Request by the U.S. Geological Survey for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during the MATRIX Marine Geophysical Survey in the Northwest Atlantic Ocean, August 2018

Submitted by

U.S. Geological Survey

to

National Marine Fisheries Service
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

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Request by the U.S. Geological Survey for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Low-Energy Marine Geophysical Survey by R/V *Hugh R. Sharp* in the Northwest Atlantic Ocean, August 2018

SUMMARY

The U.S. Geological Survey plans to conduct a seismic survey called MATRIX (Mid-Atlantic Resource Imaging Experiment) within the U.S. Exclusive Economic Zone in the Northwest Atlantic Ocean during August 2018. The seismic survey would use two to four Generator-Injector (GI) airguns with a total discharge volume of 210 in^3 to 840 in^3. The seismic surveys would take place in U.S. waters deeper than 100 m and extend to 3500 m water depth at the seaward end. The northern boundary of the survey area is 35 nm south of Hudson Canyon, and the southernmost survey would take place at approximately the latitude of Cape Hatteras. The USGS requests an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic surveys. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals inhabit the proposed project area in the Northwest Atlantic Ocean. Under the U.S. Endangered Species Act (ESA), several of these species are listed as ***endangered***, including the North Atlantic right, sei, fin, blue, and sperm whales. The USGS is proposing a marine mammal monitoring and mitigation program to minimize the potential impacts of the proposed activity on marine mammals present during completion of the proposed research and to document the nature and extent of any effects.

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

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

mammals. Substantial additional information is provided in the *Draft Environmental Assessment of a Marine Geophysical Survey (MATRIX) by the US Geological Survey in the Northwestern Atlantic Ocean, August 2018 (*USGS, 2018), submitted to the National Marine Fisheries Service on March 13, 2018. Based in part on the consultation with NMFS on this IHA, that Environmental Assessment will be updated for consistency with changes introduced into this IHA when the Environmental Assessment is finalized prior to the Proposed Action. Many sections of that Draft MATRIX EA (USGS, 2018) and of this IHA have been taken verbatim or adapted only slight from the Draft Scripps EA (LGL, 2017a) prepared for a proposed Summer 2018 low-energy survey and from the associated Scripps IHA (LGL, 2017b).

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 U.S. Geological Survey intends to conduct a seismic survey aboard the *R/V Hugh R. Sharp*, a University National Oceanographic Laboratory (UNOLS) federal fleet vessel that is owned and operated by the University of Delaware, during a cruise up to 22 days long on the northern U.S. Atlantic margin in August 2018. The program is named MATRIX, for "Mid-Atlantic Resource Imaging Experiment." The seismic survey will take place in water depths ranging from ~100 m to 3500 m, entirely within the U.S. Exclusive Economic Zone (EEZ), and acquire ~6 dip lines (roughly perpendicular to the orientation of the shelf-break) and ~3 strike lines (roughly parallel to the shelf-break) between about 35 nm south of Hudson Canyon on the north and Cape Hatteras on the south. In addition, multichannel seismic (MCS) data will be acquired along some linking/transit/interseismic lines between the main survey lines. Total data acquisition could be up to ~2400 km. Exemplary seismic lines for the program are shown in Figure 1. Some deviation in actual tracklines and timing could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment.

The purpose of the Proposed MATRIX Action is to collect data to constrain the lateral and vertical distribution of gas hydrates and shallow natural gas in marine sediments relative to seafloor gas seeps, slope failures, and geological and erosional features. To achieve the program's goals, Drs. Carolyn Ruppel and Nathan C. Miller, both of the USGS Woods Hole Coastal and Marine Science Center, propose to collect up to 9 long (80 nm or more) high-resolution MCS profiles and linking/transit/interseismic lines constituting up to ~2400 km total of new seismic data. More background on MATRIX and past research in the area and a list of acronyms are given in the Draft MATRIX EA submitted to NMFS by the USGS on March 13, 2018 (Draft MATRIX EA, USGS 2018). MATRIX is funded by the U.S. Geological Survey, with additional funding from the Bureau of Ocean Energy Management's Resource Evaluation Division, which has a long record of studying methane gas hydrates on U.S. margins and developing quantitative assessments of these deposits. The U.S. Department of Energy's National Methane Hydrates R&D Program is also providing funding for this project.

The procedures to be used for the seismic surveys would be similar to those used during previous research seismic surveys funded by NSF or conducted by the USGS and would use conventional seismic methodology. The survey will involve only one source vessel, the R/V *Hugh R. Sharp*. The source vessel will deploy two to four low-energy Generator-Injector (GI) airguns (each has discharge volume of 105 in^3) as an energy source. The GI guns could sometimes fired in a mode that gives them discharge volume of 210 in^3 each, but only at water depths greater than 1000 m (see below). An 120-channel, 1.2-km-long hydrophone streamer will be continuously towed to receive the seismic signals. In addition, up to 90 disposable sonobuoy receivers will be deployed at water depths greater than 1000 m to provide velocity control and possibly wide-angle reflections along the highest priority transects.

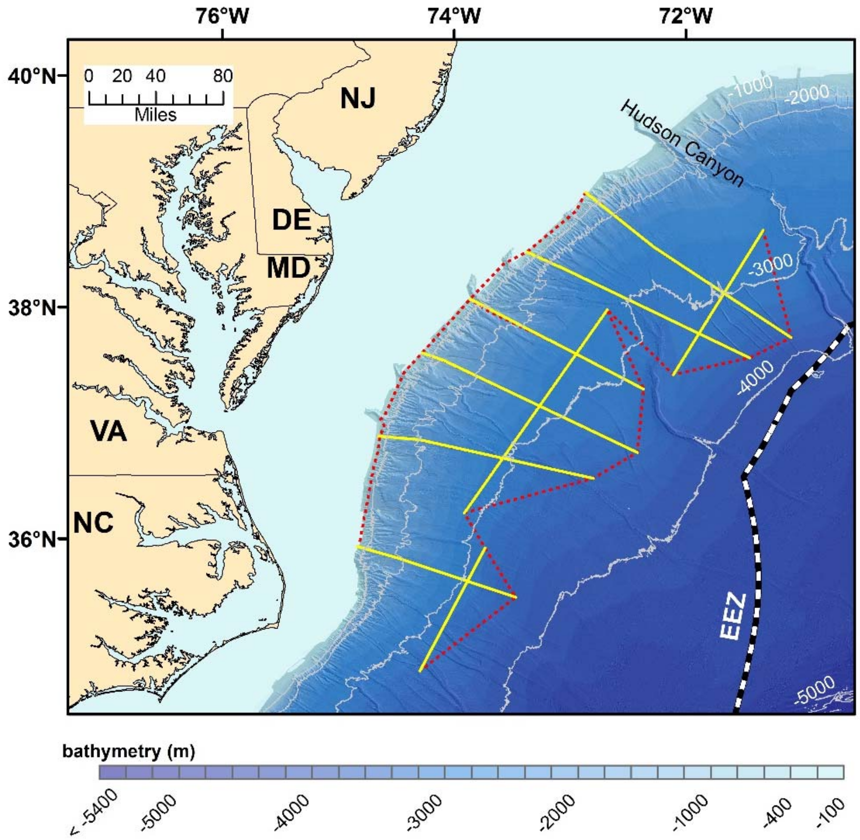

Figure 1. Exemplary seismic lines (yellow) to be acquired by the USGS during the Proposed Action, superposed on the USGS high-resolution bathymetric grid (Andrews et al., 2016). Red dashed lines are linking/transit/interseismic lines, and data will be acquired along only half of these lines. The dashed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

The **Optimal Survey** (Table 1) for the Proposed Action would acquire the portion of the solid lines in Figure 1 at greater than 1000 m water depth using the GI-guns in "GG" mode. In this mode, the 4 GI guns would produce a total of 840 in^3 of air (see (e) below), and sonobuoys would be deployed to passively record data at long distances. The rest of the survey, including the portion shallower than 1000 m water depth on the uppermost slope and the interseismic linking lines (dashed red in Figure 1), would be acquired with 4 GI guns operated in normal mode (also called GI mode), productng a total of 420 in^3 of air.

The **Base Survey** assumes that all of the solid lines in Figure 1, as well as all of the interseismic connecting lines, would be acquired using 4 GI guns operating in normal mode (GI mode), producing a total air volume of 420 in^3.

Takes (summarized in Table 7) were separately calculated for each of these surveys. However, the takes reported in Table 7 are those for the Optimal Survey, representing the maximum calculated takes and a conservative approach.

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

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

	GI mode (4x105 in^3)		GG mode (4x210 in^3)	
Optimal Survey	100-1000 m water depth on exemplary lines AND 50% of interseismic, linking lines	~750 km	Greater than 1000 m on exemplary lines	~1600 km
Base Survey	Exemplary lines plus 50% of interseismic, linking lines	2350 km		

During the cruise, the USGS would continuously use its fisheries echosounder (EK60/EK80) with 38 kHz transducer at water depths less than ~1800 m to locate water column anomalies associated with seafloor seeps emitting gas bubbles. The 38 kHz transducer would be mounted in the *R/V Sharp*'s retractable keel and would typically ping 0.5 to 2 Hz with pings of 0.256 to 1.024 ms duration. The returned signals would be detected on an EK60 or EK80 (broadband) transceiver. Based on past USGS experience with this instrument, it is unlikely to acquire useful data at water depths greater than 1800 m, although it could be used in passive mode at these depths to record broadband ambient signals in the water column. As explained later in this IHA (§ VII), no takes are requested for use of the fisheries echosounder.

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

Source Vessel Specifications

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

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

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

Owner:	University of Delaware
Operator:	University of Delaware
Flag:	United States of America
Launch Date:	2006
Domestic Tonnage:	256 T
Accommodation Capacity:	22, including 14 scientists

Airgun Description

The R/V *Hugh R. Sharp* will tow two or four 105-in^3 Sercel generator-injector (GI) airguns at a time as the primary energy source following exemplary survey lines and transit/linking/interseismic lines between the primary exemplary lines. Seismic pulses for the GI guns will be emitted at intervals of ~12 s. At speeds of ~7.4 km/h (4 kt), the shot intervals correspond to a spacing of ~25 m.

In standard GI mode, the generator chamber of each GI airgun is the primary source, the one responsible for introducing the sound pulse into the ocean, is 105 in^3. The 105 in^3 injector chamber injects air into the previously-generated bubble to reduce bubble reverberations and does not introduce more sound into the water. When shooting to sonobuoys during the Proposed Action, the GI guns will also sometimes be operated with both chambers releasing air simultaneously (i.e., “generator-generator” or “GG” mode). In GG mode, each gun simultaneously releases an air volume of 105 in^3 + 105 in^3= 210 in^3. On this cruise, four GI guns will be operated either in base mode (4x105 in^3) or GG mode (4x210 in^3) as long as compressors are functioning correctly. If compressors are not functioning properly, a backup mode consisting of two GI guns will be used. The **Backup Configuration** is described in Appendix A. The text below describes the two preferred modes for operations.

The **Base Configuration**, **Configuration 1,** will use 4 GI guns and generate 420 in^3 total volume, as shown in Figure 2. Guns will be towed at 3 m water depth, two on each side of the stern, with 8.6 m lateral (athwartships) separation between the pairs of guns and 2 m front-to-back separation between the guns on each stern tow line.

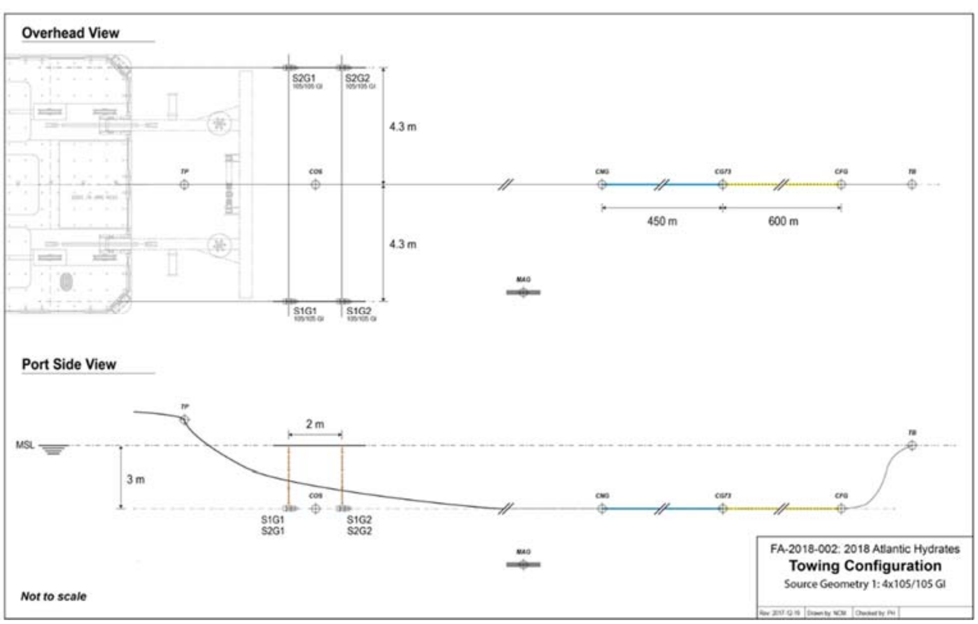

Figure 2. Base configuration (Source configuration 1): 420 in^3 total volume consisting of 4x105/105in^3 GI guns (S#G*, where # is the side and * is the gun number) firing in standard GI mode.

The **GG Configuration, Configuration 2,** will use 4 GI guns and generate 840 in^3 total volume, as shown in Figure 3. In this configuration, the guns will be fired in GG mode, as described above. Guns will be towed at 3 m water depth, two on each side of the stern, with 8.6 m lateral (athwartships) separation between the pairs of guns and 2 m front-to-back separation between the guns on each stern tow line. The GG configuration would be used **only at greater than 1000 m water depth** and on specific exemplary lines on which sonobuoy data are being collected.

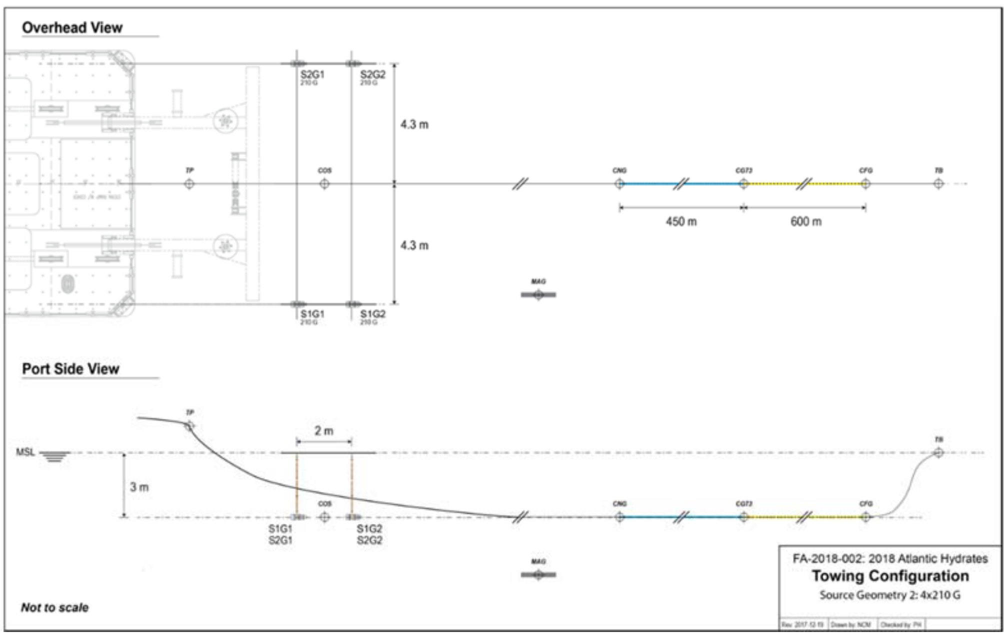

Figure 3. GG Configuration (Source configuration 2): 840 in^3 total volume consisting of 4x105/105in^3 GI guns firing both chambers simultaneously (i.e. GG mode). Guns are labelled as S#G*, where # is the side and * is the gun number.

As the GI airguns are towed along the survey line, the towed hydrophone array receives the reflected signals and transfers the data to the on-board processing system. Given the short streamer length behind the vessel (1200 m), the turning rate of the vessel while the gear is deployed is much higher than the limit of five degrees per minute for a seismic vessel towing a streamer of more typical length (e.g., 6 km or more). Thus, the maneuverability of the vessel is not strongly limited during operations.

GI Airgun Specifications

Energy Source	Two (backup configuration, Appendix A) to four (base and GG configuration) GI airguns of 105 in^3 each
Tow depth of energy source	3 m
Air discharge volume	Total volume ~210 in^3 (backup configuration, Appendix A) to 840 in^3 (limited use GG configuration

	at greater than 1000 m)
Back-to-front separation of pairs of guns	2 m
Side-to-side separation of pairs of guns	8.6 m
Dominant frequency components	0–188 Hz

The source levels for the GI gun configurations can be derived from the modeled farfield source signature, which was determined for the USGS by L-DEO using the PGS Nucleus software. Modeling information is provided below, with more complete details in Appendices B and C.

In July 2016, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). Onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat}, respectively. For impulsive sounds, such airgun pulses, the new guidance incorporates marine mammal auditory weighting functions (Fig. 4) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). As required by NMFS (2016a), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) would be used as the EZ and for calculating takes. For LF cetaceans the PTS SEL_{cum} criterion is used. For MF and HF cetaceans, the Peak SPL_{flat} yields a larger exclusion zone and is therefore used. Pinnipeds are not considered since they do not occur in the area of the Proposed Survey.

The SEL_{cum} and Peak SPL (Appendix C) for the planned airgun configurations are derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently only in the vertical direction. In the horizontal direction, the sound pressure does not always constructively interfere and stack coherently, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the interactions of the two airguns that occur near the source center and is calculated as a point source (single airgun), the modified farfield signature is a more appropriate measure of the sound source level for large arrays. For this smaller array, the modified farfield changes will be correspondingly smaller as well, but we use this method for consistency across all array sizes.

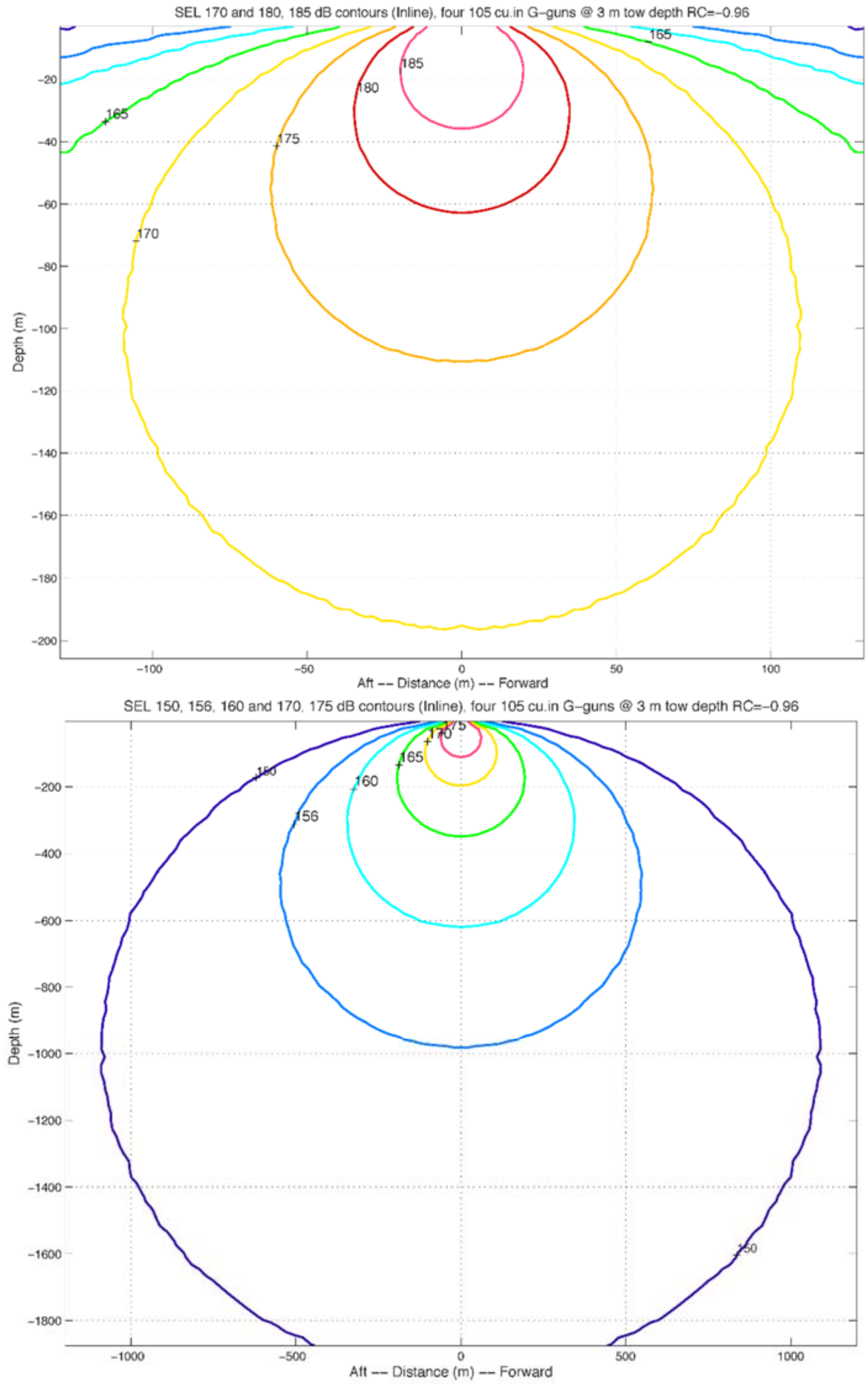

Figure 4. Modeled deep-water received sound exposure levels (SELs) from the Base Configuration (Configuration 1; four 105 in^3 GI-guns) towed at 3-m depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths, respectively. The top diagram is a blow-up of the bottom one.

