) and Mignucci-Giannoni et al. (1999a) reported one stranding record for the Virgin Islands. A group of 140 striped dolphins was seen within the proposed survey area north of Puerto Rico during winter 1995 (Roden and Mullin 2000). There is one record in the northern portion of the proposed survey area in the OBIS database (OBIS 2021).

Clymene Dolphin (*Stenella clymene*)

The Clymene dolphin only occurs in tropical and subtropical waters of the Atlantic Ocean (Jefferson et al. 2015). It inhabits areas where water depths are 700–4500 m or deeper (Fertl et al. 2003). However, there are a few records in water as shallow as 44 m (Fertl et al. 2003). In the western Atlantic, it occurs from New Jersey to Florida, the Caribbean Sea, the GoM, and south to Venezuela and Brazil (Würsig et al. 2000; Fertl et al. 2003). Mignucci-Giannoni (1996) did not report any strandings for Puerto Rico, but one stranding for Dominica.

Risso’s Dolphin (*Grampus griseus*)

Risso’s dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999). Although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018). In the western Atlantic, this species is distributed from Newfoundland to Brazil (Kruse et al. 1999). Two sightings have been reported for the Virgin Islands (Mignucci-Giannoni 1998; DoN 2002), and three strandings have been reported for Puerto Rico (Mignucci-Giannoni 1996; Mignucci-Giannoni et al. 1999a; DoN 2002). There is one record just off the southwest coast of Puerto Rico in the OBIS database (OBIS 2021).

Common Dolphin (*Delphinus delphis*)

The common dolphin is distributed in tropical to cool temperate waters of the Atlantic and the Pacific oceans from 60ºN to ~50ºS (Jefferson et al. 2015). It is common in coastal waters 200–300 m deep (Evans 1994), but it can also occur thousands of kilometers offshore (Jefferson et al. 2015). It appears to have a preference for areas with upwelling and steep sea-floor relief (Doksæter et al. 2008; Jefferson et al. 2015). Although it occurs off the U.S. east coast as far south as Florida (Perrin 2018c), its occurrence and distribution in the Caribbean are less well known (see Jefferson et al. 2009). There are no records of this species for the proposed survey areas in the OBIS database (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 ranges from the Gulf of Mexico to Uruguay in the western Atlantic (Rice 1998). However, Mignucci-Giannoni et al. (1999b) noted that there were only seven records for the Caribbean, including two strandings in Puerto Rico. DoN (2002) reported one additional strandings for Puerto Rico. The other records are for St. Vincent and Dominica (Mignucci-Giannoni et al. 1999a); this species has not been recorded for the Virgin Islands (Debrot et al. 2013). There are no records of this species for the proposed survey areas 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 and occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson 2018). In the western North Atlantic, short-finned pilot whales occur from Virginia to northern South America, including the Caribbean and Gulf of Mexico (Würsig et al. 2000). Téllez et al. (2014) reported that short-finned pilot whales in the Caribbean show substantial genetic diversity.

Numerous sightings have been made in Puerto Rico and the Virgin Islands, most of which occurred over the shelf (Mignucci-Giannoni 1998; DoN 2002). Short-finned pilot whales were observed in Mona Passage, off western Puerto Rico, during spring 2013, winter 2014, and winter 2015 (MacKay and Bacon 2019), and in the proposed survey area north of Puerto Rico during winter 1995 (Roden and Mullin 2000). Rodriguez-Ferrer et al. (2018) reported another five sightings along the shelf edge and in deep offshore waters off Puerto Rico during for 1996, 2009, and 2016, and 2018, and Swartz et al. (2002) reported several other sightings off Puerto Rico during February–March 2001. Opportunistic sightings of short-finned pilot whales have also been reported for the Dominican Republic (Whaley et al. 2006). There are three records of short-finned pilot whales and nine records of *Globicephala* sp. within or near the proposed survey areas in the OBIS database (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). The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975). In the Northwest Atlantic, killer whales occur from the polar pack ice to Florida and the Gulf of Mexico (Würsig et al. 2000). Numerous sightings have been reported for Puerto Rico and the Virgin Islands, as well as one stranding and a capture for the Dominican Republic (Mignucci-Giannoni 1998; Bolaños-Jiménez et al. 2014); sightings were made throughout the year. DoN

(2002) reported one sighting during fall within the proposed survey area, north of Puerto Rico. There are nearly 30 records within or near the proposed survey areas in the OBIS database (OBIS 2021).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but rare to uncommon throughout its range (Baird 2018b). It generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2015; Baird 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). In the Northwest Atlantic, it occurs from Maryland to the Gulf of Mexico and the Caribbean (Würsig et al. 2000). Merten and Rodriguez-Ferrer (2014) reported the first stranding and sighting of false killer whales off Puerto Rico in January and March 2013, respectively; the sighting was of two adults and a calf in offshore waters ~40 km south of Puerto Rico, and the stranding consisted of one male. Swartz et al. (2002) reported one sighting of nine individuals during March 2002 in offshore waters southwest of Puerto Rico. Rodriguez-Ferrer et al. (2018) reported one other sighting in Mona Passage in February 2018. Two sightings have been reported for the Virgin Islands (Mignucci-Giannoni 1998; DoN 2002) and one stranding (Mignucci-Giannoni 1996; Mignucci-Giannoni et al. 1999a). For the proposed survey areas, there is one record off the southern coast of Puerto Rico in the OBIS database (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). It is found in nearshore areas where the water is deep and in offshore waters (Jefferson et al. 2015). It is known to inhabit the warm waters of the Indian, Pacific, and Atlantic oceans (Jefferson et al. 2015). In the Northwest Atlantic, it occurs from the Carolinas to Texas and the West Indies, and the Gulf of Mexico (Würsig et al. 2000). A group of five pygmy killer whales stranding at Beef Island (Tortola) in the British Virgin Islands on 16 September 1995; this was the second record of this species in the Caribbean (Mignucci-Giannoni et al. 1999c); the first record was for St. Vincent (Caldwell and Caldwell 1971). Numerous other strandings records have been reported for the British Virgin Islands (Mignucci-Giannoni 1996). Another pygmy killer whale live stranded on the northwestern coast of Puerto Rico on 25 February 1997 (Rodríguez-López and Mignucci-Giannoni 1999). For the proposed survey areas, there is one record off the northeastern coast of Puerto Rico in the OBIS database (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 western Atlantic, its range extends from the Gulf of Mexico to southern Brazil (Rice 1998). There are few records for the Caribbean, but one stranding of a juvenile male was reported for Puerto Rico on 17 August 1993 (Mignucci-Giannoni 1996, 1998; Mignucci-Giannoni et al. 1999a). There are no records for the proposed survey areas 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 in the Northwest Atlantic Ocean in fall 2023. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the surveys, 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. Although NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes, no take by serious injury or lethal takes is expected, in particular not for the low-energy surveys, given the nature of the planned operations, the mitigation measures that are planned (see § XI, MITIGATION MEASURES), in addition to the general avoidance by marine mammals of loud sound.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. 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 Northwest Atlantic Ocean. 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" for the high-energy surveys.

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 (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent (Hastie et al. 2019; Martin et al. 2020), and may become less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016; Houser 2021). Although the possibility cannot be entirely excluded, it 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; Thode et al. 2020; Fernandez-Betelu et al. 2021). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Disturbance Reactions

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

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

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

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

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

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

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

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

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

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

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 µPa; at SPLs <108 dB re 1 µPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $\mathrm{CSEL}_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, decreased at $\mathrm{CSEL}_{10\text{-min}}$ >127 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, and whales were nearly silent at $\mathrm{CSEL}_{10\text{-min}}$ >160 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$. Thode et al. (2020) reported similar changes in bowhead whale vocalizations when data were analyzed for the period 2008–2014. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, despite rigorous monitoring and mitigation measures during multiple seismic surveys in 2015 (Aerts et al. 2022; Rutenko et al. 2022), data collected during a program with multiple seismic surveys in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017, 2022a,b; Sychenko et al. 2017). However, stochastic dynamic programming (SDP) model predictions showed similar reproductive success and habitat use by gray whale with or without exposure to airgun sounds during multiple seismic surveys conducted in 2015 (Schwarz et al. 2022).

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

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

During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods

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

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

Toothed Whales.—Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

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

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

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

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

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). Winsor et al. (2017) outfitted sperm whales in the Gulf of Mexico with satellite tags to examine their spatial distribution in relation to seismic surveys. They found no evidence of avoidance or changes in orientation by sperm whales to active seismic vessels. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2017), could have significant consequences on individual fitness. Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

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

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). Similar avoidance behavior and/or decreases in echolocation signals during 3-D seismic operations were reported for harbor porpoise in the North Sea (Sarnocińska et al. 2020). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

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

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

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

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, duty cycle, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b, 2020a,b,c,d,e,f, 2021a,b, 2022; Supin et al. 2016).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 µPa$^2 \cdot$ 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 µPa$^2 \cdot$ s, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

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

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (*cf.* Southall et al. 2007). Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Based on studies that exposed harbor porpoises to one-sixth-octave noise bands ranging from 1 to 88.4 kHz, Kastelein et al. (2019c,d, 2020d,e,f) noted that susceptibility to TTS increases with an increase in sound less than 6.5 kHz but declines with an increase in frequency above 6.5 kHz. At a noise band centered at 0.5 kHz (near the lower range of hearing), the SEL required to elicit a 6 dB TTS is higher than that required at frequencies of 1 to 88.4 kHz (Kastelein et al. 2021a). Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 µPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

For the harbor porpoise, Tougaard et al. (2015) 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 $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). 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. 2013a, 2021). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. A maximum TTS >45 dB was elicited from a harbor seal exposed to 32 kHz at 191 dB SEL (Kastelein et al. 2020c). For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Harbor seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5 to 40 kHz (Kastelein et al. 2020a,b), but at frequencies of 2 kHz or lower, a higher SEL was required to elicit the same TTS (Kastelein et al. 2020c). Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Similarly, no TTS was measured when a bearded seal was exposed to a single airgun pulse with an unweighted SEL of 185 dB and an SPL of 207 dB; however, TTS was elicited at 400 Hz when exposed to four to ten consecutive pulses with a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). Kastelein et al. (2021b) found that susceptibility of TTS of California sea lions exposed to one-sixth-octave noise bands centered at 2, 4, and 8 kHz is similar to that of harbor seals, but at 16 kHz, California sea lion haring is less susceptible to TTS than harbor seals (Kastelein et al. 2022).

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

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 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 noise exposure criteria for marine mammals that were released by NMFS (2016, 2018) account for the newly available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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 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 72 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2023). 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 surveys. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs, 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).

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

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

Frankel and Stein (2020) reported that gray whales responded to a 21–25 kHz active sonar by deflecting 1–2 km away from the sound. Sperm whales exposed to sounds from a low-frequency 1–2 kHz sonar transitioned to non-foraging and non-resting states, but did not respond to 4.7–5.1 kHz or 6–7 kHz sonar signals (Isojunno et al. 2016). Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al.

(2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

Despite the aforementioned information that has recently become available, 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; Kyhn et al. 2019; Landrø and Langhammer 2020); 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; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals.

In addition to masking, Erbe et al. (2019) noted that ship noise can elicit physical and behavioral responses in marine mammals, as well as stress. However, shipping noise is typically not thought to produce sounds capable of eliciting hearing damage; Trigg et al. (2020) noted that gray seals are not at risk of TTS from shipping noise, based on modeling. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016; Oakley et al. 2017). Based on modeling, Halliday et al. (2017) suggested that shipping noise can be audible more than 100 km away and could affect the behavior of a marine mammal at a distance of 52 km in the case of tankers.

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

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or have had little or no recent exposure to ships (Richardson et al. 1995). Dolphins of many species tolerate and sometimes approach vessels (e.g., Anderwald et al. 2013). Some dolphin species approach moving vessels to ride the bow or stern waves (Williams et al. 1992). Physical presence of vessels, not just ship noise, has been shown to disturb the foraging activity of bottlenose dolphins (Pirotta et al. 2015). 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). Killer whales rarely show avoidance to boats within 400 m (Duffus and Dearden 1993), but when more than one boat is nearby, they sometimes swim faster towards less confined waters (e.g., Williams et al. 2002a,b). Killer whales have also been shown to increase travelling and decrease foraging behavior because of the presence of nearby vessels (Williams et al. 2002a,b, 2009; Lusseau et al. 2009; Noren et al. 2009; Holt et al. 2021).

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 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. No injurious takes (Level A) would be 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 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, in particular during the low-energy surveys. (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 sound levels for the high-energy surveys and Level B sound levels for the high- and low-energy surveys, and we 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 off Puerto Rico in the Northwest Atlantic Ocean.

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 Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of seismic surveys. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The 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.

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 and 182 km for MCS lines during the high-energy surveys; ~200 km for the low-energy surveys) that is roughly similar to that of the entire surveys. 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 (6 OBS days and 15 MCS days for the high-energy surveys; 3 days for the low-energy surveys). 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.

We used habitat-based stratified marine mammal densities for the North Atlantic for the U.S. Navy Atlantic Fleet Testing and Training (AFTT) Area from Roberts et al. (2023) for any time of the year, when available. The habitat-based density models consisted of 10 km x 10 km grid cells. Densities in the grid cells for the AFTT Area south of 21°N were averaged per month within each of two water depth categories (intermediate and deep); for most species, only annual densities were available for averaging within the two water depth categories.

Table 4 shows estimated densities for cetacean species that could potentially occur in the proposed survey areas. For most species, the average monthly densities were the same throughout the year; densities for fin whale, sei whale, humpback whale, and Atlantic white-sided dolphin varied by month, so the highest monthly densities are shown. Densities for harbor porpoise, Atlantic white-sided dolphin, and white-beaked dolphin have been included here for the sake of completeness, even though these species are not likely to be encountered in the proposed survey areas. There is uncertainty about the representativeness of the data and the assumptions used to estimate exposures below. Thus, for some species, the densities derived from the abundance models described above may not precisely represent the densities that would be encountered during the proposed seismic surveys.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 µPa_{rms} criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 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*. Species for which densities were very low and take calculations resulted in <0.3 individuals (i.e., Atlantic white-sided dolphin, white-beaked dolphin, harbor porpoise) have been excluded from Table 5. It should be noted that the exposure estimates assume that the proposed surveys would be completed; in fact, the calculated takes for cetaceans ***have been increased by 25%*** (see below). Thus, the 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.

TABLE 4. Annual average densities of marine mammals off Puerto Rico, Northwest Atlantic Ocean.

