Request by the University of Hawaii for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Geophysical Survey by the R/V *Kairei* in the Central Pacific Ocean, September 2017

submitted by

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to

National Marine Fisheries Service
Office of Protected Resources
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Submitted 15 March 2016
Revised 12 July 2017

LGL Report FA0060

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SUMMARY

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC), in collaboration with the University of Hawaii, proposes to conduct a marine seismic survey north of Hawaii in the central Pacific Ocean during September 2017. The survey would take place in water depths ranging from 4000–5000 m partly within the exclusive economic zone (EEZ) of the Hawaiian Islands and partly in adjacent International Waters. The airgun array would consist of 32 airguns with a total volume of ~7800 in^3. The University of Hawaii requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the proposed seismic survey. 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 cetaceans could occur in the proposed survey area in the central Pacific Ocean. Several of these species are listed as ***endangered*** under the ESA, including the sei, fin, blue, and sperm whales. ESA-listed sea turtle species that could occur in the survey area include the ***endangered*** hawksbill, leatherback, and loggerhead turtles, and the ***threatened*** green and olive ridley turtles. Listed seabirds that could be encountered in the area include the ***endangered*** Hawaiian petrel, short-tailed albatross, and band-rumped storm petrel; and the ***threatened*** Newell's shearwater (USFWS 2017).

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

The proposed survey would occur north of the Hawaiian Islands in the central Pacific Ocean. It would encompass the approximate area 22.6–25.0°N and 153.5–157.4°W (Fig. 1). Water depth in the survey area ranges from ~4000–5000 m. The project is scheduled to occur during September 2017. JAMSTEC plans to use conventional seismic methodology to image a typical/stable oceanic crust, mantle, and Moho. The data obtained from the survey would be used to help better inform and further refine planning efforts for a proposed "Project Mohole" under consideration for scheduling by the International Ocean Discovery Program (IODP).

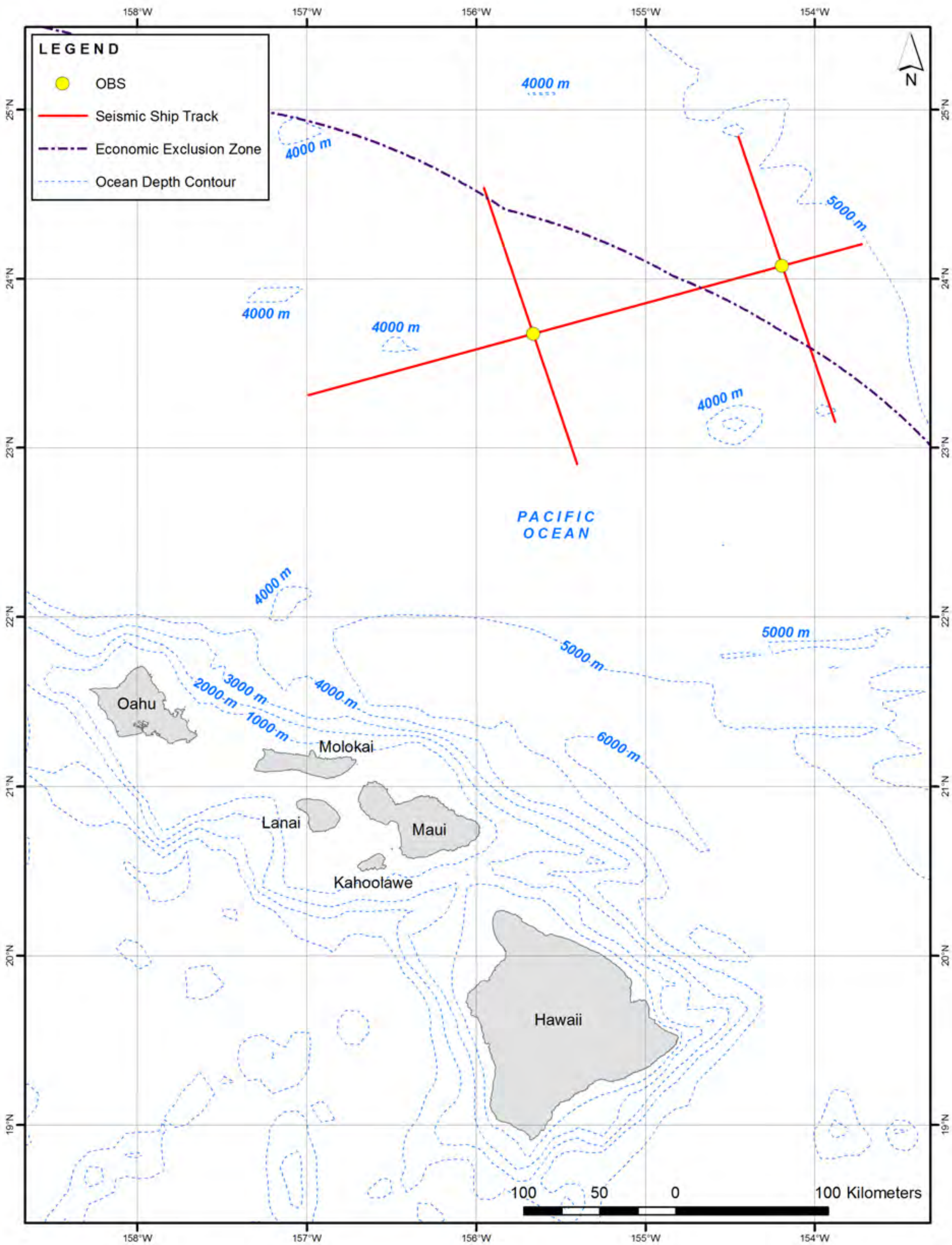

FIGURE 1. Survey area and design for the seismic survey in the central Pacific Ocean proposed for September 2017.

The survey would involve one source vessel, the R/V *Kairei*. The *Kairei* would deploy a 32-airgun array as an energy source. The receiving system would consist of one 6-km long hydrophone streamer and ocean bottom seismometers (OBSs). As the airgun array is towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs would record the returning acoustic signals internally for later analysis. Upon arrival at the survey area, two OBSs would be deployed. The streamer and airgun array would then be deployed, and seismic operations would commence. After completion of seismic operations, the OBSs would be recovered by the University of Hawaii via a separate vessel; the recovery cruise would be funded by the National Science Foundation (NSF).

The total survey effort would consist of ~1083 km of transect lines (Fig. 1); the two shorter north-south lines would each be surveyed once, while the longer west-east line would be surveyed twice. There would be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the calculations (see § VII), 25% has been added in the form of operational days, which is equivalent to adding 25% to the proposed line km to be surveyed.

In addition to the operations of the airgun array, a SeaBeam 3012 multibeam echosounder (MBES) would also be operated from the *Kairei* continuously throughout the cruise. All planned geophysical data acquisition activities would be conducted by JAMSTEC and the scientists who have proposed the study. The Principal Investigator (PI) is Dr. S. Kodaira (JAMSTEC); logistical support is provided by Dr. G. Moore (University of Hawaii). The vessel would be self-contained, and the crew would live aboard the vessel for the entire cruise.

Source Vessel Specifications

The R/V *Kairei* has a length of 106.0 m, a beam of 16.0 m, and a maximum draft of 4.7 m. Its propulsion system consists of two diesel engines, each producing 2206 kW, which drive the two propellers at 600 revolutions per minute (rpm). The operation speed during seismic acquisition would be ~8.3 km/h. When not towing seismic survey gear, the *Kairei* typically cruises at 30 km/h and has a range of ~18,000 km.

The *Kairei* would also serve as the platform from which vessel-based protected species observers (PSOs) would watch for marine mammals and sea turtles before and during airgun operations, as described in § XIII, below.

Other details of the *Kairei* include the following:

Owner:	JAMSTEC
Operator:	Nippon Marine Enterprises, Ltd.
Flag:	Japan
Gross Tonnage:	4517
Accommodation Capacity:	60 including ~22 scientists

Airgun Description

During the survey, the airgun array to be used would consist of 32 Bolt Annular Port airguns, with a total volume of ~7800 in^3. The airguns would be configured as four identical linear arrays or "strings" (Fig. 2). Each string would have eight airguns; the first and last airguns in the strings would be spaced 10 m apart. All eight airguns in each string would be fired simultaneously. The four airgun strings would be towed behind the *Kairei* and would be distributed across an area ~40 m × 10 m. The shot interval would be ~20–30 s or ~50–60 m. The firing pressure of the array would be ~2000 psi.

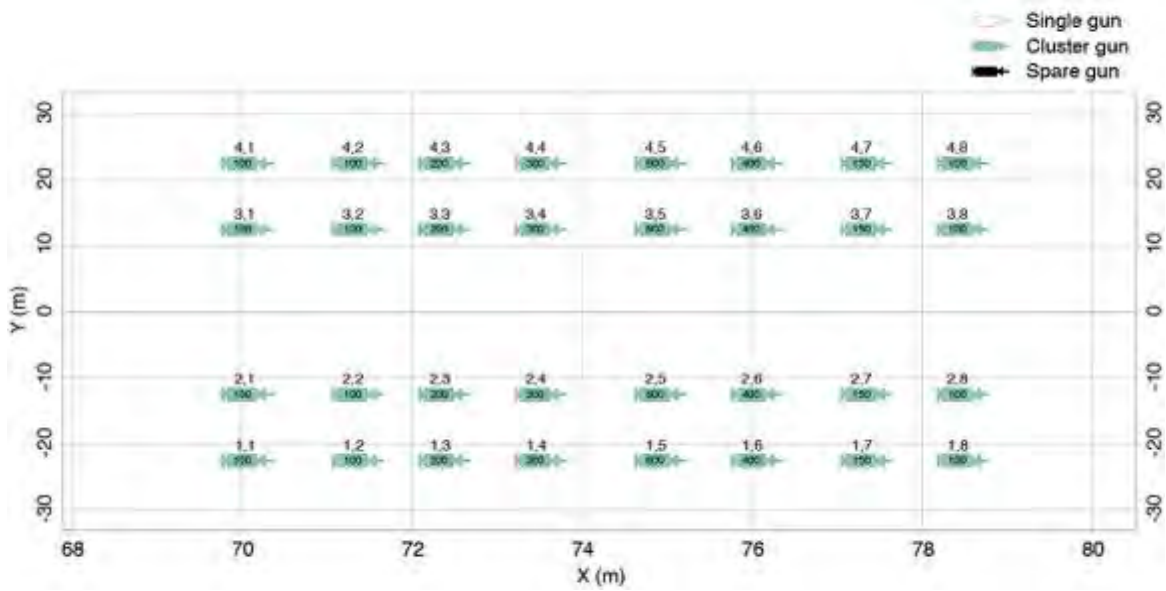

FIGURE 2. Airgun array consisting of 32 Bolt airguns totalling 7800 in^3.

During firing, a brief (~0.1 s) pulse of sound is emitted. The airguns would be silent during the intervening periods.

The tow depth of the array would be 10 m during the survey. Because the actual source is a distributed sound source (32 airguns) rather than a single point source, the highest sound levels measurable at any location in the water would be less than the nominal source level. In addition, the effective source level for sound propagating in near-horizontal directions would be substantially lower than the nominal source level applicable to downward propagation because of the directional nature of the sound from the airgun array.

32-Airgun Array Specifications

Energy Source*	Thirty-two 2000 psi Bolt airguns of 100–600 in^3, in four strings each containing eight airguns
Source output (downward)	peak-peak is 181.5 bar-m (265 dB re 1 µPa · m);
Towing depth of energy source	10 m
Air discharge volume	~7800 in^3
Dominant frequency components	2–120 Hz

*from farfield signature

Predicted Sound Levels

During the planning phase, mitigation zones for the proposed seismic survey were not derived from the farfield signature but calculated based on modeling by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1 μPa_{rms}) for Level B takes. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010) as a function of distance from the airguns for the 32-airgun array and for a single 100-in^3 airgun, which would be used during power downs. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous

ocean layer, unbounded by a seafloor). Although simple, the L-DEO model has been shown to be a robust tool for conservatively estimating mitigation radii.

The predicted sound contours for the airgun array are shown in Figure 3 as sound exposure levels (SEL) in decibels (dB) re 1 $\mu Pa^2 \cdot s$. SEL is a measure of the received energy in the pulse and represents the sound pressure level (SPL) that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are <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 (see NSF and USGS 2011). The advantage of working with SEL is that the SEL measure accounts for the total received energy in the pulse, and biological effects of pulsed sounds are believed to depend mainly on pulse energy (Southall et al. 2007). In contrast, SPL for a given pulse depends greatly on pulse duration. A pulse with a given SEL can be long or short depending on the extent to which propagation effects have "stretched" the pulse duration. The SPL will be low if the duration is long and higher if the duration is short, even though the pulse energy (and presumably the biological effects) are the same.

Although SEL is believed to be a better measure than SPL when dealing with biological effects of pulsed sound, SPL is the measure that has been most commonly used in studies of marine mammal reactions to airgun sounds. SPL is often referred to as rms or "root mean square" pressure, averaged over the pulse duration. As noted above, the rms received levels are not directly comparable to pulse energy (SEL). At the distances where rms levels are 160–190 dB re 1 µPa, the difference between the SEL and SPL values for the same pulse measured at the same location usually average ~10–15 dB, depending on the propagation characteristics of the location (Greene 1997; McCauley et al. 1998, 2000; NSF and USGS 2011). In this document, 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. Thus, we assume that 150 dB SEL ≈ 160 dB re 1 μPa_{rms}.

It should be noted that neither the SEL nor the SPL (=rms) measure is directly comparable to the peak or peak-to-peak pressure levels normally used by geophysicists to characterize source levels of airguns. Peak and peak-to-peak pressure levels for airgun pulses are always higher than the rms dB referred to in much of the biological literature (Greene 1997; McCauley et al. 1998, 2000). For example, a measured received level of 160 dB re 1 μPa_{rms} in the far field typically would correspond to a peak measurement of ~170–172 dB re 1 µPa and to a peak-to-peak measurement of ~176–178 dB re 1 µPa, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). (The SEL value for the same pulse would normally be 145–150 dB re 1 $\mu Pa^2 \cdot s$). The precise difference between rms and peak or peak-to-peak values for a given pulse depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level and (for an airgun-type source at the ranges relevant here) higher than the SEL value.

The proposed survey would acquire data with the 32-airgun array at a tow depth of 10 m and use a 100-in^3 airgun as a mitigation airgun. The deep-water radii for various sound levels obtained from L-DEO model results for the 32-airgun array and the mitigation airgun, down to a maximum water depth of 2000 m, are shown in Figures 3 and 4, respectively, and in Table 1. The 160-dB re 1 μPa_{rms} level is the behavioral disturbance criterion that is used to estimate anticipated takes for marine mammals (Level B harassment); the 175-dB re 1 μPa_{rms} level can be used to determine behavioral disturbance for sea turtles. The 195-dB re 1 μPa_{rms} distances would be used as the EZ for sea turtles, as specified by the National Marine Fisheries Service (NMFS).

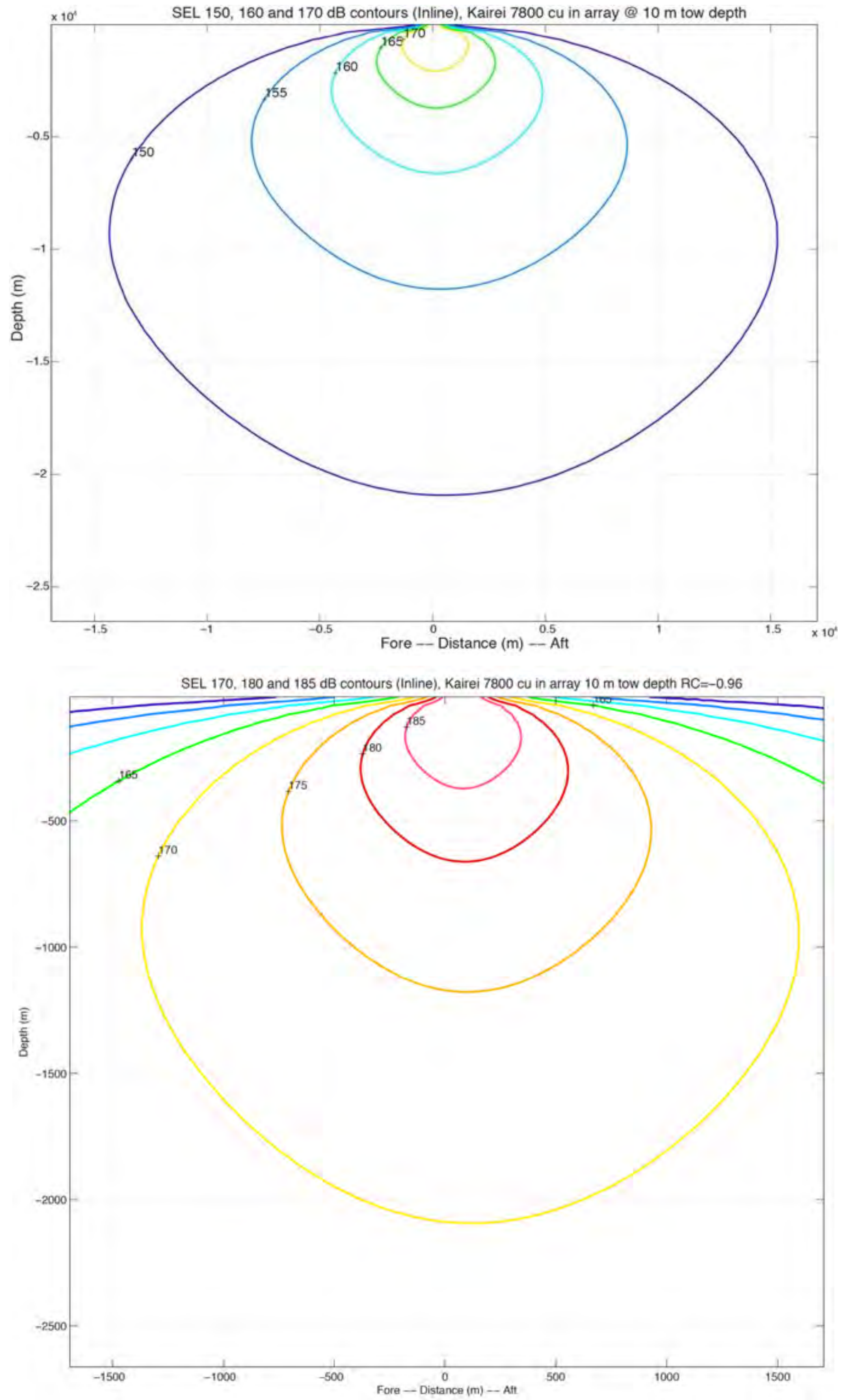

FIGURE 3. Modeled received sound levels (SELs) in deep water from the 32-airgun array that is proposed for use during the survey in the central Pacific Ocean during September 2017. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The lower plot is a zoomed-in version of the upper plot.