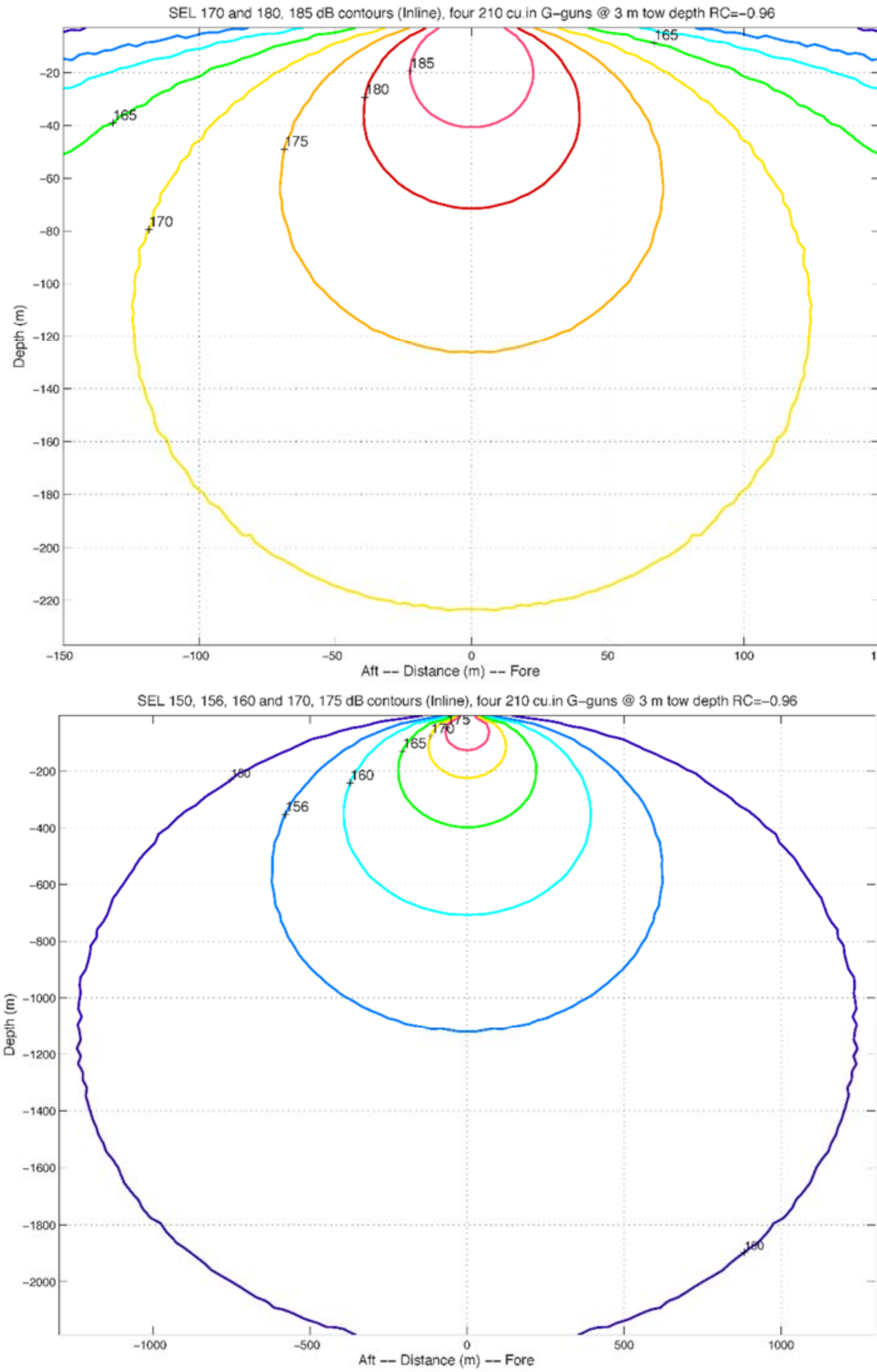

Figure 5. Modeled deep-water received sound exposure levels (SELs) from the GG configuration (Configuration 2), with four 210 in^3 GI-guns towed at 3-m depth and generating a total of 840 in^3. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths, respectively. The upper plot is a zoomed-in version of the lower plot.

Table 2. Summary of predicted distances to which sound levels ≥ 160-dB re 1 μPa_{rms} would be expected to be received during the proposed surveys in the Northwest Atlantic Ocean for the Base and GG configuration, based on modeling shown in Figures 4 and 5. Refer to Appendix A for the Backup Configuration. The Proposed Action would not involve ensonifying the seafloor at water depths shallower than 100 m. Further calculations and information are given in Appendix B.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted RMS Radii (m)
			160 dB
Base Configuration (Configuration 1) Four 105 in^3 G-guns	3	>1000 m	1091[1]
		100–1000 m	1637[2]
GG Configuration (Configuration 2) Four 210 in^3 G-guns	3	>1000 m	1244[1]
		100–1000 m	1866[2]

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

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding default values and calculating individual adjustment factors (dB) and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014). The methodology (input) for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the airgun array is shown in Table 3.

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

TABLE 3. SEL_{cum} Methodology Parameters (Sivle et al. 2014)†.

Airgun Configuration	Source Velocity (meters/second)	1/Repetition rate^ (seconds)
All Configurations	2.05778*	12.149&

†Methodology assumes propagation of 20 log R; Activity duration (time) independent
^ Time between onset of successive pulses.
*Equivalent to 4 kts
&The USGS intends to use a nominal shot interval of 25 m (~12 s at 4 kts).

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

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

Table 4. Summary Level A acoustic thresholds in meters for each source configuration and hearing group relevant to acquisition of the Base/Optimal Surveys for the Proposed Action. Corresponding values for the backup configuration of airguns, which would ideally not be used for the Base/Optimal Surveys, are provided in Tables C10 and C11.

	Hearing Group		
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**
Threshold	183 dB (SEL_{cum})	230 dB (Peak SPL_{flat})	202 dB (Peak SPL_{flat})
Base Configuration	*31.0 m*	*0.0*	*70.43 m*
GG Configuration	*39.5 m*	*0.0*	*80.5 m*

The NSF-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. Table 3 of Appendix F of the NSF-USGS PEIS shows that a quadrilateral (4 GI gun) array of 105 in^3 guns would meet the low-energy criteria if towed at 3 m depth and separated by 8 m. Based on the modeling in Table 1 and the fact that the quadrilateral array of guns to be used for the Proposed Action would be separated by only 2 m front to back and 8.6 m side to side (and will be operated occasionally in GG mode, which generates 210 in^3 of air per GI gun), the Proposed Action slightly exceeds the criteria of a low-energy activity according to the NSF-USGS PEIS. Note that the sources to be used for the Proposed Action at maximum generate less than 20% of the air (usually > 6000 in^3) typically used for seismic surveys by a range of research and private sector operators.

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

Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. This IHA application has been prepared in accordance with the current NOAA acoustic practices, and procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

Description of Operations

The survey will involve one source vessel, the R/V *Hugh R. Sharp*. The source vessel will deploy two to four low-energy Generator-Injector (GI) airguns (each has discharge volume of 105 in^3) as an energy source. An 120-channel, 1.2-km-long hydrophone streamer will be continuously towed to receive the seismic signals. In addition, up to 90 disposable sonobuoy receivers will be deployed only at water depths greater than 1000 m to provide velocity control and possibly wide-angle reflections along the highest priority transects.

The sonobuoys, which will be deployed as frequently as every 15 km along high-priority lines, record the returning acoustic signals at larger offsets than are possible with the streamer and transmit the information at radio frequencies to receivers on the ship. A maximum of ~2400 km of data will be collected (Fig. 1). Most lines are oriented subperpendicular to the strike of the margin (dip lines), but data will be acquired along some linking/interseismic lines oriented roughly parallel to the margin (strike lines) and along short strike interseismic/linking lines that connect the dip lines. Table 1 summarizes the survey plan for the Optimal and Base Surveys.

Along with the airgun operations, the USGS will use its EK60/80 fisheries echosounder with a single (38 kHz) transducer.

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

The remainder of this document relies heavily on the text in the Incidental Harassment Authorization Application submitted by Scripps Institute of Oceanography for its June-July Northwestern Atlantic Survey, as prepared by LGL (LGL, 2017b). That document will henceforth be referred to as Scripps IHA (LGL, 2017). This IHA also relies heavily on the Draft Scripps EA (LGL, 2017a) and on the Draft MATRIX EA (USGS, 2018), which will be updated for consistency with the April 2018 revisions in this IHA when the EA is finalized prior to the Proposed Action.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

Thirty-four marine mammal species could occur in the general survey area, including 7 mysticetes (baleen whales) and 27 odontocetes (toothed whales, such as dolphins) (Table 6). To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below. Five of the species that could occur in the proposed project area are listed under the ESA as ***endangered***, including the sperm, sei, fin, blue, and North Atlantic right whales. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the NSF-USGS PEIS.

One of the detailed analysis areas (DAAs) defined in the NSF-USGS PEIS §2.3.1.1 is in the Northwest (NW) Atlantic and lies at the northernmost end of the Survey Area for this Proposed Action, encompassing the area out to 1500 m water depth. The distributions of mysticetes, odontocetes, and pinnipeds in the NW Atlantic DAA are discussed in §3.6.2.1, §3.7.2.1, and §3.8.2.1 of the NSF-USGS PEIS, respectively. The rest of this section deals specifically with species distribution in the area of the Proposed Action.

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

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

Two cetacean species occur in arctic waters, and their ranges generally do not extend as far south as the proposed project area: the narwhal, *Monodon monoceros*, and the beluga, *Delphinapterus leucas*. Two additional cetacean species, the Atlantic humpback dolphin (*Souza teuszii*) found in coastal waters of western Africa, and the long-beaked common dolphin (*Delphinus capensis*) found in coastal waters of South America and western Africa, do not occur in deep offshore waters. Pinniped species that are known to occur in North Atlantic waters, but are not expected to occur in the deep offshore proposed project area, include the gray seal (*Halichoerus grypus*), harbor seal (*Phoca vitulina*), bearded seal (*Erignathus barbatus*), and walrus (*Odobenus rosmarus*).

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. The text here comes directly from the Draft MATRIX EA (USGS, 2018). Much of the following section is taken verbatim from the Draft Scripps EA (LGL, 2017), with modifications to reflect the specifics of the MATRIX project.

Mysticetes

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

NORTH ATLANTIC RIGHT WHALE (EUBALAENA GLACIALIS)

The North Atlantic right whale occurs primarily in the continental shelf waters of the eastern U.S. and Canada, from Florida to Nova Scotia (Winn et al. 1986; Jefferson et al. 2015). Survey data have identified seven major habitats or congregation areas for North Atlantic right whales: coastal waters of the southeastern United States; Great South Channel; Jordan Basin; Georges Basin along the northern edge of Georges Bank; Cape Cod and Massachusetts Bays; Bay of Fundy; and Roseway Basin on the Scotian Shelf (Hayes et al. 2017). There is a general seasonal north-south migration between feeding and calving areas (Gaskin 1982). The migration route between the Cape Cod spring/summer feeding grounds and the Georgia/Florida winter calving grounds is known as the mid-Atlantic corridor, and whales move through these waters regularly in all seasons (Reeves and Mitchell 1986; Winn et al. 1986; Kenney et al. 2001; Reeves 2001; Knowlton et al. 2002; Whitt et al. 2013). The majority of sightings (94%) along the migration corridor are within 56 km of shore (Knowlton et al. 2002).

During the summer and into fall (June–November), right whales are most commonly seen on feeding grounds in Canadian waters off Nova Scotia, with peak abundance during August, September, and early October (Gaskin 1987). Some right whales, including mothers and calves, remain on the feeding grounds through the fall and winter. However, the majority of the right whale population leaves the feeding grounds for unknown wintering habitats and returns when the cow-calf pairs return. The majority of the right whale population is unaccounted for on the southeastern U.S. winter calving ground, and not all reproductively-active females return to the area each year (Kraus et al. 1986; Winn et al. 1986; Kenney et al. 2001). Other wintering areas have been suggested, based on sparse data or historical whaling logbooks; these include the Gulf of St. Lawrence, Newfoundland and Labrador, coastal waters of New York and between New Jersey and North Carolina, Bermuda, and Mexico (Payne and McVay 1971; Aguilar 1986; Mead 1986; Lien et al. 1989; Knowlton et al. 1992; Cole et al. 2009; Patrician et al. 2009).

In more than 5000 recorded global sightings of North Atlantic right whales, there have been 11 within the polygon that bounds the exemplary surveys (OBIS, 2017). No sightings have been reported in July, August or September within the survey area (Figure 6). Given the small size of the population and their typical summer range, North Atlantic right whales should not be encountered during the USGS surveys.

HUMPBACK WHALE (MEGAPTERA NOVAEANGLIAE)

The humpback whale is found throughout all of the oceans of the world (Clapham 2009). Although considered to be mainly a coastal species, humpbacks often traverse deep pelagic areas while migrating (Clapham and Mattila 1990; Norris et al. 1999; Calambokidis et al. 2001). Humpback whales migrate between summer feeding grounds in high latitudes and winter calving and breeding grounds in tropical waters (Winn and Reichley 1985; Clapham and Mead 1999; Smith et al. 1999). The summer feeding grounds in the North Atlantic range from the northeast coast of the U.S. to the Barents Sea (Katona and Beard 1990; Smith et al. 1999). Humpbacks in the North Atlantic primarily migrate to wintering areas in the West Indies (Jann et al. 2003), but some also migrate to Cape Verde (Carrillo et al. 1999; Wenzel et al. 2009). A small proportion of the Atlantic humpback whale population remains in high latitudes in the eastern North Atlantic during winter (e.g., Christensen et al. 1992).

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

Of the more than 43,000 global sightings of humpback whale individuals or groups dating back more than 50 years in the OBIS database (2017), only 79 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, fourteen sightings occurred during July, August, or September, primarily on the continental shelf between north of Washington Canyon and the mouth of Delaware Bay (Figure 6). Three of these sitings have been at or seaward of the shelf break, near the landward ends of the two northernmost exemplay USGS seismic lines.

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

MINKE WHALE (BALAENOPTERA ACUTOROSTRATA)

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

Most minke whale sitings south of 40°N have been on the continental shelf, at water depths shallower than the proposed USGS seismic lines. Minke whales may occasionally be encountered seaward of the shelf-break during the proposed USGS surveys. Of the more than 15,000 sightings of minke whale individuals or groups dating back more than 50 years in the OBIS database, 51 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, twelve sightings comprising 21 individuals occurred during July, August, or September (Figure 6). Only two of the sightings were seaward of the shelf break, including one near Washington Canyon and another beyond the distal, deepwater termini of the three central USGS exemplary seismic transects.

Minke whales could be encountered near the survey lines in August, but this would be a rare occurrence.

BRYDE'S WHALE (BALAENOPTERA EDENI/BRYDEI)

Bryde's whale is found in tropical and subtropical waters throughout the world between 40ºN and 40ºS, generally in waters warmer than 20ºC, but at minimum 15ºC (Reeves et al. 1999; Kanda et al. 2007; Kato and Perrin 2009). It can be pelagic as well as coastal (Jefferson et al. 2015). It does not undertake long north/south migrations, although local seasonal movements toward the Equator in winter and to higher latitudes in summer take place in some areas (Evans 1987; Jefferson et al. 2015). Of 914 usable sightings in the iOBIS database, none occurred within the larger box enclosing the proposed survey in any season (Figure 6). Still, Bryde's whales could possibly be encountered in the proposed project area.

SEI WHALE (BALAENOPTERA BOREALIS)

The distribution of the sei whale is not well known, but it is found in all oceans and appears to prefer mid-latitude temperate waters (Gambell 1985a). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001; Jefferson et al. 2015). It is found in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). A small number of individuals have been sighted in the eastern North Atlantic between October and December, indicating that some animals may remain at higher latitudes during winter (Evans 1992). Sei whales have been seen from South Carolina south into the Gulf of Mexico and the Caribbean during winter (Rice 1998); however, the location of sei whale wintering grounds in the North Atlantic is unknown (Víkingsson et al. 2010).

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

Of the more than 11,000 sightings of sei whale individuals or groups dating back more than 50 years in the OBIS database, only 7 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, only two sightings, comprising three individuals in total, occurred between in July, August, or September (Figure 6). Sei whales could be encountered in the proposed project area during an August survey, but this would be an extremely rare occurrence.

FIN WHALE (BALAENOPTERA PHYSALUS)

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

In the North Atlantic, fin whales are found in summer from Baffin Bay, Spitsbergen, and the Barents Sea, south to North Carolina and the coast of Portugal (Rice 1998). In winter, they have been sighted from Newfoundland to the Gulf of Mexico and the Caribbean, and from the Faroes and Norway south to the Canary Islands (Rice 1998). Based on geographic differences in fin whale calls, Delarue et al. (2014) suggested that there are four distinct stocks in the Northwest Atlantic, including a central North Atlantic stock that and extends south along the Mid-Atlantic Ridge. Similarly, the four stocks in the Northwest Atlantic currently recognized by NAMMCO (2016) are located off West Iceland (in the Central Atlantic), Eastern Greenland, Western Greenland, and Eastern Canada.

Based on density modeling by Mannocci et al. (2017) for the western North Atlantic, higher densities are expected to occur north of 40°N; very low densities are expected south of 40°N, where the USGS surveys are entirely located. Of the more than 68,000 sightings of fin whale individuals or groups dating back more than 50 years in the OBIS database, 131 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. Of these, 29 sightings, comprising 60 individuals in total, occurred during July, August, or September (Figure 6). Fin whales could be encountered during the proposed August surveys, particularly closer to the shelf edge and near the uppermost continental slope.

BLUE WHALE (BALAENOPTERA MUSCULUS)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). It is most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Seamounts and other deep ocean structures may be important habitat for blue whales (Lesage et al. 2016). Generally, blue whales are seasonal migrants between high latitudes in summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). Their summer range in the North Atlantic extends from Davis Strait, Denmark Strait, and the waters north of Svalbard and the Barents Sea, south to the Gulf of St. Lawrence and the Bay of Biscay (Rice 1998). Although the winter range is mostly unknown, some occur near Cape Verde at that time of year (Rice 1998).

Of the more than 16,000 sightings of blue whale individuals or groups dating back more than 50 years in the OBIS database, only 2 occurred within a rectangular block containing the exemplary proposed USGS seismic survey lines. One of these, comprising a single individual, occurred during July, August, or September and was located ~85 nautical miles offshore New Jersey, on the upper continental slope between the two northernmost exemplary USGS seismic lines to be acquired down the continental slope (dip lines) and may either be an extralimital animal or a misidentification (Figure 6). While it would be a very rare occurrence, it is possible that a blue whale could be encountered in the proposed project area during an August seismic survey.

Odontocetes

SPERM WHALE (PHYSETER MACROCEPHALUS)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). Sperm whale distribution is linked to social structure: mixed groups of adult females and juvenile animals of both sexes generally occur in tropical and subtropical waters, whereas adult males are commonly found alone or in same-sex aggregations, often occurring in higher latitudes outside the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography, in waters at least 1000 m deep (Jaquet and Whitehead 1996; Whitehead 2009). They are often found far from shore, but can occur closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2009).

In the OBIS database, 686 sperm whale sightings occur within a rectangular area encompassing the survey area, and 395 occurred during July through September. As shown in Figure 6, most of these sightings are seaward of the shelf-break in deepwater, overlapping the area of the Proposed Action. Thus, sperm whales are likely to be encountered in the proposed project area during August 2018.

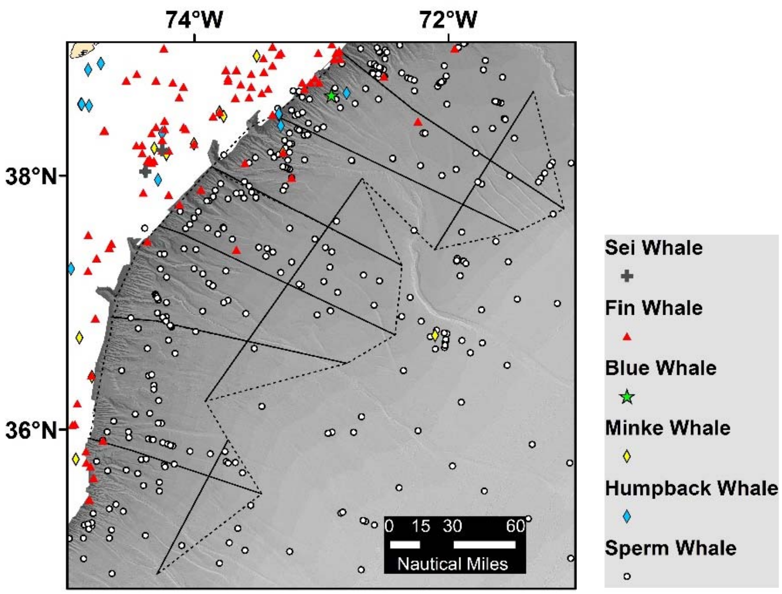

Figure 6. Sightings of endangered cetaceans and all baleen whales simultaneously overlapping the survey area and occurring during the summer (July through September) months as compiled from the iOBIS database by the USGS based on usable records. Note that there are no relevant sightings of North American right whales or Byrde's whales that meet the spatial and temporal criteria.

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

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

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. It has also been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993). This idea is also supported by the distribution of strandings in South American waters (Muñoz-Hincapié et al. 1998).

Only four of the pygmy sperm whale sightings in the OBIS database occur within the general area of the survey, and three of these were during the July through September period. Pygmy and dwarf sperm whales would likely be rare in the proposed project area.

Cuvier's Beaked Whale (Ziphius cavirostris)

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

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

NORTHERN BOTTLENOSE WHALE (HYPEROODON AMPULLATUS)

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

TRUE'S BEAKED WHALE (MESOPLODON MIRUS)

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

GERVAIS' BEAKED WHALE (MESOPLODON EUROPAEUS)

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

SOWERBY'S BEAKED WHALE (MESOPLODON BIDENS)

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

BLAINVILLE'S BEAKED WHALE (MESOPLODON DENSIROSTRIS)

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

Rough-toothed Dolphin (*Steno bredanensis*)

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

Common Bottlenose Dolphin (*Tursiops truncatus*)

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

Pantropical Spotted Dolphin (*Stenella attenuata*)

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

Atlantic Spotted Dolphin (*Stenella frontalis*)

The Atlantic spotted dolphin is distributed in tropical and warm temperate waters of the North Atlantic from Brazil to New England and to the coast of Africa (Jefferson et al. 2015). There are two forms of Atlantic spotted dolphin – a large, heavily spotted coastal form that is usually found in shelf waters, and a smaller and less-spotted offshore form that occurs in pelagic offshore waters and around oceanic islands (Jefferson et al. 2015). In the OBIS database, 125 sightings are in the general area of the surveys, and 58 were during the summer. Atlantic spotted dolphins would likely be encountered in the proposed project area.