	Density (#/km^2) in Survey Area	
	Intermediate Water Depth (100-1000 m)	*Deep Water (>1000 m)*
LF Cetaceans		
Humpback whale[1]	0.004739	0.003748
Minke whale	0.000184	0.000835
Bryde's whale	0.000085	0.000088
Fin whale[2]	0.000013	0.000006
Sei whale[3]	0.000319	0.000319
Blue whale	0.000020	0.000020
MF Cetaceans		
Sperm whale	0.005312	0.006623
Beaked whales (all)	0.009887	0.007392
Cuvier's beaked whale		
Blaineville's beaked whale		
Gervais' beaked whale		
True's beaked whale		
Risso's dolphin	0.005193	0.002232
Rough-toothed dolphin	0.006916	0.006546
Common bottlenose dolphin	0.081656	0.028930
Pantropical spotted dolphin	0.013061	0.010670
Atlantic spotted dolphin	0.021284	0.021119
Atlantic white-sided dolphin[4]	0.000006	0.000004
White-beaked dolphin	0.000000	0.000000
Spinner dolphin	0.026713	0.026492
Striped dolphin	0.001807	0.004373
Clymene dolphin	0.020654	0.021800
Fraser's dolphin	0.002539	0.002926
Common dolphin	0.001796	0.001206
Short-finned pilot whale[5]	0.023968	0.025140
Killer whale	0.000024	0.000024
False killer whale	0.003016	0.002983
Pgymy killer whale	0.001742	0.001782
Melon-headed whale	0.013398	0.013531
HF Cetaceans		
Kogia	0.004750	0.005055
Pygmy sperm whale[6]		
Dwarf sperm whale		
Harbor porpoise	0.000001	0.000001

[1] Highest densities occur during December-March. [2] Highest densities occur in August for intermediate water and January for deep water. December-March. [3] Highest densities occur during October-February. [4] Highest densities occur in February for intermediate water and March for deep water.

TABLE 5. Estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed low- and high-energy seismic surveys off Puerto Rico, Northwest Atlantic Ocean.

Species	Stock Abundance North Atlantic[1]	Abundance AFTT Area[2]	Level B Takes[3]	Level A Takes[4] (High-Energy)	Level B + Level A % of AFTT Area Abundance [5]	Requested Level A+B Take Authorization[6]
LF Cetaceans						
Humpback whale	1,396	4,990	262	12	5.5	274
Minke whale	21,968	13,784	58	3	0.4	61
Bryde's whale		536	6	0	1.2	6
Fin whale	6,802	11,672	0.4	0	0.0	2 [7]
Sei whale	6,292	19,530	22	1	0.1	23
Blue whale	402	191	1	0	0.8	1
MF Cetaceans						
Sperm whale	4,349	64,015	481	1	0.8	482
Beaked whales	5,744	65,069	539	1	0.8	540
Cuvier's beaked whale [8]	5,744		N.A.	N.A.		179
Blainevile's beaked whale [8]	10,107		N.A.	N.A.		179
Gervais' beaked whale [8]	10,107		N.A.	N.A.		179
True's beaked whale	10,107		N.A.	N.A.		3 [9]
Risso's dolphin	35,215	78,205	164	0	0.2	164
Rough-toothed dolphin	136	32,848	476	1	1.5	477
Common bottlenose dolphin	62,851	418,151	2128	4	0.5	2,132
Pantropical spotted dolphin	6,593	321,740	778	1	0.2	779
Atlantic spotted dolphin	39,921	259,519	1537	3	0.6	1,540
Spinner dolphin	4,102	152,511	1928	4	1.3	1,932
Striped dolphin	67,036	412,729	317	1	0.1	318
Clymene dolphin	4,237	181,209	1586	3	0.9	1,589
Fraser's dolphin		19,585	213	0	1.1	213
Common dolphin	172,974	473,260	88	0	0.0	88
Short-finned pilot whale [10]	28,924	264,907	1830	3	0.7	1,833
Killer whale		972	2	0	0.2	2
False killer whale	1,791	12,682	218	0	1.7	218
Pgymy killer whale		9,001	130	0	1.4	130
Melon-headed whale		64,114	985	2	1.5	987
HF Cetaceans						
Kogia spp.	7,750	26,043	354	14	1.4	368
Dwarf sperm whale [11]	7,750		177	7		184
Pygmy sperm whale [11]	7,750		177	7		184

Blank cells mean no data available. N.A. means not applicable. [1]From Hayes et al. (2022) and NMFS (2022). [2]From Roberts et al. (2023). [3]Level B takes, based on the 160-dB criterion for marine mammals, excluding exposures to sound levels equivalent to PTS thresholds. [4]Level A takes if there were no mitigation measures, for the high-energy survey only. [5]Requested take authorization expressed as % of abundance from the AFTT area including both the Gulf of Mexico and the Northwest Atlantic, from Roberts et al. (2023). [6]Requested take authorization is Level A plus Level B calculated takes, unless indicated otherwise. [7]Minimum group size (Jefferson et al. 2015). [8]Assigned 1/3 of the Level B takes for all beaked whale species combined (minus True's beaked whale) to each of Cuvier's, Blainville's, and Gervais' beaked whales. [9]Rounded up mean group size from Maze-Foley and Mullin (2006). [10]Takes were calculated using *Globicephala* sp. densities. [11]Take for *Kogia* spp. was equally divided between *K. sima* and *K. breviceps*.

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are likely to be low percentages of the regional population sizes. We calculated the percentages of population sizes that may be taken by dividing the take estimates by the population sizes based on habitat-density modeling for the AFTT area (western North Atlantic and GoM) from Roberts et al. (2023). 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 areas, 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.

Numerous marine mammals species are known to occur in the proposed survey areas. 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. (2013), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017).

Planning Phase

As discussed in § 2.4.1.1 of the PEIS, mitigation of potential impacts from the proposed 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 high-energy 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. The Puerto Rico Trench is one of the deepest in the world (8.4 km) and the widest (below 6000 m depth) on the planet. Imaging crustal and upper mantle structures that lie many kilometers beneath such deep seafloor requires a well-tuned, high-volume airgun array that can generate acoustic pulses in a broad band of frequencies that propagate through such depths with sufficient amplitude to be detected. Smaller airgun arrays do not have the capability to generate pulses suitable for such very deep, long-offset imaging. For the USGS seismic surveys of the southwestern flank of Puerto Rico in the Caribbean Sea, a low-energy source of 2 GI airguns was determined to be sufficient to meet the project goals.
2. *Survey Location and Timing*—The PIs designed the surveys to avoid high-energy source surveys tracklines and Level B predicted ensonified areas from entering the Puerto Rico coastal

zone. 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 areas throughout the year, the humpback whale is common in the region seasonally from December through March. Hurricane season typically occurs during July–September). Fall (October–December) was determined to be the most practical season for the proposed surveys based on the occurrence of marine mammals, weather conditions, other operational requirements, and availability of researchers.

3. *Mitigation Zones*—During the planning phase, mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the exclusion zones (EZ) for Level A takes (for the 36-airgun array, only) and for the Level B (160 dB re 1µPa$_{rms}$) threshold (for the 36-airgun and 2-GI airgun arrays). The background information and methodology for this are provided in Appendix A. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the various airgun sources in water depths in deep water >1000 m, down to a maximum water depth of 2000 m (see Appendix A), as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5.

The NSF and USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤180 dB re 1 µPa$_{rms}$ (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤250 in^3. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-m exclusion zone (EZ) for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach is used here for the pair of 45/105 in3 GI airguns in all water depths. A fixed 160-dB "Safety Zone" was not defined for the same suite of low-energy sources in the NSF and USGS PEIS.

Mitigation During Operations

Marine mammals and sea turtles are known to occur in the proposed survey areas. However, the number of individual animals expected to be approached closely during the proposed activities are expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include: (1) monitoring by protected species observers (PSOs) for marine mammals, sea turtles, and ESA-listed seabirds diving near the vessel, and observing for potential impacts of acoustic sources on fish; (2) passive acoustic monitoring (PAM) for the high-energy surveys only; (3) PSO data and documentation; and (4) mitigation during operations (speed or course alteration; power-down, shut-down, and ramp-up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats). It is unlikely that concentrations of large whales would be encountered within the 160-dB isopleth, but if they were, they would be avoided.

Mitigation measures that would be adopted during the proposed surveys include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures. These measures are proposed by L-DEO based on past experience and for consistency with the PEIS.

Shut-down/Power-down Procedures

The operating airgun(s) would be shut down if a marine mammal is seen within or approaching the EZs; however, shut downs would not be required for small dolphins that are most likely to approach the vessel. A shut down occurs when all airgun activity is suspended.

For recent high-energy surveys, NMFS required PSOs to establish and monitor a 500-m EZ for shut downs for marine mammals and to monitor an additional 500-m buffer zone beyond the EZ. Although Level A takes would not be anticipated for the 2 GI gun surveys, for other low-energy seismic surveys, NMFS required PSOs to establish and monitor a 100-m shut down EZ for marine mammals and a 200-m buffer zone beyond the EZ.

Following a shut down for a marine mammal, airgun activity would not resume until the animal has cleared the EZ. The marine mammal 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 and pinnipeds, or
- it has not been seen within the zone for 30 min in the case of all other marine mammals.

The airgun array would be ramped up gradually after a shut down for marine mammals. 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 (except for shutdowns for ESA-listed sea turtles and seabirds). It is proposed that, for the present surveys, 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.

For the high-energy surveys, ramp up would begin with the smallest airgun in the array. Ramp-up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals are sighted, a shut down would be implemented, respectively, as though the full array were operational. During the high-energy surveys, 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. The low-energy surveys would not use PAM, including during ramp up at night.

The proposed operational mitigation measures are standard for seismic cruises, per the PEIS. Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours. During the high-energy surveys, one observer would conduct PAM during day- and night-time seismic operations. Monitoring and mitigation measures are also described in the IHA application. A monitoring report would be provided to NMFS, both the Permits and Conservation Division and the ESA Interagency Cooperation Division.

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

XII. PLAN OF COOPERATION

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

(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;

(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;

(iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and

(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activity would take place in the Northwest Atlantic Ocean, and no activities would take place in traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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 surveys, 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 during the high energy surveys. 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 4 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 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:

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 near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring and would summarize the dates and locations of seismic operations and all marine mammal observations. 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) and foreign agencies, and would comply with their requirements.

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LIST OF APPENDICES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes for the high-energy surveys and safety zones (160 dB re 1µPa$_{\text{rms}}$) for Level B takes for the high- and low-energy surveys. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the 36-airgun array, two 45/105 in^3 GI airguns, and for a single 1900LL 40-in^3 airgun, which would be used during power downs. Models for the 36-airgun array and 40-in^3 airgun used a 12-m tow depth, whereas the model for the two GI airguns used a 3-m tow depth. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (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 high-energy surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m, and the USGS low-energy surveys would use two GI airguns at a 3-m tow depth. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m for the 36-airgun array (Fig. A-1), the 2 GI airguns (Fig. A-2), and for the 40-in^3 airgun (Fig. A-3). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS. No effort would occur in shallow water during the proposed surveys.

Table A-1 shows the distances at which the 160-dB and 175-dB re 1µPa_{rms} sound levels are expected to be received for the 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 (2017), to determine behavioral disturbance for turtles. A recent retrospective analysis of acoustic propagation of R/V *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[2] 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). It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise. Tougaard et al. (2022) indicate that there is empirical evidence to support the thresholds for very-high frequency cetaceans and pinnipeds in water, but caution that above 10 kHz for porpoise and outside of 3–16 kHz for seals, there are differences between the TTS thresholds and empirical data.

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[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).

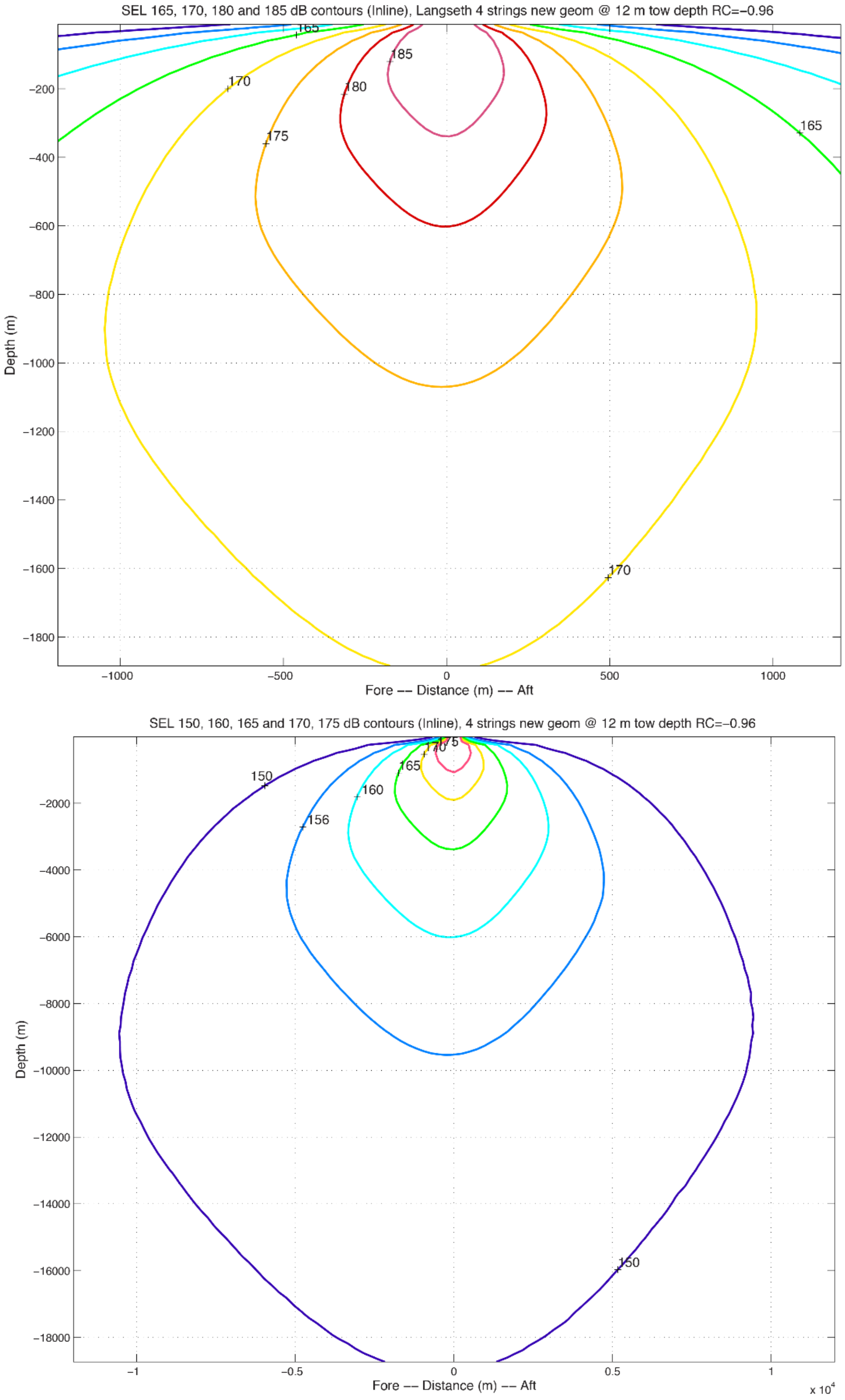


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys off Puerto Rico. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