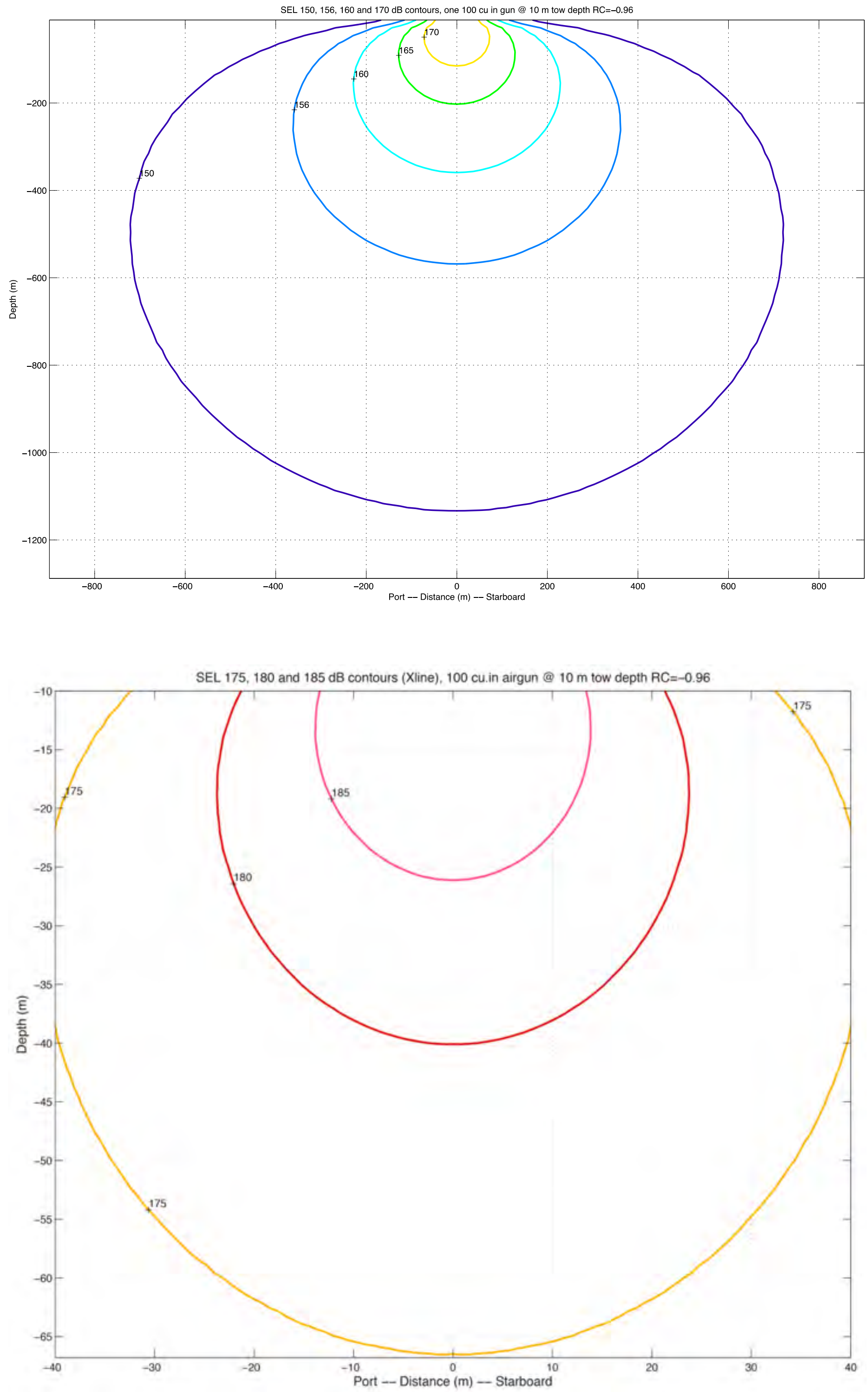

FIGURE 4. Modeled received sound levels (SELs) in deep water from the single 100-in^3 airgun towed at 10 m depth, which is proposed for use as a mitigation airgun during the survey in the central Pacific Ocean during September 2017. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The lower plot is a zoomed-in version of the upper plot.

TABLE 1. Predicted distances to which sound levels ≥160-, 175-, and 195-dB re 1 μPa_{rms} are expected to be received in deep water during the proposed survey in the central Pacific Ocean, September 2017. This assumes that received levels on an RMS basis are, numerically, 10 dB higher than the SEL values shown in Figures 3 and 4. The 160-dB criterion (Level B harassment) applies to all marine mammals; the 175-dB criterion (behavioral disturbance) applies to sea turtles. The 195-dB criterion is used as the EZ for turtles.

Source and Volume	**Tow Depth (m)**	**Predicted RMS Distances (m) in deep (>1000 m) water**		
		195 dB	**175 dB**	**160 dB**
1 airgun, 100 in^3	10	14	127	722
4 strings, 32 airguns, 7800 in^3	10	344	2782	9289

In July 2016, the National Oceanic and Atmospheric Administration's (NOAA) NMFS released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016a). The new 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. For impulsive sources, 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 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); however, no pinnipeds are expected to occur in the proposed survey area. As required by NMFS (2016a), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances.

The SEL_{cum} and Peak SPL for the *Kairei* array 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 (right) below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the modified farfield signature is a more appropriate measure of the sound source level for large arrays.

To estimate SEL_{cum} and Peak SPL, we used the acoustic modeling developed at L-DEO (same as used for Level B takes) with a small grid step in both the inline and depth directions. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays which we do using the NUCLEUS software to estimate the notional signature and the MATLAB software to calculate the pressure signal at each mesh point of a grid. Although pinnipeds are not expected to occur in the proposed survey area, the modeling and calculations for pinnipeds have been included here for the sake of completeness.

The methodology (input) for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the full 32-airgun array and the single 100-in^3 mitigation airgun is shown below. For the full array, the results for single shot SEL source level modeling are shown in Table 2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the full 32-airgun array are shown in Table 3.

Safe Distance Methodology Parameters (Sivle et al. 2014)†

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	21.5982

† Methodology assumes propagation of 20 log R. Activity duration (time) independent. Both, the source velocity and 1/Repetition rate were used as inputs to the NMFS User Spreadsheet.
^ Time between onset of successive pulses.

For example, the method of calculating new thresholds for the LF cetaceans for the full array is done by estimating a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. The model is run first for a single shot without applying any weighting function; the maximum 183 dB SEL_{cum} isopleth was located at 398.7906 m from the source. Then, the model is run for a single shot with the LF cetacean weighting function applied to the full spectrum; the maximum 183 dB SEL_{cum} isopleth was located at 109.3958 m from the source. The difference between 398.7906 m and 109.3958 m gives an adjustment factor of -11.23 dB assuming a propagation of 20log10(Radial distance) (See Table 2). However, for MF and HF cetaceans, and OW and PW pinnipeds, the modeling for a single shot with the weighted function applied leads to 0-m isopleths; the adjustment factors thus cannot be derived the same way as for LF cetaceans. Hence, for MF and HF cetaceans, and OW and PW pinnipeds, the difference between weighted and unweighted spectral source levels at each frequency up to 3 kHz was integrated to actually calculate these adjustment factors in dB. These calculations also account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014) shown below.

Figure 5 shows the impact of weighting functions by hearing group. Figures 6–8 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure 9 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

The thresholds for Peak SPL_{flat} for the full 32-airgun array, as well as the distances to the PTS thresholds, are shown in Table 4. Figures 10–12 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot, with a high pass filter applied for each hearing group. Figures 13–15 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot and, without applying a high pass filter.

TABLE 2. Results for single shot SEL source level modeling for the 32-airgun array with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Radial Distance (m) (no weighting function)	398.7906 (Fig. 7)	320.4764 (Fig. 7)	10190 (Fig. 6)	320.4764 (Fig. 7)	29.5437 (Fig. 8)
Modified Farfield SEL	235.0149	235.1159	235.1635	235.1159	232.4093*
Radial Distance (m) (with weighting function)	109.3958 (Fig. 9)	N.A	N.A	N.A	N.A
Adjustment (dB)	-11. 23	N.A	N.A	N.A	N.A

N.A. means not applicable or not available.

*Note that the modified farfield signature for the 203 SEL_{cum} threshold obtained as 203+20*log10(29.5437) is smaller than the other ones, because this SEL_{cum} level is located close to the source where array effects, as described in the text, are the strongest.

For the single 100-in^3 mitigation airgun, the results for single shot SEL source level modeling are shown in Table 5. The weighting function calculations, thresholds for Peak SPL, and the distances to the PTS thresholds for the single mitigation airgun are shown in Table 6. Figure 16 shows the impact of weighting functions by hearing group for the mitigation airgun. Figures 17–18 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure 19 shows the modeled received sound levels for single shot SEL with auditory weighting for LF cetaceans. Figures 20–21 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot, without any filters, for various hearing groups. Figures 22–24 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot and, with the application of a high pass filter for various hearing groups.

The new NMFS guidance drew from recommendations for new science-based noise exposure criteria described in Southall et al. (2007); however, it did not alter the current threshold, 160 dB re 1 μPa_{rms}, for Level B harassment (behavior). In addition, this application has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

Enforcement of mitigation zones via power downs and shut downs would be implemented in the Operational Phase, as described in § XI.

Description of Operations

The source vessel *Kairei* would deploy an array of 32 airguns as an energy source at a tow depth of 10 m. The receiving system would consist of one 6-km long hydrophone streamer and OBSs. As the airgun array is towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system. The OBSs would record the returning acoustic signals internally for later analysis.

TABLE 3. Results for single shot SEL source level modeling for the full 32-airgun array with weighting function calculations for the SEL_{cum} criteria for the full 32-airgun array, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	R/V Kairei - Greg Moore
PROJECT/SOURCE INFORMATION (Please include any assumptions)	source : 4 string (4*8 = 32 APG gun) 7800 cu.in at 10m towed depth
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	21.5982

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

^ Time between onset of successive pulses.

Modified farfield SEL	235.0149	235.1159	235.1635	235.1159	232.4093
Source Factor	1.46917E+22	1.50374E+22	1.52031E+22	1.50374E+22	8.06329E+21

RESULTANT ISOPLETHS*

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	**752.8**	**0.0**	**1.7**	**16.5**	**0.0**

Marine Mammal Hearing G
Low-frequency (LF) cetaceans: ba
Mid-frequency (MF) cetaceans: d toothed whales, beaked whales, bottl
High-frequency (HF) cetaceans: t porpoises, *Kogia*, river dolphins, ceph *Lagenorhynchus cruciger & L. australis*
Phocid pinnipeds (PW):true seals
Otariid pinnipeds (OW):sea lions a

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)†	**-11.23**	**-56.60**	**-65.92**	**-25.92**	**-32.43**

OVERIDE Using LDEO Modeling

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

25	#VALUE!	#VALUE!	#VALUE!	#VALUE!
26	#VALUE!	#VALUE!	#VALUE!	#VALUE!
1.00554784	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.956233431	#VALUE!	#VALUE!	#VALUE!	#VALUE!

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183 dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*$\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see Spectrum levels in Figure 5).

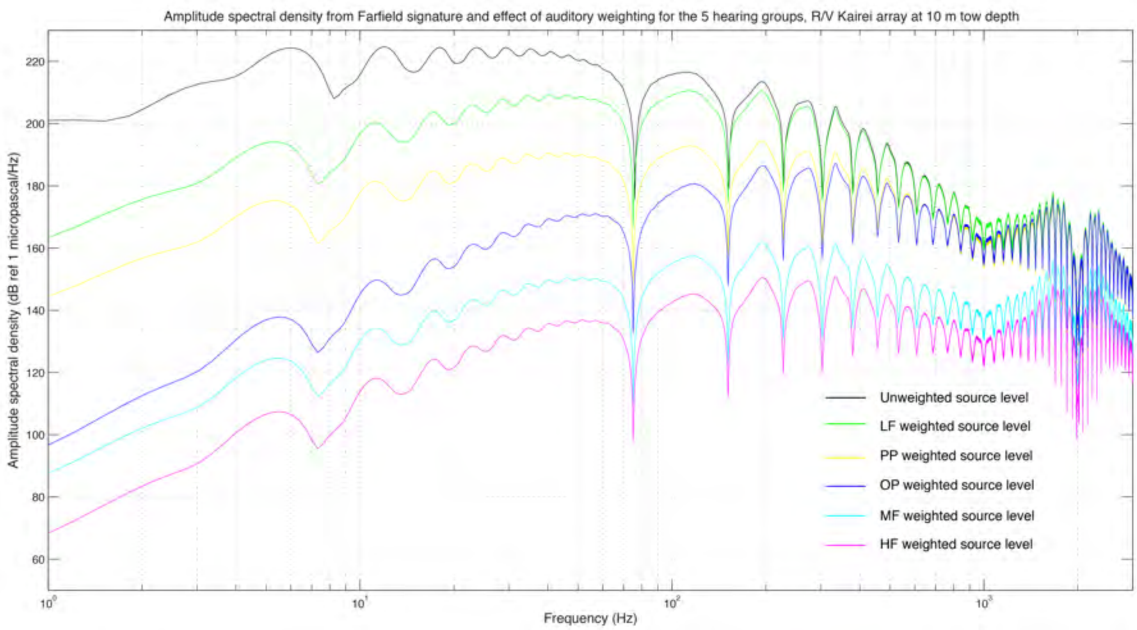

FIGURE 5. Modeled amplitude spectral density of the 32-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User spreadsheet.

TABLE 4. 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 full 32-airgun array during the proposed seismic survey in the central Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance (m) (no High Pass filter)	73.7857 (Fig. 14)	6.02 (Fig. 15)	516.4529 (Fig. 13)	84.1116 (Fig. 14)	2.1124 (Fig. 15)
Modified Farfield Peak*	256.3594	245.5919*	256.2606	256.4971	238.4955*
Radial Distance (m) (with High Pass Filter)	72.399 (Fig. 10)	N.A.	14.62 (Fig. 11)	54.18 (Fig. 12)	N.A.
Adjustment (dB)	-0.16	N.A.	-30.96	-3.82	N.A.
High pass filter corner frequency (Hz)	7	150	275	50	60
PTS Peak Isopleth to threshold (m) (radius)	**61.5** (Fig. 10)	**0**	**14.5** (Fig. 11)	**49.4** (Fig. 12)	**0**

N.A. means not applicable or not available.

* Note that the Modified Farfield Peak SPL is smaller for the 230 and 232 Peak thresholds because those levels are located within 6 m from the source where array effects are the strongest.

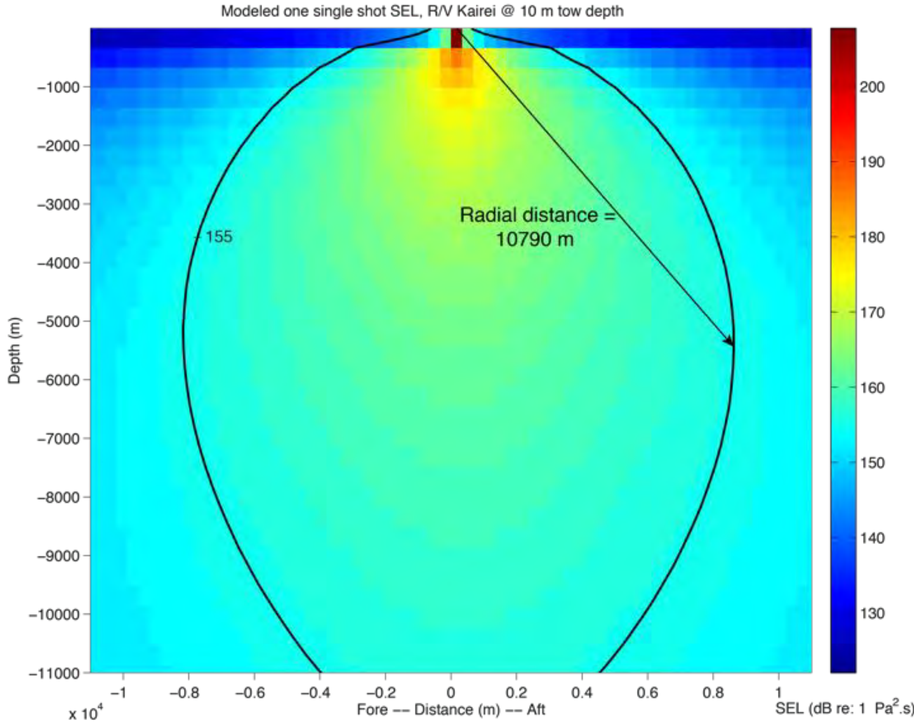

FIGURE 6. Modeled received sound levels (SELs) in deep water from the 32-airgun array of the R/V *Kairei*. The plot provides the distance from the geometrical center of the source array (radial distance) to the 155-dB SEL isopleth (10,790 m).

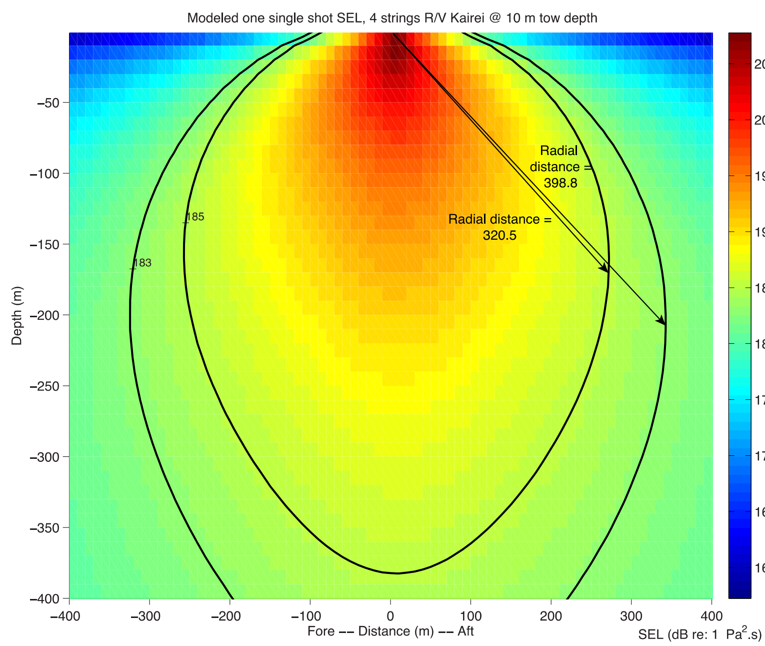

FIGURE 7. Modeled received sound levels (SELs) in deep water from the 32-airgun array of the R/V *Kairei*. The plot provides the distance from the geometrical center of the source array to the 183–185 dB SEL isopleth.