Striped Dolphin (*Stenella coeruleoalba*)

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

Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)

The Atlantic white-sided dolphin occurs in cold temperate and subpolar waters in the North Atlantic; in the western Atlantic, its range is from ~38°N to southern Greenland (Jefferson et al. 2015). It appears to prefer deep waters of the outer shelf and slope, but can also occur in shallow and pelagic waters (Jefferson et al. 2015). In the OBIS database, 28 sightings of the Atlantic white-sided dolphin occur in the general area of the survey, and 9 of these are during the summer months. Atlantic white-sided dolphins could be encountered in the proposed project area.

White-beaked Dolphin (*Lagenorhynchus albirostris*)

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

Short-beaked Common Dolphin (*Delphinus delphis*)

The short-beaked common dolphin is distributed in tropical to cool temperate waters of the Atlantic and the Pacific oceans from 60ºN to ~50ºS (Jefferson et al. 2015). It is common in coastal waters 200–300 m deep (Evans 1994), but it can also occur thousands of kilometers offshore; the pelagic range in the North Atlantic extends south to ~35ºN (Jefferson et al. 2015). It appears to have a preference for areas with upwelling and steep sea-floor relief (Doksæter et al. 2008; Jefferson et al. 2015). Fewer than 0.1% of the nearly 43,000 of short-beaked common dolphins in the OBIS database occur in the general area of the survey, and only three were during the summer months. Short-beaked common dolphins could be encountered in the proposed project area.

Risso’s Dolphin (*Grampus griseus*)

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

Pygmy Killer Whale (*Feresa attenuata*)

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

False Killer Whale (*Pseudorca crassidens*)

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

KILLER WHALE (ORCINUS ORCA)

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

SHORT-FINNED PILOT WHALE (GLOBICEPHALA MACRORHYNCHUS)

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

LONG-FINNED PILOT WHALE (GLOBICEPHALA MELAS)

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

MELON-HEADED WHALE (PEPONOCEPHALA ELECTRA)

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

The Roberts et al. (2015) model density grid for the melon-headed whale has only two values for abundance: zero in most of the U.S. EEZ and 0.240833 animals per 100 km^2 in the rest of the modeled area. There are no melon-headed whales in waters shallower than 1000 m in the model in the area of the Proposed Action, meaning that take calculations only capture potential animals in deeper waters. Melon-headed whales may be encountered during the seismic surveys, but they would likely be almost exclusively in deeper water and are more likely near the southern survey transects than the northern ones.

HARBOR PORPOISE (PHOCOENA PHOCOENA)

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

FRASER'S DOLPHIN (LAGENODELPHIS HOSEI)

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

SPINNER DOLPHIN (STENELLA LONGIROSTIS)

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

CLYMENE'S DOLPHIN (STENELLA CLYMENE)

The following is taken verbatim from the Final EA for the ENAM project (LGL, 2014). The Clymene dolphin only occurs in tropical and subtropical waters of the Atlantic Ocean (Jefferson et al. 2008). In the western Atlantic, it occurs from New Jersey to Florida, the Caribbean Sea, the Gulf of Mexico, and south to Venezuela and Brazil (Würsig et al. 2000; Fertl et al. 2003). It is generally sighted in deep waters beyond the shelf edge (Fertl et al. 2003). Based on the USGS analysesi, 23 sightings of the 140 that are usable in the OBIS database are within the overall rectangular area that encloses the surveys, and 14 of these are during the summer months.

Table 5. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic project area in the Northwest Atlantic Ocean. Elements of this table were adopted directly from the Draft Scripps EA (LGL, 2017) and the ENAM EA (RPS, 2014c), with supplementary information from other sources for the populations. The iOBIS information in the far right columns was compiled by the USGS for this Draft EA using a polygon that roughly enclosed the entire area of the Proposed Action. Usable iOBIS sightings exclude those with dates entered in an incorrect format. Note that some iOBIS sightings lack dates, but were included in the overall count of usable sightings. The algorithm arbitrarily assigned those sightings without dates to January. Abundance values are mostly taken from the Draft Scripps EA (LGL 2017), with some additional values added as footnoted.

Species	Occurrence near survey location	Habitat	Abundance in North Atlantic	ESA[1]	IUCN[2]	CITES[3]	Usable iOBIS sightings compiled by USGS	Subset of sightings within survey area polygon	Subset of sightings in area that occurred July-Sept
Mysticetes									
North Atlantic right whale	Rare	Mainly coastal and shelf	440-736[4]	EN	EN	I	5695	11	0
Humpback whale	Uncommon	Mainly nearshore waters and	11,570[6]	NL (Atlantic)	LC	I	41354	79	14
Common minke whale	Uncommon	Coastal, offshore	157,000[7]	NL	LC	I	15843	51	12
Bryde's whale	Uncommon	Coastal,	N.A.	NL	DD	I	914	0	0
Sei whale	Uncommon	Mostly pelagic	10,300[8]	EN	EN	I	11127	7	2
Fin whale	Possible	Slope, mostly pelagic	24,887[9]	EN	EN	I	68029	131	29
Blue whale	Rare	Coastal, shelf, pelagic	855[10]	EN	EN	I	16949	2	1
Odontocetes									
Sperm whale	Likely	Usually deep pelagic, steep topography	13,190[11]	EN	VU	I	53789	686	395
Pygmy sperm whale (Kogia)	Possible	Deep waters off shelf	3785[12,13]	NL	DD	II	432	4	3
Dwarf sperm whale (Kogia)	Possible	Deep waters off shelf		NL	DD	II			
Cuvier's beaked whale	Possible	Slope, pelagic	3532[12]	NL	LC	II	1675	155	76
Northern bottlenose whale	Possible	Pelagic	~40,000[15]	NL	DD	I	2293	1	0
True's beaked whale	Possible	Pelagic	7092[12,14]	NL	DD	II	25	2	1
Gervais beaked whale	Possible	Pelagic	7092[12,14]	NL	DD	II	121	0	0
Sowerby's beaked whale	Possible	Pelagic	7092[12,14]	NL	DD	II	246	11	9
Blainville's beaked whale	Possible	Pelagic	7092[12,14]	NL	DD	II	574	1	1
Rough-toothed dolphin	Possible	Mostly pelagic	N.A.	NL	LC	II	1052	9	7

Table 6 (continued)									
Species	**Occurrence near survey location**	**Habitat**	**Abundance in North Atlantic**	**ESA[1]**	**IUCN[2]**	**CITES[3]**	**Usable iOBIS sightings compiled by USGS**	**Subset of sightings within survey area polygon**	**Subset of sightings in area that occurred July-Sept**
Clymene dolphin	Likely	Deepwater	6068[20]	NL	DD	II	140	23	14
Spinner dolphin	Possible	Coastal	NA [22]	NL	DD	II	2278	0	0
Common bottlenose dolphin	Likely	Coastal, shelf, pelagic	77,532[16]	NL	LC	II	57879	1873	776
Fraser's dolphin	Possible	Deep offshore	492 * (sum of abundance in Roberts et al. 2016 grid)	NL	LC	II	177	3	2
Pantropical spotted dolphin	Possible	Shelf, slope, pelagic	3333[12]	NL	LC	II	4240	48	29
Melon-headed whale	Possible	Seaward of continental	3451 northern	NL	LC	II	327	0	0
Atlantic spotted dolphin	Likely	Shelf, offshore	44,715[12]	NL	DD	II	7655	125	58
Striped dolphin	Likely	Off continental shelf	54,807[12]	NL	LC	II	15620	183	95
Atlantic white-sided dolphin	Possible	Coastal, shelf	48,819[12]	NL	LC	II	7932	28	9
Short-beaked common dolphin	Likely	Shelf, pelagic, high relief	70,184[12]	NL	LC	II	42829	43	3
Risso's dolphin	Likely	Shelf, slope,	18,250[12]	NL	LC	II	7241	471	238
Pygmy killer whale	Uncommon	Pelagic	N.A.	NL	DD	II	204	3	3
False killer whale	Uncommon	Pelagic	442	NL	DD	II	1173	2	1
Killer whale	Uncommon	Coastal, widely distributed	15,014[17]	NL	DD	II	3077	3	0
Long-finned pilot whale	Likely	Mostly pelagic	5636[12] 780,000[18]	NL	DD	II	9082	51	16
Short-finned pilot whale	Likely	Mostly pelagic, high-relief	21,515[12] 780,000[18]	NL	DD	II	2514	414	105
Harbor porpoise	Uncommon	Coastal and shelf, also pelagic	79,833[19]	NL	LC	II	49502	7	1
White Beaked Dolphin	Uncommon	Cold waters < 200 m	2003[21]	NL	LC	II	2717	1	0

N.A. Not available or not assessed. NL = Not listed.
[1] U.S. Endangered Species Act: EN = Endangered.
[2] Codes for IUCN classifications: EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient. Classifications are from the IUCN Red List of Threatened Species (IUCN 2017)
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2017); Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[4] Based on Pettis et al. (2017), Hayes et al. (2017), and IWC (2017)
[5] Doniol-Valcroze (2015)
[6] West Indies breeding ground (Stevick et al. 2003)
[7] Central (50,000), Northeast Atlantic (90,000), and West Greenland (17,000) populations (IWC 2017)
[8] North Atlantic (Cattanach et al. 1993)
[9] Central and Northeast Atlantic for 2001 (Víkingsson et al. 2009)
[10] Central and Northeast Atlantic for 2001 (Pike et al. 2009)
[11] For the northeast Atlantic, Faroes-Iceland, and the U.S. east coast (Whitehead 2002)
[12] Western North Atlantic (Hayes et al. 2017)
[13] Both *Kogia* species
[14] All *Mesoplodon* spp. combined
[15] Eastern North Atlantic (NAMMCO 1995)
[16] Offshore, Western North Atlantic (Hayes et al. 2017)
[17] Northeast Atlantic (Foote et al. *in* NAMMCO 2016)
[18] *Globicephala sp*. combined, Central and Eastern North Atlantic (IWC 2017)
[19] Gulf of Maine/Bay of Fundy stock (Hayes et al. 2017)
[20] Waring et al. (2008); Note that the Roberts et al. (2016) abundance grid would correspond to 12526 individuals.
[21] From NMFS stock assessment. http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2007dowb-wn.pdf
[22] Spinner dolphins have no minimum population assessment. https://www.nefsc.noaa.gov/publications/tm/tm228/190_spinner.pdf

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.

Much of the following material is taken verbatim from the Scripps IHAA (LGL, 2017b), with adaptations to the particulars of the USGS MATRIX effort.

The USGS 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 during August 2018. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the GI airguns used during the surveys, by a fisheries echosounder, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the GI airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. Because of the characteristics of the proposed study and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely and are not requested.

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.

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

The following material is taken directly from the Draft Scripps EA (LGL, 2017a) and/or the Scripps IHAA (LGL, 2017b), with modifications to reflect the particulars of the USGS MATRIX program as described in detail in the Draft MATRIX EA (USGS, 2018).

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII, and refer to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the fisheries echosounder.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the Northwest Atlantic Ocean during August 2018. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned surveys, as called for in § VI.

Summary of Potential Effects of Airgun Sounds

The following text is taken verbatim from the Scripps IHAA (LGL, 2017), with very minor changes to ensure consistency with USGS nomenclature.

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. 2015, 2016). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

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

TOLERANCE

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

MASKING

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

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. Sills et al. (2017) reported that recorded airguns sounds masked the detection of low-frequency sounds by ringed and spotted seals, especially at the onset of the airgun pulse when signal amplitude was variable.

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). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017). Various authors have noted that some marine mammals that show no obvious avoidance or behavioral changes may still be adversely affected by sound (e.g., Weilgart 2007; Wright et al. 2011; Gomez et al. 2016).

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

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

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995).

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

More recent studies examining the behavioral responses of humpback whales to airguns have also been conducted off eastern Australia (Cato et al. 2011, 2012, 2013, 2016), although results are not yet available for all studies. Dunlop et al. (2015) reported that humpback whales responded to a vessel operating a 20 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 array was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Responses to ramp up and use of a 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Overall, the results showed that humpbacks were more likely to avoid active airgun arrays (of 20 and 140 in^3) within 3 km and at levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017). These results are consistent with earlier studies (e.g., McCauley et al. 2000). Although there was no clear evidence of avoidance by humpbacks on their summer feeding grounds in southeast Alaska, there were subtle behavioral effects at distance up to 3.2 km and received levels of 150 to 172 re 1 µPa on an approximate rms basis (Malme et al. 1985).

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007).

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

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

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

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) or 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b).

Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

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

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

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

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. In addition, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years.

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

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

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

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment.

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

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). However, foraging behavior can be altered upon exposure to airgun sound (e.g., Miller et al. 2009) which, according to Farmer et al. (2017), could have significant consequences on individual fitness. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity during periods with airgun operations

(Sidorovskaia et al. 2014).

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

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 μPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). 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). 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. (2012a) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013a). The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

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

HEARING IMPAIRMENT AND OTHER PHYSICAL EFFECTS

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

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

Recent data have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 $\mu Pa^2 \cdot s$ (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).

Recent studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise.

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

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (*cf.* Southall et al. 2007; NMFS 2016a). Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012c, 2013b,c, 2014, 2015a) have indicated that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012c) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB. Kastelein et al. (2013b) exposed a harbor porpoise to a long, continuous 1.5-kHz tone, which induced a 14-dB TTS with a total SEL of 190 dB. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

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

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

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

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

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{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 (see § XI and § XIII). Also, many marine mammals and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves would reduce or (most likely) avoid any possibility of hearing impairment. Aarts et al. (2016) noted that an understanding of animal movement is necessary in order to estimate the impact of anthropogenic sound on cetaceans.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale stranding along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2016). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 64 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2017a). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=110E5E8F-3A65-4BEC-9D25-5D843A0284D3), it was Dr. Knapp's (a geologist from the

University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico.

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

Possible Effects of Other Acoustic Sources

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

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

“Category 2 active acoustic sources (as defined by NEFSC) have moderate to very high output frequencies (10 to 180 kHz), generally short ping durations, and are typically focused (highly directional) to serve their intended purpose of mapping specific objects, depths, or environmental features. A number of these sources, particularly those with relatively lower sound frequencies coupled with higher output levels can be operated in different output modes (e.g., energy can be distributed among multiple output beams) that may lessen the likelihood of perception by and potential impact on marine life.” The USGS Proposed Action would use only the 38 kHz transducer.

“Category 2 active acoustic sources are likely to be audible to some marine mammal species. Among the marine mammals, most of these sources are unlikely to be audible to whales and most pinnipeds, whereas they may be detected by odontocete cetaceans (and particularly high frequency specialists such as harbor porpoise). There is relatively little direct information about behavioral responses of marine mammals, including the odontocete cetaceans, but the responses that have been measured in a variety of species to audible sounds (see Nowacek et al. 2007; Southall et al. 2007 for reviews) suggest that the most likely behavioral responses (if any) would be short-term avoidance behavior of the active acoustic sources.

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

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

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

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 Hugh R. Sharp* could affect marine animals in the proposed project area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015) and humpback whales (Blair et al. 2016).

While vessel noise from *R/V Hugh R. Sharp* could affect marine animals in the proposed project area, the ship was Navy-designed as a "quiet vessel" and produces underwater radiated noise at levels below the International Council on Exploration of the Seas (ICES) noise curve at 8 knots (cruising speed). Note that the USGS Proposed Surveys will be carried out at ~4 knots, which requires the use of only one generator on the *R/V Hugh R. Sharp*. According to the ship's radiated noise measurement report (2009), this mode of operation produces two primary signals at less than 200 kHz: 83 kHz with SEL of 146 dB re 1 µPa at 1 yard and 163 kHz with SEL of 151 dB re 1 µPa at 1 yard.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and

Branstetter 2013; Sills et al. 2017). In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

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

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

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

There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels.

The NSF-USGS PEIS concluded that project vessel sounds would not be at levels expected to cause anything more than possible localized and temporary behavioral changes in marine mammals, and would not be expected to result in significant negative effects on individuals or at the population level. In addition, in all oceans of the world, large vessel traffic is currently so prevalent that it is commonly considered a usual source of ambient sound.

Another concern with vessel traffic is the potential for striking marine mammals (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the NSF-USGS PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels (McKenna et al. 2015). The NSF-USGS PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. During the proposed cruise, most (70%) of the seismic survey effort is expected to occur at a speed of ~15 km/h, and 30% is expected to occur at 9 km/h. However, the number of seismic survey km are low relative to other fast-moving vessels in the area. There has been no history of marine mammal vessel strikes with any of the vessels in the U.S. academic research fleet in the last two decades.

Numbers of Marine Mammals that could be "Taken by Harassment"

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. In the sections below, we describe methods to estimate the number of potential exposures to Level B and Level A sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys in the Northwest Atlantic Ocean. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

It is assumed that, during simultaneous operations of the airgun array and the fisheries sonar (EK60/80), any marine mammals close enough to be affected by the MBES and SBP 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 EK60/80, given their characteristics (e.g., narrow downward-directed beam) and other considerations described in the Draft MATRIX EA (USGS, 2018). Such reactions are not considered to constitute "taking" (NMFS 2001), and indeed NOAA vessels (e.g., *Okeanos Explorer* and others), as well as other U.S. federal fleet vessels, routinely use the fisheries EK60/EK80 and other non-airgun sound sources with no mitigation procedures. Therefore, no additional take allowance is included for animals that could be affected by sound sources other than airguns.

BASIS FOR ESTIMATING "TAKE BY HARASSMENT"

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on abundances (numbers) of marine mammals expected to occur in the area of the Proposed Action in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Likewise, animals are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

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

Due to the heterogeneous species' densities in the Survey Area and the USGS's direct use of quantitative species density grids from Roberts et al. (2016) in estimating the impact of the surveys on cetaceans, it would be inappropriate to report the type of generic species density values commonly given in some Environmental Assessments produced for research seismic surveys. Instead, Table 6 gives calculated species density and standard deviation in the area containing the entire Proposed Action as determined from the Roberts et al. (2016) density grid and summarizes group size, as taken primarily from the Draft Scripps EA (LGL, 2017).

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

The estimated numbers of individuals potentially exposed to Level B are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 7 shows the estimates of the number of cetaceans that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the Proposed Action for the Base Survey and the Optimal Survey if no animals moved away from the survey vessel. The *Requested Take Authorization* is given in the far right column of Table 7 and represents 25% more than the number of takes calculated using the ArcGIS-based quantitative method devised by the USGS. The requested takes are sometimes increased to account for the size of animal groups (Table 6), to capture the possibility that a rare species could be encountered and taken during the surveys, or to account for the fact that the species is particularly abundant and take up to 1% of population size should be considered.

The calculated takes in Table 7 also assume that the proposed surveys would be completed. In fact, it is unlikely that the entire survey pattern (exemplary lines plus 50% of the interseismic, linking lines) would be completed given the limitations on ship time, likely logistical challenges (compressor and GI gun repairs), time spent on transits and refueling, and the historical problems with weather during August in the Northwest Atlantic. In fact, USGS calculated timelines indicate that 25 days, including contingency, could be required to complete the full survey pattern. In fact, 22 days or fewer would be scheduled for this survey with the ship operator. The lines that are actually acquired would be dependent on weather, strength of the Gulf Stream (affects ability to tow the streamer in the appropriate geometry), and other considerations.

Thus, fewer takes would be expected than have been calculated or requested. Nonetheless, as is common practice, the requested takes ***have been increased by 25%*** (see below). Thus, the estimates estimates of the numbers of marine mammals potentially exposed to Level B sounds≥160 dB re 1 μPa_{rms} are precautionary (conservative) and probably overestimate the actual numbers of marine mammals that could be involved.

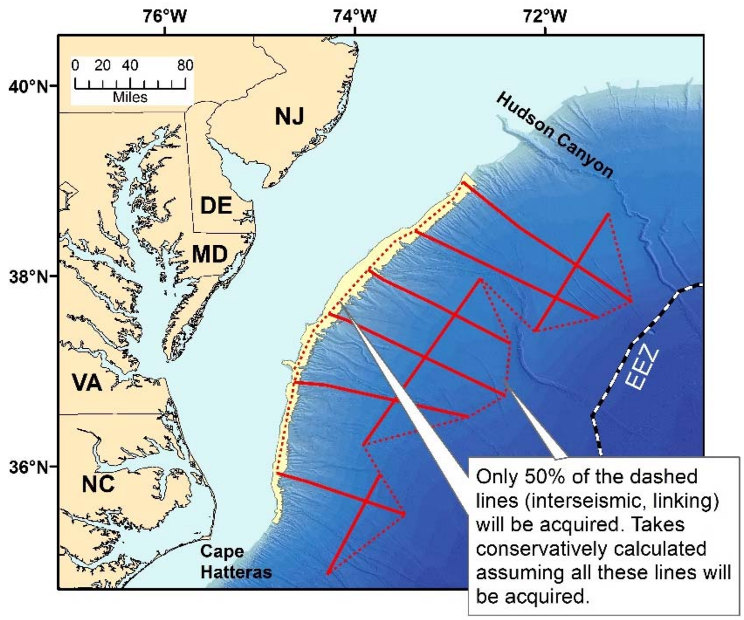

Figure 7. The Base Survey would acquire data along the exemplary lines (solid) and 50% of the interseismic linking lines using the base configuration of the GI guns (4 guns at 105 in^3 each). The Optimal Survey would acquire data on the exemplary lines using the GG gun configuration (4 guns at 210 in^3 each for the portions of these lines at greater than 1000 m water depth). For the Optimal Survey, the portion of the exemplary lines between 100 and 1000 m (yellow shading; bathymetry from Andrews et al., 2016) plus 50% of the linking interseismic lines with the base configuration. Takes are calculated for the entire survey pattern shown here even though only 50% of the linking, interseismic lines would be acquired.

In addition, it is possible that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the NSF-USGS PEIS and in this document. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (NMFS 2013).

Table 6. Mean density and standard deviation of species' population in a polygon enclosing the entire survey based on ArcGIS analysis of the Roberts et al. (2016) grids. Month 8 (August) is used when

available. Otherwise, the generalized annual grid is used.