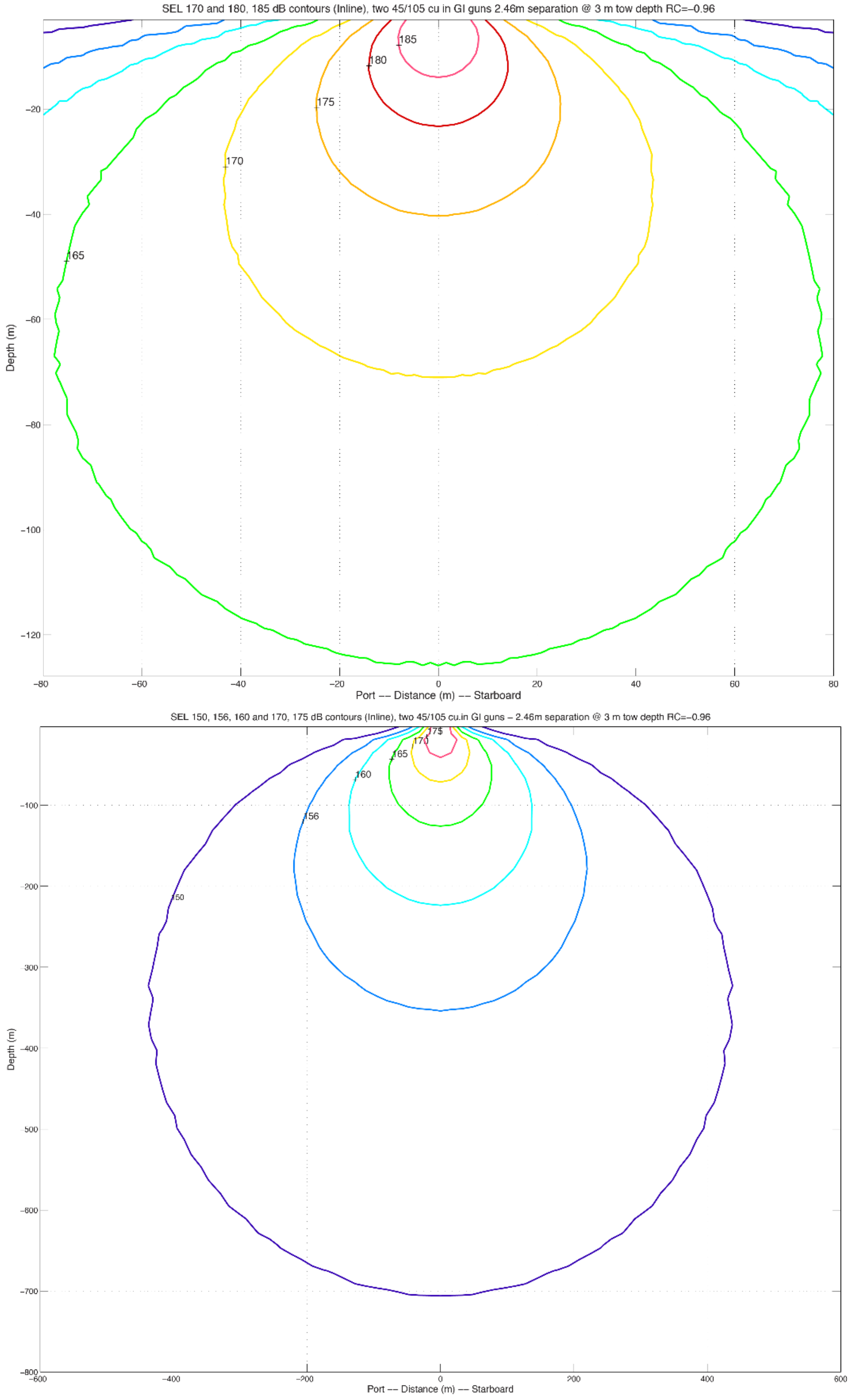


FIGURE A-2. Modeled deep-water received sound exposure levels (SELs) from the two 45/100 in^3 GI airguns at a 3-m tow depth planned for use during the proposed USGS surveys off southern Puerto Rico. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

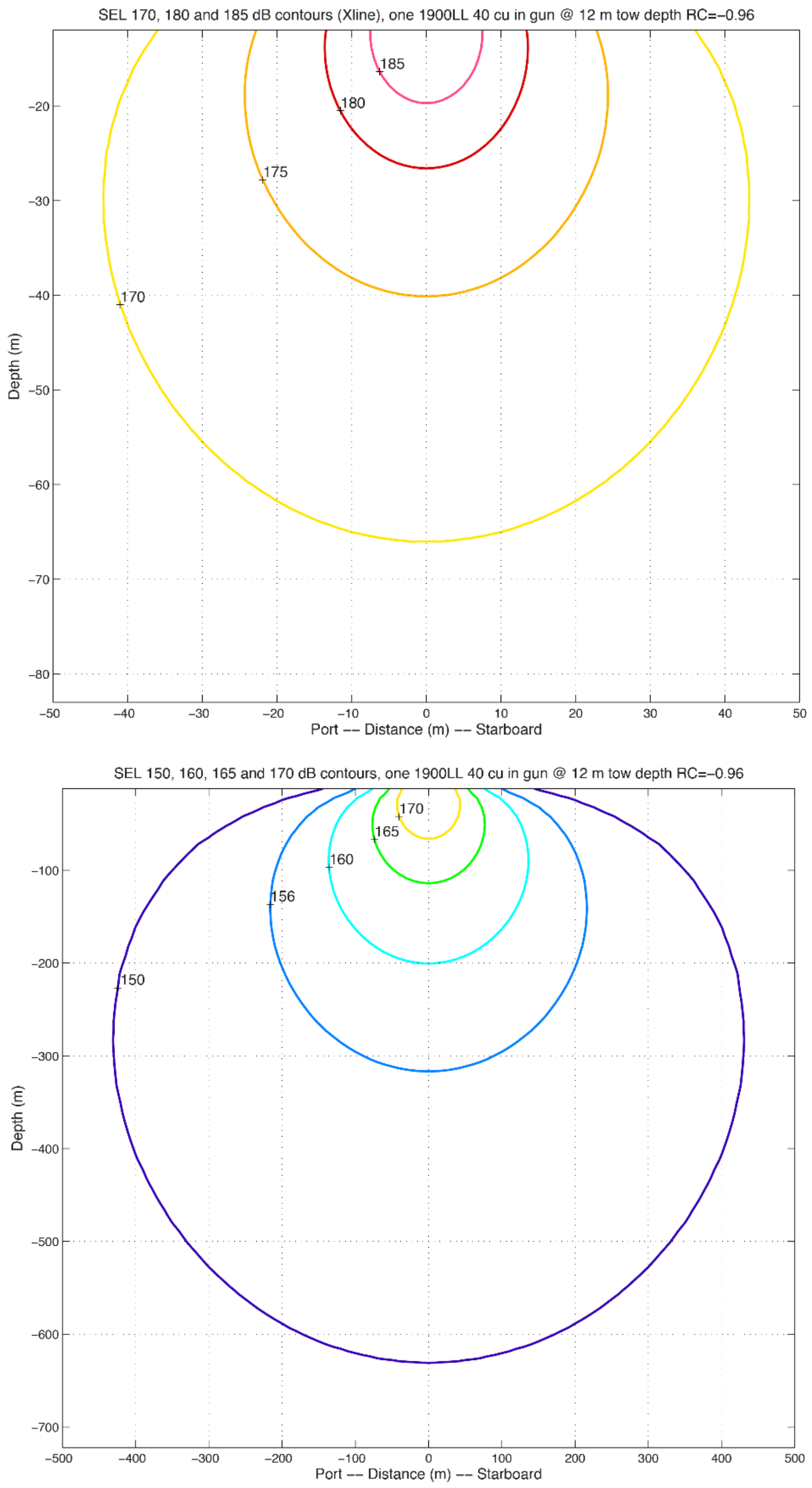


FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun towed at a 12-m depth, which is planned for use during power downs during the proposed high-energy surveys off Puerto Rico. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-6. Level B. Predicted distances to which sound levels ≥160-dB re 1 μPa$_{rms}$ could be received during the proposed surveys off Puerto Rico. The 160-dB criterion applies to all hearing groups of marine mammals, and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]	77[1,3]
		100–1000 m	647[2]	116[2]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]	1,864[1]
		100–1000 m	10,100[2]	2,796[2]
Two 45/105 in^3 GI airguns	3	>1000 m	438[1]	78[1,3]
		100–1000 m	657[2]	117[2]

[1] Distance is based on L-DEO model results. [2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths. [3] An EZ of 150 m would be used as the shut-down distance for sea turtles and ESA listed seabirds in all water depths.

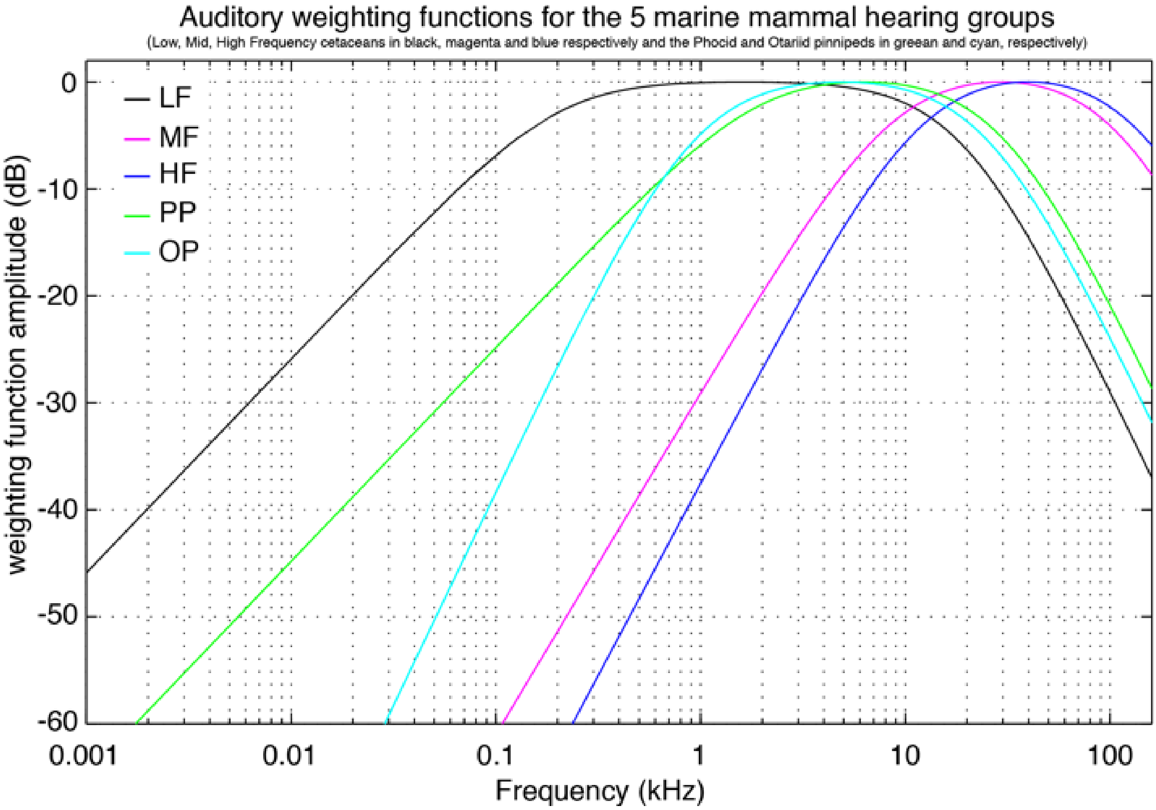


FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

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

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

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.16067 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 SEL_{cum} PTS thresholds (Level A) for the 36-airgun array and the single 40-in^3 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 SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -12.91 dB assuming a propagation of $20\log_{10}$(Radial distance) (Table A-2).

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

TABLE A-2. Results for modified farfield SEL source level modeling for the 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 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

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

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

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 SEL_{cum}, 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.