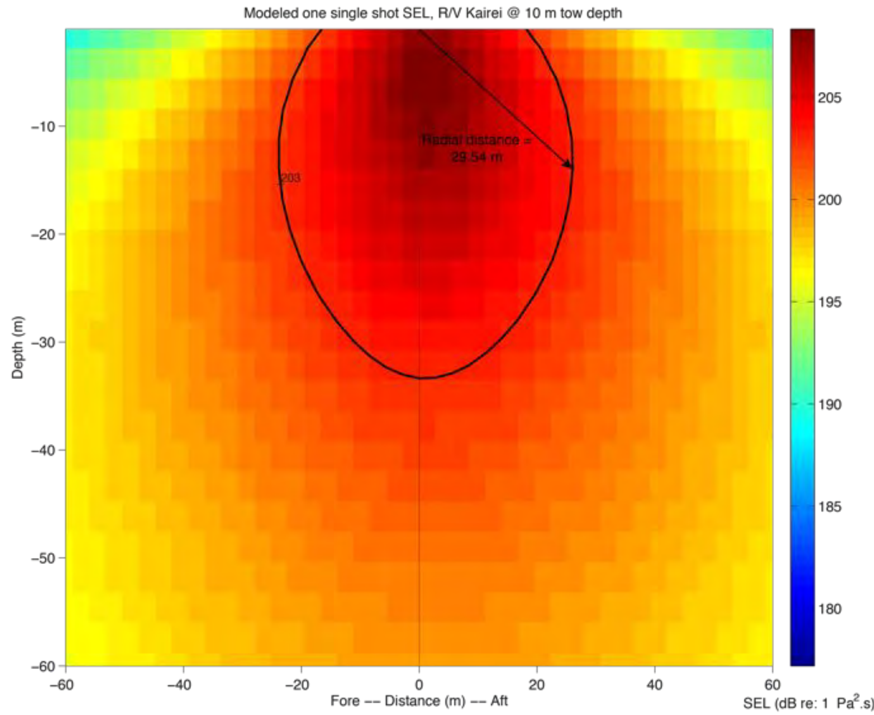

FIGURE 8. Modeled received sound levels (SELs) in deep water from the 32-airgun array of the R/V *Kairei*. The plot provides the distance from the geometrical center of the source array to the 203 dB SEL isopleth.

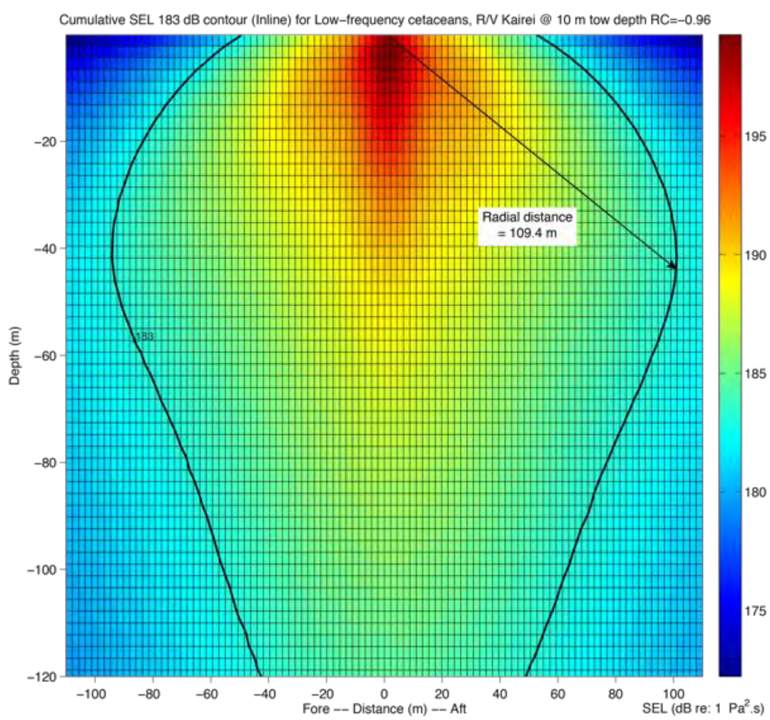

FIGURE 9. Modeled received sound exposure levels (SELs) from the 32-airgun array at a 10-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the new technical guidance. The plot provides the radius to the 183-dB SEL_{cum} isopleth for one shot.

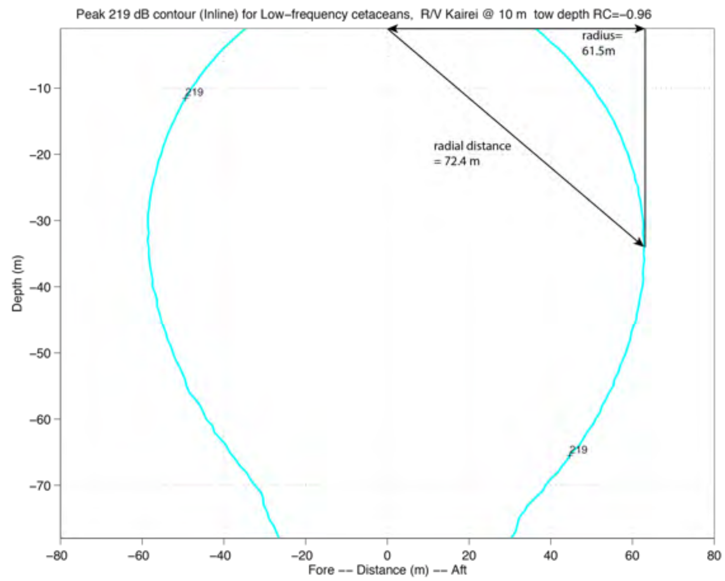

FIGURE 10. Modeled deep-water received Peak SPL from the 32-airgun array of the R/V *Kairei* at a 10-m tow depth after applying a high pass filter (7 Hz) for the LF cetaceans as described in the new acoustic guidance. The plot provides the radius to the 219-dB Peak isopleth (61.5 m) for one shot. The radial distances between the source and where the 219-dB isopleth is the largest before (73.78 m) and after (72.4 m) applying a high pass filter allows us to determine that the adjustment in dB produced by the filter is -0.16 dB.

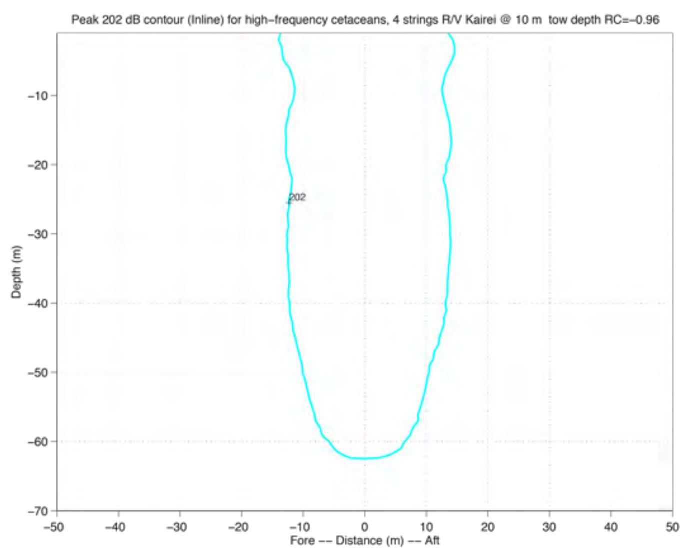

FIGURE 11. Modeled deep-water received Peak SPL from the 32-airgun array at a 10-m tow depth after applying a high pass filter (275 Hz) for the HF cetaceans as described in the new acoustic guidance. The plot provides the radius to the 202-dB Peak isopleth for one shot. The radial distances between the source and where the 202-dB isopleth is the largest before (516.45) and after (14.62 m) applying a high pass filter allows us to determine that the adjustment in dB produced by the filter is -30.96 dB.

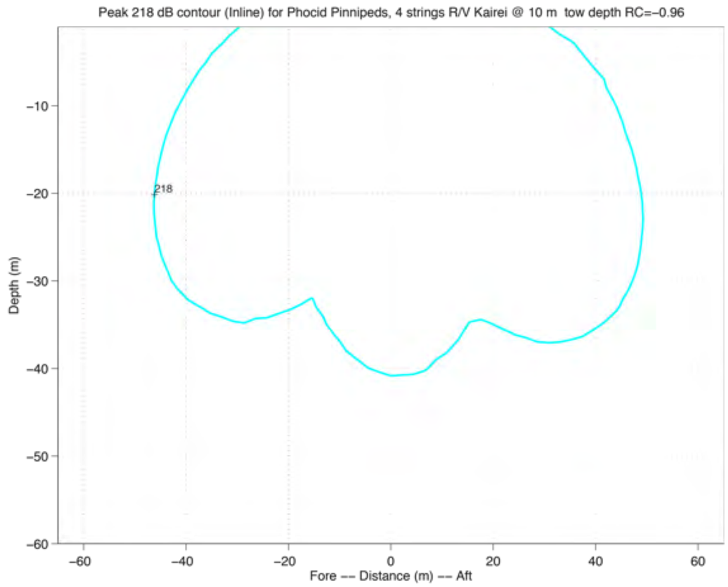

FIGURE 12. Modeled deep-water received Peak SPL from the 32-airgun array at a 10-m tow depth after applying a high pass filter (50 Hz) for the Phocid Pinnipeds as described in the new acoustic guidance. The plot provides the radius to the 218-dB Peak isopleth for one shot.

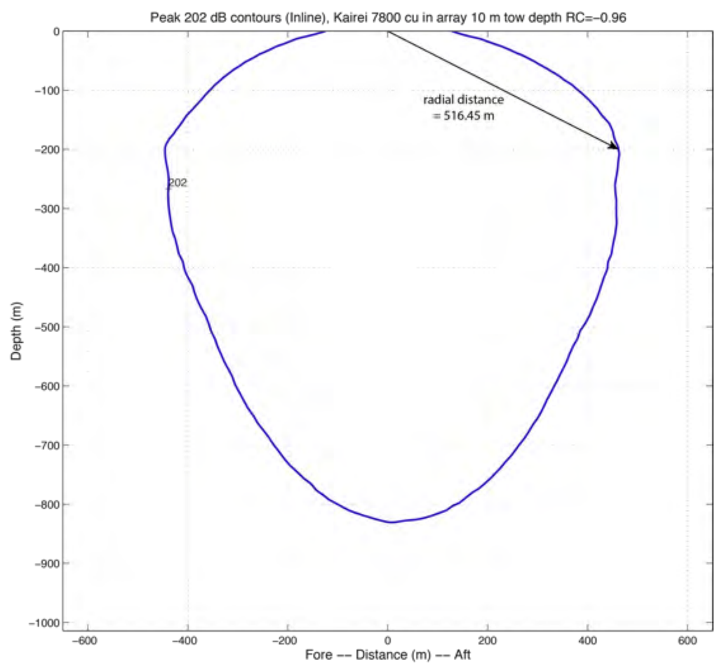

FIGURE 13. Modeled deep-water received Peak SPL from the 32-airgun array at a 10-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth (516.45 m) without a high pass filter.

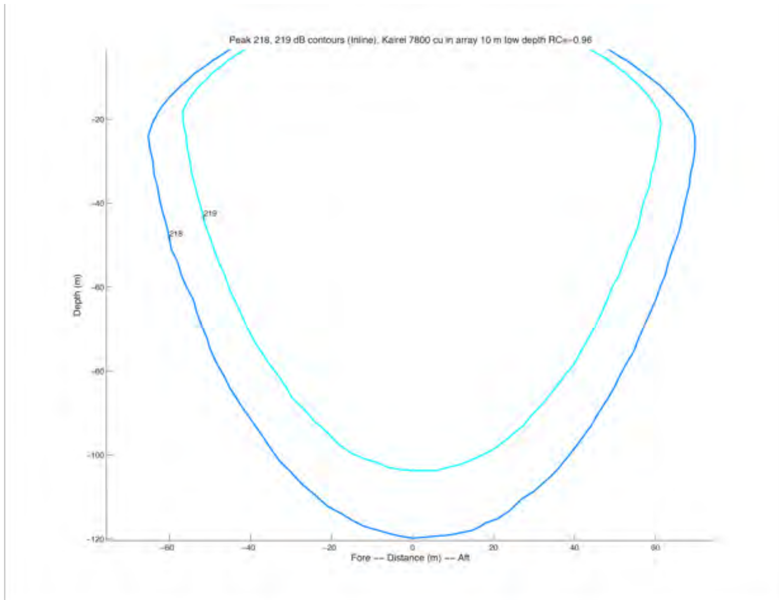

FIGURE 14. Modeled deep-water received Peak SPL from the 32-airgun array at a 10-m tow depth. The plot provides the radial distances from the source geometrical center to the 218–219 dB Peak isopleths (84.11 and 73.78 m, respectively) without high pass filters.

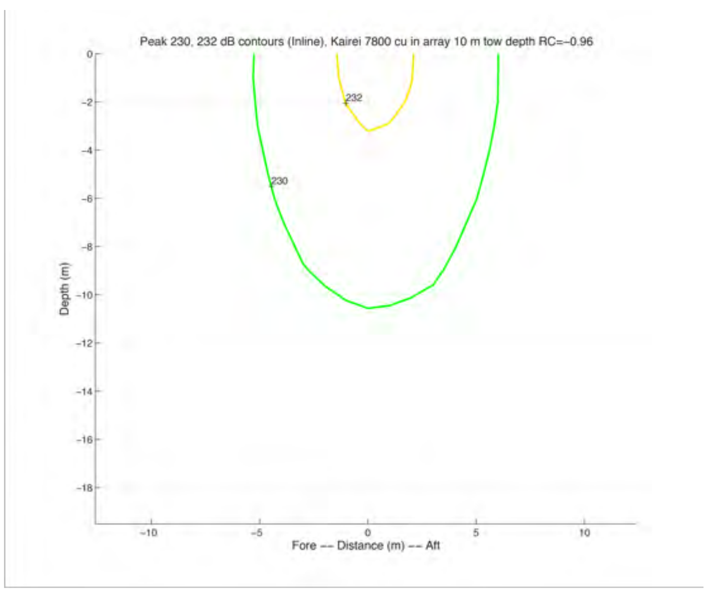

FIGURE 15. Modeled deep-water received Peak SPL from the 32-airgun array at a 10-m tow depth. The plot provides the radial distances from the source geometrical center to the 230–232 dB Peak isopleths (6.02 and 2.11 m, respectively) without high pass filters.

TABLE 5. Results for single shot SEL source level modeling for the single 100 in^3 mitigation airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 log_{10} (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	18.646 (Fig. 18)	14.8534 (Fig. 18)	501.8187 (Fig. 17)	14.8534 (Fig. 18)	2.0285 (Fig. 18)
Modified Farfield SEL	208.4117	208.4365	209.0109	208.4365	209.1435
Distance (m) (with weighting function)	4.48 (Fig. 19)	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.82	N.A.	N.A.	N.A.	N.A.

N.A. means not applicable or not available.

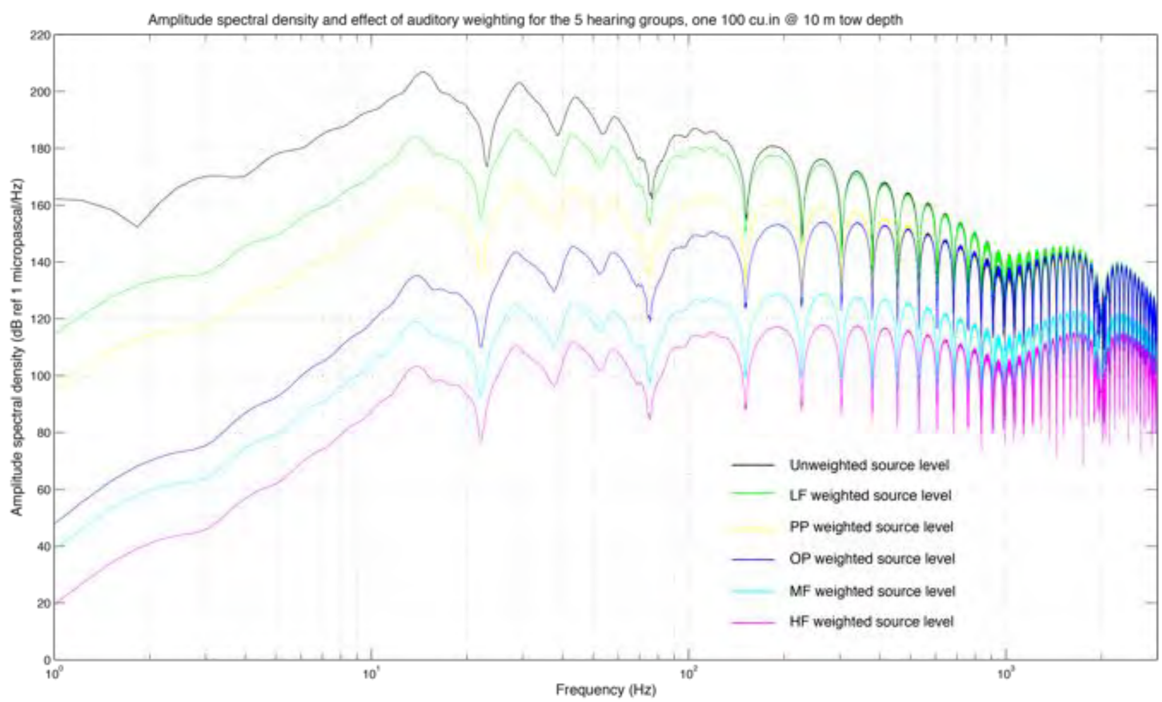

FIGURE 16. Modeled amplitude spectral density of the single 100 in^3 mitigation airgun at a 10 m tow depth and effect of the auditory weighting functions for the various hearing groups. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User spreadsheet.