	Mean Density Per 100 km² in Polygon Enclosing Total Survey	Std Deviation on Mean Density Per 100 km²	Group Size	Source[1]
Mysticetes				
Low-Frequency Cetaceans				
North Atlantic Right Whale (*Eubalaena glacialis*)	0.00002	0.00013	1	J
Humpback Whale (*Megaptera novaeangliae*)	0.002	0.007	2	W
Minke Whale (*Balaenoptera acutorostrata*)	0.002	0.004	1	W
Bryde's Whale (*Balaenoptera edeni/brydei*)	<0.001	NA	1	W
Sei Whale (*Balaenoptera borealis*)	0.005	0.02	1.42	W
Fin Whale (*Balaenoptera physalus*)	0.041	0.077	1.71	W
Blue Whale (*Balaenoptera musculus*)	<0.001	NA	1	W
Odontocetes				
Mid-Frequency Cetaceans				
Sperm Whale (*Physeter macrocephalus*)	2.18	0.909	1.6	W
Cuvier's Beaked Whale (*Ziphius cavirostris* True's Beaked Whale (*Mesoplodon mirus*) Gervais' Beaked Whale (*Mesoplodon europaeus*) Sowerby's Beaked Whale (*Mesoplodon bidens*) Blainville's Beaked Whale (*Mesoplodon densirostris*)	2.42	2.51	3	W
Northern Bottlenose Whale (*Hyperoodon ampullatus*)	0.035	0.014	4-10	NOAA[5]
Rough-toothed Dolphin (*Steno bredanensis*)	0.068	0.006	10	J
Common Bottlenose Dolphin (*Tursiops truncatus*)	8.446	7.143	19	P
Pantropical Spotted Dolphin (*Stenella attenuata*)	0.607	0.055	26.3	P
Atlantic Spotted Dolphin (*Stenella frontalis*)	20.17	14.514	26.3	P
Striped Dolphin (*Stenella coeruleoalba*)	18.72	12.47	9.69	W
Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)	0.064	0.083	14.71	W
White-beaked Dolphin (*Lagenorhynchus albirostris*)	<0.001	0.003	3	W
Short-beaked Common Dolphin (*Delphinus delphis*)	20.17	45.57	9.15	W
Risso's Dolphin (*Grampus griseus*)	2.683	5.01	11.5	P
Pygmy Killer Whale (*Feresa attenuata*)	No data	No data	12	J
False Killer Whale (*Pseudorca crassidens*)	0.008	NA	1	W
Killer Whale (*Orcinus orca*)	<0.001	NA	5	W
Short-finned Pilot Whale (*Globicephala macrorhynchus*) Long-finned Pilot Whale (*Globicephala melas*)	4.153	2.738	25.76	W
Clymene's dolphin (*Stenella clymene*)	1.365	1.262	60-80	NOAA[2]
Spinner dolphin (*Stenella longirostis*)	0.04	0.004	---	---
Fraser's dolphin (*Lagenodelphis hosei*)	0.042	0.051	10-100	NOAA[3]
Melon-headed whale (*Peponocephala electra*)	0.109	0.12	>100	NOAA[4]
High Frequency Cetaceans				
Harbor Porpoise (*Phocoena phocoena*)	0.009	0.019	3.6	P
Pygmy Sperm Whales (*Kogia breviceps*) Dwarf Sperm Whales (*Kogia sima*)	0.093	0.008	1.8	P

[1] Group sizes compiled primarily from the Draft Scripps EA (LGL, 2017); J = Jefferson et al., 2015; P = Palka, 2006; W=Waring et al., 2008. False killer whale group size based on that of unidentified small whales; Palka used data from the Northeast Navy Operating Area Offshore Stratum.[2]http://www.nmfs.noaa.gov/pr/species/mammals/dolphins/clymene-dolphin.html
[3]https://www.fisheries.noaa.gov/species/frasers-dolphin; [4] http://www.nmfs.noaa.gov/pr/species/mammals/whales/melon-headed-whale.html; [5]http://www.nmfs.noaa.gov/pr/species/mammals/whales/northern-bottlenose-whale.html

TABLE 7. Estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the Northwest Atlantic Ocean in August 2018. As detailed in §1, the **base survey** corresponds to 4 GI guns producing a total of 420 in^3 of air. The **optimal survey** acquires the exemplary seismic lines with 4 GI guns operated in GG mode (840 in^3 of air) and interseismic linking lines collected with 4 GI guns operated at 105 in^3 each. Species in italics are listed under the ESA as *endangered*. Requested takes in **bold** have been increased over the calculations to reflect group size or other issues, as explained in the text.

Species	Base Survey[2]		Optimal Survey[2]		Max Level A Take	Max Level B Take for Optimal or Base Surveys +25%	Popula-tion used from Table 6	Level A + (Level B+25 %) as % of Pop.[5]	Requested Take Authorization (all Level B)[6]
	Level A[3]	Level B[4]	Level A[3]	Level B[4]					
LOW FREQUENCY CETACEANS									
North Atlantic right whale	0	*0*	0	*0*	0	*0*	*440*	*0*	*0*
Humpback whale	0	0	0	0	0	0	11,570	<0.1	1[7]
Minke whale	0	0	0	0	0	0	157,000	<0.1	0
Bryde's whale	0	0	0	0	0	0	N.A.	N.A.	0
Sei whale	0	*1*	*0*	*1*	0	*1*	*10,300*	*<0.01*	*1*
Fin whale	0	*4*	*0*	*4*	0	*5*	*24,887*	*0.02*	*5*
Blue whale	0	*0*	*0*	*0*	0	*0*	*855*	*<0.1*	*0*
MID-FREQUENCY CETACEANS									
Sperm whale	*0*	*119*	*0*	*128*	0	*160*	*13,190*	*1.2*	*160*
Cuvier's beaked whale True's beaked whale Gervais beaked whale Sowerby's beaked whale Blainville's beaked whale	0	94[11]	0	103[11]	0	128	3,532 7092[9] (non-Cuvier)	1.2, As proportion of total beaked whale population	128 (sum of all beaked whale takes)
Northern bottlenose whale	0	2	0	2	0	2	40,000	0.01	5
Rough-toothed dolphin	0	4	0	5	0	8	NA	N.A.	**60**
Common bottlenose dolphin	0	572	0	606	0	757	77,532	0.98	757
Pantropical spotted dolphin	0	38	0	40	0	50	3,333	1.5	50
Atlantic spotted dolphin	0	1191	0	1278	0	1598	44,715	3.6	1598
Striped dolphin	0	1086	0	1167	0	1458	54,807	2.7	1458
Atlantic white-sided dolphin	0	5	0	5	0	6	48,819	<0.1	**15**
White-beaked dolphin	0	0	0	0	0	0	2003	0	0
Short-beaked common dolphin	0	1253	0	1296	0	1620	70,184	2.3	1620
Risso's dolphin	0	181	0	189	0	236	18,250	1.5	236
Pygmy killer whale	0	1	0	1	0	1	NA	N.A.	1
False killer whale	0	1	0	1	0	1	442	0.15	1
Killer whale	0	3	0	3	0	4	15,014	0.03	4
Long-finned pilot whale	0	215	0	231	0	288	5,636-16,058[8]	1.7-4.9[10]	278 (sum of pilot whales)
Short-finned pilot whale					0		21,515	1.3[10]	
Clymene's dolphin	0	91	0	97	0	121	6,068	2	121
Spinner dolphin	0	3	0	3	0	3	ND	ND	3
Fraser's dolphin	0	3	0	3	0	4	492	0.8	**5**
Melon-headed whale	0	8	0	8	0	10	3451	0.3	10
HIGH-FREQUENCY CETACEANS									
Pygmy/dwarf sperm whale	0	6	0	7	0	9	3,785	0.2	9

Harbor porpoise	0	0	0	0	0	0	79,833	<0.01	0

[1] See text for density sources. N.A. = population size not available (see Table 6).
[2] Take calculated using method described in text and discussed with NMFS on USGS-managed webinar on March 8, 2018.
[3] Level A takes if there were no mitigation measures. Ensonified areas are based on PTS thresholds.
[4] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.
[5] Level A and B takes (used by NMFS as proxy for number of individuals exposed), expressed as % of population.
[6] Requested takes (Level A+Level B); increased to mean group size in some instances (see Table 9 for sources).
[7] Very small take requested because these species are very abundant, but the calculated take is zero based on the Duke density maps, which cannot capture all of the complexity in species distribution. In fact, the map of summer season sitings compiled from the OBIS database (Figure 6) by the applicant shows that humpback whales have been seen in the northern part of the Proposed Action area during this period.
[8] Low end estimate from https://www.nefsc.noaa.gov/publications/tm/tm241/86_F2016_longfinnedpilotwhale.pdf. High end estimate from TNASS (Western North Atlantic) surveys that counted pilot whales in habitat where the whales present are interpreted to be solely long-finned pilot whales, as described in the NMFS FR notice, 82 FR 26244.
[9] The combined number for *Mesoplodon sp*. Is the only one provided by NOAA in: https://www.nefsc.noaa.gov/publications/tm/tm228/91_blainvilles.pdf
[10] Calculated assuming that all takes were attributed to each of the two types of pilot whales, even though the take calculated for pilot whales represents the sum of the takes for the two types. Thus, the calculation shown here yields a maximum possible percentage of the population.
11 The species density maps treat beaked whales as an entire guild. Furthermore, NEFSC states that the population breakdown among the four species of beaked whales other than Cuvier's is unknown (https://www.nefsc.noaa.gov/publications/tm/tm228/91_blainvilles.pdf). The calculated take mathematically represents the sum of all beaked whale takes. The sum cannot be broken into individual species because the underlying data were for the guild and the fractional representation of each species among the total is unknown.

POTENTIAL NUMBER OF MARINE MAMMALS EXPOSED

As noted above, the number of cetaceans that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) for marine mammals on one or more occasions has been estimated by combining the gridded animal abundances available from the Duke University cetacean density website (http://seamap.env.duke.edu/models/Duke-EC-GOM-2015/) with the exemplary track lines/linking lines and Level B PTS threshold buffers calculated by LDEO. The method intersects the ensonified area along each track line for the appropriate Level B threshold buffer with the gridded animal abundances. For each block of the underlying abundance grid intersected by the trackline and associated ensonified area, the take is calculated as the percentage of that block's area that is ensonified multipled by the abundance of animals in the block. The takes are summed along each trackline and linking line and added to determine the total take for the surveys. The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Sharp* approaches. The amount of overlap of the ensonified area is minimal and confined to areas of turns at the ends of exemplary survey lines or where linking lines join exemplary lines. The small amount of overlap reflects in part the fact that most exemplary dip lines are spaced at more than 20 km.

Total estimated takes for the entire survey are reported in Table 7 for the Optimal and Base surveys. The table also reports the maximum take of each species for the two survey configurations (see below) with 25% added as a buffer and the requested take authorization. The Optimal Survey includes most dip lines and one strike line acquired with the GG configuration (840 in^3 of air), with the remaining lines and linking lines acquired using the base (4x105 in^3 or 420 in^3 of air) configuration (Figure 7). Note that this is an overestimate since it assumes that **all** of the interseismic linking lines would have data acquisition, even though at most only half of the lines will be acquired. Some of the linking lines would not even be surveyed with seismic methods since transit between exemplary lines is faster with no streamer in the water, and such transits provide an opportunity to fix gear, refuel compressors, and address other issues. The take calculations for the Base Survey assume all of the exemplary lines and linking lines are acquired with the base (420 in^3 of air) configuration and, again, that all of the interseismic linking lines are acquired.

The *maximum* estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the survey area is 5185 for the Optimal Survey (Table 7). This number was calculated assuming that seismic data would be acquired along all the shelf-break and deepwater interseismic connecting lines shown in the red dashed pattern in Figure 1 and assuming the maximum source levels are used for the major exemplary seismic lines (Optimal Survey). At most, only about half of the interseismic connecting lines will be acquired at either the shelf-break or deepwater. The maximum Level B take estimate of 5185 cetaceans includes ~133 cetacean individuals listed under the ESA: 1 sei whale, 4 fin whales, 128 sperm whales, and no blue or North Atlantic right whales. Adding the nominal 25% extra take to these values, the sperm whale figure represents 1.2% of the estimated population, fin whale take is ~0.02%, and sei whale take is 0.01%. Most Level B exposures would accrue to mid-frequency cetaceans. The largest potential takes would be for species that are plentiful and widespread, such as Atlantic spotted dolphin, striped dolphin, short-beaked common dolphin, and common bottlenose dolphin.

The take authorizations requested in the last column of Table 7 are precautionary and assume that certain extralimital mysticetes could be encountered during the Proposed Survey. For example, although no minke or humpback whales have historically been observed within the study area during the summer months, these species are very abundant in the North Atlantic, and a single Level B take has been requested for each species. Note also that the basis of the Take Authorization Request is the maximum A + B takes +25% for the Base and Optimal surveys, so the requested takes are very conservative. Were an equipment failure to force the Proposed Action to be carried out with the Base Configuration, takes would be far smaller based on the much smaller MZ given in Appendix A.

All of the calculated takes fall well within the typical definition of "small takes" as implemented under the MMPA. Some of the requested takes, but not all, have been increased to account for the average group size (Table 6). In other cases, group size was not taken into consideration. For example, melon-headed whales often occur in very large groups, but the requested take has been kept at the calculated value of 10 individuals. Harbor porpoise take is requested due to the sheer abundance of these animals and the remote possibility that they could occur extralimitally in the Proposed Survey Area. In some cases, the take request was increased to 1% of the population for particularly abundant species that are likely to be encountered in the Survey Area (e.g., common bottlenose dolphin).

Per NMFS requirement, estimates of the numbers of cetaceans that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups, if there were no mitigation measures (shut downs when PSOs observed animals approaching or inside the EZs), are also given in Table 7. Level A takes were determined to be less than 0.5 individuals (and thus recorded as 0, the nearest whole number) for all species and for both survey configurations, even after the calculated takes were increased by 25%, as is common practice. Even those small calculated take numbers likely overestimate actual Level A takes because the predicted Level A EZs are very small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. Level A takes are considered highly unlikely and are not requested.

CONCLUSIONS

The Proposed Action would involve towing an array of two to four GI airguns that introduce pulsed sounds into the ocean. Routine vessel operations and use of a fisheries sonar are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

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

In § 3.6.2, 3.7.2, and 3.8.2, the NSF-USGS PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some cetaceans in the Northwest Atlantic DAA, that Level A effects were highly unlikely, and that operations were unlikely to adversely affect ESA-listed species. No Level A takes are requested for the Proposed Action. For five past NSF-funded seismic surveys and the 2014/15 USGS ECS survey (RPS, 2014a), NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2015b, 2016b,c, NMFS 2017a,b).

In the Draft MATRIX EA (USGS, 2018), estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the regional population sizes (Table 7).

The take calculations are likely to yield significant overestimates of the actual number of animals that would be exposed to and would react to the seismic sounds, particularly because most mammals, except some delphinids, tend to move away from sound sources. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

In decades of seismic surveys carried out by the U.S. academic research fleet, PSOs and other crew members have not observed any seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., to be considered takes) have almost always been much lower than predicted and authorized takes. For example, during the NSF-funded, ~5000-km, 2-D ENAM seismic survey conducted by the 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 the ~2700 km, 2-D ECS seismic survey conducted by the USGS aboard the R/V *Langseth* in the northwestern Atlantic Ocean in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014b). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The 160-dB zone, which is based on predicted sound levels, is thought to be conservative given the type of acoustic modeling used to calculate the distance from the source to this isopleth; thus, not all animals detected within this zone would be expected to have been exposed to actual sound levels >160 dB.

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 project area, so the proposed activities 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 activity.

XI. MITIGATION MEASURES

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

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

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 USGS-led or NSF-funded seismic research cruises as approved by NMFS, and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Planning Phase

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

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

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

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

For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results (Figures 2 and 3) to determine the distance from the airguns where the received sound level is 160 dB re 1µPa_{rms}. Table 2 shows the distances at which the 160- and 175-dB re 1µPa_{rms} sound levels are expected to be received for the GI airgun configurations. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS to determine behavioral disturbance for sea turtles.

NMFS guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a) established new thresholds for PTS onset or Level A Harassment (injury), for marine mammal species. The summary distances to the PTS thresholds for the various marine mammal hearing groups are provided in Table 3, with the detail provided in Appendix C.

The NSF-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. Table 3 of Appendix F of the NSF-USGS PEIS shows that a quadrilateral (4 GI gun) array of 105 in^3 guns would meet the low-energy criteria if towed at 3 m depth and separated by 8 m. Based on the modeling in Table 1 and the fact that the quadrilateral array of guns to be used for the Proposed Action would be separated by only 2 m front to back and 8.6 m side to side (and will be operated occasionally in GG mode, which generates 210 in^3 of air per GI gun), the Proposed Action slightly exceeds the criteria of a low-energy activity according to the NSF-USGS PEIS. Note that the sources to be used for the Proposed Action at maximum generate less than 20% of the air (usually > 6000 in^3) typically used for seismic surveys by a range of research and private sector operators.

In § 2.4.2 of the NSF-USGS PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-m EZ for low-energy acoustic sources in water depths >100 m. For the Proposed Action, which does not meet the ≤180 dB re 1 μPa_{rms} Level A criterion formerly applied by NMFS and outlined in Appendix F of the NSF-USGS PEIS, the actual calculated EZ (Table 4 and Appendix C) based on the 2016 NMFS Acoustic Guidelines are substantially smaller than this prescribed 100 m EZ. Adopting the calculated EZ instead of the prescribed 100 m EZ would therefore result in a less conservative approach to protection of marine mammals (and turtles) and higher actual takes during the Proposed Action. Thus, the Proposed Action will voluntarily adopt a 100 m EZ for marine mammals. If marine mammals or sea turtles are detected in or about to enter the appropriate EZ, the airguns would be shut down immediately. Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. A fixed 160-dB "Safety Zone" was not defined in the NSF-USGS, nor was the mitigation zone criteria changed by NMFS for marine mammals in the interim; therefore, L-DEO model results for the appropriate gun configuration are used here to determine the 160-dB radius (Table 2).

Mitigation During Operations

Mitigation measures that would be adopted include (1) vessel speed or course alteration, provided that doing so would not compromise operational safety requirements, (2) GI-gun power down to decrease the size of the EZ; (3) GI-airgun shut down when mammals or other protected species are within or about to enter EZs; and (4) ramp-up procedures.

SPEED OR COURSE ALTERATION

If a marine mammal or sea turtle is detected outside the EZ and, based on its position and the relative motion is considered likely to enter the adopted 100 m EZ, the vessel's speed and/or direct course could be changed. This would be done if operationally practicable while minimizing the effect on the planned science objectives. The activities and movements of the marine mammal or sea turtle (relative to the seismic vessel) would then be closely monitored to determine whether the animal is approaching the applicable EZ. If the animal appears likely to enter the EZ, further mitigating actions would be taken, i.e., either further course alterations or a power down or shut down of the seismic source. Typically, during seismic operations, the source vessel is unable to change speed or course and one or more alternative mitigation measures (see below) would need to be implemented.

POWER-DOWN

A power down involves decreasing the number of airguns in use such that the radius of the threshold zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. The acoustic source would also be powered down in the event an ESA-listed seabird were observed diving or foraging close to the designated EZ. During a power down, one airgun would be left operating (mitigation gun). The continued operation of one airgun is intended to alert marine mammals and turtles to the presence of the seismic vessel in the area. In contrast, a shut down, which is described below, occurs when all airgun activity is suspended.

If a marine mammal or turtle is detected outside the EZ but is likely to enter the EZ, the airguns could be powered down before the animal is within the EZ. Likewise, if a mammal or turtle is already within the EZ when first detected, the airguns would be powered down immediately to reduce the size of the EZ. During the initial power down of the airgun array, one 105 in^3 airgun would be operated. If a marine mammal or turtle is detected within or near the smaller calculated EZ around that single airgun, that airgun would also be shut down (see next subsection). While we do not access to separate modeling for a single 105 in^3 airgun, the EZ for the two 105 in^3 configuration (backup configuration; see Appendix C) provides cautionary (conservative) EZ radii. The maximum (HF) cetacean EZ calculated for two 105 in^3 is less than 43 m, so ~45 m would be conservatively adopted as the radius of the reduced EZ around a single airgun to which a power-down might occur if a protected species enters the 100 m EZ.

Following a power down, full array airgun activity could resume via ramp-up (add one gun every 5 minutes) once the marine mammal or turtle has cleared the EZ. As excerpted directly from the NSF-USGS PEIS (§ES6.1) and modified to exclude animals not relevant to the study area, the animal would be considered to have cleared the EZ if:

- is visually observed to have left the EZ;
- has not been seen within the EZ for 15 min in the case of small odontocetes; or
- has not been seen within the EZ for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales; or
- the vessel has moved outside the applicable EZ in which the animal in question was last seen.

When moving at 4 knots, the vessel progresses ~2 m/s. Thus, the 100 m EZ would be cleared in under 1 minute. The largest Level B zone (175 dB zone calculated for turtles is 291 m, for the base GI gun configuration at 100-1000 m water depth, per the Draft MATRIX EA (USGS, 2018); note that the GG configuration would not be used shallower than 1000 m) could be cleared in less than 2.5 minutes.

SHUT-DOWN PROCEDURES

If (a) a marine mammal or turtle is detected about to enter or is already within the EZ; (b) the vessel's movement cannot maintain the animal outside the EZ; and (c) the power down of the airguns (see above) will not be fast enough to prevent the animal from entering the EZ, the GI airguns would be shut down immediately. In consultation with NMFS, exceptions may be made for some delphinids. The operating airguns would also be shut down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ and power down will not reduce the size of the EZ enough to avoid the bird's activity counting as a "take." Following a shut down, PSOs will conduct observations for at least 30 minutes. Seismic activity would not resume until the marine mammal or turtle has cleared the EZ, the ship has moved away from the last sighting of the animal for 4 minuts, or the PSO is confident that the animal has left the vicinity of the vessel. As excerpted directly from the NSF-USGS PEIS (§ES6.1) and modified to exclude animals not relevant to the study area, the animal would be considered to have cleared the EZ zone if

- is visually observed to have left the EZ;
- has not been seen within the EZ for 15 min in the case of small odontocetes; or

- has not been seen within the EZ for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales; or
- the vessel has moved outside the applicable EZ in which the animal in question was last seen.

As noted above, when moving at 4 knots, the vessel progresses ~2 m/s. Thus, the 100 m EZ would be cleared in under 1 minute. The largest Level B zone (175 dB zone calculated for turtles is 291 m, for the base GI gun configuration at 100-1000 m water depth, per the Draft MATRIX EA (USGS, 2018); note that the GG configuration would not be used shallower than 1000 m).