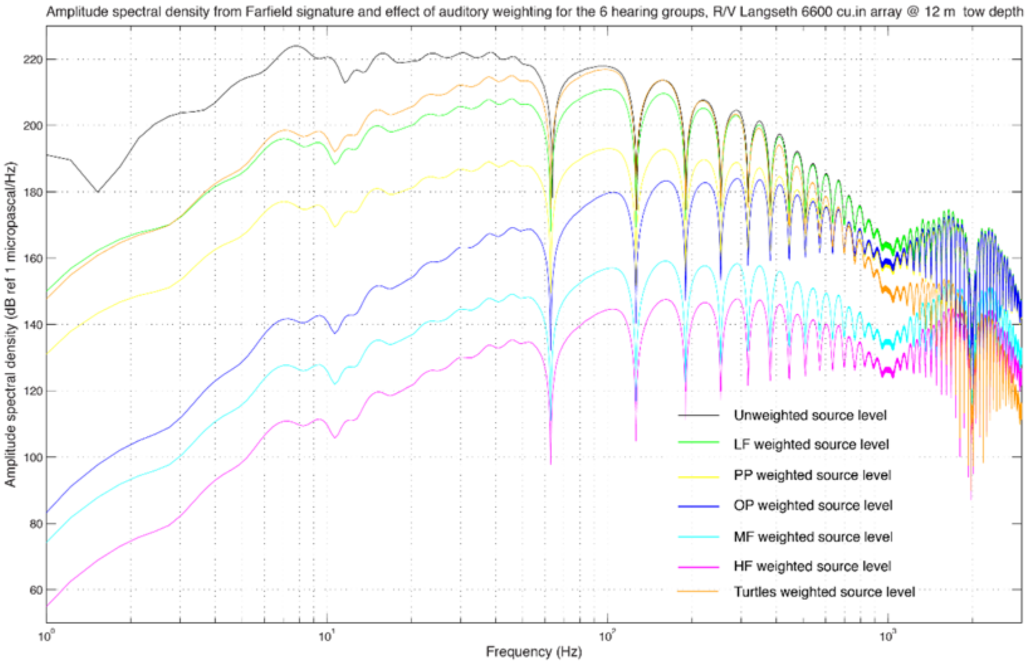
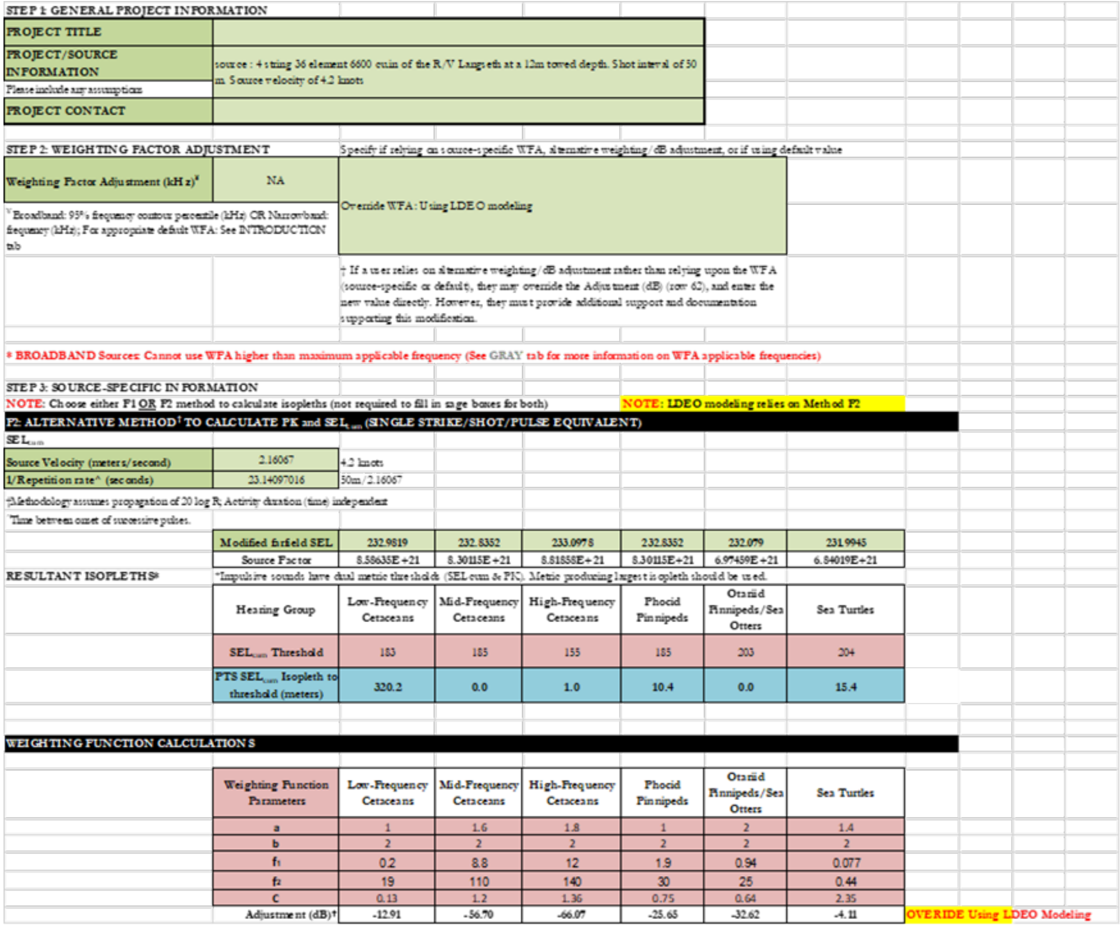


FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are 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.

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.



STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION Please include any assumptions	source : 4 string 36 element 6600 cuin of the R/V Langseth at a 12m towed depth. Shot interval of 50 m. Source velocity of 4.2 knots
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)[¥]	NA	Override WFA: Using LDEO modeling

[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

* BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	23.14097016	50m/2.16067

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

^Time between onset of successive pulses.

Modified farfield SEL	232.9819	232.8352	233.0978	232.8352	232.079	231.9945
Source Factor	8.58635E+21	8.30115E+21	8.81858E+21	8.30115E+21	6.97459E+21	6.84019E+21

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles
SEL_{cum} Threshold	183	185	155	185	203	204
PTS SEL_{cum} Isopleth to threshold (meters)	**320.2**	**0.0**	**1.0**	**10.4**	**0.0**	**15.4**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters	Sea Turtles	
a	1	1.6	1.8	1	2	1.4	
b	2	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	0.077	
f_2	19	110	140	30	25	0.44	
C	0.13	1.2	1.36	0.75	0.64	2.35	
Adjustment (dB)†	-12.91	-56.70	-66.07	-25.65	-32.62	-4.11	OVERIDE Using LDEO Modeling

†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-5).

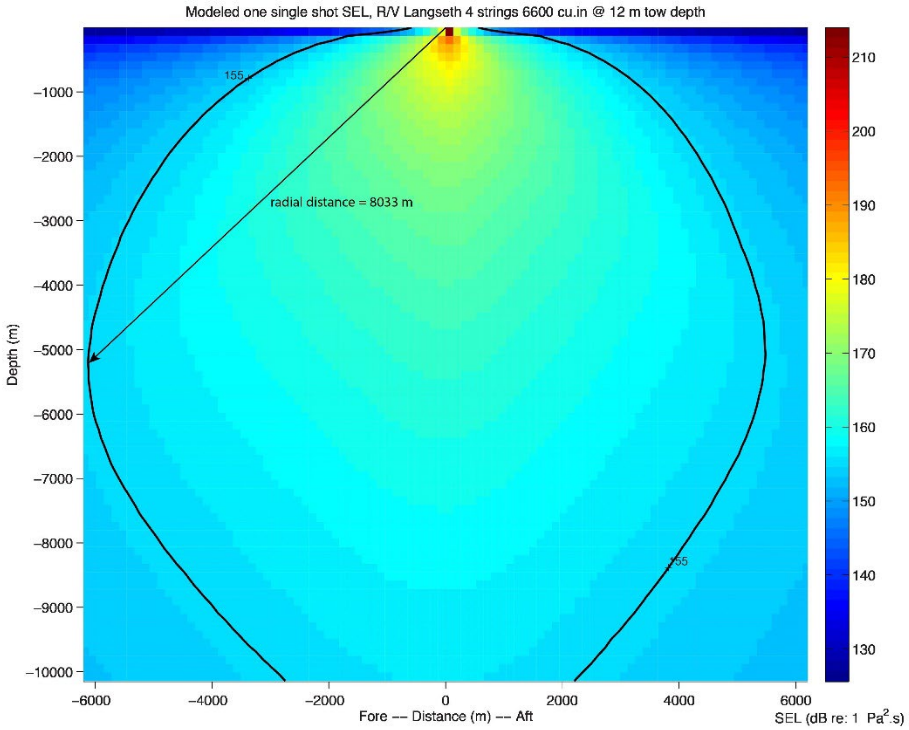


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of 20log$_{10}$(radial distance).

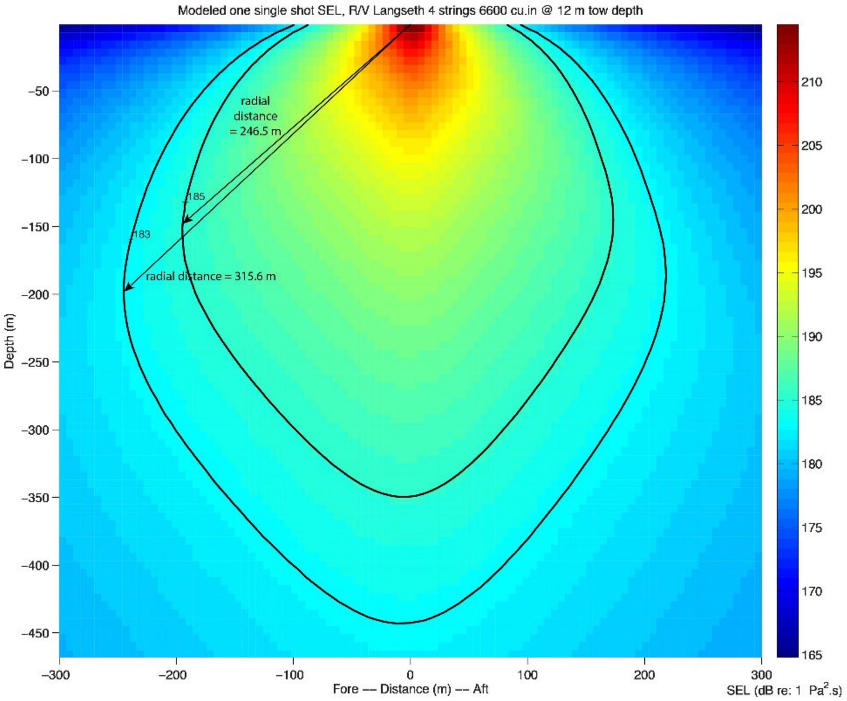


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

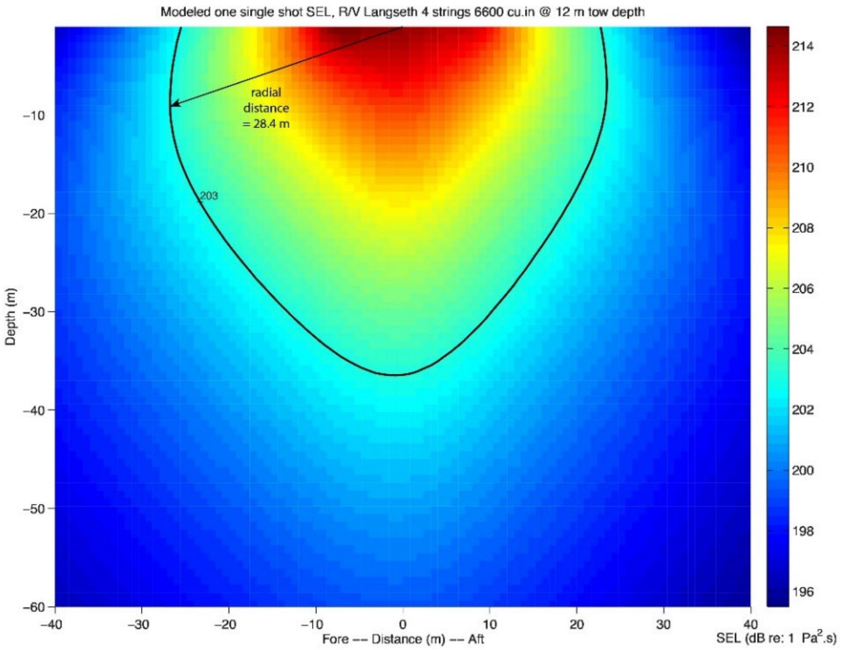


FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (28.4 m).

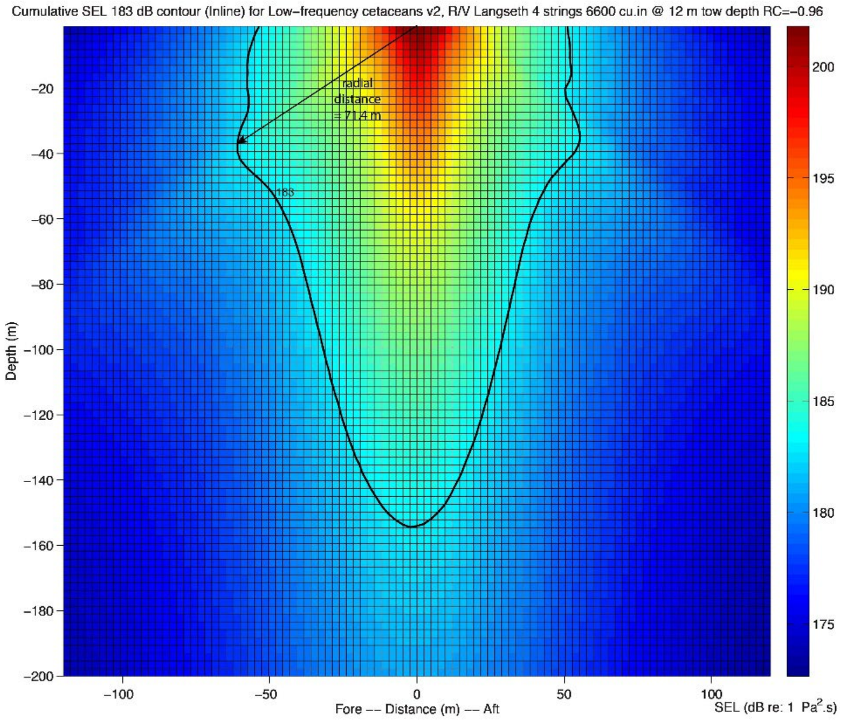


FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one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

The thresholds for Peak SPL_{flat} 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 SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

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

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

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.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
PTS SEL_{cum}	**320.2**	0	1.0	10.4	0	**15.4**
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	10.6

[1] Using the 50-m shot interval provides more conservative distances than the 400-m shot interval.