TABLE 6. Results for single shot SEL source level modeling for the 100-in^3 mitigation airgun with weighting function calculations for the SEL_{cum} criteria for the 100-in^3 mitigation airgun, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION Please include any assumptions	
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	21.5982

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

^ Time between onset of successive pulses.

Modified farfield SEL	208.4117	208.4365	209.0109	208.4365	209.1435
Source Factor	**3.21183E+19**	**3.23022E+19**	**3.68699E+19**	**3.23022E+19**	**3.8013E+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)	**1.1**	**0.0**	**0.0**	**0.0**	**0.0**

Marine Mammal Hearing G
Low-frequency (LF) cetaceans: ba
Mid-frequency (MF) cetaceans: d toothed whales, beaked whales, bottl
High-frequency (HF) cetaceans: t porpoises, *Kogia*, river dolphins, ceph *Lagenorhynchus cruciger* & *L. australis*
Phocid pinnipeds (PW): true seals
Otariid pinnipeds (OW): sea lions a

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
a	1	1.6	1.8	1	2
b	2	2	2	2	2
f_1	0.2	8.8	12	1.9	0.94
f_2	19	110	140	30	25
C	0.13	1.2	1.36	0.75	0.64
Adjustment (dB) †	**-12.82**	**-61.31**	**-70.45**	**-30.44**	**-37.22**

OVERIDE Using LDEO Modeling

$$W(f) = C + 10\log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

25	#VALUE!	#VALUE!	#VALUE!	#VALUE!
26	#VALUE!	#VALUE!	#VALUE!	#VALUE!
1.00554784	#VALUE!	#VALUE!	#VALUE!	#VALUE!
0.956233431	#VALUE!	#VALUE!	#VALUE!	#VALUE!

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183 dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*$\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see Spectrum levels in Figure 16).

TABLE 7. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the single 100-in³ mitigation airgun during the proposed seismic survey in the central Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance (m) (no High Pass filter)	3.335 (Fig. 20)	0.9405 (Fig. 20)	23.96 (Fig. 21)	3.741 (Fig. 20)	0.7675 (Fig. 20)
Modified Farfield Peak*	229.4619	229.4672	229.5897	229.4598	229.7016
Radial Distance (m) (with High Pass Filter)	3.21 (Fig. 22)	N.A.	3.67 (Fig. 23)	2.3 (Fig. 24)	N.A.
Adjustment (dB)	-0.33	N.A.	-16.29	-4.22	N.A.
High pass filter corner frequency (Hz)	7	150	275	50	60
PTS PK Isopleth to threshold (m)	**3.2** (Fig. 22)	**0**	**3.7** (Fig. 23)	**2.3** (Fig. 24)	**0**

N.A. means not applicable or not available.

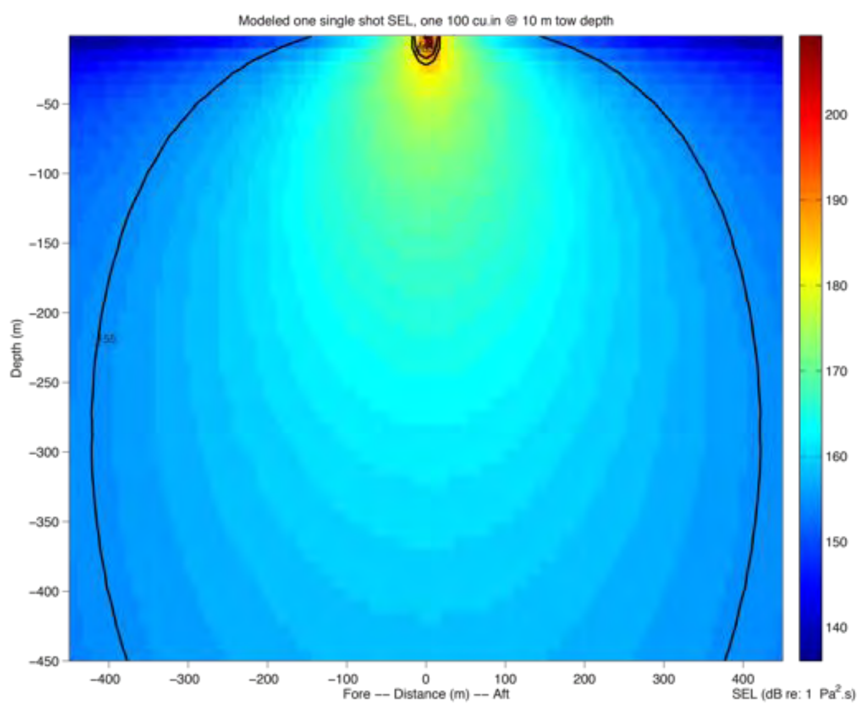

FIGURE 17. Modeled received sound levels (SELs) in deep water from one 100 in³ airgun at a 10 m tow depth. The plot provides the radial distance from the airgun to the 155-dB SEL isopleth (501.81 m).

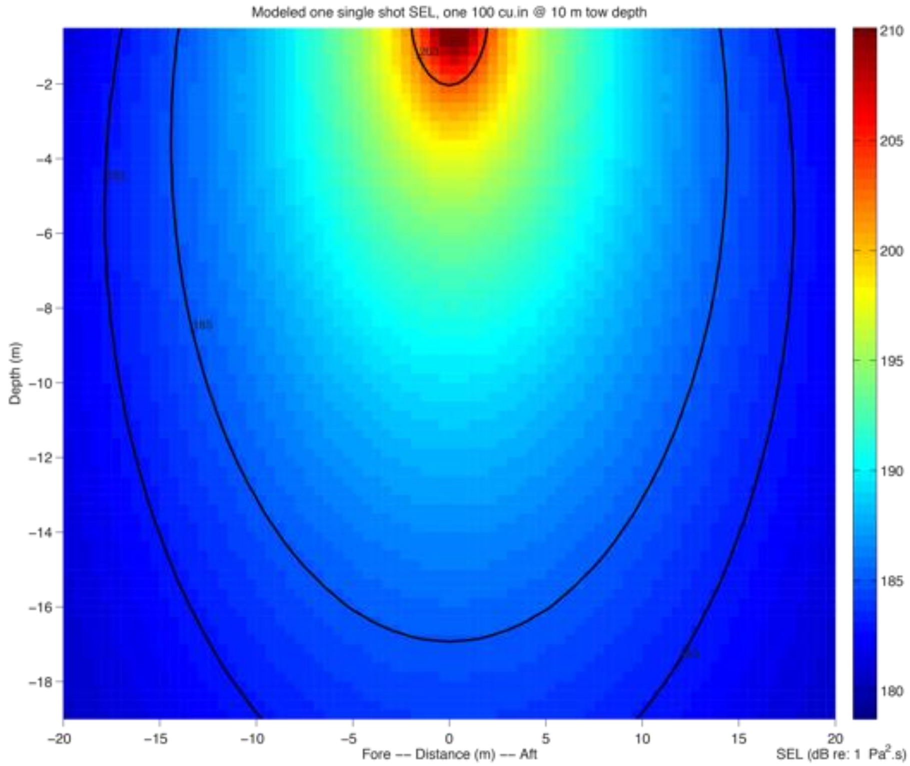

FIGURE 18. Modeled received sound levels (SELs) in deep water from one 100 in^3 airgun at a 10 m tow depth. The plot provides the radial distances from the airgun to the 183- 185- and 203 dB SEL isopleths.

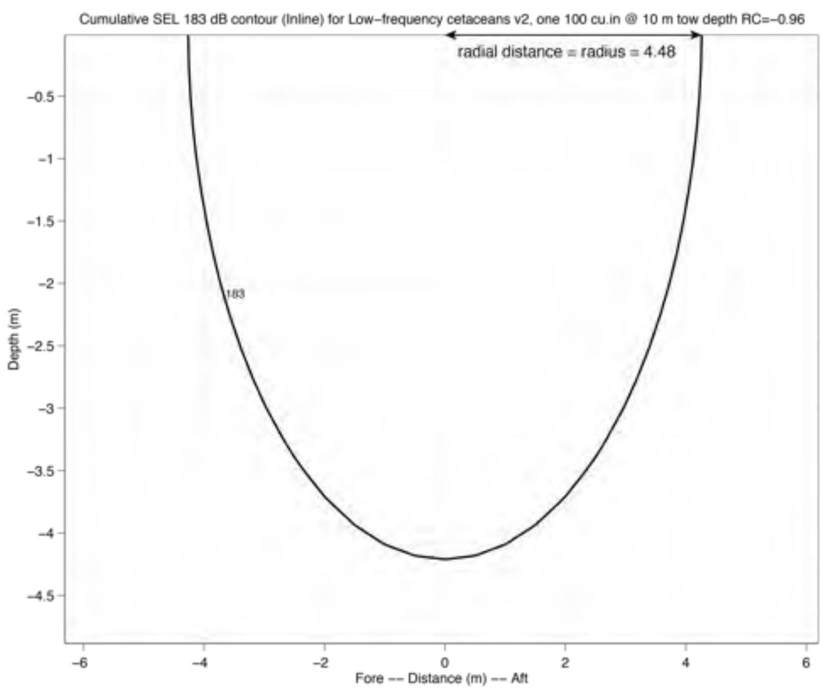

FIGURE 19. Modeled received sound exposure levels (SELs) from one 100 in^3 airgun at a 10-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the new technical guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot.

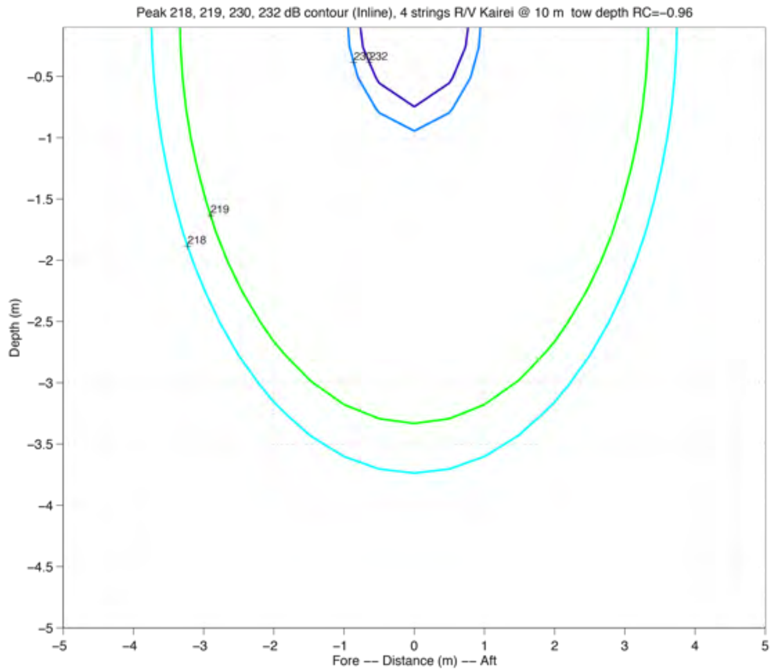

FIGURE 20. Modeled deep-water received Peak SPL from one 100 in³ airgun at a 10-m tow depth. The plot provides the radial distances from the source geometrical center to the 218-, 219-, 230-, and 232-dB Peak isopleths (3.74, 3.33, 0.94, 0.77 m, respectively).

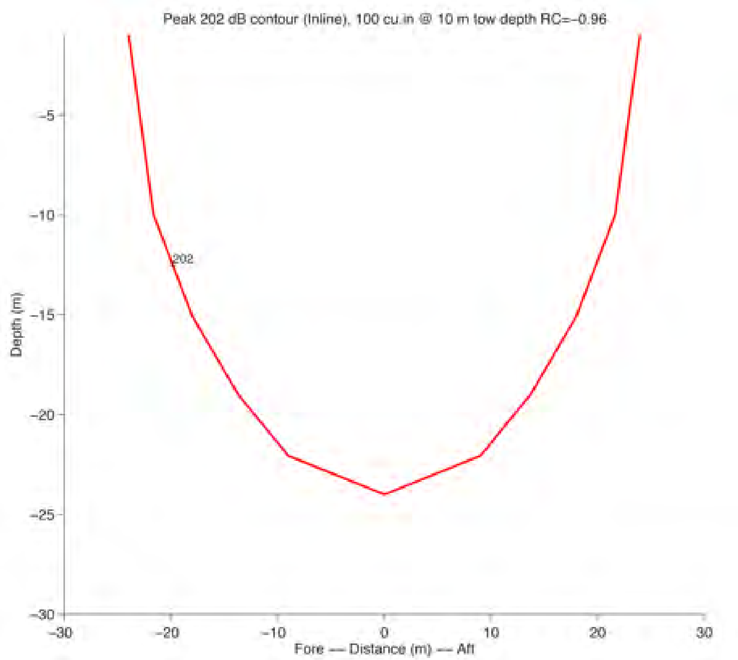

FIGURE 21. Modeled deep-water received Peak SPL from one 100 in³ airgun at a 10-m tow depth. The plot provides the radial distances from the source geometrical center to the 202-dB Peak isopleth (23.96 m).

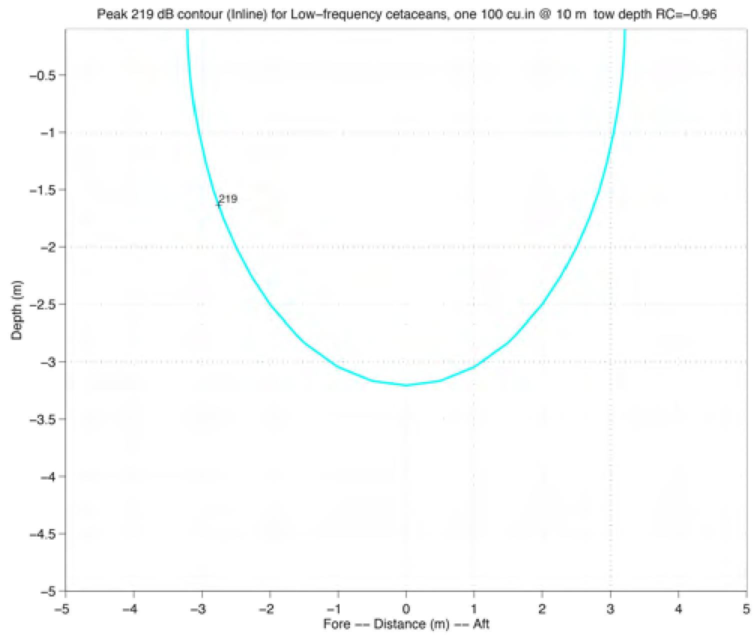

FIGURE 22. Modeled deep-water received Peak SPL from one 100 in^3 airgun at a 10-m tow depth after applying a high pass filter (7 Hz) for the LF cetaceans. The plot provides the radius to the 219-dB Peak isopleth for one shot (3.21 m). The radial distances between the source and where the 219 dB isopleth is the largest before (73.78 m) and after (72.4 m) applying a high pass filter allows us to determine an adjustment in dB produced by filter of 0.16 dB.

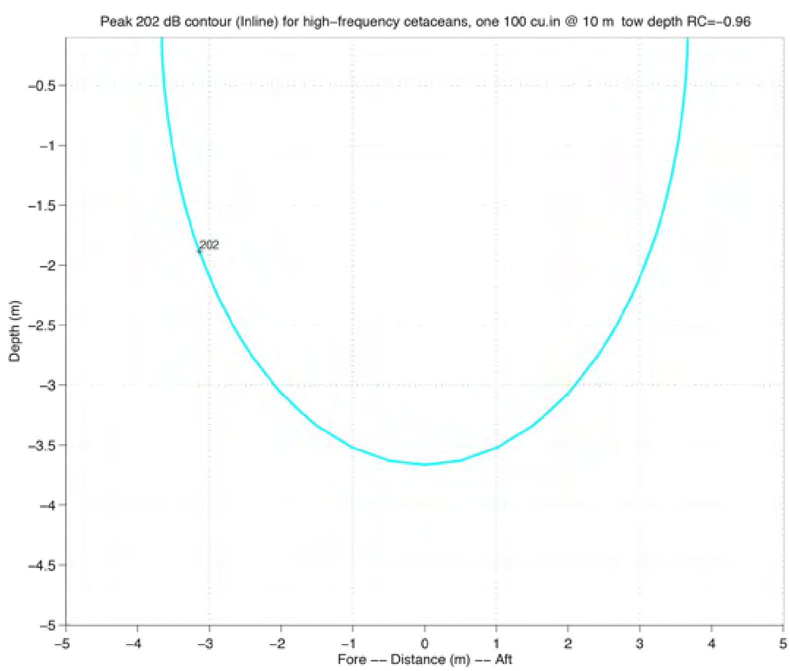

FIGURE 23. Modeled deep-water received Peak SPL from one 100 in^3 airgun at a 10-m tow depth after applying a high pass filter (275 Hz) for the HF cetaceans as described in the new acoustic guidance. The plot provides the radius to the 202-dB Peak isopleth for one shot (3.67 m).

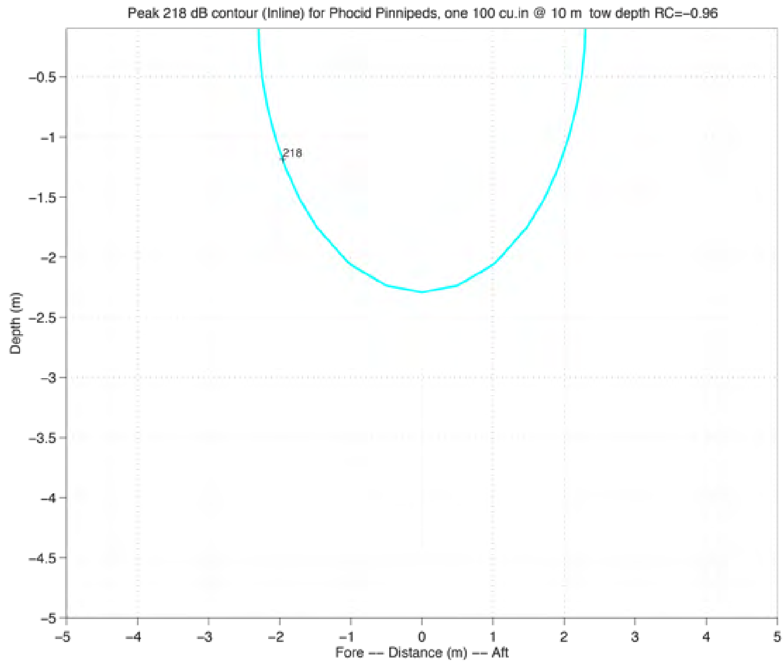

FIGURE 24. Modeled deep-water received Peak SPL from 100 in^3 airgun at a 10-m tow depth after applying a high pass filter for the Phocid Pinnipeds (50 Hz) as described in the new acoustic guidance. The plot provides the radius to the 218-dB Peak isopleth for one shot (2.3 m).