The airgun array will be shut down if a North Atlantic right whale is observed at any distance from the vessel and will remain shut down 30 minutes after the last sighting.

RAMP-UP PROCEDURES

A ramp-up procedure would be followed when the GI airguns begins operating after a specified period without GI airgun operations. PSOs will conduct observations for at least 30 minutes prior to the initiation of the ramp up. The ramp-up period to use of the full 4 airguns would be 20 min, with one gun added every 5 minutes. If one gun had been operating during a power-down (see above), ramp up to the full array would take 15 minutes, with one additional gun added every 5 minutes. Ramp up would not occur if a marine mammal or sea turtle has not cleared the 100 m EZ, as described earlier. Ramp up would begin with one (additional) GI airgun at 105 in^3, and the second (additional) GI airgun would be added after 5 min and so forth. Only after all 4 guns were firing at 105 in^3 could power be increased to run the sources in GG mode (210 in^3 each). During ramp up, the PSOs would monitor the EZ. If marine mammals or turtles are sighted, a power down or shut down would be implemented as though the full array were operational.

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 within the U.S. EEZ, and no activities would take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

Most of this section is taken verbatim from the Scripps IHAA application (LGL, 2017b) and adapted for the USGS circumstances outlined in this application and in the Draft MATRIX EA (USGS, 2018).

The USGS will arrange for professional marine mammal monitoring during the project, in order to implement the proposed mitigation measures that require real-time monitoring, and to satisfy the anticipated monitoring requirements of the IHA. The proposed Monitoring Plan is described below. The USGS 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. The USGS is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

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

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

The flying bridge on the *R/V Hugh R. Sharp* is ~10.6 m above the water's surface and is a suitable platform from which PSOs would watch for marine mammals and turtles. Standard equipment for marine mammal observers would be 7 x 50 marine, anti-fog reticle binoculars and optical range finders. At night, night-vision equipment would be available. The observers would be in communication with ship's officers on the bridge and scientists in the vessel's operations laboratory, so that they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

PSO Data and Documentation

The following is taken verbatim from the recent IHAA submitted by Scripps and prepared by LGL (LGL, 2017b). Since these are standard procedures, they do not require adaptation for this IHAA. PSOs would record data to estimate the numbers of marine mammals, turtles, and diving ESA-listed seabirds exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. They would also record any observations of fish potentially affected by the sound sources. Data would be used to estimate numbers of marine mammals potentially 'taken' by harassment (as defined in the MMPA). They would also provide information needed to order a power down or shut down of the airguns when a marine mammal, sea turtle, or diving ESA-listed seabird is within or near the EZ.

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

i. 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.

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

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

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

Results from the vessel-based observations would provide

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

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

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

The USGS would coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in this area. The USGS would coordinate with applicable U.S. agencies (e.g., NMFS), and would comply with their requirements.

XV. LITERATURE CITED

Many of the biological references are taken directly from the Draft Scripps EA (LGL, 2017a), as incorporated in the Draft MATRIX EA (USGS, 2018) by reference. Some references taken from the Scripps IHAA (LGL, 2017b). Updates have been made where necessary to reflect additional or alternate information used by or accessed by the U.S. Geological Survey. All access dates for online information refer to LGL's activities in preparation of the Draft Scripps EA (LGL, 2017a) when these dates are in 2017.

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APPENDICES

Appendix A: Backup Configuration Information and Calculations

In the case of compressor failure or other equipment problems, the airguns could be operated in the backup, 2 GI gun, configuration. The exclusion/mitigation zones for this configuration are significantly smaller than those for the configurations (Base and GG) targeted for the Optimal and Base Surveys. Thus, takes calculated for the other configurations are larger and therefore more conservative than applicable to the Backup Configuration. For the sake of completeness, information about the backup configuration is provided here and calculations of the sound source levels are given in Appendix C. **Backup Configuration** (Configuration 3) is 2 GI guns producing 210 in^3 total volume, as shown in Figure A1. If a compressor were offline, this lowest-energy configuration would be used to sustain data acquisition. Guns will be towed at 3 m water depth of the port towpoint on the stern, with 2 m front-to-back separation between the guns.

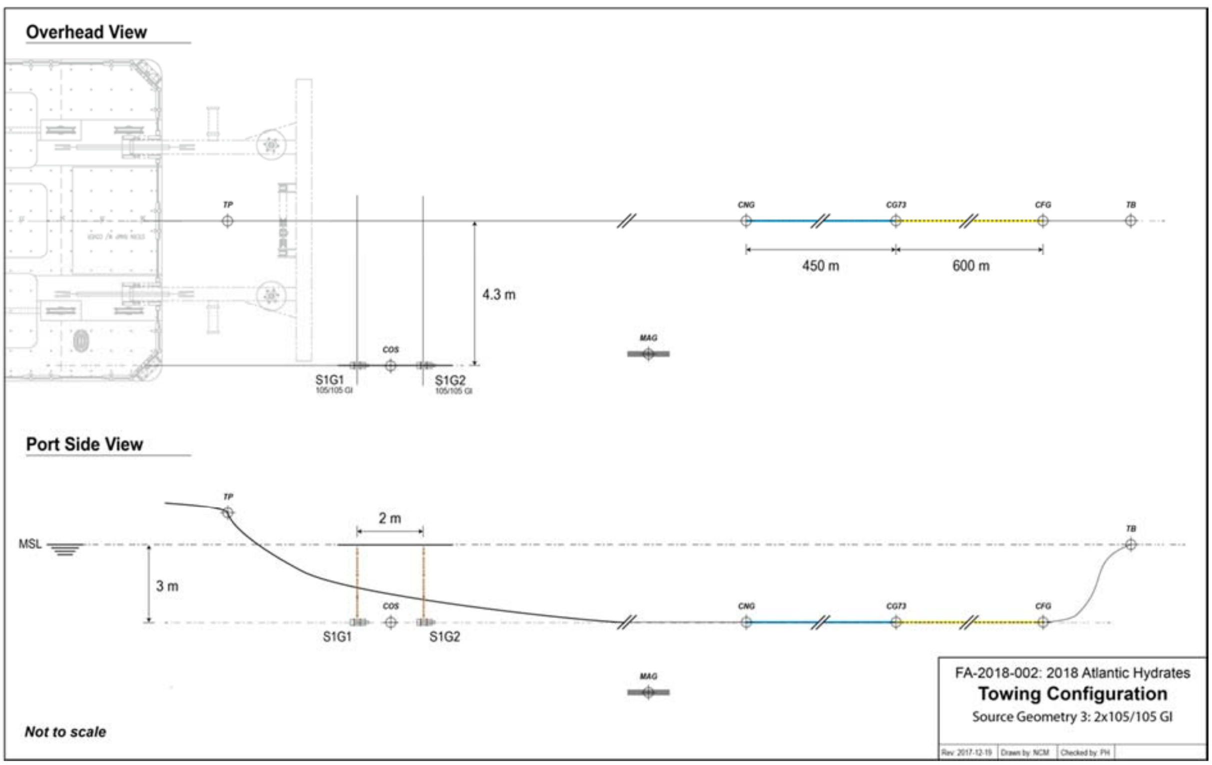

Figure A1. **Backup configuration** (Source configuration 3): 210 in^3 total volume consisting of 2x105/105in^3 GI guns firing in standard GI mode. Guns are labelled as S#G*, where # is the side and * is the gun number.

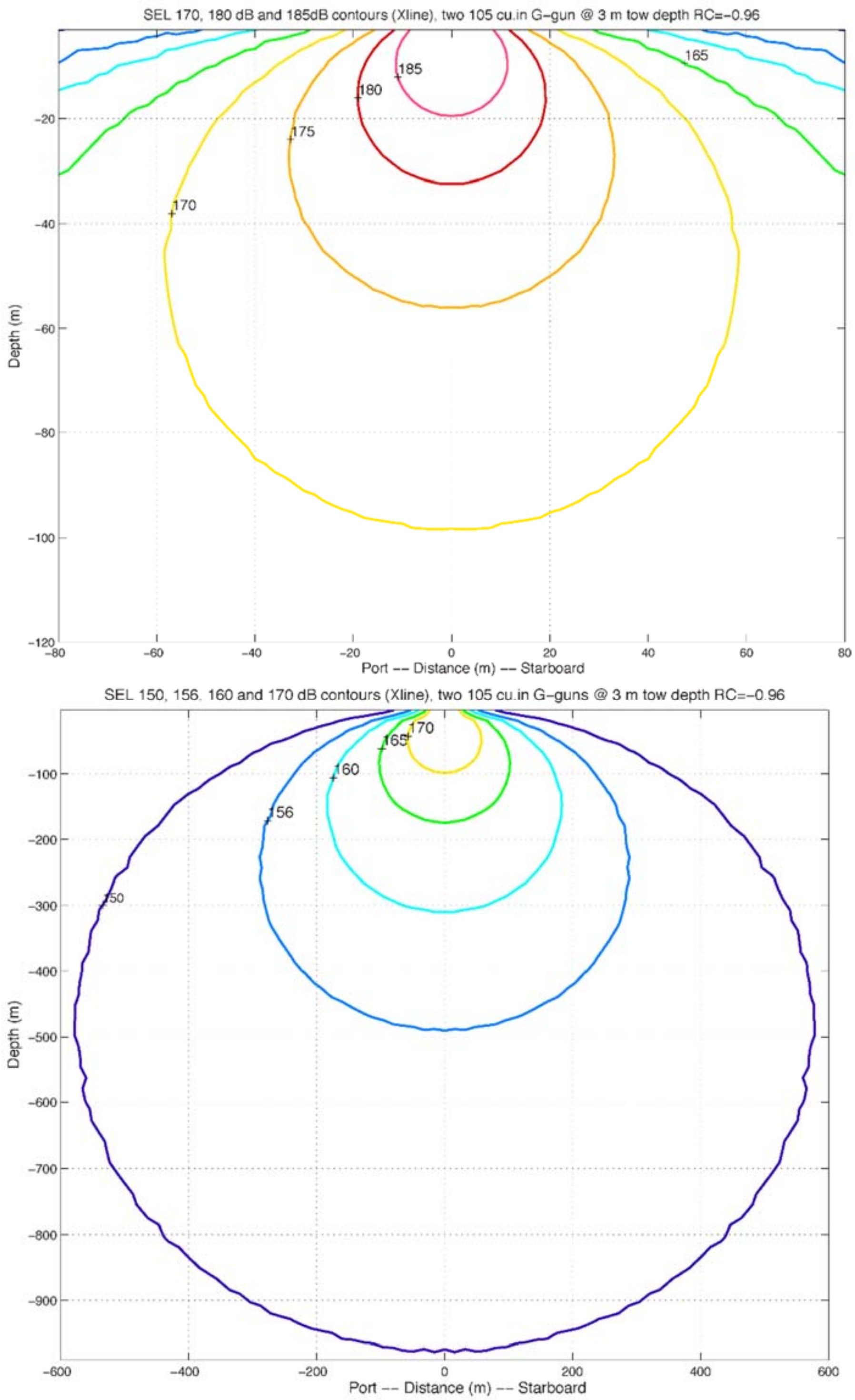

FIGURE A2. Modeled deep-water received sound exposure levels (SELs) from the backup configuration (Configuration 3; two 105 in^3 GI-guns) at a 3-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150 and 165-dB SEL isopleths as a proxy for the 160 and 175-dB rms isopleths, respectively. The upper plot is a blow-up of the lower plot.

Appendix B: Sound Exposure Levels (SEL): Scaling Analyses and All Results

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

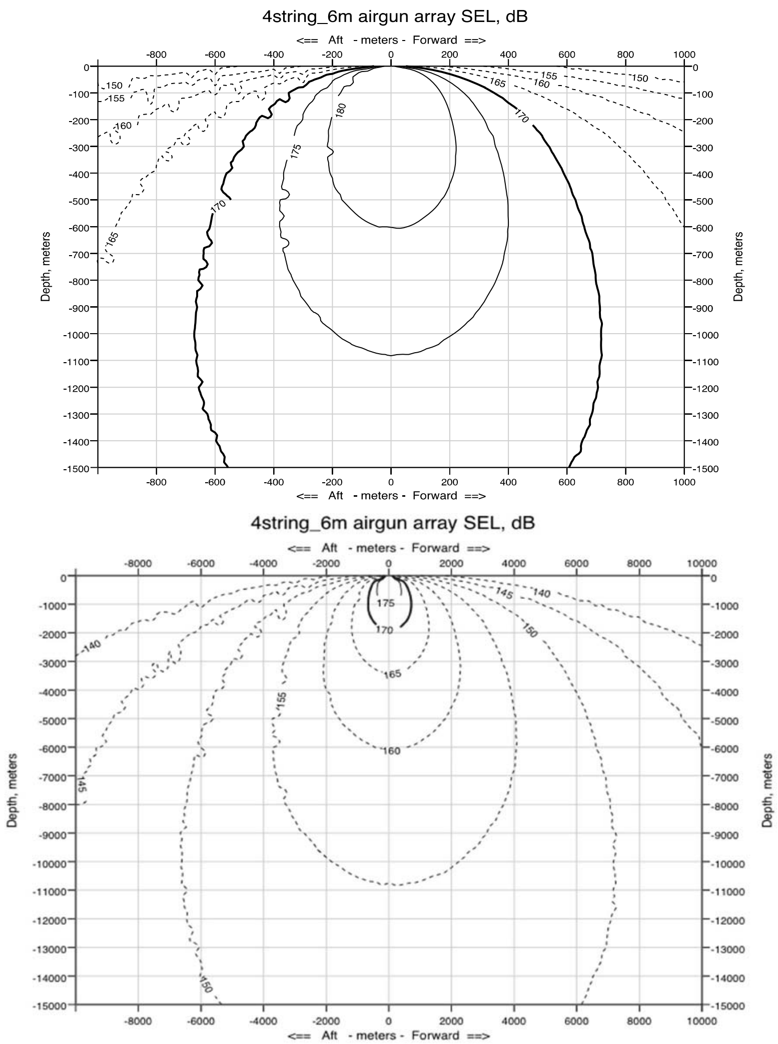

FIGURE B1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. These values are used along with a scaling factor to determine SELs for shallow-water deployments with the three proposed configurations. Received rms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

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

- the <u>150-decibel (dB)</u> Sound Exposure Level (SEL)[1] corresponds to deep-water maximum radii of

[1] SEL (measured in dB re 1 µPa^2 · s) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than

1090.6 m for the four 105 in^3 airguns at 3 m tow depth (Fig. 5), and 7,244 m for the 6600 in^3 at 6-m tow depth, yielding scaling factors of 0.151 to be applied to the shallow-water 6-m tow depth results.

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

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

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

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

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

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

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

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

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

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

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

- the 150-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 578.152 m for the two 105 in^3 airguns at 3 m tow depth (Fig. 7), and 7,244 m for the 6600 in^3 at 6-m tow depth (Fig. 8), yielding scaling factors of 0.080 to be applied to the shallow-water 6-m tow depth results.

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1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO's model.

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

- Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 58.395 for the two 105 in^3 airguns at 3 m tow depth (Fig. 2) and 719 m for the 6600 in^3 at 6-m tow depth (Fig. 4), yielding the same 0.081 scaling factor.
- the 185-decibel (dB) Sound Exposure Level (SEL) corresponds to deep-water maximum radii of 11.343 m for the two 105 in^3 at 3-m tow depth, and 126.3 m for a 6-m tow depth, yielding a scaling factor of 0.089 to be applied to the shallow-water 6-m tow depth results.

Measured 160-, 175-, 180-, 190- and 195-dB re 1µPa_{rms} distances in shallow water for the 36-airgun *R/V Langseth* array towed at 6 m depth were 17.5 km, 2.84 km, 1.6 km, 458 m and 240 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the tow depth and discharge volume differences between the 6600 cu.in airgun array at 6 m tow depth and the 110 cu.in airgun array at 3 m tow depth yields distances of 1.4 km, 227 m, 130 m, 38 m and 21 m, respectively.

Table B1. Predicted distances to which sound levels ≥ 195, 190-, 180-, 175-, and 160-dB re 1 μPa$_{rms}$ are expected to be received during the proposed surveys in the Northwest Atlantic Ocean. The Proposed Action will not involve ensonifying the seafloor at water depths shallower than 100 m.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted rms Radii (m)				
			195 dB	190dB	180 dB	175 dB	160 dB
Base Configuration (Configuration 1) Four 105 in^3 G-guns	3	>1000 m	100[4]	100[4]	110[4]	194[1]	1091[1]
		100–1000 m	100[4]	100[4]	165[4]	291[2]	1637[2]
GG Configuration (Configuration 2) Four 210 in^3 G-guns	3	>1000 m	100[4]	100[4]	125[1]	220[1]	1244[1]
		100–1000 m	100[4]	100[4]	188[2]	330[2]	1866[2]
Backup Configuration (Configuration 3) Two 105 in^3 G-guns	3	>1000 m	100[4]	100[4]	100[4]	102[1]	578[1]
		100–1000 m	100[4]	100[4]	100[4]	153[2]	867[2]

[1] Distance is based on L-DEO model results.
[2] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
[4] Modeled distances based on empirically derived measurements in the GoM are smaller than 100 m. Therefore, we use 100 m for these mitigation zone according to accepted practice.

Appendix C. Supporting Documentation for Level A Acoustic Modeling

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

BASE CONFIGURATION:

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

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

Source Velocity (meters/second)	2.05778*
1/Repetition rate^ (seconds)	12.149**

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

Table C1: Table showing the results for one single SEL SL modeling without and with applying weighting function to the 5 hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SELcum threshold is the largest. A propagation is of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	183 dB	185 dB	155 dB	185 dB	203 dB
Distance(m) (no weighting function)	34.3541	28.0537	907.6353	28.0537	N/A (<1m)
Modified Farfield SEL*	213.7196	213.9598	214.1582	213.9598	203
Distance (m) (with weighting function)	15.6980	N/A	N/A	N/A	N/A
Adjustment (dB)	-6.80	N/A	N/A	N/A	N/A

* Propagation of 20 log R

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

TABLE C2. Results for single shot SEL source level modeling for the four 105 in^3 airguns with weighting function calculations for SEL_{cum} criteria.

F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)

VERSION 1.1: Aug-16

KEY

(green)	Action Proponent Provided Information
(pink)	NMFS Provided Information (Acoustic Guidance)
(blue)	Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Carolyn Ruppel -
PROJECT/SOURCE INFORMATION	source : SIO portable system = 4 x 105 cu.in GI-gun at a 3m towed depth - (2 m separation in the fore-aft direction, 8.6 m in the port- starboard 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.

* 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)	2.05778
1/Repetition rate^ (seconds)	12.149

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

^Time between onset of successive pulses.

Modified farfield SEL	213.7196	213.9598	214.1582	213.9598	203
Source Factor	1.93829E+20	2.04852E+20	2.14427E+20	2.04852E+20	1.64233E+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)	31.0	0.0	0.0	0.4	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)†	-6.80	-54.02	-63.18	-23.74	-29.86

OVERIDE Using LDEO Modeling

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)	31.0	0.0	0.0	0.4	0.0

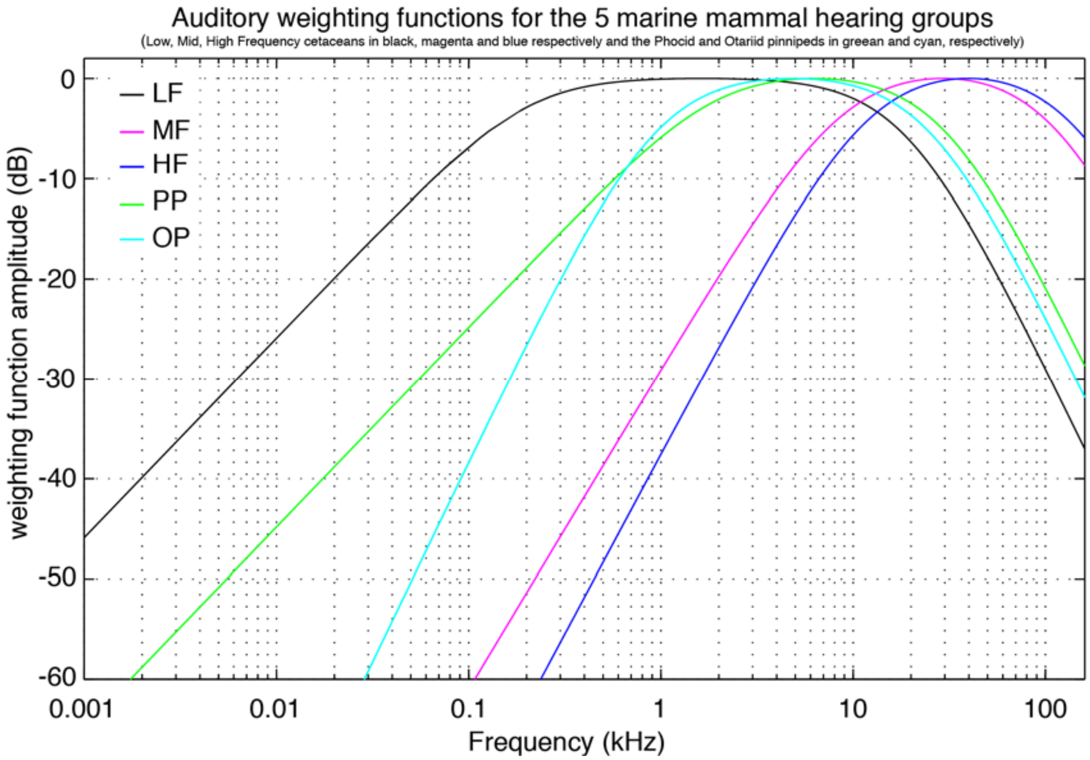

FIGURE C1: Auditory weighting functions for the 5 marine mammal hearing groups defined by NOAA's Acoustic Guidelines.