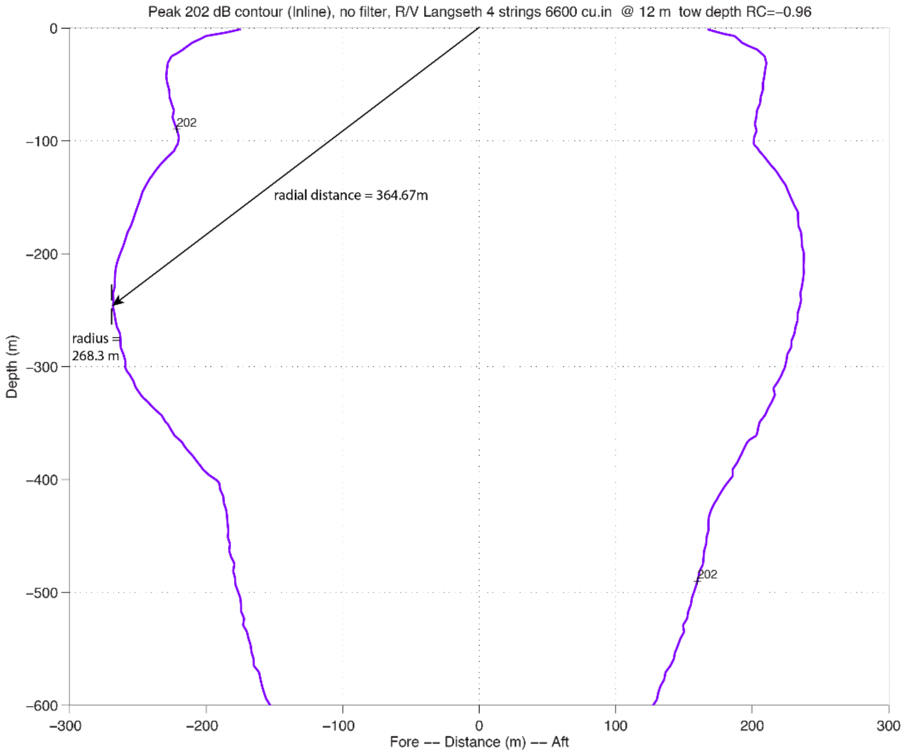


FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

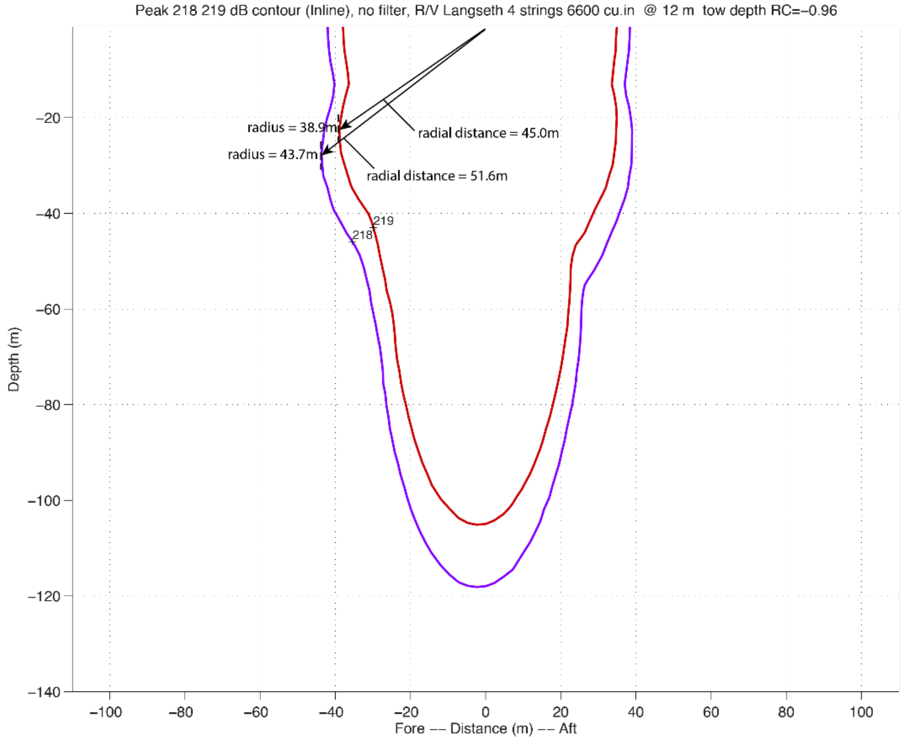


FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

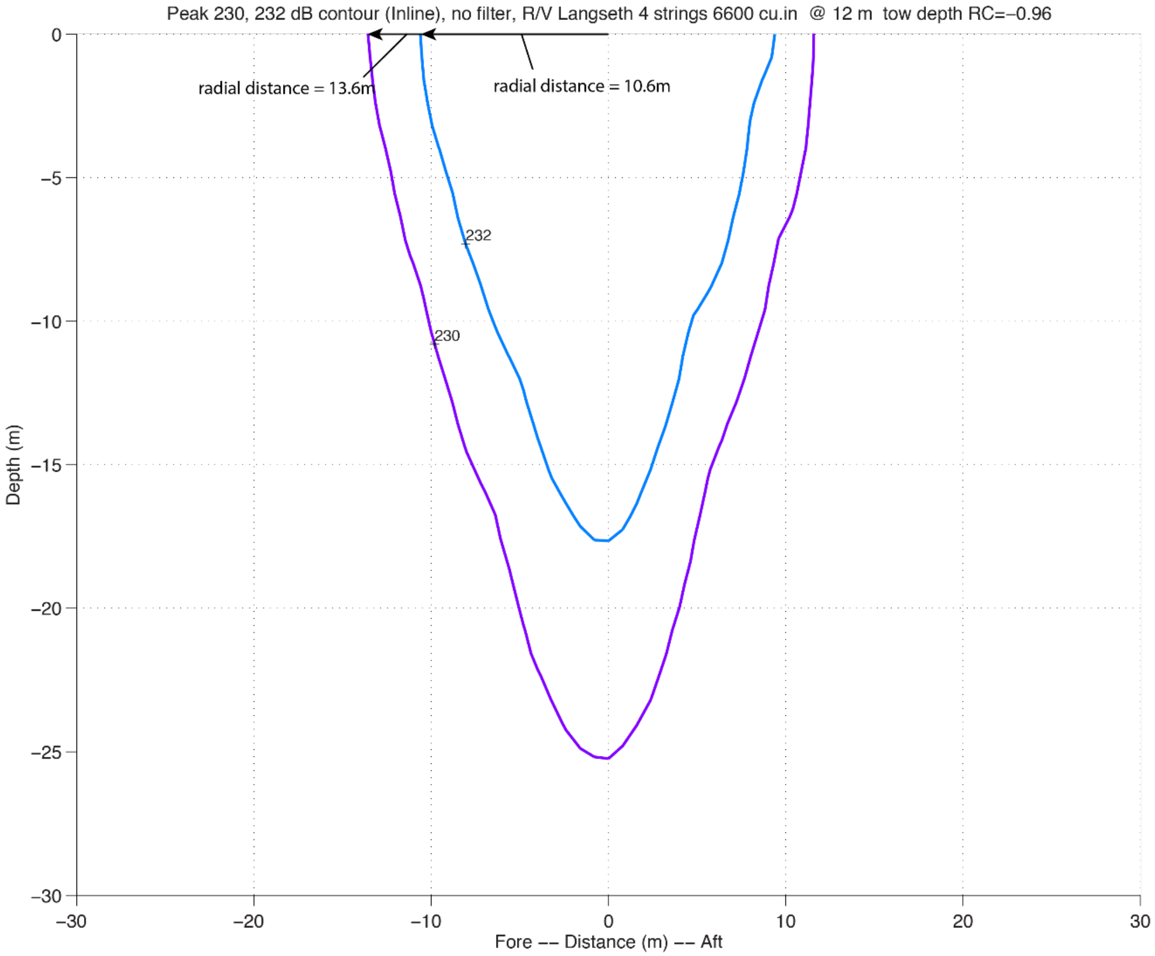


FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

For the single 40 in^3 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 in^3 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 in^3 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-6. Results for single shot SEL source level modeling for the 40 in^3 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$_{cum}$ threshold is the largest. A propagation of 20 log$_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL$_{cum}$ Threshold	**183**	**185**	**155**	**185**	**203**
Distance (m) (no weighting function)	9.9893	7.8477	294.0371	7.8477	0.9278
Modified Farfield SEL*	202.9907	202.8948	204.3680	202.8948	202.3491
Distance (m) (with weighting function)	2.3852	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.44	N.A.	N.A.	N.A.	N.A.

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

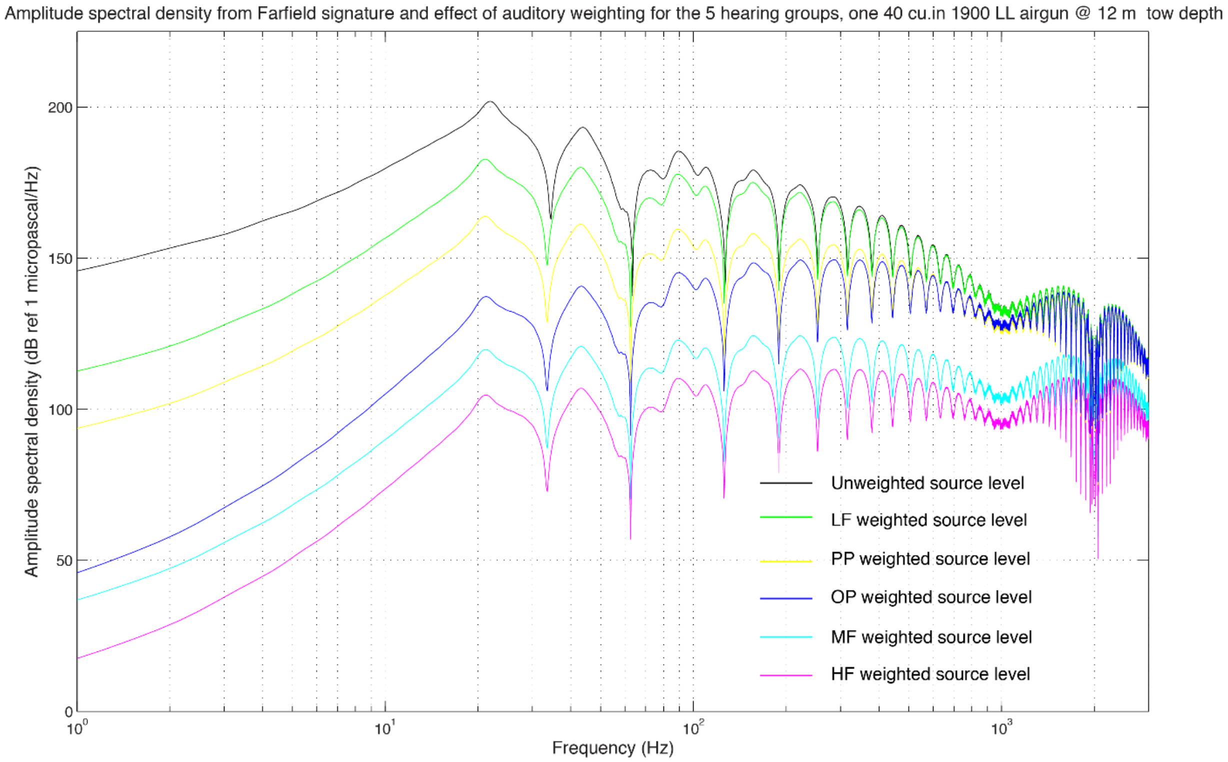
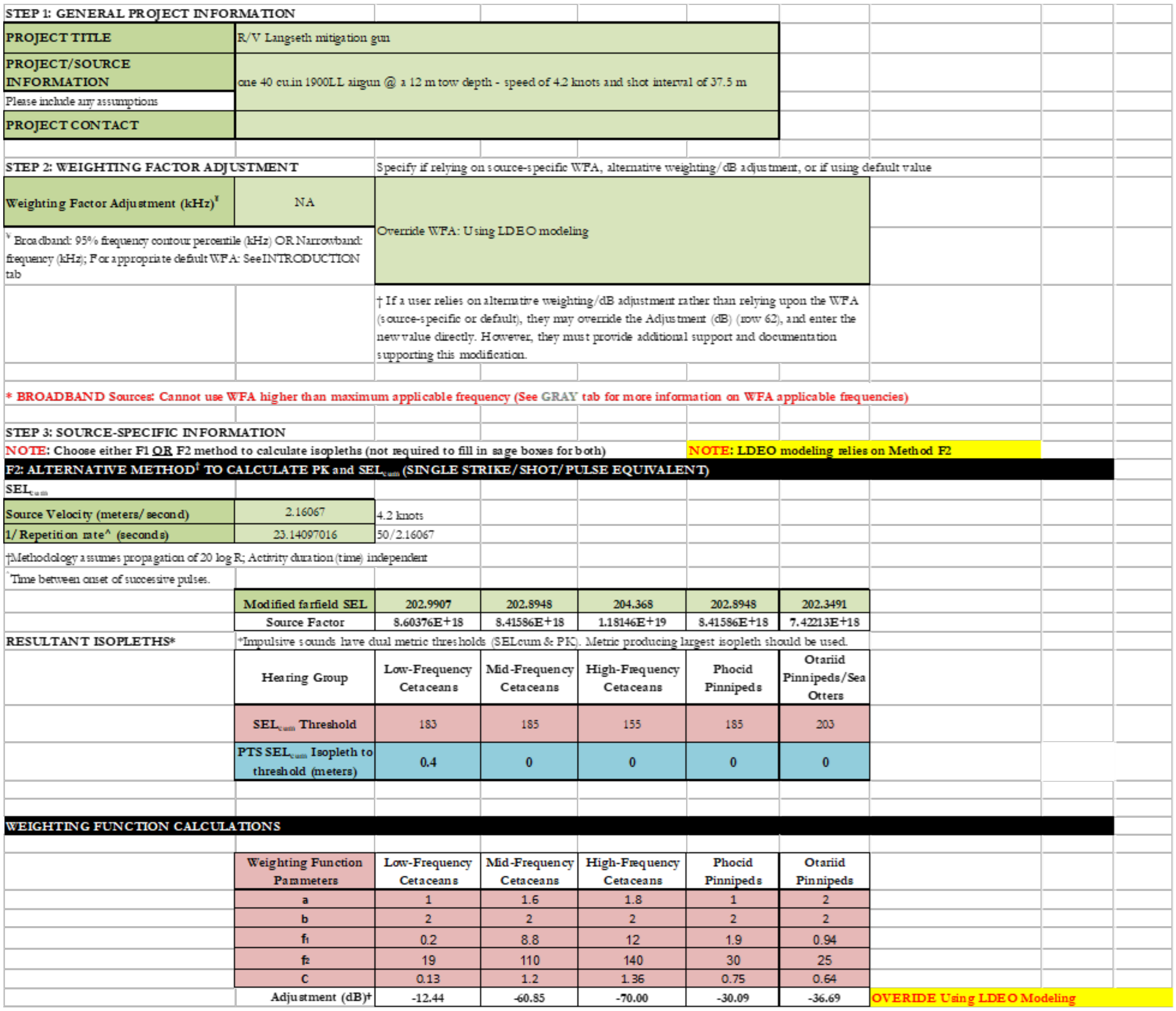


FIGURE A-13. Modeled amplitude spectral density of the 40-in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are 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-in^3 airgun with weighting function calculations for the SEL$_{cum}$ criteria, as well as resulting isopleths to thresholds for various hearing groups.



STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Langseth mitigation gun
PROJECT/SOURCE INFORMATION Please include any assumptions	one 40 cu.in 1900LL airgun @ a 12 m tow depth - speed of 4.2 knots and shot interval of 37.5 m
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)$^¥$	NA	Override WFA: Using LDEO modeling

$^¥$ Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

*** BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)**

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL$_{cum}$

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	23.14097016	50/2.16067

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

^Time between onset of successive pulses.