Upon arrival at the survey area, two OBSs would be deployed near the locations shown in Figure 1. The streamer and airgun array would then be deployed, and seismic operations would commence. After completion of seismic operations, the OBSs would be recovered by the University of Hawaii. The OBS sites depicted on Figure 1 are representative of the desired configuration for the proposed survey; final sites, however, would be determined during the actual survey as some sites may be deemed unsuitable to achieve the research goals. The OBSs that would be used during the cruise would have a maximum height and diameter of 1 m. The anchors are ~1 m × 1 m iron grates weighing ~40 kg.

The planned seismic survey would consist of ~1083 of transect lines (Fig. 1). There would be additional seismic operations in the survey area associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In our calculations (see § VI), 25% has been added for those additional operations.

In addition to the operations of the airgun array, a SeaBeam 3012 MBES would also be operated from the *Kairei* continuously throughout the cruise to map the ocean floor, but not during transit to and from the survey area. The SeaBeam 3012 MBES operates at 12 kHz and is hull-mounted on the *Kairei*. The transmitting beamwidth is 2° fore–aft and 150° (max.) athwartship, or 120° (in water up to 4500 m deep), 100° (up to 8000 m), and 90° (up to 11,000 m). The maximum source level is 241 dB re 1 μPa · m_{rms}. It has 301 beams in equiangular and multi-ping mode. The swatch coverage can be decreased from maximum down to 60°, leaving the number of reception beams constant. If the coverage is below 60°, the number of beams is decreased. The ping width/length has selectable values of 3, 5, 7, 10, 14, or 20 ms.

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 would encompass the approximate area 22.6–25.0°N and 153.5–157.4°W in the central Pacific Ocean north of Hawaii, partly within the Hawaiian Islands EEZ and partly in International Waters. Representative survey tracklines are shown in Figure 1; however, some deviation in actual track lines could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Water depth in the survey area ranges from ~4000 to 5000 m. The *Kairei* would likely depart from Honolulu and return to Honolulu, HI; however, this may change depending on other logistical issues and projects planned on the *Kairei*.

Seismic operations would be carried out for ~5.5 days, including 3.5 days within the Hawaiian Islands EEZ and 2 days in International Waters, starting ~15 September. The exact dates of the activities depend on logistics and weather conditions. Seasonality of the proposed survey operations does not affect the ensuing analysis (including take estimates), because the best available species densities for any time of the year have been used.

III. Species and Numbers of Marine Mammals in Area

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

Twenty-four species of marine mammals (6 mysticetes and 18 odontocetes) could potentially occur in the proposed survey area in the central Pacific Ocean. To avoid redundancy, we have included the information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition.

Of the 24 cetacean species that may occur within or near the survey area in the central Pacific Ocean, four are listed under the U.S. ESA as ***Endangered***: the fin, sei, blue, and sperm 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 Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011), referred to herein as the NSF/USGS PEIS. The general distributions of marine mammals in the eastern tropical Pacific (ETP) are discussed in § 3.6.2.5 and § 3.7.2.5 of the PEIS for mysticetes and odontocetes, respectively. The rest of this section deals with species distribution in the proposed survey area north of Hawaii. Information on the occurrence near the proposed survey area, habitat, population size, and conservation status for each of the cetacean species is presented in Table 8.

Although two additional marine mammals, the ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) and Deraniyagala's beaked whale (*M. hotaula*), are known to occur south of the Hawaii Islands, they are unlikely to occur in the proposed survey area north of Hawaii and are not discussed further here. Additionally, although there are a few historical records of the North Pacific right whale

TABLE 8. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area in the central Pacific Ocean.

Species	Occurrence in Area at Time of Survey	Habitat	Abun-dance in Hawaii [1]	Abun-dance in Hawaii [2]	Abundance in North Pacific or ETP	ESA[3]	IUCN[4]	CITES[5]
Mysticetes								
Humpback whale	Rare	Mainly nearshore, banks	7120-10,425[6]	N.A.	21,063[7]	NL[8]	LC	I
Minke whale	Rare	Coastal	N.A.	N.A.	>22,000[9]	NL	LC	I
Bryde's whale	Uncommon	Pelagic, coastal	798	1751	21,000[10]	NL	DD	I
Sei whale	Rare	Mostly pelagic	178	391	7260-12,620[11]	EN	EN	I
Fin whale	Rare	Slope, pelagic	58	154	13,620-18,680[12]	EN	EN	I
Blue whale	Rare	Pelagic, coastal	81	133	1400[13], 1647[14]	EN	EN	I
Odontocetes								
Sperm whale	Common	Pelagic, steep topography	3354	4559	26,300[15]	EN	VU	I
Pygmy sperm whale	Common	Deep, off shelf	7138[16]	N.A.	N.A.	NL	DD	II
Dwarf sperm whale	Common	Deep, shelf, slope	17,519[16]	N.A.	11,200[17]	NL	DD	II
Cuvier's beaked whale	Uncommon	Slope, pelagic	1941	723	20,000[13]	NL	LC	II
Indo-Pacific beaked whale	Common	Pelagic	4571	7619	291[18]	NL	DD	II
Blainville's beaked whale	Uncommon	Pelagic	2338	2105	25,300[19]	NL	DD	II
Rough-toothed dolphin	Common	Mainly pelagic	6288	72,528	107,633[20]	NL	LC	II
Common bottlenose dolphin	Common	Coastal, shelf, deep	5950	21,815	335,834[20]	NL	LC	II
Pantropical spotted dolphin	Common	Coastal, pelagic	15,917	55,795	1,297,092[21]	NL	LC	II
Spinner dolphin	Common	Coastal, pelagic	3351[15]	N.A.	1,797,716[22]	NL	DD	II
Striped dolphin	Common	Off shelf	20,650	61,201	964,362[20]	NL	LC	II
Fraser's dolphin	Common	Pelagic	16,992	51,491	289,300[13]	NL	LC	II
Risso's dolphin	Common	Shelf, slope, mounts	7256	11,613	110,457[20]	NL	LC	II
Melon-headed whale	Common	Pelagic	5794[23]	8666	45,400[13]	NL	LC	II
Pygmy killer whale	Common	Pelagic, coastal	3433	10,640	38,900[13]	NL	DD	II
False killer whale	Uncommon	Pelagic	1540[24]	N.A.	39,800[13]	NL	DD	II
Killer whale	Rare	Widely distributed	101	146	8500[25]	NL	DD	II
Short-finned pilot whale	Common	Pelagic, high-relief	12,422	19,503	589,315[26]	NL	DD	II

N.A. = Not available, not applicable, or not assessed; ETP = Eastern Tropical Pacific

[1] Estimates derived from summer–fall shipboard surveys by Bradford et al. (2013) and presented in Carretta et al. (2015), unless otherwise noted

[2] Based on Bradford et al. (2017)

[3] U.S. ESA (NMFS 2017): EN = Endangered, NL = Not listed

[4] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2015): CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient

[5] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2016): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled

[6] Hawaii wintering area, 2004–2006 (Calambokidis et al. 2008)

[7] North Pacific, 2004–2006 (Barlow et al. 2011)

[8] Out of the 14 distinct population segments (DPS) of humpbacks, the Hawaii DPS is not listed as threatened or endangered (NMFS 2016b).

[9] North West Pacific and Okhotsk Sea (IWC 2015)
[10] Western North Pacific (IWC 2015)
[11] Tillman (1977)
[12] Ohsumi and Wada (1974)
[13] ETP (Wade and Gerrodette 1993)
[14] Eastern North Pacific Stock (Calambokidis 2013)
[15] Northeastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005)
[16] Barlow (2006)
[17] Wade and Gerrodette (1993); estimate for ETP mostly for *K. sima* but may also include *K. breviceps*
[18] ETP (Ferguson and Barlow 2003)
[19] This estimate includes all species of the genus *Mesoplodon* in the ETP (Wade and Gerrodette 1993)
[20] ETP for 2006 (Gerrodette et al. 2008)
[21] ETP for 2006 for the two offshore spotted dolphin stocks (Gerrodette et al. 2008)
[22] ETP for 2006 for the eastern and whitebelly spinner dolphin, stocks (Gerrodette et al. 2008)
[23] Hawaiian Islands Stock (Aschettino 2010)
[24] Hawaii pelagic stock (Bradford et al. 2015)
[25] ETP (Ford 2009)
[26] Estimate is for *G. macrorhynchus* and *G. melas* in the ETP (Gerrodette and Forcada 2002)

(*Eubalaena japonica*) in Hawaiian waters (DoN 2005), and there are rare records of northern elephant seals (*Mirounga angustirostris*), these species very likely do not occur in the proposed survey area and are not discussed further. The ***endangered*** Hawaiian monk seal (*Neomonachus schauisnlandi*) mainly occurs within the 500-m isobath around the Northwestern Hawaiian Islands, but lower numbers are also found in the Main Hawaiian Islands (NMFS 2014); it is not expected to occur in the offshore proposed survey area.

Systematic line-transect surveys have been conducted within the Hawaiian Islands EEZ during July–December 2002 (Barlow et al. 2004; Barlow 2006) and August–December 2010 (Bradford et al. 2013); sighting information from these surveys is included in the species descriptions below. Except for Bryde's whales, baleen whales are expected to be rare in the study area during the proposed survey; most individuals would be at northern-latitude feeding areas during September.

Mysticetes

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the World (Clapham 2009), with recent genetic evidence suggesting three separate subspecies: North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). Nonetheless, genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Jackson et al. 2014; Bettridge et al. 2015). Although considered to be mainly a coastal species, the humpback whale often traverses deep pelagic areas while migrating (e.g., Mate et al. 1999; Garrigue et al. 2015).

North Pacific humpback whales migrate between summer feeding grounds along the Pacific Rim and the Bering and Okhotsk seas, and winter calving and breeding areas in subtropical and tropical waters (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008). In the North Pacific, humpbacks winter in four different breeding areas: (1) along the coast of Mexico; (2) along the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Fleming and Jackson 2011; Bettridge et al. 2015). These breeding areas are recognized as the Hawaii, Central America, Mexico, and Western Pacific DPSs (NMFS 2016b). There is a low level of interchange of whales among the wintering areas and among northern feeding areas (e.g., Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008; Baker et al. 2013).

In U.S. Pacific waters, four stocks are currently recognized: (1) California/Oregon/Washington, (2) Central North Pacific, (3), Western North Pacific, and (4) American Samoa (Carretta et al. 2015). Calambokidis et al. (2008) estimated that >50% of the population in the entire North Pacific winters in Hawaiian waters. Hawaii is the primary wintering area for whales from summer feeding areas in the Gulf of Alaska, southeast Alaska, and northern British Columbia, Canada; some individuals from the Bering Sea feeding area also winter in Hawaii (Calambokidis et al. 2008). Even though photo-identification studies showed that Hawaii is connected to various feeding grounds in Alaska (Calambokidis et al. 2008), genetic data indicated that it was significantly different from most feeding areas, except the Northern Gulf of Alaska and eastern Aleutians, and all other breeding areas (Baker et al. 2013).

Humpbacks use Hawaiian waters for breeding from December to April; peak abundance occurs from late February to early April (Mobley et al. 2001). Most humpbacks have been sighted there in water depths <180 m (Fleming and Jackson 2011), but Frankel et al. (1995) detected singers up to 13 km from shore at depths up to 550 m.

During vessel-based line-transect surveys in the Hawaiian Islands EEZ in July–December 2002, one humpback whale was sighted on 21 November at ~20.3°N, 154.9°W (Barlow et al. 2004), and one was sighted during surveys in 13 August–1 December 2010; the date and location of that sighting were not reported (Bradford et al. 2013). In the OBIS database, there are 577 records for the Hawaiian Islands EEZ (OBIS 2016); except for one sighting ~110 km northeast of Kauai, most records have been reported within 100 km from land. The closest sighting to the proposed survey area was made at 22.3°N, 158.1°W, ~160 km from the western-most survey line; all other records were >200 km from the survey area. In addition, one sighting was made in April 1997 in offshore waters to the north of the survey area at 29.1°N, 155.3°W (Barlow and Taylor 2005 *in* OBIS 2016).

Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2008). Three stocks of minke whales are recognized in U.S. Pacific waters: the Alaska, Hawaii, and California/Oregon/Washington stocks (Carretta et al. 2015). The minke whale is generally believed to be uncommon in Hawaiian waters; however, several studies using acoustic detections suggest that minke whales may be more common than previously thought (Rankin et al. 2007; Oswald et al. 2011; Martin et al. 2012). A lack of sightings is likely related to misidentification or low detection capability in poor sighting conditions (Rankin et al. 2007). The minke whale is thought to occur seasonally in Hawaii, from November through March (Rankin and Barlow 2005).

Two minke whale sightings were made west of 167°W, one in November 2002 and one in October 2010 during surveys of the Hawaiian Islands EEZ (Barlow et al. 2004; Bradford et al. 2013; Carretta et al. 2015). Numerous additional sightings in the EEZ were made by observers on Hawaii-based longline fishing vessels, including at least one in the proposed survey area (Carretta et al. 2015). There are 2 records in the OBIS database for the Hawaiian Islands EEZ (OBIS 2016), neither of which is near the proposed survey area. Acoustic detections have been recorded around the Hawaiian Islands during fall–spring surveys in 1997 and 2000–2006 (Rankin and Barlow 2005; Barlow et al. 2008; Rankin et al. 2008), and from seafloor hydrophones positioned ~50 km from the coast of Kauai during February–April 2006 (Martin et al. 2012). Similarly, passive acoustic detections of minke whales have been recorded at ALOHA station (22.75°N, 158°W) from October to May for decades (Oswald et al. 2011).

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

Bryde's whale occurs in all tropical and warm temperate waters in the Pacific, Atlantic, and Indian oceans, between 40°N and 40°S (Kato and Perrin 2009). It is one of the least known large baleen whales, and its taxonomy is still under debate (Kato and Perrin 2009). *B. brydei* is commonly used to refer to the larger form or "true" Bryde's whale and *B. edeni* to the smaller form; however, some authors apply the name *B. edeni* to both forms (Kato and Perrin 2009).

Although there is a pattern of movement toward the Equator in the winter and the poles during the summer, Bryde's whale does not undergo long seasonal migrations, remaining in warm (>16°C) water year-round (Kato and Perrin 2009). Bryde's whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2008).

In Hawaii, Bryde's whales are typically seen offshore (e.g., Barlow et al. 2004; Barlow 2006), but Hopkins et al. (2009) reported a Bryde's whale within 70 km of the Main Hawaiian Islands. During summer–fall surveys of the Hawaiian Islands EEZ, 13 sightings were made in 2002 (Barlow 2006) and 32 sightings were made during 2010 (Bradford et al. 2013). Bryde's whales were primarily sighted in the western half of the Hawaiian Islands EEZ, with the majority of sightings associated with the Northwestern Hawaiian Islands; none was made in or near the proposed survey area (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013; Carretta et al. 2015). There are no records for the Hawaiian Islands EEZ in the OBIS database (OBIS 2016).

Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2009), but appears to prefer mid-latitude temperate waters (Jefferson et al. 2008). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2009). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001).

During summer in the North Pacific, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to southern California, as well as in the western Pacific from Japan to Korea. In Hawaii, the occurrence of sei whales is considered rare (DoN 2005). However, 6 sightings were made during surveys in the Hawaiian Islands EEZ in July–December 2002 (Barlow 2006), and 1 sighting was made just outside of the EEZ, east of the proposed survey area at ~24.5°N, 150°W (Barlow et al. 2004). All sightings occurred in November; none of the sightings within the EEZ was made near the proposed survey area (Barlow et al. 2004). Bradford et al. (2013) reported 2 sightings in the northwestern portion of the Hawaiian Islands EEZ during summer–fall surveys in 2010. Hopkins et al. (2009) sighted 1 group of 3 subadult sei whales northeast of Oahu in November 2007; breeding and calving areas for this species in the Pacific are unknown, but those sightings suggest that Hawaii may be an important reproductive area (Hopkins et al. 2009). There is one record for the Hawaiian EEZ in the OBIS database south of the Hawaiian Islands (OBIS 2016).

Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the world's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar 2009). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2008). The fin whale most commonly occurs offshore, but can also be found in coastal areas (Aguilar 2009). Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar

2009). However, recent evidence suggests that some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015).

The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex, and not all populations follow this simple pattern (Jefferson et al. 2008). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

North Pacific fin whales summer from the Chukchi Sea to California and winters from California southwards (Gambell 1985). In the U.S., three stocks are recognized in the North Pacific: California/Oregon/Washington, Hawaii, and Northeast Pacific (Carretta et al. 2015). Information about the seasonal distribution of fin whales in the North Pacific has been obtained from the detection of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are recorded in the North Pacific year-round (e.g., Moore et al. 2006; Stafford et al. 2007, 2009). In the central North Pacific, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b).

Thompson and Friedl (1982) suggested that fin whales occur in Hawaiian waters during fall and winter; they are generally considered uncommon at that time (DoN 2005). During spring and summer, their occurrence in Hawaii is considered rare (DoN 2005). There were 5 sightings of fin whales during summer–fall surveys in 2002, most to the northwest of the Main Hawaiian Islands (Barlow et al. 2004) and 2 sightings in the Hawaiian Islands EEZ during summer–fall 2010 (Bradford et al. 2013); there were no sightings in or near the proposed survey area (Carretta et al. 2015). Two additional sightings in the EEZ were made by observers on Hawaii-based longline fishing vessels, including one near the proposed survey area (Carretta et al. 2015). There is one record for the Hawaiian EEZ in the OBIS database south of the Hawaiian Islands (OBIS 2016).