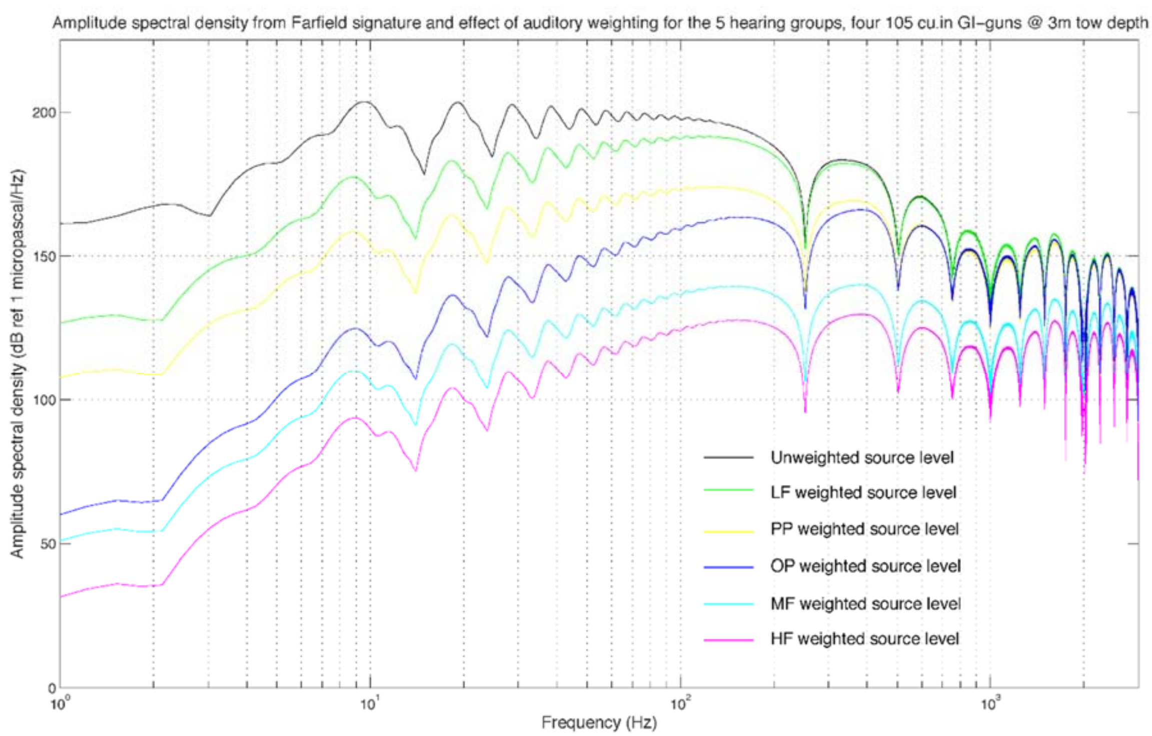

FIGURE C2: Modeled amplitude spectral density of the four 105 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, High Frequency

Cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted source level at each frequency and to derive the adjustment factors for the Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, and High Frequency Cetaceans as inputs into the NMFS user spreadhseet. Note that pinnipeds will not be encountered during the Proposed Action, but modeling is done here for the sake of completeness.

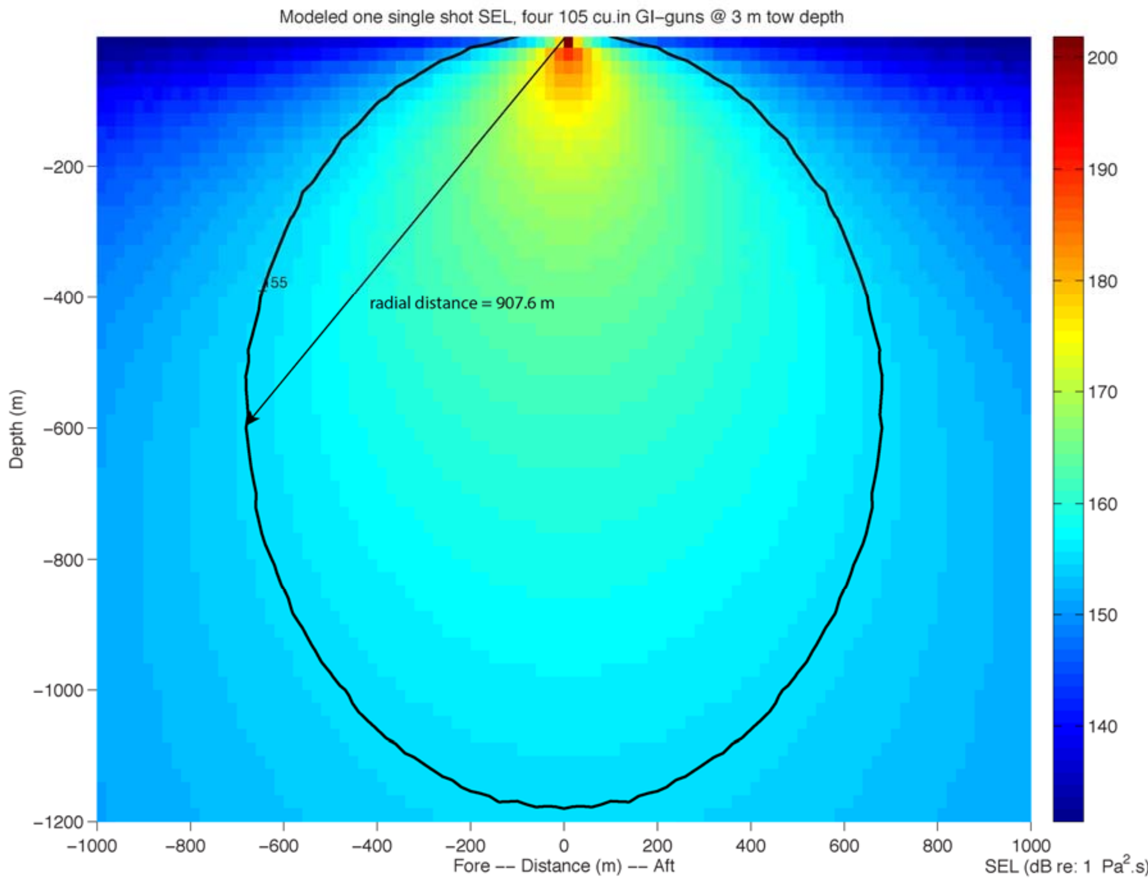

FIGURE C3: Modeled received sound levels (SELs) in deep water from the four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (907.6 m).

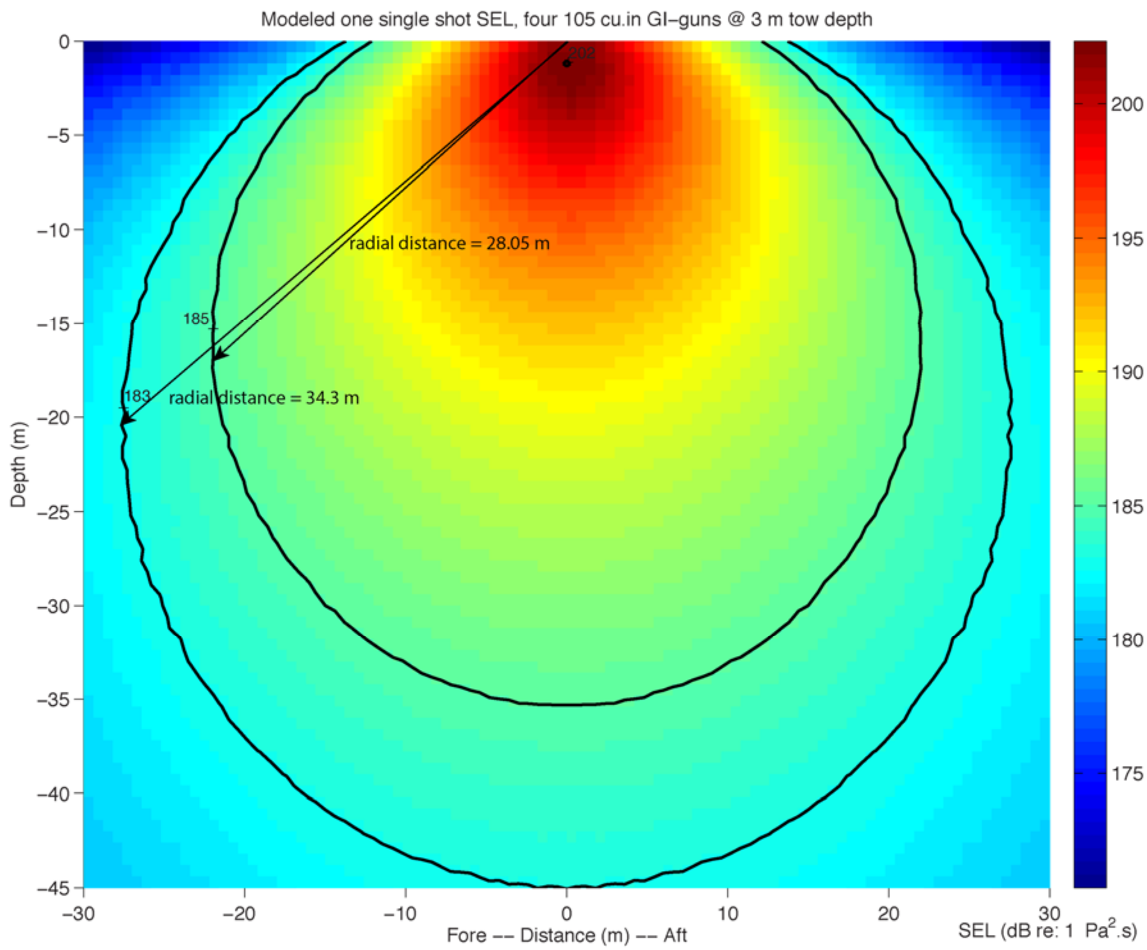

FIGURE C4 : Modeled received sound levels (SELs) in deep water from the four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183 and 185 dB SEL isopleths

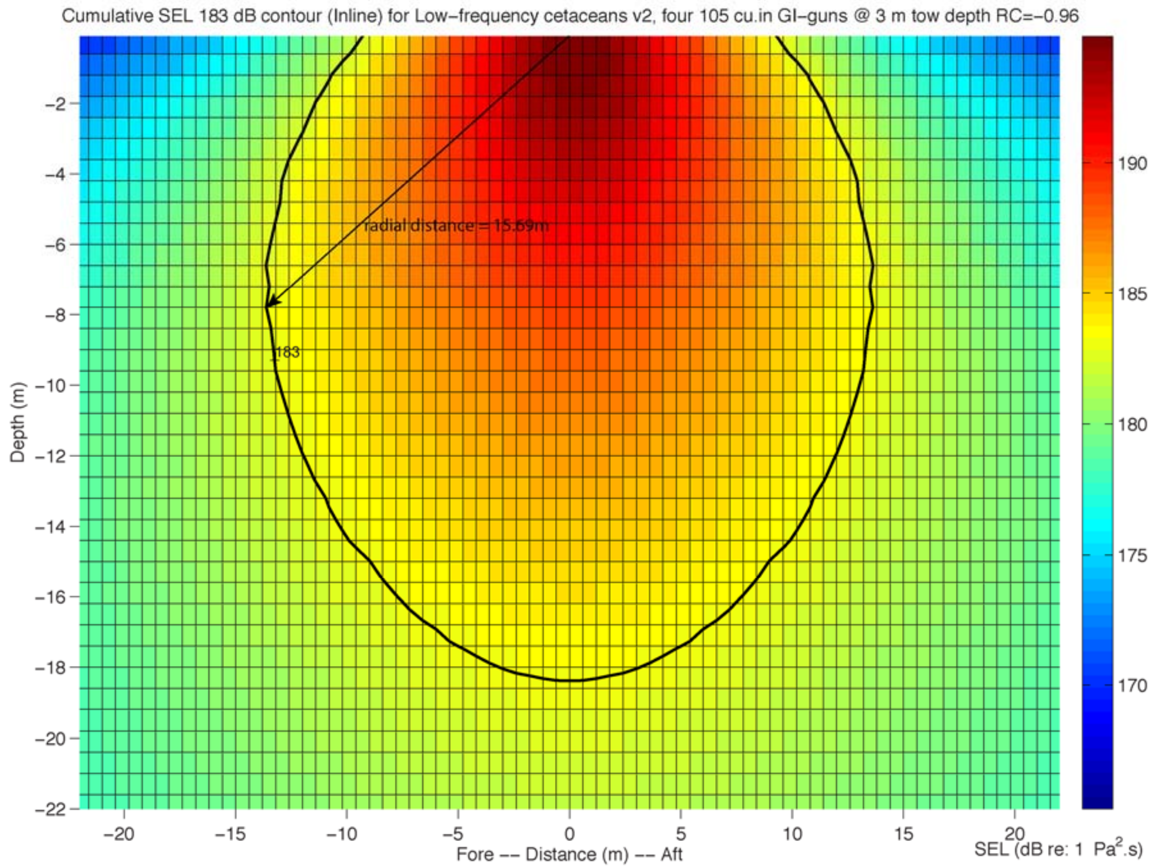

FIGURE C5: Modeled received sound exposure levels (SELs) from the four 105 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum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

Peak Sound Pressure Level :

TABLE C3. LEVEL A. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the four 105 cu.in airguns at a 3 m tow depth during the proposed seismic survey in the north western Atlantic Ocean. While the modified PK farfield value (calculated as PK threshold $+20\log_{10}$(radius)) is reported here, it is irrelevant since the calculations no longer rely on applying band pass filters.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PK Threshold (dB)	219	230	202	218	232
Modified PK farfield (dB)	239.0	N/A	239.0	239.1	N/A
Radius to threshold (meters)	10.03	N/A (0)	70.426	11.35	N/A (0)

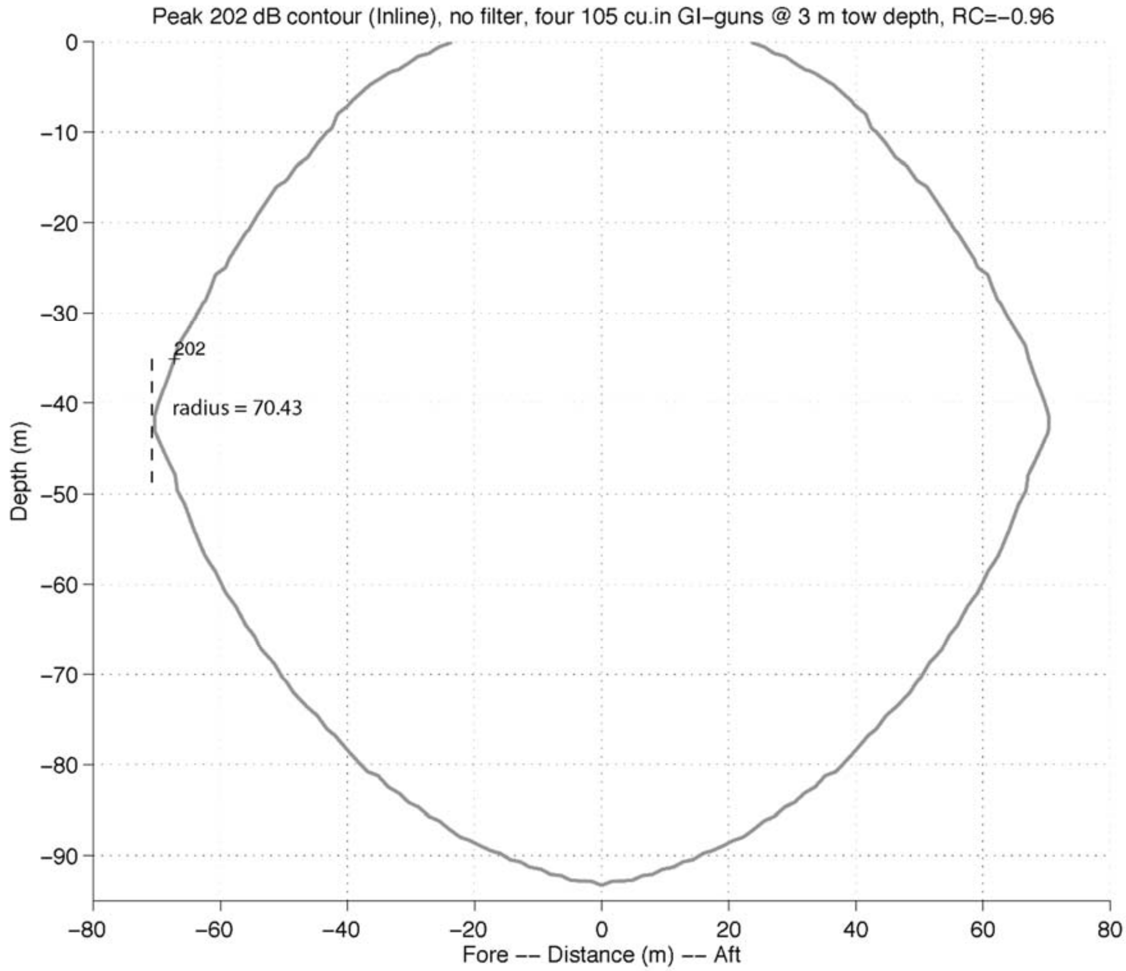

FIGURE C6: Modeled deep-water received Peak SPL from the four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (70.43 m).

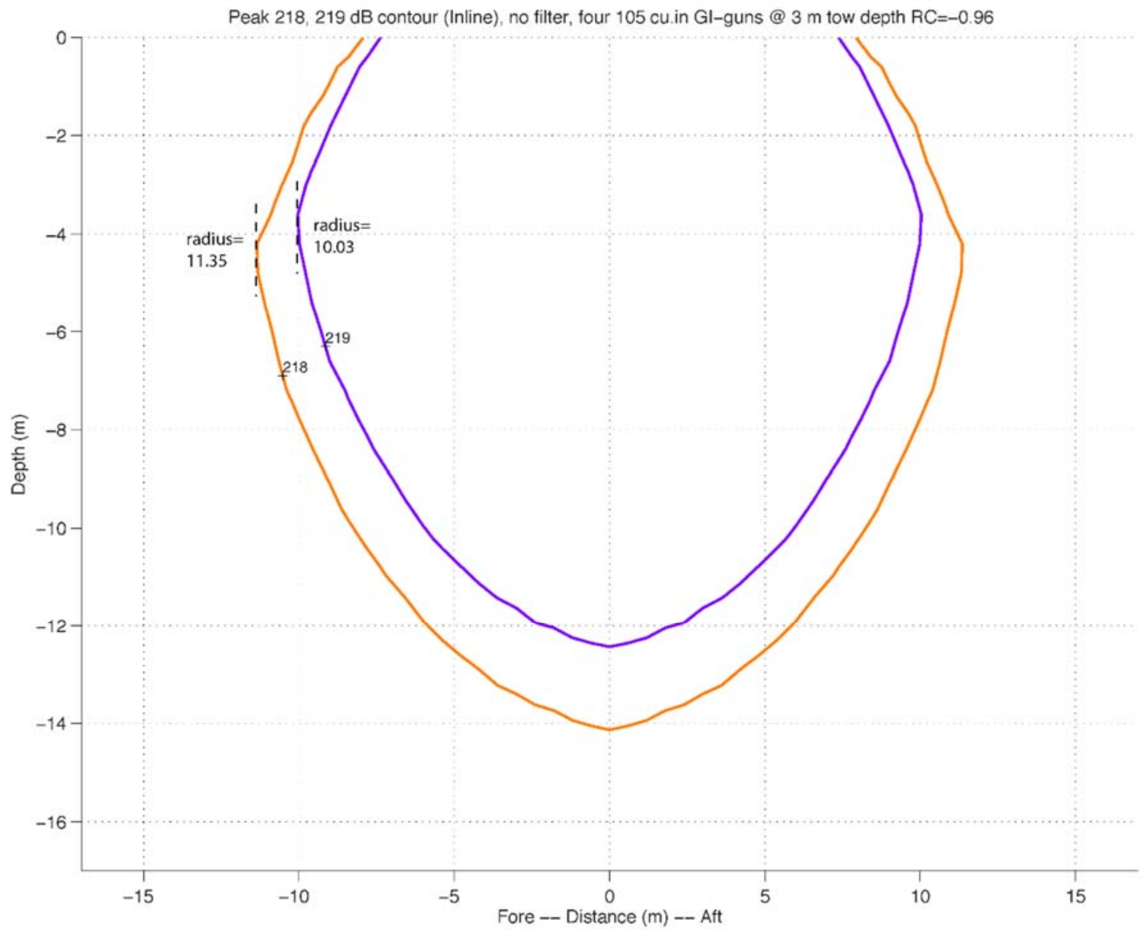

FIGURE C7: Modeled deep-water received Peak SPL from four 105 cu.in GI-guns at a 3-m tow depth. The plot provides the radius of the 218 and 219 dB peak isopleths.

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

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

SEL_{cum} Threshold	183	185	155	185	203
Distance(m) (no weighting function)	39.4216	30.8975	1029.1	30.8975	1.8439
Modified Farfield SEL*	214.9147	214.7985	215.2492	214.7985	208.3147
Distance (m) (with weighting function)	17.7149	N/A	N/A	N/A	N/A
Adjustment (dB)	-6.9479	N/A	N/A	N/A	N/A

* Propagation of 20 log R

For the Low Frequency Cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 39.42 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL cum isopleth is located at 17.71 m from the source. Difference between 17.71 m and 39.42 m gives an adjustment factor of -6.95 dB assuming a propagation of 20log10(R).

TABLE C5. Results for single shot SEL source level modeling for the four 210 in^3 airguns with weighting function calculations for SEL_{cum} criteria.

F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)

VERSION 1.1: Aug-16

KEY

(green)	Action Proponent Provided Information
(pink)	NMFS Provided Information (Acoustic Guidance)
(blue)	Resultant Isopleth

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Carolyn Ruppel -
PROJECT/SOURCE INFORMATION Please include any assumptions	source : SIO portable system = 4 x 210 cu.in GI-gun at a 3m towed depth - (2 m separation in the fore-aft direction, 8.6 m separation in the port-starboard direction)
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.

* 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)	2.05778
1/Repetition rate^ (seconds)	12.149

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

^Time between onset of successive pulses.