Modified farfield SEL	202.9907	202.8948	204.368	202.8948	202.3491
Source Factor	8.60376E+18	8.41586E+18	1.18146E+19	8.41586E+18	7.42213E+18

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/Sea Otters
SEL$_{cum}$ Threshold	183	185	155	185	203
PTS SEL$_{cum}$ Isopleth to threshold (meters)	0.4	0	0	0	0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-12.44	-60.85	-70.00	-30.09	-36.69	OVERIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log$_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-13).

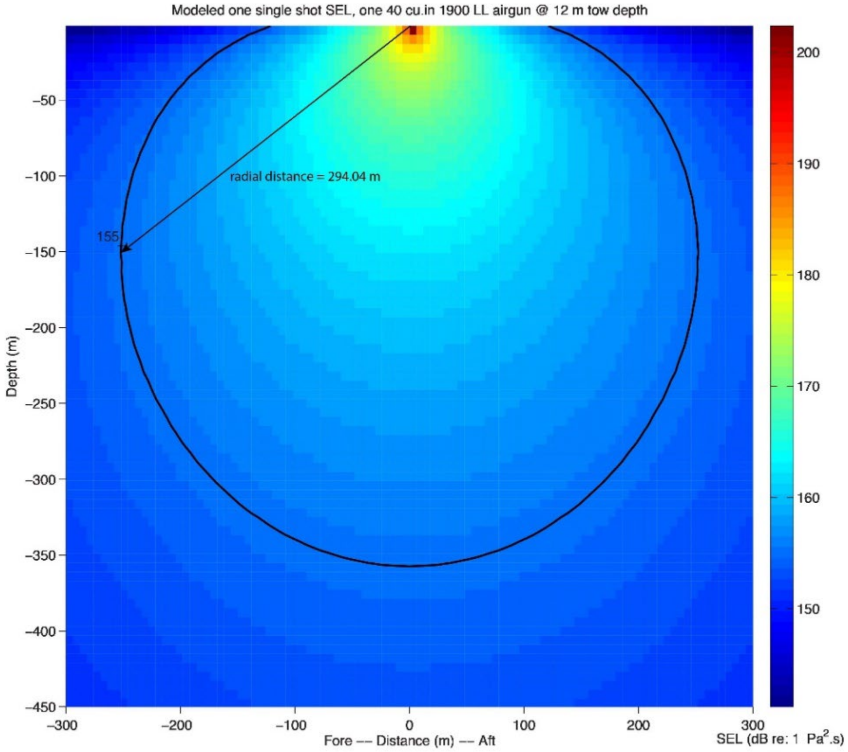


FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

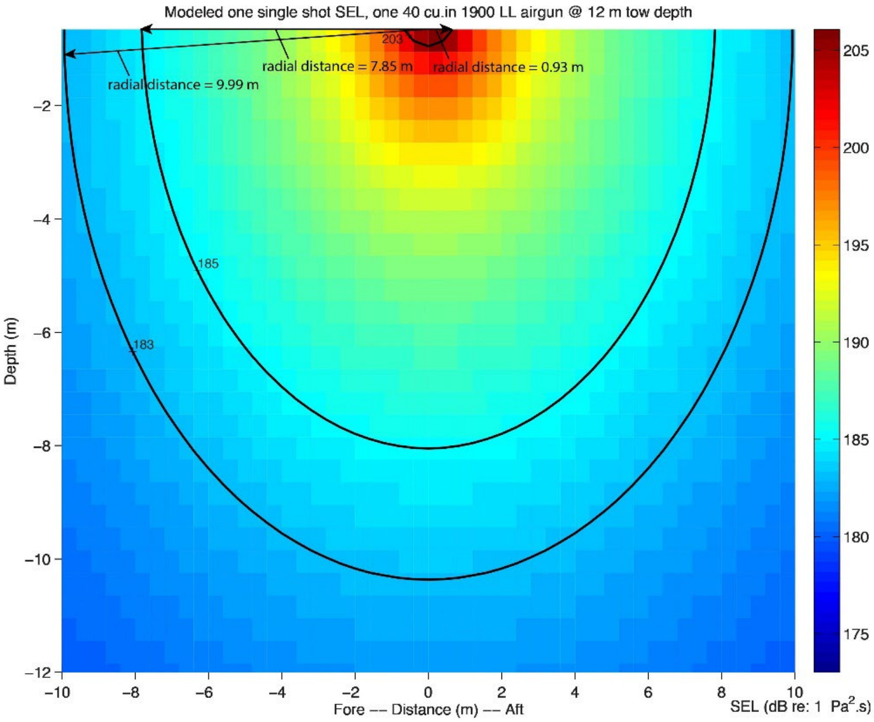


FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

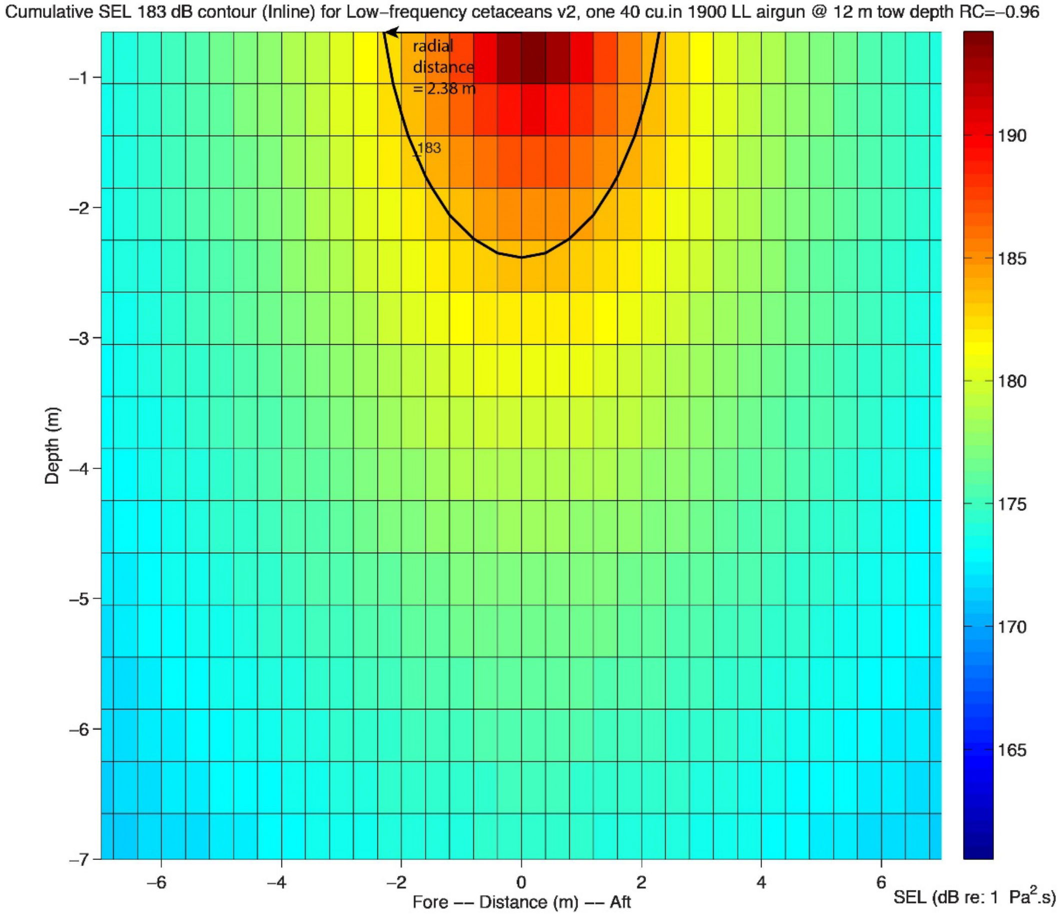


FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in^3 mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL$_{cum}$ isopleth 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$_{flat}$) 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 Puerto Rico.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/ Sea Turtles
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	1.76	N.A.	12.47	1.98	N.A.
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.

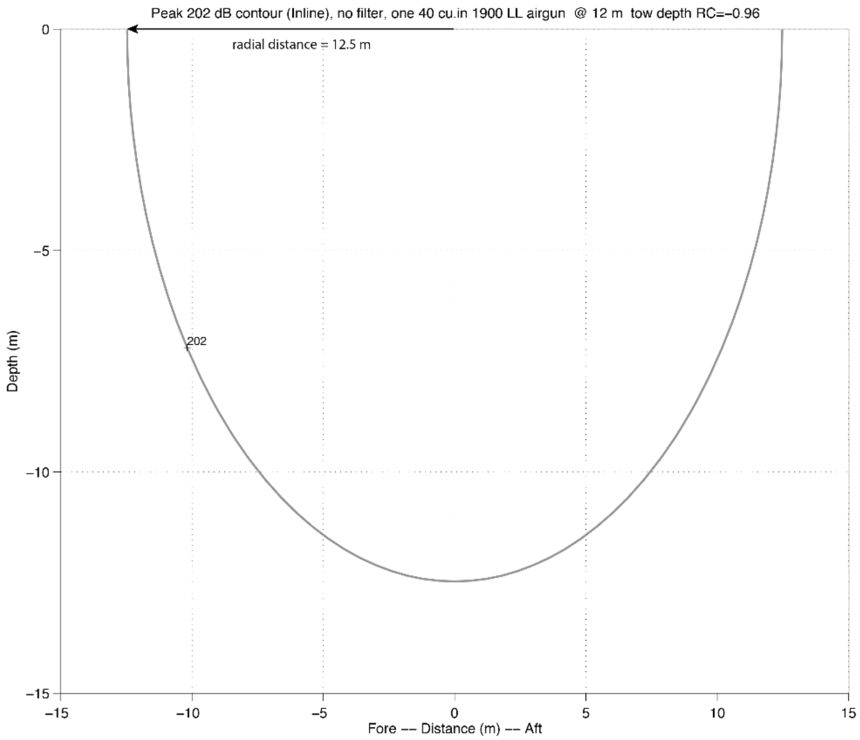


FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

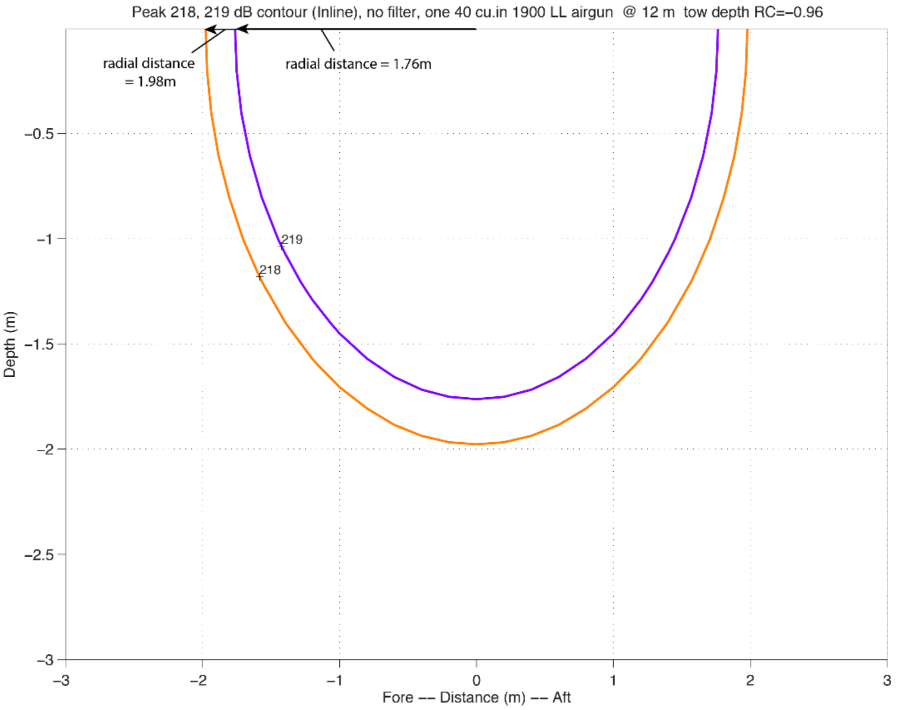


FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

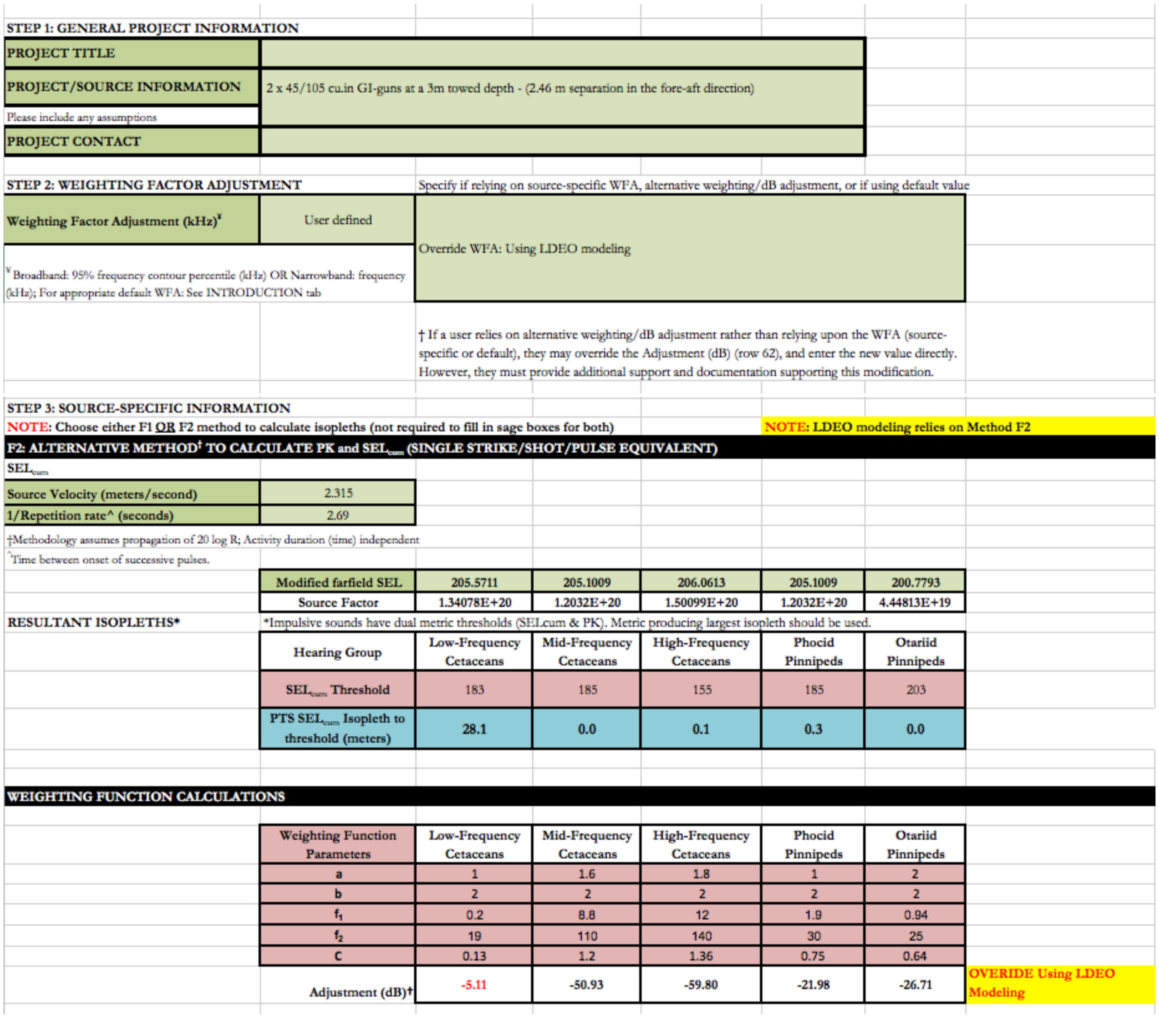
For the two GI airguns, the results for single shot SEL source level modeling are shown in Table A-9. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the two GI airguns are shown in Table A-10. Figure A-19 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-20–A-21 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-22 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the two GI airguns, as well as the distances to the PTS thresholds, are shown in Table A-11. Figures A-23–A-25 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

TABLE A-9. Results for single shot SEL source level modeling for the two GI airguns 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_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance (m) (no weighting function)	12.0317	10.1169	357.3250	10.1169	0.7744
Modified Farfield SEL*	205.5711	205.1009	206.0613	205.1009	200.7793
Distance (m) (with weighting function)	7.4621	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-5.1139	N.A.	N.A.	N.A.	N.A.