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. 2008). Blue whale migration is less well defined than for some other rorquals, and their movements tend to be more closely linked to areas of high primary productivity, and hence prey, to meet their high energetic demands (Branch et al. 2007). Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in the winter, where they mate and give birth (Lockyer and Brown 1981). Some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b).

In the North Pacific, blue whale calls are received year-round (Moore et al. 2002, 2006). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections in the North Pacific. Although it has been suggested that there are at least five subpopulations in the North Pacific (Reeves et al. 1998), analysis of calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (e.g., Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggest that there are two separate populations: one in the eastern and one in the central North Pacific (Carretta et al. 2015). The Eastern North Pacific Stock includes whales that that feed primarily off California from June to November and winter off Central America (Calambokidis et al. 1990; Mate et al. 1999); the Central North Pacific Stock feeds off Kamchatka, south of the Aleutians, and in the Gulf of Alaska during summer (Stafford 2003; Watkins et al. 2000b) and migrates to the western and central Pacific (including Hawaii) to breed in winter (Stafford et al. 2001;

Carretta et al. 2015). Call types from both stocks have been recorded near Hawaii during August–April, although eastern calls were more prevalent (Stafford et al. 2001). Western calls were mainly detected during December–March, whereas eastern calls peaked during August and September and were rarely heard during October–March (Stafford et al. 2001).

Blue whales are considered rare in Hawaii (DoN 2005; Carretta et al. 2015). No sightings were made in the Hawaiian Islands EEZ during surveys in July–December 2002 (Barlow et al. 2004; Barlow 2006). One sighting was made in the Northwestern Hawaiian Islands during August–October 2010 (Bradford et al. 2013). Three additional sightings in the EEZ were made by observers on Hawaii-based longline fishing vessels during 1994–2009, including one in the proposed survey area (Carretta et al. 2015). There are no records for the Hawaiian EEZ in the OBIS database or near the proposed survey area (OBIS 2016).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution from the edge of the polar pack ice to the Equator (Whitehead 2009). Sperm whale distribution is linked to its social structure: mixed groups of adult females and juveniles of both sexes generally occur in tropical and subtropical waters at latitudes less than ~40° (Whitehead 2009). After leaving their female relatives, males gradually move to higher latitudes with the largest males occurring at the highest latitudes and only returning to tropical and subtropical regions to breed. 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). They are often found far from shore, but can be found closer to oceanic islands that rise steeply from deep ocean waters (Whitehead 2009).

Sperm whales are widely distributed in Hawaiian waters throughout the year (Mobley et al. 2000). During summer–fall surveys of the Hawaiian Islands EEZ, 43 sightings were made in 2002 (Barlow 2006) and 41 were made in 2010 (Bradford et al. 2013). Sightings were widely distributed across the EEZ during both surveys; numerous sightings occurred in and adjacent to the proposed survey area (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013). There are ~110 records for the Hawaiian Islands EEZ in the OBIS database, including ~60 historical whaling records; 10 of the whaling records are in the proposed survey area (OBIS 2016).

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

The pygmy and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2009). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted, but dwarf sperm whales may be more pelagic with a preference for deeper water (McAlpine 2009).

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2008). 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 ETP (Wade and Gerrodette 1993). During small-boat surveys around the Hawaiian Islands in 2000–2012, dwarf sperm whales were sighted in all water depth categories up to 5000 m deep, but the highest sighting rates were in water 500–1000 m deep (Baird et al. 2013).

Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas. In the Hawaiian Islands, an insular resident population of dwarf sperm whales occurs within ~20 km from shore (Baird et al. 2013). During summer–fall surveys of the Hawaiian Islands EEZ in 2002, 2 sightings of pygmy sperm whales, 5 sightings of dwarf sperm whales, and 1 sighting of an unidentified *Kogia* sp. were made; all sightings were made in the western portion of the EEZ (Barlow et al. 2004; Barlow 2006). During summer–fall surveys of the Hawaiian Islands EEZ in 2010, 1 dwarf sperm whale and 1 unidentified *Kogia* sp. were sighted (Bradford et al. 2013). No sightings were made in or near the proposed survey area (Carretta et al. 2015). There are 6 pygmy sperm whale records for the Hawaiian Islands EEZ in the OBIS database, none north of the Hawaiian Islands (OBIS 2016). There are 74 records of dwarf sperm whales for the Hawaiian EEZ, none in the proposed survey area (OBIS 2016).

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is the most widespread of the beaked whales, occurring in almost all temperate, subtropical, and tropical waters and even some sub-polar and polar waters (MacLeod et al. 2006). It is likely the most abundant of all beaked whales (Heyning and Mead 2009). Cuvier's beaked whale is found in deep water over and near the continental slope (Jefferson et al. 2008). Ferguson et al. (2006) reported that in the ETP, the mean water depth where Cuvier's beaked whales were sighted was ~3.4 km. During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made in water depths of 500–4000 m (Baird et al. 2013).

During summer–fall surveys of the Hawaiian Islands EEZ, 3 sightings of Cuvier's beaked whale were made in the western portion of the EEZ in 2002 (Barlow 2006) and 23 were made in the EEZ in 2010 (Bradford et al. 2013). Most of the sightings in 2010 were made in nearshore waters of the Northwestern Hawaiian Islands, none in or near the proposed survey area (Carretta et al. 2015). Resighting and telemetry data suggest that a resident insular population may exist, distinct from offshore, pelagic Cuvier's beaked whales (e.g. McSweeney et al 2007; Baird et al. 2013). There are 65 records for the Hawaiian Islands EEZ, none to the north of the Hawaiian Islands (OBIS 2016).

Indo-Pacific Beaked Whale (*Indopacetus pacificus*)

The Indo-Pacific beaked whale, also known as Longman's beaked whale, was until recently one of the least known cetacean species, but it is now one of the more frequently sighted beaked whales (Pitman 2009a). Since 2003, there have been at least 65 at-sea sightings and 8 strandings worldwide. Based on this information, it is now known that the Indo-Pacific beaked whale occurs in tropical waters throughout the Indo-Pacific, with records from 10°S to 40°N. The Indo-Pacific beaked whale is most often sighted in waters with temperatures ≥26°C and depth >2000 m, and sightings have also been reported along the continental slope (Anderson et al. 2006; Pitman 2009a).

During summer–fall surveys of the Hawaiian Islands EEZ, 1 sighting was made in 2002 and 3 were made in 2010, none near the proposed survey area (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013). There is one record in the OBIS database for the Hawaiian EEZ, just to the west of the Big Island (OBIS 2016).

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 common (Pitman 2009b). During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made in water up to 4000 m deep, with the highest sighting rates in water 3500–4000 m deep (Baird et al. 2013).

During summer–fall shipboard surveys of the Hawaiian Islands EEZ, 3 sightings were made in 2002 and 2 were made in 2010, all in the western portion of the EEZ (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013). In addition, there were 4 sightings of unidentified *Mesoplodon* there in 2002 (Barlow et al. 2004; Barlow 2006) and 10 in 2010 (Bradford et al. 2013). Studies by McSweeney et al. (2007), Schorr et al. (2009), and Baird et al. (2013) suggest the existence of separate insular and offshore Blainville's beaked whales in Hawaiian waters. There are 49 records for the Hawaiian EEZ in the OBIS database, none in the proposed survey area (OBIS 2016).

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994; Jefferson 2009). In the Pacific, it occurs from central Japan and northern Australia to Baja California, Mexico, and southern Peru (Jefferson 2009). It generally occurs in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2008). During small-boat surveys around the Hawaiian Islands in 2000–2012, it was sighted in water as deep as 5000 m, with the highest sighting rates in water >3500 m deep (Baird et al. 2013).

The rough-toothed dolphin is expected to be one of the most abundant cetaceans in the proposed survey area (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013). During summer–fall surveys of the Hawaiian Islands EEZ, rough-toothed dolphins were observed throughout the EEZ and near the proposed survey area; there were 18 sightings in 2002 and 24 sightings in 2010 (Barlow 2006; Barlow et al. 2004; Bradford et al 2013). There are 181 records for the Hawaiian EEZ in the OBIS database, none within the proposed survey area (OBIS 2016). The closest sighting was made at 22.4°N, 157.8°W, ~130 km from the western-most survey line.

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin occurs in tropical, subtropical, and temperate waters throughout the World (Wells and Scott 2009). Generally, there are two distinct bottlenose dolphin ecotypes, one mainly found in coastal waters and one mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). As well as inhabiting different areas, these ecotypes differ in their diving abilities (Klatsky 2004) and prey types (Mead and Potter 1995). Photo-identification studies have suggested that the 1000-m isobath serves as the boundary between resident insular stocks of the Main Hawaiian Islands and the Hawaii pelagic stocks (Martien et al 2012). During small-boat surveys around the Hawaiian Islands in 2000–2012, the bottlenose dolphin was sighted in water as deep as 4000 m, with the highest sighting rates in water >500 m deep (Baird et al. 2013).

Common bottlenose dolphins have been observed during summer–fall surveys of the Hawaiian EEZ, mostly in nearshore waters but also in offshore waters, including near the proposed survey area (see map in Carretta et al. 2015); 15 sightings were made in 2002 (Barlow 2006) and 19 sightings were made in 2010 (Bradford et al. 2013). There is also one bycatch record for fall–winter and one sighting record for spring–summer for the proposed survey area (DoN 2005). There are 213 records for the Hawaiian EEZ in the OBIS database, none within 200 km of the proposed survey area (OBIS 2016).

Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin is one of the most abundant cetaceans and is distributed worldwide in tropical and some subtropical waters (Perrin 2009a), between ~40°N and 40°S (Jefferson et al. 2008). It is found primarily in deeper waters and rarely over the continental shelf or continental shelf edge (Davis et al. 1998), but can also be found in coastal, shelf, and slope waters (Perrin 2009a). During small-boat surveys around the Hawaiian Islands in 2000–2012, it was sighted in all water depth categories, with the lowest sighting rate in water <500 m (Baird et al. 2013).

There are two forms of pantropical spotted dolphin: coastal and offshore. The offshore form inhabits tropical, equatorial, and southern subtropical water masses; the pelagic individuals around the Hawaiian Islands belong to a stock distinct from those in the ETP (Dizon et al 1991; Perrin 2009a). Spotted dolphins are commonly seen together with spinner dolphins in mixed-species groups, e.g., in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and in the Marquesas Archipelago (Gannier 2002).

The pantropical spotted dolphin is expected to be one of the most abundant cetaceans in the proposed survey area. It has been seen during summer–fall surveys of the Hawaiian Islands EEZ including near the proposed survey area (see map in Carretta et al. 2015); 14 sightings were made in 2002 (Barlow 2006) and 12 sightings were made in 2010 (Bradford et al. 2013). There are >400 records for the Hawaiian Islands EEZ in the OBIS database, none within 200 km of the proposed survey area (OBIS 2016).

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, including oceanic tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2008). It is generally considered a pelagic species (Perrin 2009b), but can also be found in coastal waters and around oceanic islands (Rice 1998). During small-boat surveys around the Hawaiian Islands in 2000–2012, it was sighted in water as deep as 3000 m, with the highest sighting rates in water >500 m deep (Baird et al. 2013).

In the ETP, it is associated with warm, tropical surface water, similar in distribution to the pantropical spotted dolphin (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994). Spinner dolphins and pantropical spotted dolphins have been sighted in mixed-species groups in the ETP (Au and Perryman 1985), off Hawaii (Psarakos et al. 2003), and in the Marquesas Archipelago (Gannier 2002). In Hawaii, spinner dolphins belong to a stock (*S.l. longirostris*; Gray's spinner) that is separate from animals in the ETP (Dizon et al. 1991).

There are six separate stocks managed within the Hawaiian Islands EEZ (Carretta et al. 2015); only individuals of the Hawaii pelagic stock are expected to overlap with the proposed survey area. Spinner dolphins have been sighted near the proposed survey area during summer–fall surveys of the Hawaiian Islands EEZ (see map in Carretta et al. 2015); 8 sightings were made in 2002 (Barlow 2006) and 4 were made in 2010 (Bradford et al. 2013). There are 221 records for the Hawaiian Islands EEZ in the OBIS database, none within 200 km of the proposed survey area (OBIS 2016).

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994a; Jefferson et al. 2008). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (Archer 2009). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2008). During small-boat surveys around the Hawaiian Islands in

2000–2012, sightings were made in water depths of 1000–5000 m, with the highest sighting rates in water deeper than 3000 m (Baird et al. 2013).

The striped dolphin is expected to be one of the most abundant cetaceans in the proposed survey area. It has been sighted near the proposed survey area during summer–fall shipboard surveys of the Hawaii Islands EEZ (see map in Carretta et al. 2015); 15 sightings were made in 2002 (Barlow 2006) and 25 sightings were made in 2010 (Bradford et al. 2013). There are 30 records for the Hawaiian Islands EEZ in the OBIS database, none within 200 km of the proposed survey area (OBIS 2016).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is a tropical oceanic species distributed between 30°N and 30°S that generally inhabits deeper, offshore water (Dolar 2009). It occurs rarely in temperate regions and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). In the ETP, they were sighted at least 15 km from shore in waters 1500–2500 m deep (Dolar 2009).

Fraser's dolphin is one of the most abundant cetaceans in the Hawaiian Islands EEZ (Barlow 2006; Bradford et al. 2013). Summer–fall shipboard surveys of the EEZ resulted in 2 sightings of Fraser's dolphin in 2002 and 4 in 2010, all in the western portion of the EEZ (Barlow 2006; Bradford et al. 2013; Carretta et al. 2015). There are 2 records for the Hawaiian Islands EEZ in the OBIS database, none in the proposed survey area (OBIS 2016).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide (Kruse et al. 1999). It occurs between 60ºN and 60ºS, where surface water temperatures are at least 10ºC (Kruse et al. 1999). Water temperature appears to be an important factor affecting its distribution (Kruse et al. 1999). Although it occurs from coastal to deep water, it shows a strong preference for mid-temperate waters of the continental shelf and slope (Jefferson et al. 2014). During small-boat surveys around the Hawaiian Islands in 2000–2012, sighting rates were highest in water >3000 m deep (Baird et al. 2013).

During summer–fall surveys of the Hawaiian Islands EEZ, 7 sightings were made in 2002 (Barlow 2006) and 10 were made in 2010 (Bradford et al. 2013). The majority of sightings were south of 20ºN, but some were made near the proposed survey area (see map in Carretta et al. 2015). There are 10 records for the Hawaiian EEZ in the OBIS database, none within the proposed survey area (OBIS 2016). One sighting was made at 22.4°N, 157.8°W, ~130 km from the proposed survey area (Barlow and Taylor 2005).

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is an oceanic species found worldwide in tropical and subtropical waters from ~40°N to 35°S (Jefferson et al. 2008). It is commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997; Huggins et al. 2005). It occurs most often in deep offshore waters and occasionally in nearshore areas where deep oceanic waters occur near the coast (Perryman 2009). During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made in all water depths up to 5000 m (Baird et al. 2013).

Photo-identification and telemetry studies have revealed that there are two distinct populations of melon-headed whales in Hawaiian waters, the Hawaiian Islands stock and a resident stock associated with the western coast of the Big Island (Aschettino et al. 2012; Oleson et al. 2013). Aschettino (2010) provided an abundance estimate of 5794 for the main Hawaiian Islands population and 447 for Hawaii residents. Bradford et al. (2013) provided an estimate of 2860 for the Hawaiian population. Satellite telemetry data revealed distant pelagic movements, associated with feeding, nearly to the edge of the

Hawaiian Islands EEZ; the most distal telemetry locations were near the proposed survey area at ~22.3°N, 154.0°W (Oleson et al. 2013).

During summer–fall surveys of the Hawaiian Islands EEZ in 2002 and 2010 there was a single sighting each year; neither was located near the proposed survey area (Barlow et al. 2004; Bradford et al. 2013). There are 53 records for the Hawaiian EEZ in the OBIS database; all sightings were >200 km from the proposed survey area (OBIS 2016).

Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical and subtropical waters (Donahue and Perryman 2009), generally not ranging south of 35°S (Jefferson et al. 2008). In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. In Hawaiian waters, the pygmy killer whale is found in nearshore waters but rarely offshore (Carretta et al. 2015). During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made in water up to 3000 m deep (Baird et al. 2013).

Pygmy killer whales were recorded during summer–fall surveys of the Hawaiian Islands EEZ: 3 sightings in 2002 (Barlow et al. 2004; Barlow 2006) and 5 in 2010 (Bradford et al. 2013), none near the proposed survey area (Barlow et al. 2004; Bradford et al. 2013). There are 46 records for the Hawaiian Islands EEZ in the OBIS database; all sightings were >200 km from the proposed survey area (OBIS 2016).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but generally uncommon throughout its range (Baird 2009). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2009). The false killer whale generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2008; Baird 2009). During small-boat surveys around the Hawaiian Islands in 2000–2012, the highest sighting rates occurred in water >3500 m deep (Baird et al. 2013).

Telemetry, photo-identification, and genetic studies have identified three independent populations of false killer whales in Hawaiian waters: main (insular) Hawaiian Islands, Northwestern Hawaiian Islands, and surrounding pelagic stock (Chivers et al. 2010; Baird et al. 2010, 2013; Bradford et al. 2014). The population size of the Hawaii pelagic stock based on 2002 line-transect survey data was estimated at 484 (Barlow and Rankin 2007). Analysis of 2010 survey data resulted in an estimate of 1540 outside of 40 km of the Main Hawaiian Islands; however, this estimate may be positively biased because of increased sighting rates attributable to vessel attraction (Bradford et al. 2015). The population of false killer whales inhabiting the Main Hawaiian Islands is thought to have declined dramatically since 1989; the reasons for this decline are still uncertain, although interactions with longline fisheries have been suggested (Reeves et al. 2009; Bradford and Forney 2014). During 2008–2012, 26 false killer whales were observed hooked or entangled by longline gear within the Hawaiian Islands EEZ or adjacent high-seas waters; 22 of those were assessed as seriously injured (Bradford and Forney 2014).

During summer–fall surveys of the Hawaiian Islands EEZ, 2 sightings were made in 2002 (Barlow et al. 2004; Barlow 2006) and 14 were made in 2010 (Bradford et al. 2013), none of the on-effort sightings was near the proposed survey area (see map in Carretta et al. 2015). However, locations of false killer whale and unidentified blackfish takes observed during the 2008–2012 Hawaii-based longline fisheries have been reported in the proposed survey area (Bradford and Forney 2014; see map in Carretta

et al. 2015). There are 47 records for the Hawaiian EEZ in the OBIS database; none of the sightings was made north of the Hawaiian Islands (OBIS 2016).