Modified farfield SEL	214.9147	214.7985	215.2492	214.7985	208.3147
Source Factor	2.55229E+20	2.4849E+20	2.75664E+20	2.4849E+20	5.5838E+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)	39.5	0.0	0.1	0.5	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)†	-6.94	-54.84	-64.11	-24.04	-30.75	OVERIDE Using LDEO Modeling

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)	39.5	0.0	0.1	0.5	0.0

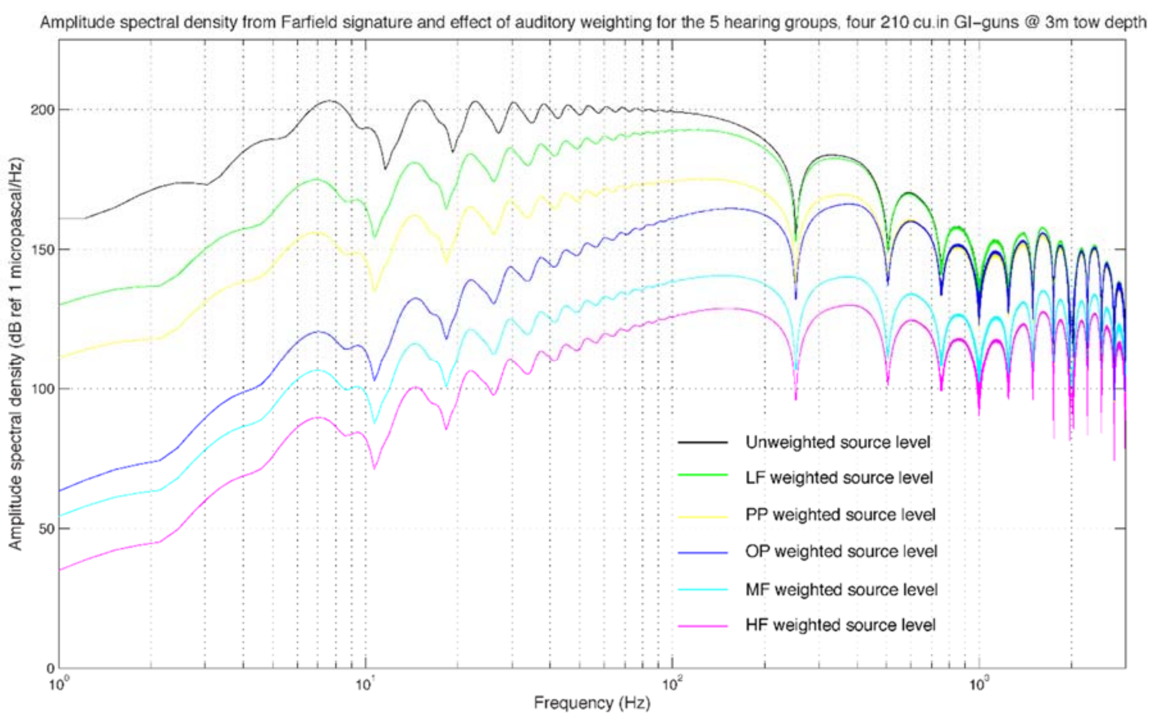

FIGURE C8: Modeled amplitude spectral density of the four 210 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, High Frequency Cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted source level at each frequency and to derive the adjustment factors for the Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, and High Frequency Cetaceans as inputs into the NMFS user spreadhseet.

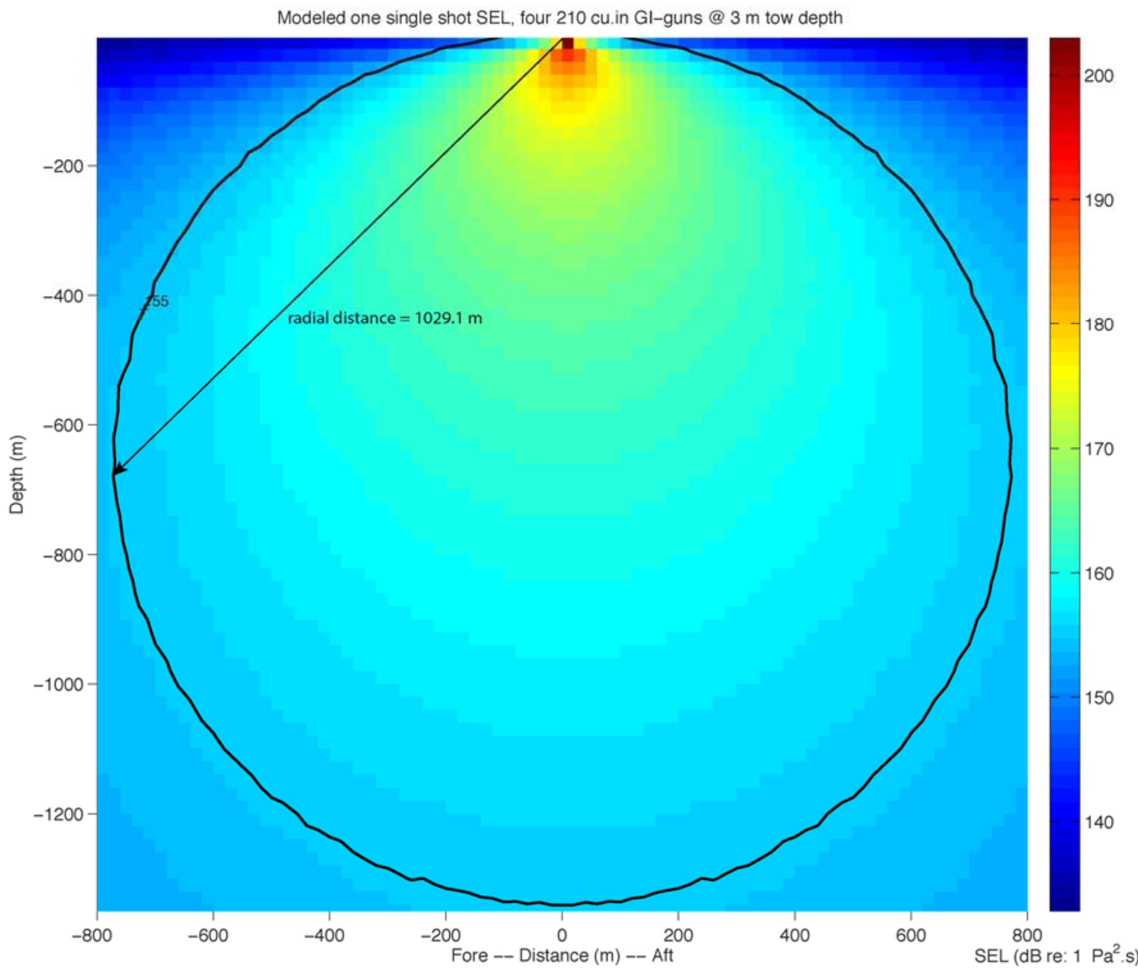

FIGURE C9: Modeled received sound levels (SELs) in deep water from the four 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (1029.1 m).

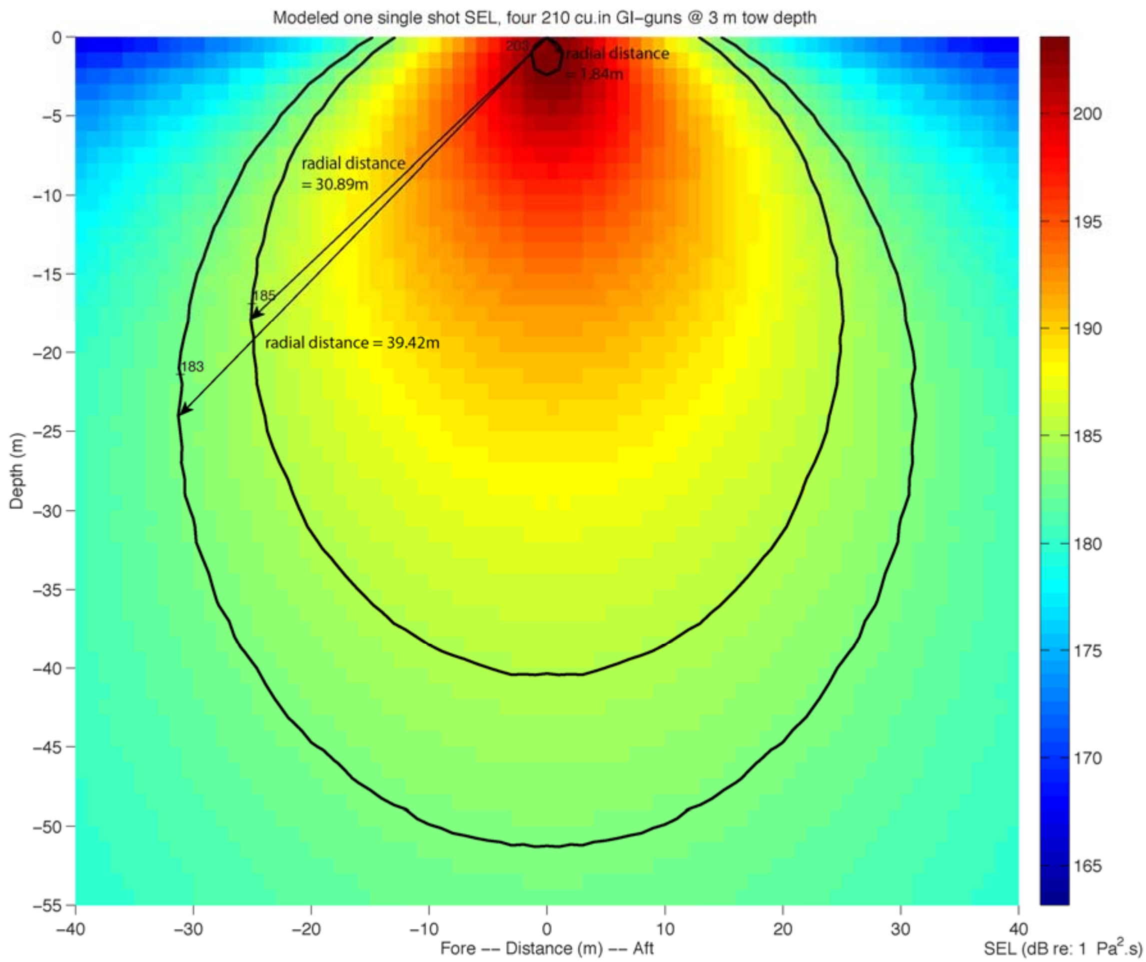

FIGURE C10 : Modeled received sound levels (SELs) in deep water from the four 210 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185 and 203 dB SEL isopleths

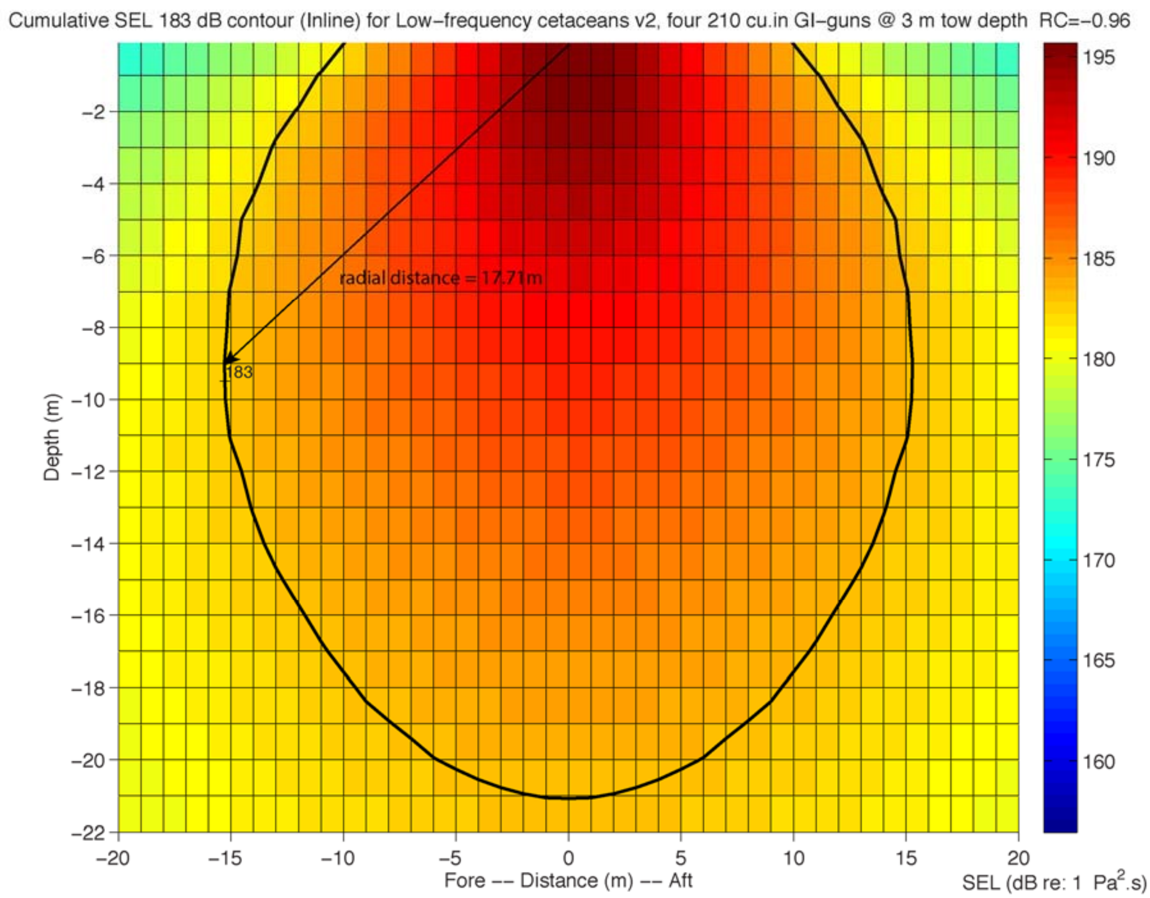

FIGURE C11: Modeled received sound exposure levels (SELs) from the four 210 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum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

Peak Sound Pressure Level :

TABLE C6. LEVEL A. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the four 210 cu.in airguns at a 3 m tow depth during the proposed seismic survey in the north western Atlantic Ocean. While the modified PK farfield value (calculated as PK threshold $+20\log_{10}$(radius)) is reported here, it is irrelevant since the calculations no longer rely on applying band pass filters.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PK Threshold	219	230	202	218	232
Modified PK farfield (dB)	240.2	N/A	240.1	240.3	N/A
Radius to threshold (meters)	11.56	N/A (0)	80.50	13.04	N/A (0)

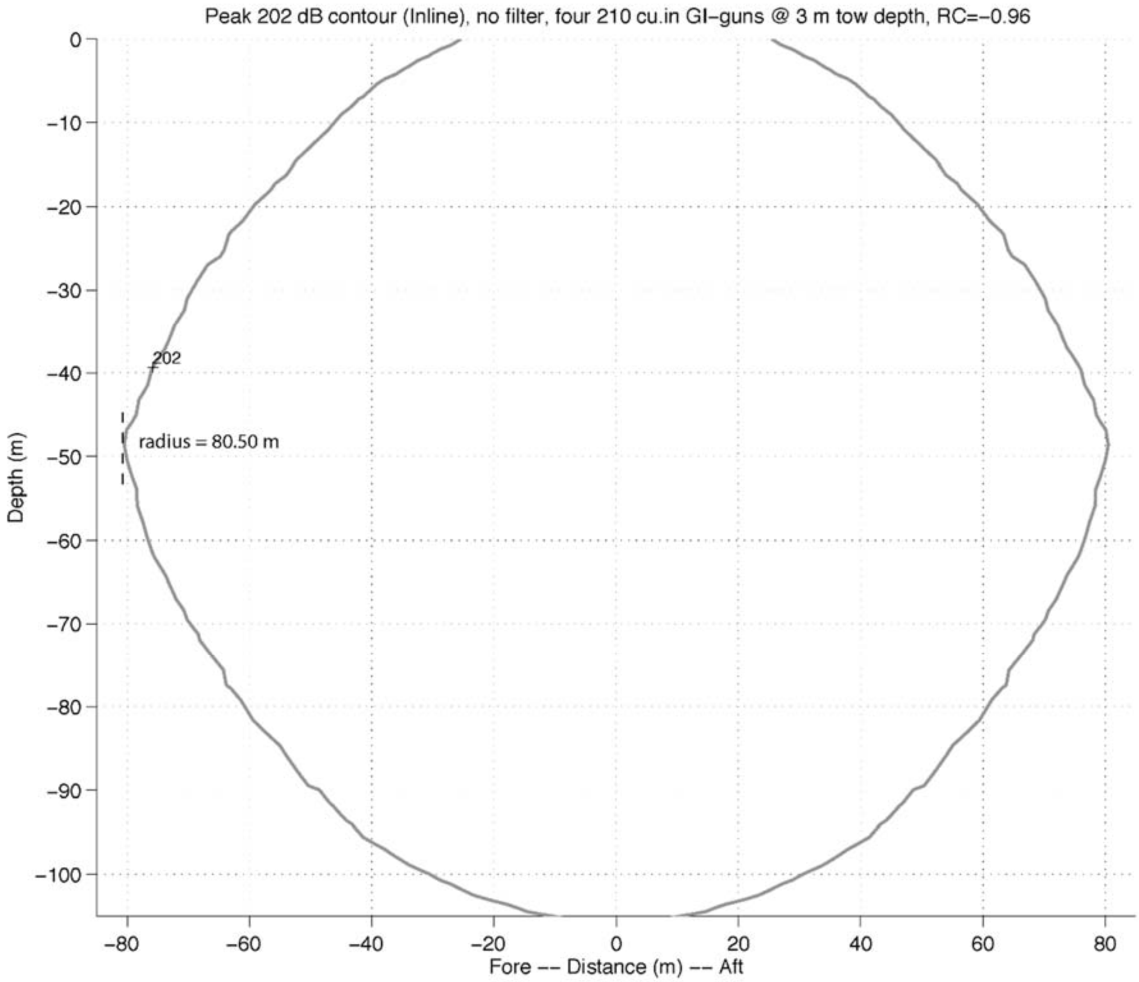

FIGURE C12: Modeled deep-water received Peak SPL from four 210 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (80.50 m).

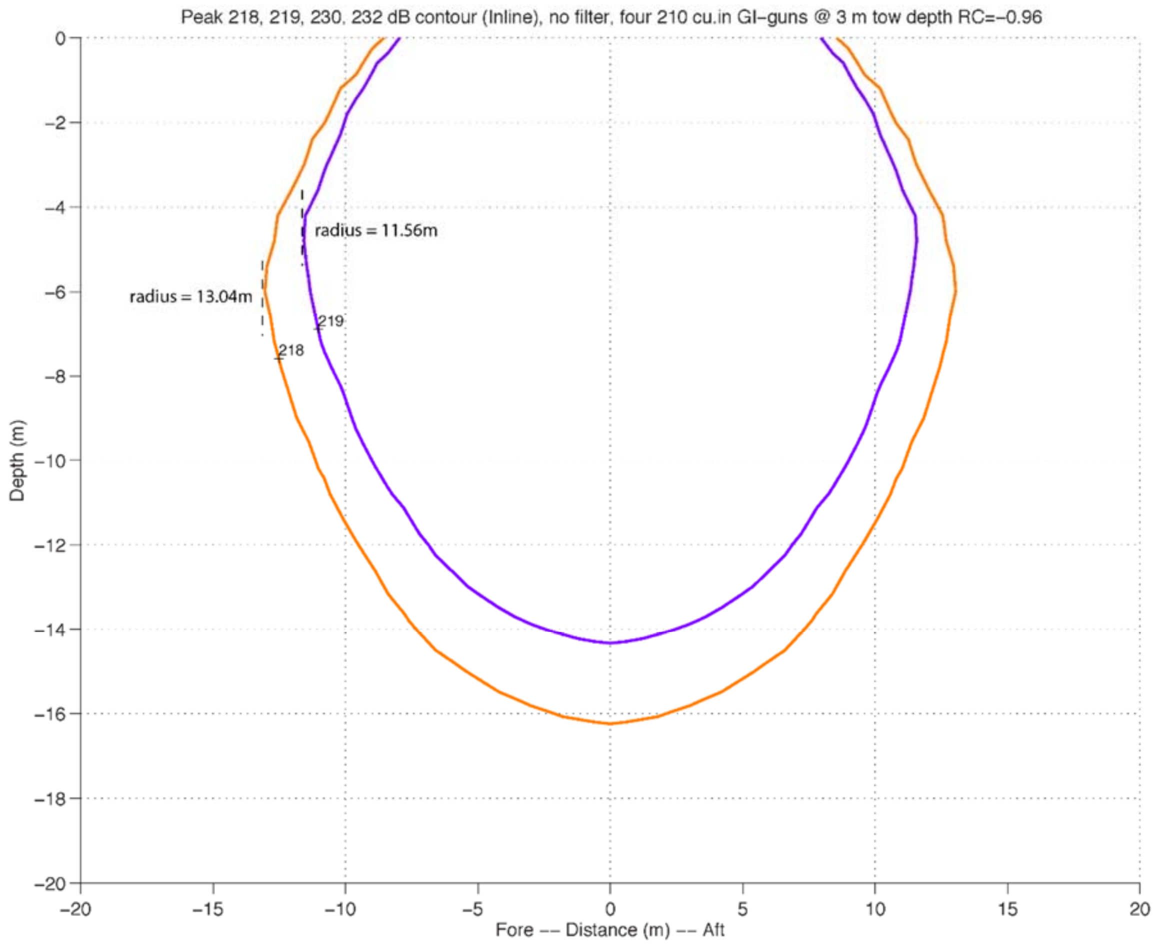

FIGURE C13: Modeled deep-water received Peak SPL from two 210 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 218 and 219 dB peak isopleths.

BACKUP CONFIGURATION

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

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

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

SEL_{cum} Threshold	183	185	155	185	203
Distance(m) (no weighting function)	17.9821	14.5253	459.5354	14.5352	2.2227
Modified Farfield SEL*	208.0968	208.2425	208.2464	208.2425	209.9376
Distance (m) (with weighting function)	9.1754	N/A	N/A	N/A	N/A
Adjustment (dB)	- 5.84	N/A	N/A	N/A	N/A

* Propagation of 20 log R

For the Low Frequency Cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 17.98 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL cum isopleth is located at 9.17 m from the source. Difference between 17.98 m and 9.17 m gives an adjustment factor of -5.84 dB assuming a propagation of 20log10(R).

TABLE C8. Results for single shot SEL source level modeling for the two 105 in^3 airguns with weighting function calculations for SEL_{cum} criteria.

F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)

VERSION 1.1: Aug-16

KEY

(green)	**Action Proponent Provided Information**
(pink)	**NMFS Provided Information (Acoustic Guidance)**
(blue)	**Resultant Isopleth**

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Carolyn Ruppel -
PROJECT/SOURCE INFORMATION Please include any assumptions	source : SIO portable system = 2 x 105 cu.in GI-gun at a 3m towed depth - (2 m separation in the fore-aft direction)
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	Default used

[¥] 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)	2.05778
1/Repetition rate^ (seconds)	12.149

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

^Time between onset of successive pulses.