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

TABLE A-10. Results for single shot SEL source level modeling for the two 45/105 in^3 GI airguns with weighting function calculations for the SEL$_{cum}$ criteria, as well as resulting isopleths to thresholds for various hearing groups.



STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION	2 x 45/105 cu.in GI-guns at a 3m towed depth - (2.46 m separation in the fore-aft direction)
Please include any assumptions	
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)[¥]	User defined	Override WFA: Using LDEO modeling

[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL$_{cum}$

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	2.69

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

^Time between onset of successive pulses.

Modified farfield SEL	**205.5711**	**205.1009**	**206.0613**	**205.1009**	**200.7793**
Source Factor	**1.34078E+20**	**1.2032E+20**	**1.50099E+20**	**1.2032E+20**	**4.44813E+19**

RESULTANT ISOPLETHS*

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

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**
SEL$_{cum}$ Threshold	183	185	155	185	203
PTS SEL$_{cum}$ Isopleth to threshold (meters)	**28.1**	**0.0**	**0.1**	**0.3**	**0.0**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	**-5.11**	**-50.93**	**-59.80**	**-21.98**	**-26.71**	**OVERIDE Using LDEO Modeling**

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log$_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-19).

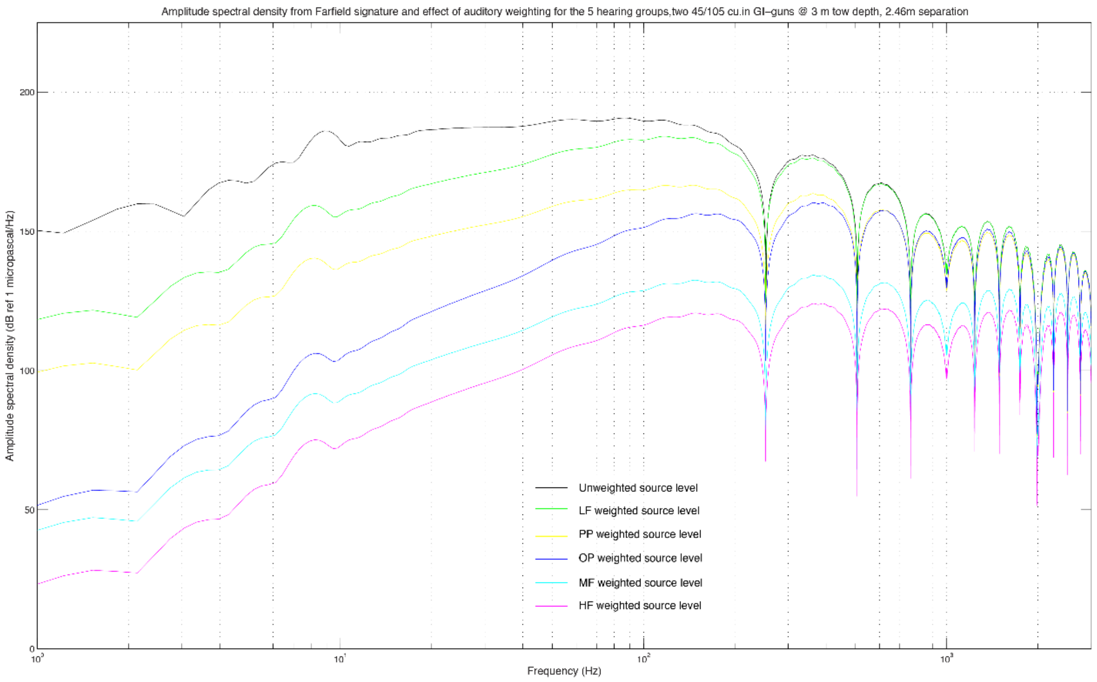


FIGURE A-19. Modeled amplitude spectral density of the two 45/105 in^3 GI airguns farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral 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.

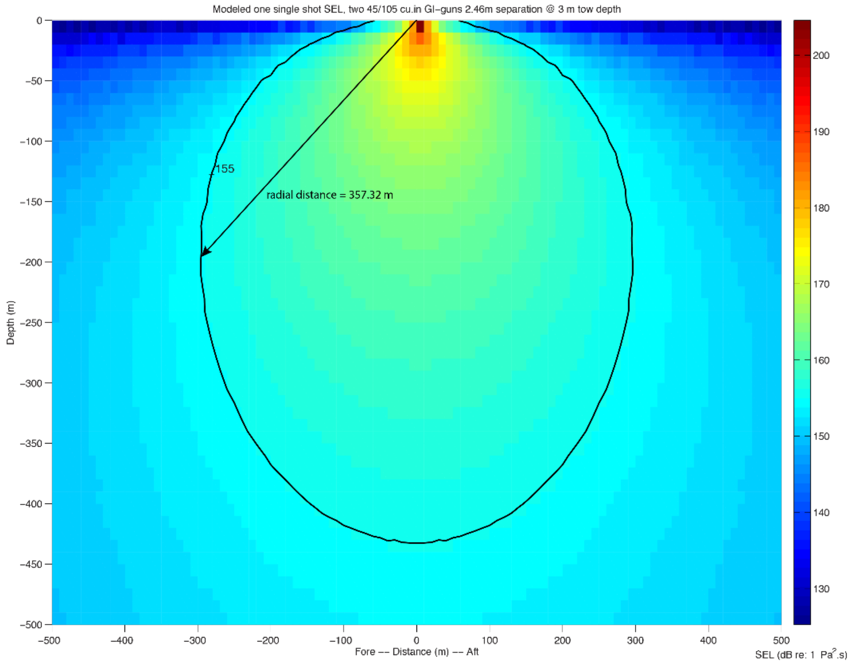


FIGURE A-20. Modeled received sound levels (SELs) in deep water from two 45/105 in^3 GI airguns separated by 2.46 m a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (357.32 m).

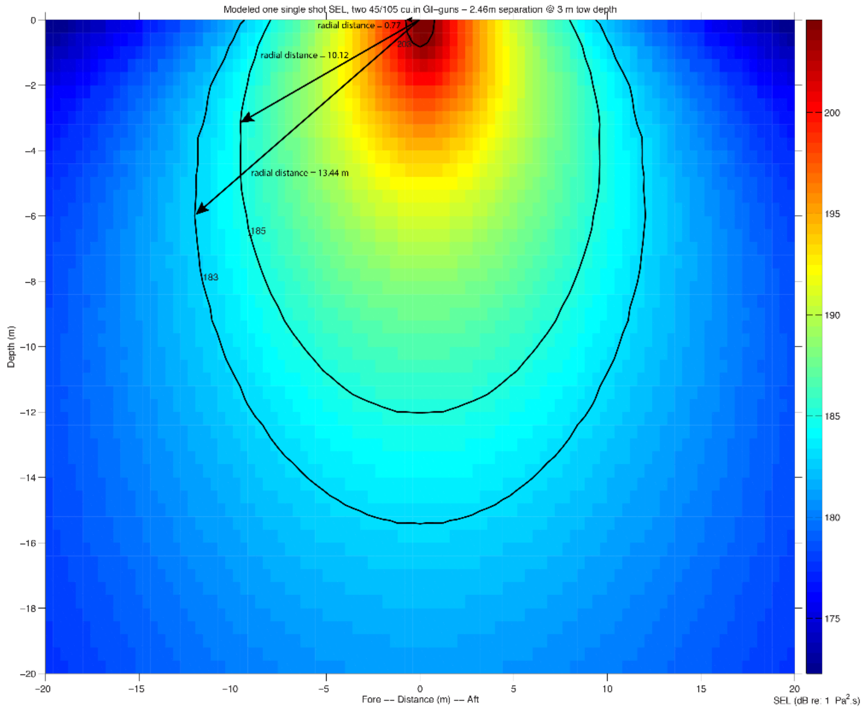


FIGURE A-21. Modeled received sound levels (SELs) in deep water from two 45/105 in^3 GI airguns separated by 2.46 m a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

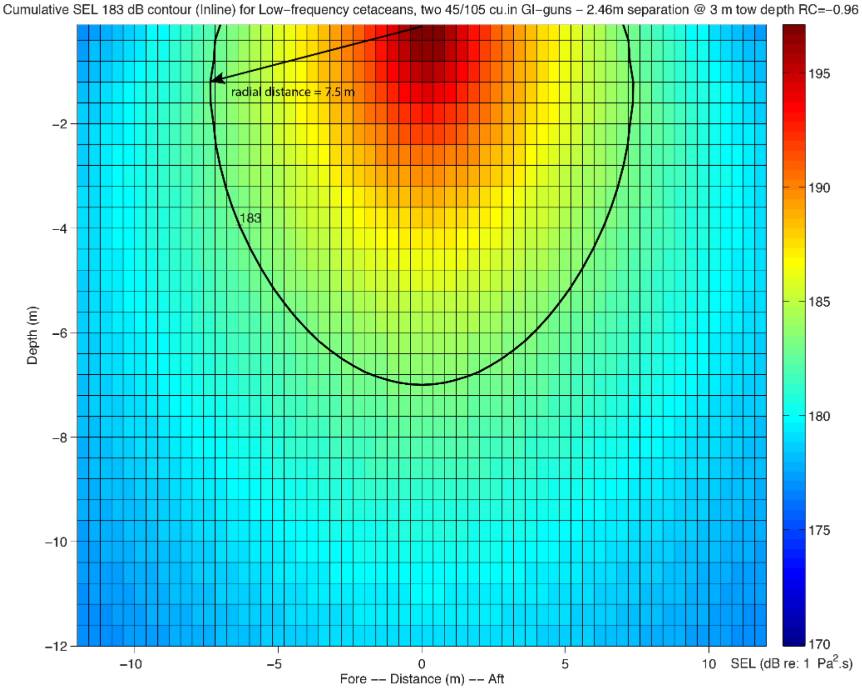


FIGURE A-22. Modeled received sound exposure levels (SELs) from two 45/105 in^3 GI airguns separated by 2.46 m a 3-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-21 and this figure allows us to estimate the adjustment in dB.

TABLE A-11. 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 marine mammal hearing groups that could be received from two 45/105 in^3 GI airguns during the proposed USGS seismic surveys off southern Puerto Rico.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds/ Sea Turtles
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	5.49	1.10	35.34	6.13	0.45

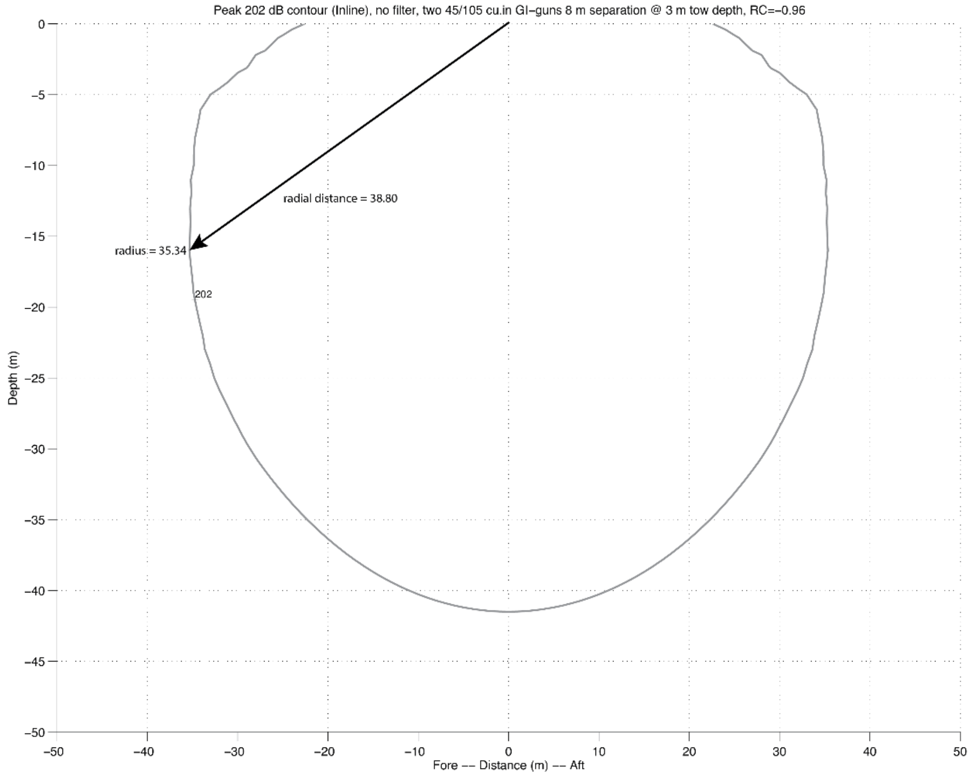


FIGURE A-23. Modeled deep-water received Peak SPL from two 45/105 in^3 GI airguns separated by 2.46 m a 3-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