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; 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). High densities of the species occur in high latitudes, especially in areas where prey is abundant. Killer whale movements generally appear to follow the distribution of their prey, which includes marine mammals, fish, and squid.

Killer whales are rare in the Hawaii Islands EEZ. Baird et al. (2006) reported 21 sighting records in Hawaiian waters between 1994 and 2004. During summer–fall surveys of the Hawaiian Islands EEZ, 2 sightings were made in 2002 (Barlow et al. 2004; Barlow 2006) and 1 was made in 2010 (Bradford et al. 2013), none near the proposed survey area (Barlow et al. 2004; Bradford et al. 2013; Carretta et al. 2015). Numerous additional sightings in and north of the EEZ have been made by observers on longliners, some in and near the proposed survey area (Carretta et al. 2015). There is one record for the Hawaiian Islands EEZ in the OBIS database, west of Oahu (OBIS 2016).

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical and warm temperate waters; it is seen as far south as ~40ºS but is more common north of ~35ºS. It is generally nomadic, but may be resident in certain locations, including Hawaii. Pilot whales occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson 2009). During small-boat surveys around the Hawaiian Islands in 2000–2012, it was sighted in water as deep as 5000 m, with the highest sighting rates in water depths of 500–2500 m (Baird et al. 2013).

Photo-identification and telemetry studies suggest there may be insular and pelagic populations of short-finned pilot whales in Hawaiian waters (Mahaffy 2012; Oleson et al. 2013). Genetic research is also underway to assist in delimiting population stocks for management (Carretta et al. 2015). During summer–fall surveys of the Hawaiian Islands EEZ, 25 sightings were made in 2002 (Barlow 2006) and 36 were made in 2010 (Bradford et al. 2013), including near the proposed survey area in and outside the EEZ (Barlow et al. 2004; Carretta et al. 2015). One fall–winter sighting has been reported for the area (DoN 2005), and possible takes have also been reported by observers on Hawaii-based longliners during 2007–2011 in and near the proposed survey area (Carretta et al. 2015).

There are 532 records for the Hawaiian EEZ in the OBIS database, none in the proposed survey area (OBIS 2016); the closest sighting was made at 22.3°N, 158.1°W, ~160 km away (Barlow and Taylor 2005).

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.

The University of Hawaii requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic survey in the central Pacific Ocean during September 2017. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near

the activities are exposed to the pulsed sounds generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. However, per NMFS requirement, small numbers of Level A takes are also being requested for the remote possibility of low-level physiological effects. 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.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, and refer to recent literature that has become available since the NSF/USGS PEIS was released in 2011, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the NSF/USGS PEIS.
- Then we summarize the potential impacts of operations by the echosounder. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the NSF/USGS PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed survey in the central Pacific Ocean. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as well Level A "takes", as required by NMFS. Acoustic modeling was conducted by L-DEO, determined to be acceptable by NMFS to use in the calculation of estimated takes under the MMPA (e.g., NMFS 2013a,b).

Summary of Potential Effects of Airgun Sounds

As noted in the NSF/USGS PEIS (§ 3.6.4.3 and § 3.7.4.3), the effects of sounds from airguns on cetaceans 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; Erbe et al. 2015). In some cases, a behavioral response to a sound may in turn reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015). Here, we focus on effects of sounds on cetaceans, as pinnipeds are not expected to occur in the proposed survey area. Detailed information on the possible effects on pinnipeds can be found in § 3.8.4.3 of the NSF/USGS PEIS.

Tolerance

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

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very 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. Thus, airgun sounds could have masking effects and reduce the communication range especially of large whales (Nieukirk et al. 2012; Blackwell et al. 2013; Wittekind et al. 2016).

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 seismic pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Cerchio et al. 2014). 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; Cerchio et al. 2014). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001), 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 (New et al. 2013). 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 (e.g., Lusseau and Bejder 2007; Weilgart 2007; Nowacek et al. 2015). 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 might be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species. Detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys.

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

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

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. from 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although, sample sizes were small (Stone 2015). On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis (Malme et al. 1985). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years, indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007).

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

Results from the closely related *bowhead whale* 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.

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Off St. Lawrence Island in the northern Bering Sea, it was estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re

1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms} (Malme et al. 1986, 1988).

There was no indication that western gray whales exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioural 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 behaviour 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 (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 avoidance response to high sound levels in the area (Muir et al. 2016). The 2001 seismic program, as well as a subsequent survey in 2010, involved a comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs of sound above about 163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). The lack of strong avoidance or other strong responses was presumably in part a result of the mitigation measures; effects probably would have been more significant without such intensive mitigation efforts.

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. All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median CPA ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km). 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. 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. 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. 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. Minke whales were seen significantly farther from the vessel during periods with than without seismic operations. 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).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year, and 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 marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994 to 2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations. 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. 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.

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). Bottlenose dolphins exposed to multiple airgun pulses exhibited some anticipatory behavior (Schlundt et al. 2016).

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), but foraging behavior can be altered upon exposure to airgun sound (e.g., Miller et al. 2009). Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Preliminary data from the Gulf of Mexico show 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 to 2010 indicated that detection rates of beaked whales were significantly higher ($p<0.05$) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that harbor porpoises show stronger avoidance of seismic operations than do Dall's porpoises. Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating; 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 µPa2 · s). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). 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 $\mu Pa_{0\text{-peak}}$. In contrast, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). 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, which tend to be less responsive than the more responsive cetaceans. NMFS is currently developing new guidance for predicting behavioural effects (Scholik-Schlomer 2015). As behavioural

responses are not consistently associated with received levels, Gomez et al. (2016) recommended that a response/no response dichotomous approach be used when assessing behavioral reactions.

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 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. 2012a,b; 2013b,c, 2014, 2015a, 2016; Ketten 2012; Supin et al. 2016).

Recent data have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Schlundt et al. (2016) and 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).

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 (see § 3.6.4.3, § 3.7.4.3, and Appendix E of the NSF/USGS PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans (cf. Southall et al. 2007). Some cetaceans could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012a) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB (Kastelein et al. 2012a). Kastelein et al. (2013b) 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.

Based on the best available information at the time, Southall et al. (2007) recommended a TTS threshold for exposure to single or multiple pulses of 183 dB re 1 $\mu Pa^2 \cdot s$ for all cetaceans. 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 closest point of approach to a seismic vessel is 1 km or more could experience TTS. 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. There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

The new noise exposure criteria for marine mammals that were recently released by NMFS (2016a) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{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), and HF cetaceans (e.g., porpoise and *Kogia* spp.).

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.

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, but TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). 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, recent 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 survey would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter the survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

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. 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.

There is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. However, 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. Additionally, 10 cases of 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. 2106).

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 and some odontocetes, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Possible Effects of Other Acoustic Sources

The SeaBeam 3012 MBES would be operated from the source vessel during the proposed survey. A review of the expected potential effects (or lack thereof) of MBESs on cetaceans appears in § 3.6.4.3, § 3.7.4.3, and Appendix E of the NSF/USGS PEIS.

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales (*Peponocephala electra*; Southall et al. 2013) off Madagascar. During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza

Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES have expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

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

There is no available information on marine mammal behavioral response to MBES sounds (Southall et al. 2013). Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency active sonars (e.g., Miller et al. 2012; Sivle et al. 2012), mid-frequency active sonars (e.g., Tyack et al. 2011; Melcón et al. 2012; Miller et al. 2012, 2014; Sivle et al. 2012, 2015; DeRuiter et al. 2013a,b; Goldbogen et al. 2013; Antunes et al. 2014; Baird et al. 2014; Kastelein et al. 2015a; Wensveen et al. 2015; Friedlaender et al. 2016; Isojunno et al. 2016), and high-frequency active sonars (Kastelein et al. 2015c,d). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

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

Deng et al (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders, and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels.

Despite the aforementioned information that has recently become available, and in agreement with § 3.6.7 and § 3.7.7 of the NSF/USGS PEIS, the operation of the MBES is not likely to impact marine

mammals, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal given the movement and speed of the vessel.

Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear.

Vessel noise from the *Kairei* could affect marine animals in the proposed survey areas. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels. 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). 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. 2015, 2016; Tenessen and Parks 2016). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016; 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; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals.

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

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

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

The 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 of the NSF/USGS PEIS. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel.

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

All takes would be anticipated to be Level B "takes by harassment", involving temporary changes in behavior. As required by NMFS, Level A takes were also calculated; given the very small exclusion zones and the proposed mitigation measures to be applied, injurious takes would not be expected. (However, as noted earlier, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.)

In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic program. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the proposed seismic survey. 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 other sources, any marine mammals close enough to be affected by the MBES would already be affected by the airguns. However, whether or not the airguns are operating simultaneously with the other sources, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the MBES, given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § 3.6.4.3, § 3.7.4.3, and Appendix E of the NSF/USGS PEIS. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that could be affected by sound sources other than airguns.

Basis for Estimating "Takes"

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of 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, e.g., PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Likewise, they are less likely to

approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

For most cetacean species, we used densities calculated by Bradford et al. (2017) from summer–fall vessel-based surveys that are part of the Hawaiian Island Cetacean Ecosystem Assessment Survey (HICEAS). The surveys were conducted by NMFS' Southwest Fisheries Science Center (SWFSC) and Pacific Islands Fisheries Science Center (PIFSC) in 2010 using two NOAA research vessels, one during 13 August–1 December and the other during 2 September–29 October. The densities were estimated using a multiple-covariate line-transect approach (Buckland et al. 2001; Marques and Buckland 2004). We used density estimates for pygmy and dwarf sperm whales and spinner dolphins, not calculated from the 2010 surveys, for the "Outer EEZ stratum" of the 2002 summer–fall vessel-based HICEAS conducted by SWFSC (Barlow 2006) using line-transect methodology (Buckland et al. 2001). The density estimate for the false killer whale was based on the pelagic stock density calculated by Bradford et al. (2015) using line-transect methodology (Buckland et al. 2001).

All densities were corrected for trackline detection probability bias [$f(0)$] and availability [$g(0)$] bias by the authors. Bradford et al. (2017) used $g(0)$ values estimated by Barlow (2015), whose analysis indicated that $g(0)$ had previously been overestimated, particularly for high sea states. Barlow (2006) used earlier estimates of $g(0)$, so densities used here for pygmy and dwarf sperm whales and spinner dolphins likely are underestimates. Density estimates were not available for humpback and minke whales and were assumed to be zero because those species likely would not occur in the survey area during summer–fall. The density for the "Sei or Bryde's whale" category identified by Bradford et al. (2017) was allocated between sei and Bryde's whales according to their proportionate densities.

There is some uncertainty related to the estimated density data and the assumptions used in their calculations, as with all density data estimates. However, the approach used here is based on the best available data. The calculated exposures that are based on these densities are best estimates for the proposed survey.

The estimated numbers of individuals potentially exposed 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 9 shows the density estimates calculated as described above and the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic survey offshore Hawaii, if no animals moved away from the survey vessel. The *Requested Take Authorization* is given in the far right column of Table 9. For all species, including those for which densities were not available or zero, we have included a *Requested Take Authorization* for the mean group size for species where that number was higher than the calculated take. Species for which the *Requested Take Authorization* was increased to the mean group size and the relevant sources include blue and killer whales (Bradford et al. 2017), minke whale (Jackson et al. 2008), humpback whale (Mobley et al. 2001), and spinner dolphin (Barlow 2006).

It should be noted that the following estimates of exposures assume that the proposed survey would be completed; in fact, the calculated takes ***have been increased by 25%*** (see below). Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF/USGS PEIS. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from

TABLE 9. Densities and estimates of the possible numbers of individuals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic survey offshore Hawaii in September 2017. The proposed sound source consists of a 32-airgun array with a total discharge volume of ~7800 in^3. Species in italics are listed under the ESA as endangered. The column of numbers in boldface shows the numbers of Level B "takes" for which authorization is requested.

Species	Estimated Density[1] (#/1000 km^2)	Calculated Take, NMFS Daily Method[2]		Level A + Level B as % of Pop.[5]	Requested Take Authorization[6]
		Level A[3]	Level B[4]		
LF Cetaceans					
Humpback whale	0	0	0	0	**2**[7]
Minke whale	0	0	0	0	**1**[7]
Bryde's whale	0.97	2	25	0.13	**27**
Sei whale	*0.22*	*0*	*6*	*0.06*	***6***
Fin whale	*0.06*	*0*	*2*	*0.01*	***2***
Blue whale	*0.05*	*0*	*1*	*0.06*	***3***[7]
MF Cetaceans					
Sperm whale	*1.86*	*0*	*51*	*0.19*	***51***
Cuvier's beaked whale	0.30	0	8	0.04	**8**
Indo-Pacific beaked whale	3.11	0	85	1.12	**85**
Blainville's beaked whale	0.86	0	24	0.09	**76**
Mesoplodont (unidentified)[8]	1.89	0	52	0.21	**-**
Rough-toothed dolphin	29.6	0	812	0.75	**812**
Common bottlenose dolphin	8.99	0	246	0.07	**246**
Pantropical spotted dolphin	23.3	0	639	0.05	**639**
Spinner dolphin	0.83	0	23	<0.01	**32**[7]
Striped dolphin	25.0	0	685	0.07	**685**
Fraser's dolphin	21.0	0	577	0.20	**577**
Risso's dolphin	4.74	0	130	0.12	**130**
Melon-headed whale	3.54	0	97	0.21	**97**
Pygmy killer whale	4.35	0	119	0.31	**119**
False killer whale	0.60	0	16	0.04	**16**
Killer whale	0.06	0	2	0.08	**5**[7]
Short-finned pilot whale	7.97	0	218	0.04	**218**
HF Cetaceans					
Pygmy sperm whale	3.19	0	87	1.22	**87**
Dwarf sperm whale	7.82	0	214	1.22	**214**

[1] No correction factors were applied to these calculations; see text for density sources.
[2] Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area to levels ≥160 dB re 1 μPa$_{rms}$ on one selected day (see text) multiplied by the number of survey days (5.5), times 1.25; daily ensonified areas = full 160-dB area (3986.6 km^2) minus ensonified area for the appropriate PTS threshold (5.8, 302.9, and 0 km^2 for HF, LF, and MF cetaceans, respectively).
[3] Level A takes if there were no mitigation measures.
[4] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.
[5] Requested Level A and B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population in the North Pacific, ETP, or Hawaii (see Table 8).
[6] Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated; includes takes in the EEZ of the Hawaiian Islands and International waters.
[7] Requested take authorization (Level B only) increased to mean group size (see text for sources).
[8] All *Mesoplodon* sp. are expected to be Blainville's beaked whale, so we added the requested takes to that species.

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 2013d). 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 2013d).

Potential Number of Marine Mammals Exposed to Airgun Sounds

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) on one or more occasions have been estimated using a method required by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day. The area expected to be ensonified on that day was determined by entering the planned survey line(s) totaling 200 km of ship trackline into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB and Level A threshold buffers around each seismic line, and then calculating the total area within the buffers. The ensonified areas were then multiplied by the number of survey days (5.5) increased by 25%; this is equivalent to adding an additional 25% to the proposed line km.

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 (power downs or shut downs when PSOs observed animals approaching or inside the EZs), were also calculated (Table 9). The predicted Level A exclusion zone is extremely small, and mitigation measures would reduce the chances, if not eliminate, any such takes. Only two Level A takes of Bryde's whales were calculated. Level A takes are considered highly unlikely.

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the proposed survey area within the Hawaiian Islands EEZ is 4120 (Table 9). That total includes 60 cetaceans listed as ***Endangered*** under the ESA: 51 sperm whales, 6 sei whales, 2 fin whales, and 1 blue whale, representing 0.19%, 0.06%, 0.01%, and 0.06% of their regional populations, respectively. In addition, 169 beaked whales could be exposed. Most (87%) of the cetaceans potentially exposed would be delphinids; the rough-toothed, striped, pantropical spotted, and Fraser's dolphins are expected to be the most common delphinid species in the area, with estimates of 812, 685, 639, and 577 exposed to ≥160 dB re 1 μPa_{rms}, respectively (0.05–0.75% of the regional populations).

Conclusions

The proposed seismic survey would involve towing a 32-airgun array with a total discharge volume of ~7800 in^3 that introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". In § 3.6.7 and § 3.7.7, 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 mysticete and odontocete species, and that Level A effects were highly unlikely. Nonetheless, NMFS requires potential Level A "takes" to be calculated for the Proposed Action.

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are low

percentages of the regional population sizes (Table 9). The estimates are likely overestimates of the actual number of animals that would be exposed to and would react to the seismic sounds. The reasons for that conclusion are outlined above. 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 cetaceans would be expected from the proposed activity.

VIII. Anticipated Impact on Subsistence

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

There is no subsistence hunting near the proposed survey area, so the proposed 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 survey 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 anthropogenic sounds on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses, injuries, or mortalities (Aguilar de Soto 2016; Carroll et al. 2016). Potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), and Fay and Popper (2012); they include pathological, physiological, and behavioral effects.

Radford et al. (2014) suggested that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed included mortality, mortal injury, recoverable injury, TTS, masking, and behavioral effects. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015; Carroll et al. 2016).

More details on the effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the NSF/USGS PEIS. 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. The same conclusion would apply to the proposed survey.

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 cetaceans that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned activity.

XI. Mitigation Measures

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

Marine mammals and sea turtles are known to occur in the proposed study area. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental 'take' of marine mammals and other endangered species. The proposed activity would take place in the EEZ of the Hawaiian Islands as well as in International Waters.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activities. This document has been prepared in accordance with the current NOAA acoustic practices and on best practices recommended in Richardson et al (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

Planning Phase

After considering what energy source level was necessary to achieve the research goals, the PIs determined the use of the 32-airgun array with a total volume of ~7800 in^3 would be required. Given the research goals, location of the survey and associated deep water, this energy source level was viewed appropriate. Most marine mammal species are expected to occur in the area year-round. However, as the project is proposed for summer, most baleen are expected to occur in higher latitudes at the time of the survey. Thus, altering the timing of the proposed project would result in no net benefits for those species.