RESULTANT ISOPLETHS*

Modified farfield SEL	**208.0968**	**208.2425**	**208.2464**	**208.2425**	**209.9376**
Source Factor	**5.31055E+19**	**5.49173E+19**	**5.49667E+19**	**5.49173E+19**	**8.11371E+19**

*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)	**10.6**	**0.0**	**0.0**	**0.1**	**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)†	-5.84	-53.99	-63.14	-23.74	-29.82	**OVERIDE Using LDEO Modeling**

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)	10.6	0.0	0.0	0.1	0.0

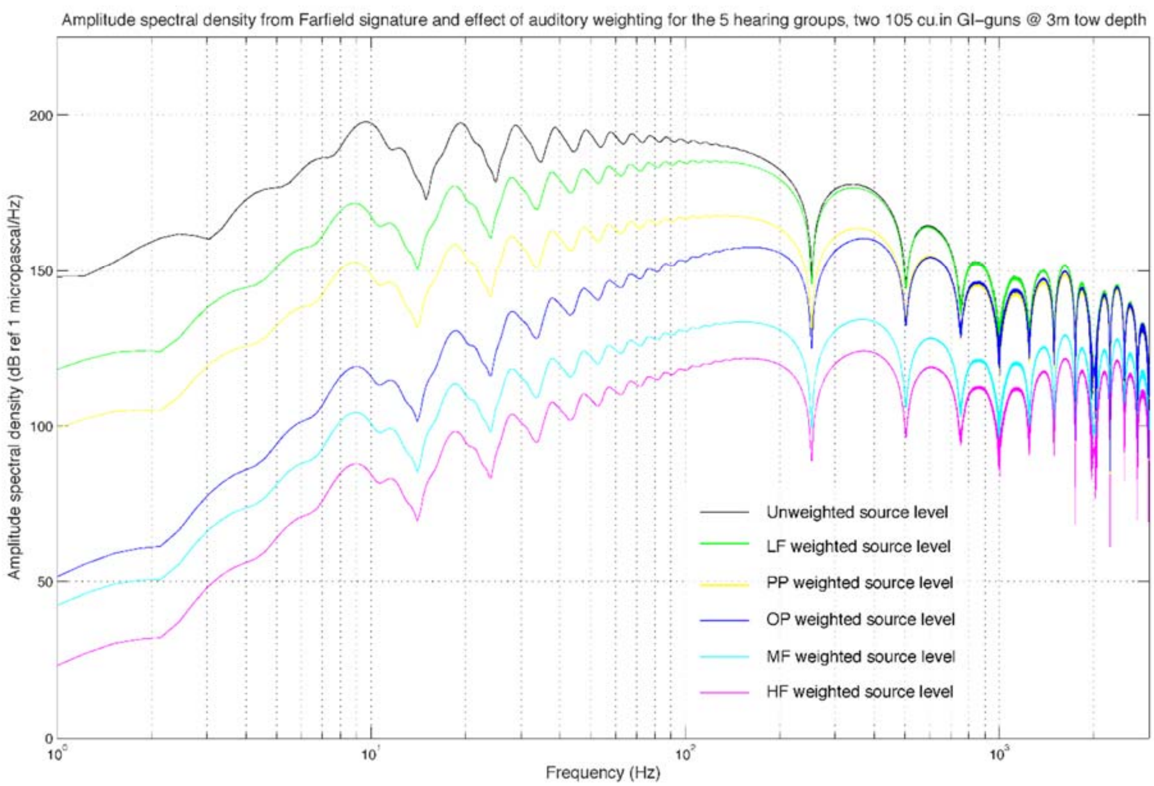

FIGURE C14: Modeled amplitude spectral density of the two 105 cu.in airgun farfield signature. Amplitude spectral density before (black) and after (green, yellow, blue, cyan, magenta) applying the auditory weighting function for the Low Frequency Cetaceans, Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, High Frequency Cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted source level at each frequency and to derive the adjustment factors for the Phocid Pinnipeds, Otariid Pinnipeds, Mid Frequency Cetaceans, and High Frequency Cetaceans as inputs into the NMFS user spreadhseet.

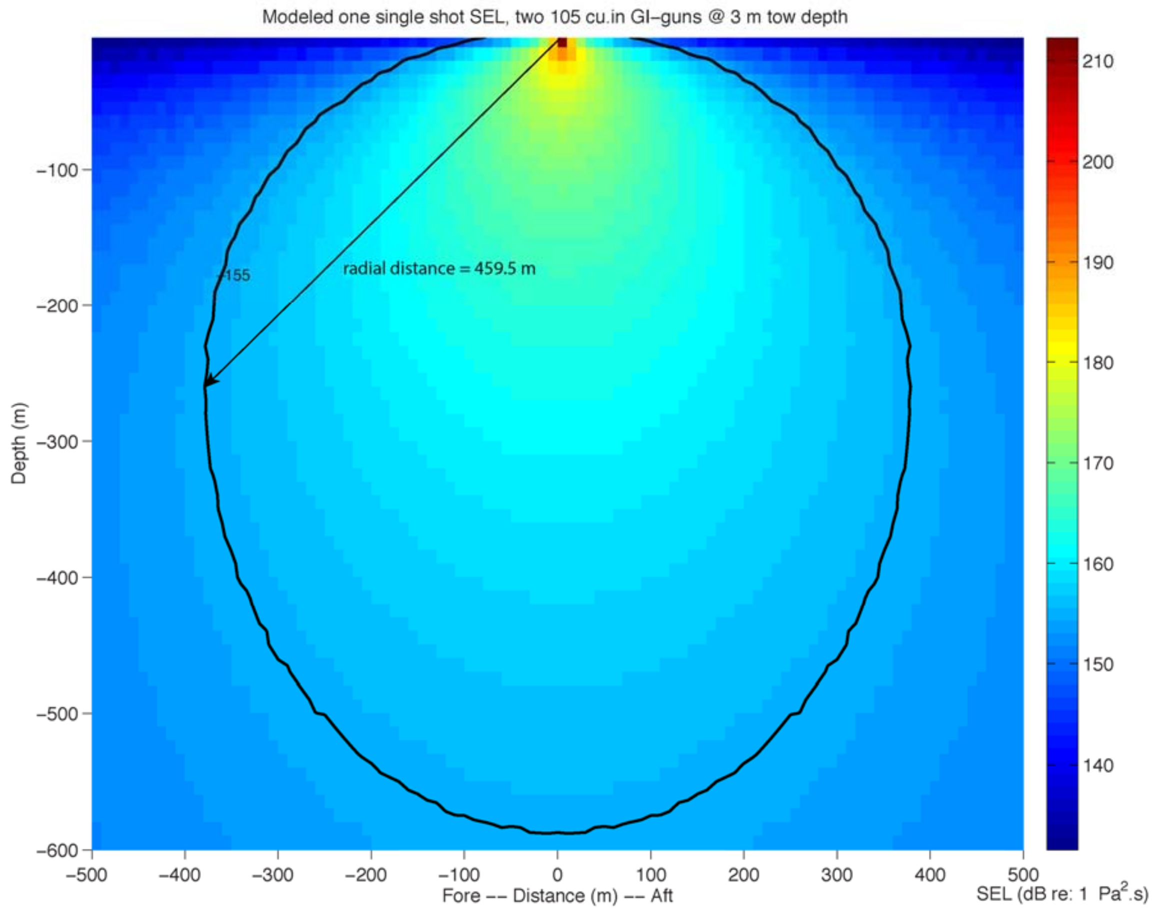

FIGURE C15: Modeled received sound levels (SELs) in deep water from the two 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (459.5 m).

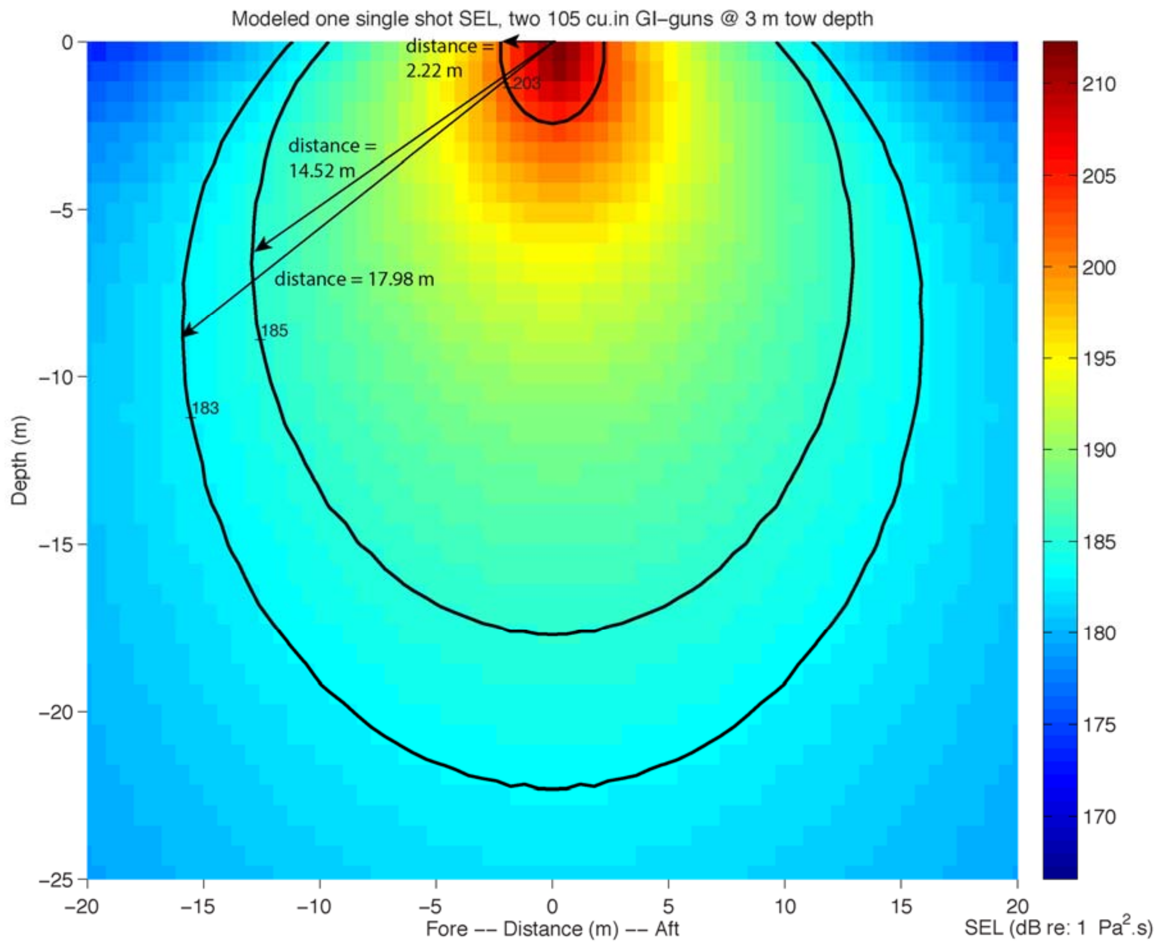

FIGURE C16: Modeled received sound levels (SELs) in deep water from the two 105 cu.in GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183 and 185 dB SEL isopleths

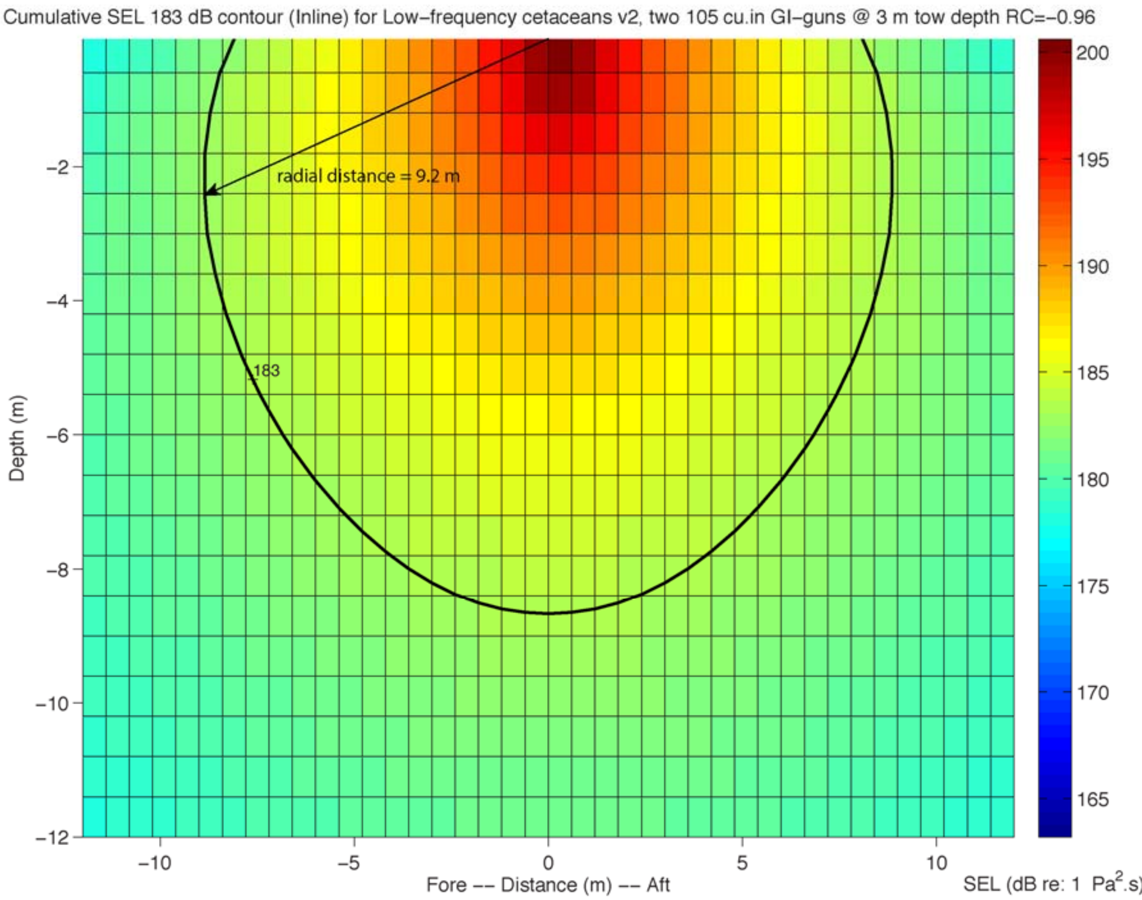

FIGURE C17: Modeled received sound exposure levels (SELs) from the two 105 cu.in GI-guns at a 3-m tow depth, after applying the auditory weighting function for the Low Frequency Cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. 4 (17.98 m) and this figure (9.17 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level :

TABLE C9. LEVEL A. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the two 105 cu.in airguns at a 3 m tow depth during the proposed seismic survey in the north western Atlantic Ocean. While the modified PK farfield value (calculated as PK threshold $+20\log_{10}$(radius)) is reported here, it is irrelevant since the calculations no longer rely on applying band pass filters.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PK Threshold	219	230	202	218	232
Modified PK farfield (dB)	235.3	234.0	234.5	235.3	232.7
Radius to threshold (meters)	6.52	1.58	42.32	7.31	1.08

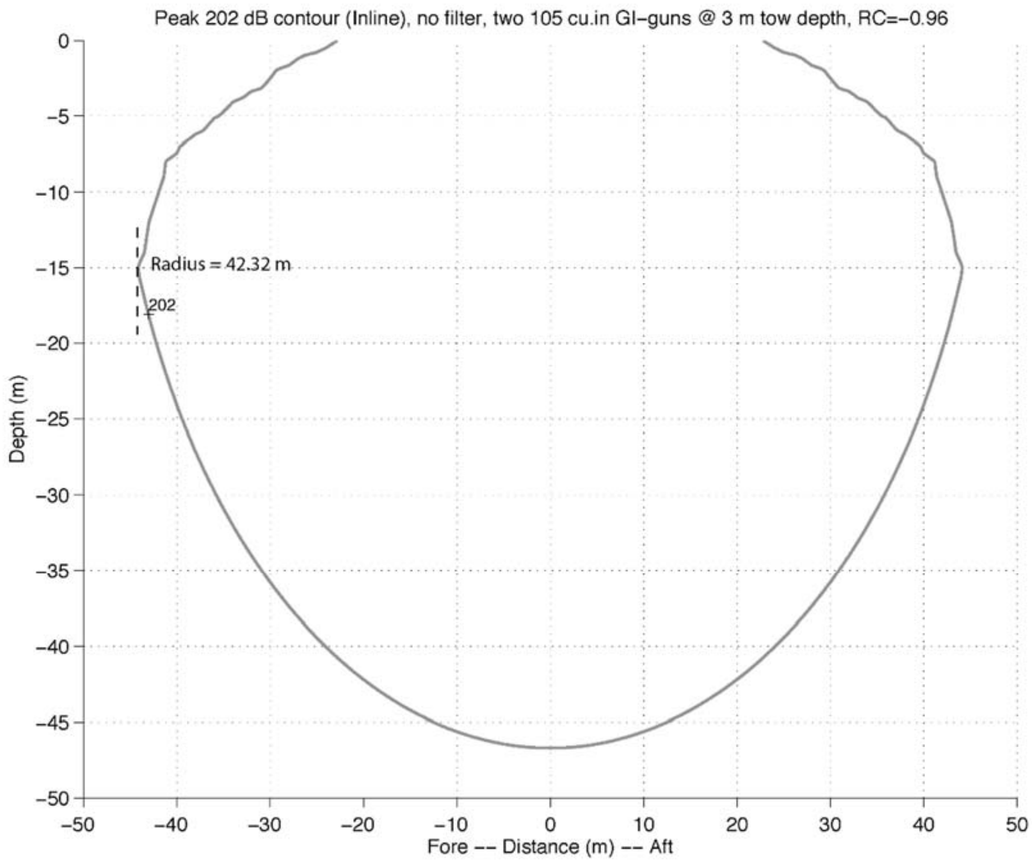

FIGURE C18: Modeled deep-water received Peak SPL from two 105 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (42.32 m).

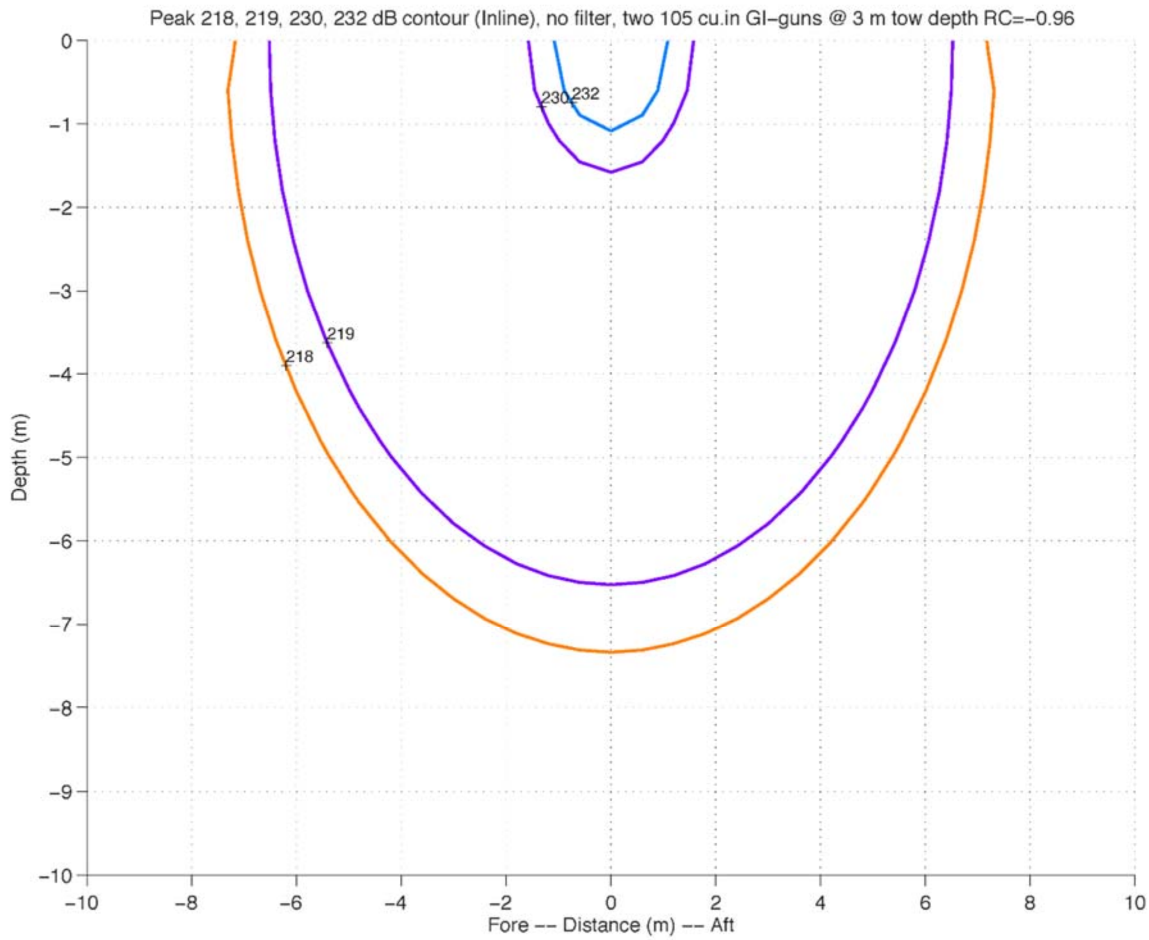

FIGURE C19: Modeled deep-water received Peak SPL from two 105 cu.in airguns at a 3-m tow depth. The plot provides the radius of the 218-219-230 and 232 dB peak isopleths.

Summary Tables for PTS SEL_{cum} and Peak SPL_{flat}.

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

	Hearing Group		
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**
SEL_{cum} Threshold	183 dB	185 dB	155 dB
Base Configuration	*31.0 m*	*0.0*	*0.0*
GG Configuration	*39.5 m*	*0.0*	*0.1 m*

Backup Configuration	*10.6 m*	*0.0*	*0.0*

TABLE C11. SUMMARY LEVEL A. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources and predicted radial distances to Level A thresholds in meters for the three source configurations.

	Hearing Group		
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**
PK Threshold	219 dB	230 dB	202 dB
Base configuration	*10.03 m*	*N/A (0)*	*70.426 m*
GG configuration	*11.56 m*	*N/A (0)*	*80.50 m*
Backup configuration	*6.52 m*	*1.58 m*	*42.32 m*