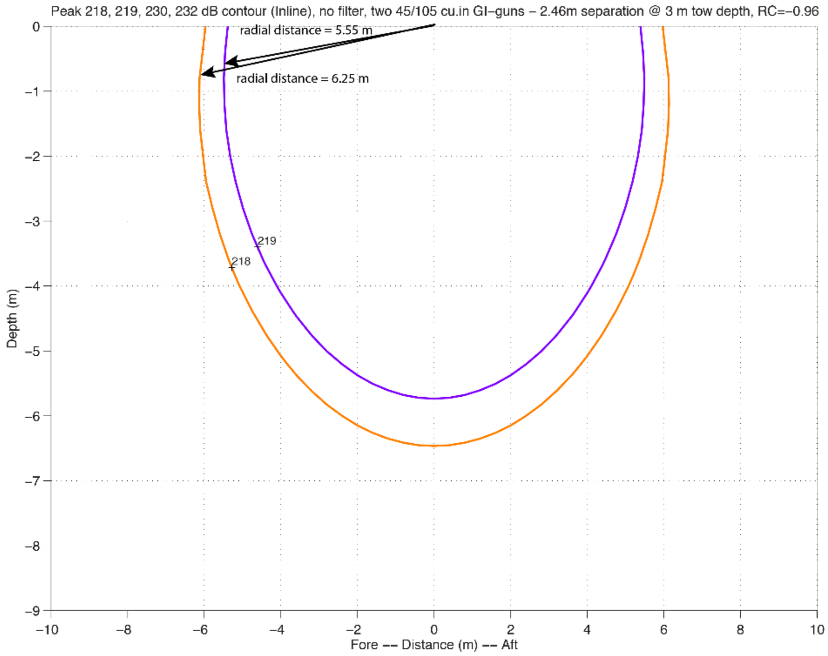


FIGURE A-24. Modeled deep-water received Peak SPL from two 45/105 in^3 GI airguns separated by 2.46 m a 3-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

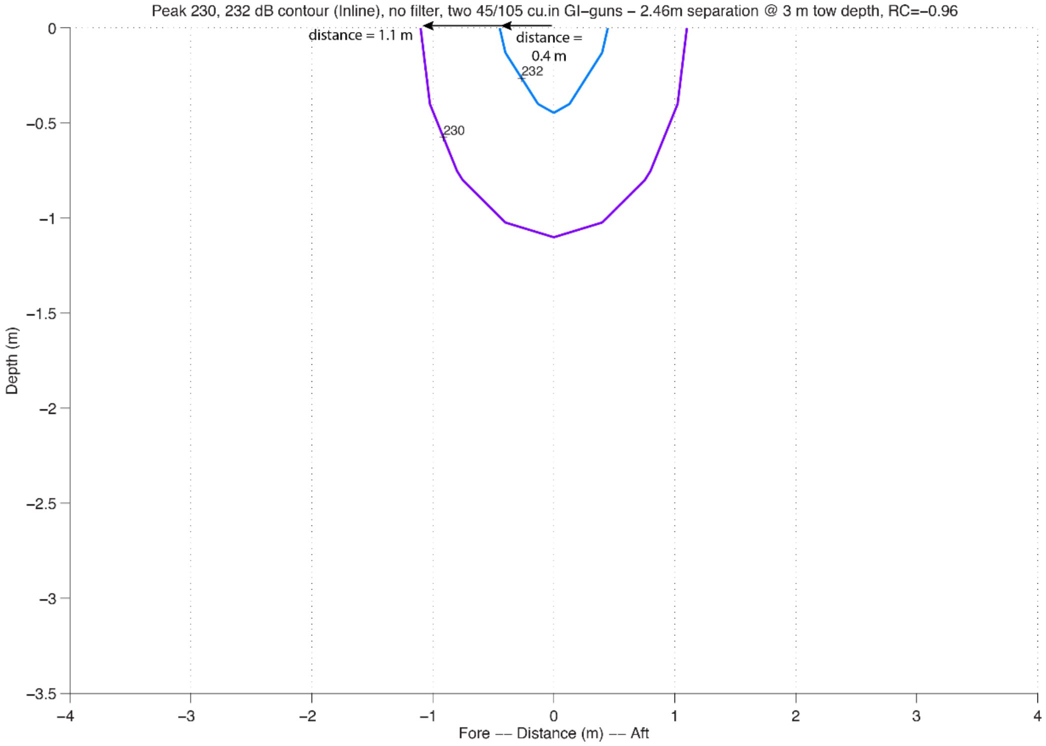


FIGURE A-25. Modeled deep-water received Peak SPL from two 45/105 in^3 GI airguns separated by 2.46 m a 3-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

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APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

Level B takes were determined for both the low- and high-energy seismic surveys, whereas Level A takes were only determined for the high-energy surveys. The ensonified areas that were used to calculate Level A and B takes are provided in Appendix C. Marine mammal densities were derived from habitat-based density models from Roberts et al. (2023). The detailed take calculations are shown in Table B-1. Population sizes for marine mammals are unknown for the Caribbean Sea and Puerto Rico and the U.S. Virgin Islands. The percentage of the population estimated to be taken was calculated for each species using the numbers from estimates for the AFTT area (western North Atlantic and GoM) from Roberts et al. (2023), which is the same dataset from which densities were calculated.

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TABLE B-2. Take estimates for the low-energy and the high-energy seismic surveys off Puerto Rico.

						Level B Ensonified Area (km^2)			Level A Ensonified Area (km^2)	Level B Takes							
Species	Intermediate 100-1000 m	Deep >1000 m	Stock Abundance North Atlantic[1]	Abundance AFTT Area[2]	Hearing Group	USGS Intermediate 100-1000 m	USGS Deep >1000 m	High-Energy Source Deep >1000 m	Large Source Survey	USGS Intermediate 100-1000 m	USGS Deep >1000 m	High-Energy Source Deep >1000 m	Level B Takes (Both surveys)	Only Level B Takes minus Level A (Both Surveys)	Level A Takes[4] (High-Energy only)	Level B + Level A % of AFTT Area Abundance [5]	Requested Level A+B Take Authorization[6]
LF Cetaceans																	
Humpback whale	0.004739	0.003748	1,396	4,990	LF	428	378	72,112	3,260	2	1	270	274	262	12	5.5	274
Minke whale	0.000184	0.000835	21,968	13,784	LF	428	378	72,112	3,260	0	0	60	61	58	3	0.4	61
Bryde's whale	0.000085	0.000088		536	LF	428	378	72,112	3,260	0	0	6	6	6	0	1.2	6
Fin whale	0.000013	0.000006	6,802	11,672	LF	428	378	72,112	3,260	0	0	0	0	0.4	0	0.0	2 [7]
Sei whale	0.000319	0.000319	6,292	19,530	LF	428	378	72,112	3,260	0	0	23	23	22	1	0.1	23
Blue whale	0.000020	0.000020	402	191	LF	428	378	72,112	3,260	0	0	1	1	1	0	0.8	1
MF Cetaceans																	
Sperm whale	0.005312	0.006623	4,349	64,015	MF	428	378	72,112	138	2	3	478	482	481	1	0.8	482
Beaked whales	0.009887	0.007392	5,744	65,069	MF	428	378	72,112	138	4	3	533	540	539	1	0.8	540
Cuvier's beaked whale [8]	N.A.	N.A.	5,744		MF	428	378	72,112	138	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	179
Blaineville's beaked whale [8]	N.A.	N.A.	10,107		MF	428	378	72,112	138	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	179
Gervais' beaked whale [8]	N.A.	N.A.	10,107		MF	428	378	72,112	138	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	179
True's beaked whale	N.A.	N.A.	10,107		MF	428	378	72,112	138	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3 [9]
Risso's dolphin	0.005193	0.002232	35,215	78,205	MF	428	378	72,112	138	2	1	161	164	164	0	0.2	164
Rough-toothed dolphin	0.006916	0.006546	136	32,848	MF	428	378	72,112	138	3	2	472	477	476	1	1.5	477
Common bottlenose dolphin	0.081656	0.028930	62,851	418,151	MF	428	378	72,112	138	35	11	2,086	2132	2128	4	0.5	2,132
Pantropical spotted dolphin	0.013061	0.010670	6,593	321,740	MF	428	378	72,112	138	6	4	769	779	778	1	0.2	779
Atlantic spotted dolphin	0.021284	0.021119	39,921	259,519	MF	428	378	72,112	138	9	8	1,523	1540	1537	3	0.6	1,540
Spinner dolphin	0.026713	0.026492	4,102	152,511	MF	428	378	72,112	138	11	10	1,910	1932	1928	4	1.3	1,932
Striped dolphin	0.001807	0.004373	67,036	412,729	MF	428	378	72,112	138	1	2	315	318	317	1	0.1	318
Clymene dolphin	0.020654	0.021800	4,237	181,209	MF	428	378	72,112	138	9	8	1,572	1589	1586	3	0.9	1,589
Fraser's dolphin	0.002539	0.002926		19,585	MF	428	378	72,112	138	1	1	211	213	213	0	1.1	213
Common dolphin	0.001796	0.001206	172,974	473,260	MF	428	378	72,112	138	1	0	87	88	88	0	0.0	88
Short-finned pilot whale [10]	0.023968	0.025140	28,924	264,907	MF	428	378	72,112	138	10	10	1,813	1833	1830	3	0.7	1,833
Killer whale	0.000024	0.000024		972	MF	428	378	72,112	138	0	0	2	2	2	0	0.2	2
False killer whale	0.003016	0.002983	1,791	12,682	MF	428	378	72,112	138	1	1	215	218	218	0	1.7	218
Pgymy killer whale	0.001742	0.001782		9,001	MF	428	378	72,112	138	1	1	128	130	130	0	1.4	130
Melon-headed whale	0.013398	0.013531		64,114	MF	428	378	72,112	138	6	5	976	987	985	2	1.5	987
HF Cetaceans																	
Kogia spp.	0.004750	0.005055	7,750	26,043	HF	428	378	72,112	2,731	2	2	365	368	354	14	1.4	368
Dwarf sperm whale [11]	N.A.	N.A.	7,750		HF	428	378	72,112	2,731	N.A.	N.A.	182	184	177	7	N.A.	184
Pygmy sperm whale [11]	N.A.	N.A.	7,750		HF	428	378	72,112	2,731	N.A.	N.A.	182	184	177	7	N.A.	184

Notes: Some values do not add up exactly due to rounding. Where population sizes are blank, it means none were available. N.A. = not available or not applicable. NA = North Atlantic. GoM = Gulf of Mexico. Pop. = population.

[1] From Hayes et al. (2022) and NMFS (2022).

[2] From Roberts et al. (2023).

[3] Based on population sizes in the AFTT area (U.S. Atlantic and Gulf of Mexico) from habitat-based density modeling by Roberts et al. (2023).

APPENDIX C: ENSONIFIED AREAS FOR TAKE CALCULATIONS

The ensonified areas that were used to calculate Level A and B takes for the high-energy seismic surveys are detailed in Table C-1, whereas those used to calculate Level B takes for the low-energy surveys are shown in Table C-2.

TABLE C-1. Areas expected to ensonified during the proposed high-energy surveys off Puerto Rico.

Survey Type	Survey Zone	Criterion	Daily Ensonified Area (km^2)	Total Survey Days	25% Increase	Total Ensonified Area (km^2)	Relevant Isopleth (m)
Marine Mammals							
OBS	Shallow <100 m	160 dB	0	7	1.25	0	25,494
OBS	Intermediate 100-1000 m	160 dB	89.7	7	1.25	784.6	9,468
OBS	Deep >1000 m	160 dB	2793.1	7	1.25	24439.6	6,733
MCS	Shallow <100 m	160 dB	0	13	1.25	0	25,494
MCS	Intermediate 100-1000 m	160 dB	89.7	13	1.25	1457.2	9,468
MCS	Deep >1000 m	160 dB	2254.5	13	1.25	36635.0	6,733
	Overall	**160 dB**	**5226.9**	**19**	**1.25**	**63316.4**	
Sea Turtles							
OBS	Shallow <100 m	160 dB	0	7	1.25	0	25,494
OBS	Intermediate 100-1000 m	160 dB	38.7	7	1.25	338.7	9,468
OBS	Deep >1000 m	160 dB	753.9	7	1.25	6596.9	6,733
MCS	Shallow <100 m	160 dB	0	13	1.25	0	25,494
MCS	Intermediate 100-1000 m	160 dB	38.7	13	1.25	629.0	9,468
MCS	Deep >1000 m	160 dB	604.8	13	1.25	9828.2	6,733
	Overall	**160 dB**	**1436.2**	**19**	**1.25**	**17392.8**	
Hearing Groups							
OBS	All zones	LF Cetacean	133.4	7	1.25	1,167.5	320.2
OBS	All zones	MF Cetacean	5.7	7	1.25	49.5	13.6
OBS	All zones	HF Cetacean	111.8	7	1.25	978.1	268.3
OBS	All zones	Otariid	4.4	7	1.25	38.6	10.6
OBS	All zones	Phocid	18.2	7	1.25	159.2	43.7
OBS	All zones	Sea Turtle	6.4	7	1.25	56.1	15.4
MCS	All zones	LF Cetacean	107.8	13	1.25	1,752.0	320.2
MCS	All zones	MF Cetacean	4.6	13	1.25	74.3	13.6
MCS	All zones	HF Cetacean	90.3	13	1.25	1,467.7	268.3
MCS	All zones	Otariid	3.6	13	1.25	57.9	10.6
MCS	All zones	Phocid	14.7	13	1.25	238.8	43.7
MCS	All zones	Sea Turtle	5.2	13	1.25	84.1	15.4

TABLE C-2. Areas expected to ensonified during the proposed low-energy USGS surveys off Puerto Rico.

Survey Zone	Criterion	Daily Ensonified Area (km^2)	Total Survey Days	25% Increase	Total Ensonified Area (km^2)	Relevant Isopleth (m)
Marine Mammals						
Deep >1000 m	160 dB	100.9	3	1.25	378.4	438
Intermediate 100-1000 m	160 dB	114.1	3	1.25	427.9	657
Overall	**160 dB**	**215.0**	**3**	**1.25**	**806.3**	
Sea Turtles						
Deep >1000 m	175 dB	17.7	3	1.25	66.4	78
Intermediate 100-1000 m	175 dB	20.0	3	1.25	75.0	117
Overall	**160 dB**	**37.7**	**3**	**1.25**	**141.4**	