Mitigation Zones

During the planning phase, the Level B safety zone (Table 1) for the proposed survey was calculated based on modeling by L-DEO. Table 1 shows the distances at which the 160-, 175-, and 195-dB re 1 µPa$_{rms}$ sound levels are expected to be received for the 32-airgun array and the 100-in^3 mitigation airgun. 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 can be used to determine behavioral disturbance for sea turtles. The 195-dB distance would be used as the EZ for sea turtles, as specified by NMFS. The proposed survey would acquire data with the 32-airgun array at a tow depth of 10 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m. A more detailed description of the modeling process used to develop the mitigation zones can be found in § I.

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 distances to the PTS thresholds for the various marine mammal hearing groups have been calculated based on modeling by L-DEO and are provided in Tables 4 and 5 for the 32-airgun array, and Tables 8 and 9 for the single 100-in^3 mitigation airgun. The PTS thresholds were calculated

based on NMFS guidance, and apply to the full 32-airgun array for all marine mammals, except bow-riding delphinids. Shut-down distances for the single mitigation airgun also use the calculated distances to PTS thresholds for various marine mammal groups (Tables 8 and 9).

Enforcement of the EZs zones via power and shut downs would be implemented during operations, as noted below.

Mitigation During Operations

Mitigation measures that would be adopted during the proposed survey include (1) power-down procedures, (2) shut-down procedures, and (3) ramp-up procedures.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the mitigation zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. During a power down, one airgun would be operated. 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 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 would 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. During a power down of the airgun array, the 100-in^3 airgun would be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun (Tables 8 and 9), it would be shut down (see next subsection).

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

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

During airgun operations following a shut down whose duration has exceeded the time limits specified above, the airgun array would be ramped up gradually. Ramp-up procedures are described below. Under a power-down scenario, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity. Furthermore, under these circumstances, ramp-up procedures may unnecessarily extend the length of the survey time needed to collect seismic data. Ramp up would not be implemented after an extended power down. Therefore, this practice is not included here as part of the monitoring and mitigation plan.

Shut-down Procedures

The operating airgun(s) would be shut down if a marine mammal or turtle is seen within or approaching the EZ for the single airgun. Shut downs would be implemented (1) if an animal enters the EZ of the single airgun after a power down has been initiated, or (2) if an animal is initially seen within the EZ of the single airgun when more than one airgun (typically the full array) is operating. Airgun activity would not resume until the marine mammal or turtle has cleared the EZ, or until the PSO is confident that the animal has left the vicinity of the vessel. Criteria for judging that the animal has cleared the EZ would be as described in the preceding subsection.

Ramp-up Procedures

A ramp-up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that, for the present survey, this period would be ~12 min. Ramp up would not occur if a marine mammal or sea turtle has not cleared the EZ as described earlier.

Ramp up would begin with the smallest airgun in the array (100 in^3). Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down would be implemented as though the full array were operational.

If the complete EZ has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up would not commence unless at least one airgun (100 in^3 or similar) has been operating during the interruption of seismic survey operations. Given these provisions, it is likely that the airgun array would not be ramped up from a complete shut down at night or in thick fog, because the outer part of the safety zone for that array would not be visible during those conditions. If one airgun has operated during a power-down period, a return to full power would be permissible at night or in poor visibility, on the assumption that marine mammals and turtles would be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away. Ramp up of the airguns would not be initiated if a sea turtle or marine mammal is sighted within or near the applicable EZs during the day or night. Currently, under a power-down scenario, however, a single mitigation airgun still would be operating to alert and warn animals of the on-going activity and therefore ramp-up is viewed unnecessary.

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 central Pacific Ocean, 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...

JAMSTEC and the University of Hawaii propose to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. JAMSTEC and the University of Hawaii's proposed Monitoring Plan is described below. JAMSTEC and the University of Hawaii 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. JAMSTEC and the University of Hawaii area 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 airgun operations and nighttime start ups (if applicable) of the airguns. Airgun operations would be suspended when marine mammals or turtles 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. Observations would also be made during daytime periods when the *Kairei* is underway without seismic operations, such as during transits.

During seismic operations, four visual PSOs would be based aboard the *Kairei*. PSOs would be appointed by JAMSTEC with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals and sea turtles around the seismic vessel. Use of two simultaneous observers would increase the effectiveness of detecting animals around the source vessel. However, during meal times, only one PSO may be on duty. PSO(s) would be on duty in shifts of duration no longer than 4 h. Other crew would also be instructed to assist in detecting marine mammals and turtles and in implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew would be given additional instruction regarding how to do so.

The *Kairei* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the PSO would have a good view around the entire vessel. During daytime, the PSO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye.

Passive Acoustic Monitoring

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

The PAM system consists of hardware (i.e., hydrophones) and software. The "wet end" of the system consists of a towed hydrophone array that is connected to the vessel by a tow cable. A deck cable would connect the tow cable to the electronics unit on board where the acoustic station, signal conditioning, and processing system would be located. The acoustic signals received by the hydrophones are amplified, digitized, and then processed by the software.

One acoustic PSO or PSAO (in addition to the 4 visual PSOs) would be on board. The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey area during airgun operations, and during most periods when the *Kairei* is underway while the airguns are not operating. However, PAM may not be possible if damage occurs to the array or back-up systems during operations. One visual or acoustic PSO would monitor the acoustic detection system at any one time in shifts no longer than 6 hrs, by listening to the signals via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. A bioacoustician would design and set up the PAM system and be present to operate and oversee PAM.

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

PSO Data and Documentation

PSOs would record data to estimate the numbers of marine mammals and turtles exposed to various received sound levels and to document apparent disturbance reactions or lack thereof. Data would be used to estimate numbers of animals potentially 'taken' by harassment (as defined in the MMPA). They would also provide information needed to order a power down or shut down of the airguns when a marine mammal or sea turtle is within or near the EZ.

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

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

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

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

Results from the vessel-based observations would provide

1. The basis for real-time mitigation (airgun power down or shut down).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals and turtles in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals and turtles 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.

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, and all marine mammal and turtle sightings (dates, times, locations, activities, associated seismic survey activities). 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.

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

XV. Literature Cited

Aguilar, A. 2009. Fin whale *Balaenoptera physalus*. p. 433-437 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Aguilar de Soto, N. 2016. Peer-reviewed studies on the effects of anthropogenic noise on marine invertebrates: from scallop larvae to giant squid. p. 17-26 *In:* The effects of noise on aquatic life II, Springer, New York, NY. 1292 p.

Aguilar Soto, N., M. Johnson, P.T. Madsen, P.L. Tyack, A. Bocconcelli, and J.F. Borsani. 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? **Mar. Mamm. Sci.** 22(3):690-699.

Anderson, R.C., R. Clark, P.T. Madsen, C. Johnson, J. Kiszka, and O. Breysse. 2006. Observations of Longman's beaked whale (*Indopacetus pacificus*) in the western Indian Ocean. **Aquat. Mamm.** 32(2):223-231.

Anderwald, P., A. Brandecker, M. Coleman, C. Collins, H. Denniston, M.D. Haberlin, M. O'Donovan, R. Pinfield, F. Visser, and L. Walshe. 2013. Displacement responses of a mysticete, an odontocete, and a phocid seal to construction-related vessel traffic. **Endang. Spec. Res.** 21(3):231-240.

Antunes, R., P.H. Kvadsheim, F.P.A. Lam, P.L. Tyack, L. Thomas, P.J. Wensveen, and P.J.O. Miller. 2014. High thresholds for avoidance of sonar by free-ranging long-finned pilot whales (*Globicephala melas*). **Mar. Poll. Bull.** 83(1):165-180.

Archer, F.I. 2009. Striped dolphin *Stenella coeruleoalba*. p. 1127-1129 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Aschettino, J.M. 2010. Population size and structure of melon-headed whales (*Peponocephala electra*) around the main Hawaiian Islands: evidence of multiple populations based on photographic data. M.Sc. Thesis, Hawai'i Pacific University. 177 p.

Aschettino, J.M., R.W. Baird, D.J. McSweeney, D.L. Webster, G.S. Schorr, J.L. Huggins, K.K. Martien, S.D. Mahaffy, and K.L. West. 2012. Population structure of melon-headed whales (*Peponocephala electra*) in the Hawaiian Archipelago: evidence of multiple populations based on photo-identification. **Mar. Mamm. Sci.** 28(4):666-689.

Atkinson, S., D. Crocker, D. Houser, and K. Mashburn. 2015. Stress physiology in marine mammals: How well do they fit the terrestrial model? **J. Comp. Physiol. B** 185(5):463-486.

Au, D.K.W. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. **Fish. Bull.** 83(4):623-643.

Azzara, A.J., W.M. von Zharen, and J.J. Newcomb. 2013. Mixed-methods analytic approach for determining potential impacts of vessel noise on sperm whale click behavior. **J. Acoust. Soc. Am.** 134(6):4566-4574.

Baird, R.W. 2009. False killer whale *Pseudorca crassidens*. p. 405-406 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Baird, R.W., D.L. Webster, D.J. McSweeney, A.D. Ligon, G.S. Schorr, and J. Barlow. 2006. Diving behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawaii. **Can. J. Zool.** 84(8):1120-1128.

Baird, R.W., G.S. Schorr, D.L. Webster, D.J. McSweeney, M.B. Hanson, and R.D. Andrews. 2010. Movements and habitat use of satellite-tagged false killer whales around the main Hawaiian Islands. **End. Spec. Res.** 10:107-121.

Baird, R.W., D.L. Webster, J.M. Aschettino, G.S. Schorr, and D.J. McSweeney. 2013. Odontocete cetaceans around the main Hawaiian Islands: Habitat use and relative abundance from small-boat sighting surveys. **Aquat. Mamm.** 39(3):253-269.

Baird, R.W., S.W. Martin, D.L. Webster, and B.L. Southall. 2014. Assessment of modeled received sound pressure levels and movements of satellite-tagged odontocetes exposed to mid-frequency active sonar at the Pacific Missile Range Facility: February 2011 through February 2013. Prepared for U.S. Pacific Fleet, submitted to NAVFAC PAC by HDR Environmental, Operations and Construction, Inc. Accessed in December 2015 at www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA602847.

Baker, C.S. and L.M. Herman. 1989. Behavioral responses of summering humpback whales to vessel traffic: Experimental and opportunistic observations. NPS-NR-TRS-89-01. Rep. from Kewalo Basin Mar. Mamm. Lab., Univ. Hawaii, Honolulu, HI, for U.S. Natl. Park Serv., Anchorage, AK. 50 p. NTIS PB90-198409.

Baker, C.S., L.M. Herman, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Rep. from Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. Nat. Mar. Fish. Serv., Seattle, WA. 78 p.

Baker, C.S., L.M. Herman, B.G. Bays, and G.B. Bauer. 1983. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska: 1982 season. Rep. from Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. Nat. Mar. Mamm. Lab., Seattle, WA. 30 p.

Baker, C.S., D. Steel, J. Calambokidis, E. Falcone, U. Gonzalez-Peral, J. Barlow, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban, P.R. Wade, D. Weller, B.H. Witteveen, and M. Yamaguchi. 2013. Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. **Mar. Ecol. Prog. Ser.** 494:291-306.

Barlow, J. 2006. Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. **Mar. Mamm. Sci.** 22(2):446-464.

Barlow, J. 2015. Inferring trackline detection probabilities, *g*(0), for cetaceans from apparent densities in different survey conditions. **Mar. Mamm. Sci.** 31(3):923-943.

Barlow, J. and S. Rankin. 2007. False killer whale abundance and density: preliminary estimates for the PICEAS study area south of Hawaii and new estimates for the US EEZ around Hawaii. Admin. Rep. LJ-07-02, Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 15 p.

Barlow, J. and B. Taylor. 2005. Estimates of sperm whale abundance in the northeast temperate Pacific from a combined visual and acoustic survey. **Mar. Mamm. Sci.** 21(3):429-445.

Barlow, J., S. Rankin, E. Zele, and J. Appler. 2004. Marine mammal data collected during the Hawaiian Islands cetacean and ecosystem assessment survey (HICEAS) conducted aboard the NOAA ships *McArthur* and *David Starr Jordan*, July–December 2002. NOAA Tech. Memo. NMFS-SWFSC-362. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 39 p.

Barlow, J., S. Rankin, A. Jackson, and A. Henry. 2008. Marine mammal data collected during the Pacific Islands cetacean and ecosystem assessment survey (PICEAS) conducted aboard the NOAA ship *McArthur II*, July–November 2005. NOAA Tech. Memo. NMFS-SWFSC-420. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 27 p.

Barlow, J., J. Calambokidis, E.A. Falcone, C.S. Baker, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D.K. Mattila, T.J. Quinn, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban R., P. Wade, D. Weller, B.H. Witteveen, and M. Yamaguchi. 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. **Mar. Mamm. Sci.** 279(4):793-818.

Barros, N.B., D.A. Duffield, P.H. Ostrom, D.K. Odell, and V.R. Cornish. 1998. Nearshore vs. offshore ecotype differentiation of *Kogia breviceps* and *K. simus* based on hemoglobin, morphometric and dietary analyses. Abstr. World Mar. Mamm. Sci. Conf., Monaco, 20–24 January 1998.

Barry, S.B., A.C. Cucknell, and N. Clark. 2012. A direct comparison of bottlenose dolphin and common dolphin behaviour during seismic surveys when airguns are and are not being utilised. p. 273-276 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Bernstein, L. 2013. The Washington Post: Health, science, and environment. Panel links underwater mapping sonar to whale stranding for first time. Published 6 October 2013. Accessed in December 2015 at http://www.washingtonpost.com/national/health-science/panel-links-underwater-mapping-sonar-to-whale-stranding-for-first-time/2013/10/06/52510204-2e8e-11e3-bbed-a8a60c601153_story.html.

Bettridge, S., C.S. Baker, J. Barlow, P.J. Clapham, M. Ford, D. Gouveia, D.K. Mattila, R.M. Pace III, P.E. Rosel, G.K. Silber, and P.R. Wade. 2015. Status review of the humpback whale (*Megaptera novaeangliae*) under the Endangered Species Act. NOAA Tech. Memo. NMFS-SWFSC-540. Nat. Mar. Fish. Service, Southwest Fish. Sci. Center, La Jolla, CA. 240 p.

Blackwell, S.B., C.S. Nations, T.L. McDonald, C.R. Greene, Jr., A.M. Thode, M. Guerra, and A.M. Macrander. 2013. Effects of airgun sounds on bowhead whale calling rates in the Alaskan Beaufort Sea. **Mar. Mamm. Sci.** 29(4):E342-E365.

Blackwell, S.B., C.S. Nations, T.L. McDonald, A.M. Thode, D. Mathias, K.H. Kim, C.R. Greene, Jr., and A.M. Macrander. 2015. Effects of airgun sounds on bowhead whale calling rates: Evidence for two behavioral thresholds. **PLoS ONE** 10(6):e0125720. http://dx.doi.org/10.1371/journal.pone.0125720.

Bradford, A.L. and K.A. Forney. 2014. Injury determinations for cetaceans observed interacting with Hawaii and American Samoa longline fisheries during 2008–2012. NOAA Tech. Memo. NMFS-PIFSC-41. Nat. Mar. Fish. Serv., Pac. Isl. Fish. Sci. Center, Honolulu, HI. 38 p. + app.

Bradford, A.L., K.A. Forney, E.M. Oleson, and J. Barlow. 2013. Line-transect abundance estimates of cetaceans in the Hawaiin EEZ. PIFSC Working Pap. WP-13-004, 29 March 2013. Nat. Mar. Fish. Serv., Pac. Isl. Fish. Sci. Center, Honolulu, HI. 16 p.

Bradford, A.L., K.A. Forney, E.M. Oleson, and J. Barlow. 2014. Accounting for subgroup structure in line-transect abundance estimates of false killer whales (*Pseudorca crassidens*) in Hawaiian waters. **PLoS ONE** 9(2):e90464. http://dx.doi.org/10.1371/journal.pone.0090464.

Bradford, A.L., E.M. Oleson, R.W. Baird, C.H. Boggs, K.A. Forney, and N.C. Young. 2015. Revised stock boundaries for false killer whales (*Pseudorca crassidens*) in Hawaiian waters. NOAA Tech Memo. NMFS-PIFSC-47. Nat. Mar. Fish. Serv., Pac. Isl. Fish. Sci. Center, Honolulu, HI. 29 p.

Bradford, A.L., Forney, K.A., Oleson, E.M., and J. Barlow. In prep. Line-transect abundance estimates of cetaceans in the Hawaiian EEZ. 34 p.

Branch, T.A., K.M. Stafford, D.M. Palacios, C. Allison, J.L. Bannister, C.L.K. Burton, E. Cabrera, C.A. Carlson, B. Galletti Vernazzani, P.C. Gill, R. Hucke-Gaete, K.C.S. Jenner, M.-N.M. Jenner, K. Matsuoka, Y.A. Mikhalev, T. Miyashita, M.G. Morrice, S. Nishiwaki, V.J. Sturrock, D. Tormosov, R.C. Anderson, A.N. Baker, P.B. Best, P. Borsa, R.L. Brownell Jr, S. Childerhouse, K.P. Findlay, T. Gerrodette, A.D. Ilangakoon, M. Joergensen, B. Kahn, D.K. Ljungblad, B. Maughan, R.D. McCauley, S. Mckay, T.F. Norris, Oman Whale and Dolphin Research Group, S. Rankin, F. Samaran, D. Thiele, K. Van Waerebeek, and R.M. Warneke. 2007. Past and present distribution, densities, and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. **Mamm. Rev.** 37(2):116-175.

Branstetter, B.K., J.S. Trickey, H. Aihara, J.J. Finneran, and T.R. Liberman. 2013. Time and frequency metrics related to auditory masking of a 10 kHz tone in bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 134(6):4556-4565.

Branstetter, B.K., K.L. Bakhtiari, J.S. Trickey, and J.J. Finneran. 2016. Hearing mechanisms and noise metrics related to auditory masking in bottlenose dolphins (*Tursiops truncatus*). p. 109-116 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Breitzke, M. and T. Bohlen. 2010. Modelling sound propagation in the Southern Ocean to estimate the acoustic impact of seismic research surveys on marine mammals. **Geophys. J. Int.** 181(2):818-846.

Bröker, K., J. Durinck, C. Vanman, and B. Martin. 2013. Monitoring of marine mammals and the sound scape during a seismic survey in two license blocks in the Baffin Bay, West Greendland, in 2012. p. 32 *In*: Abstr. 20th Bienn. Conf. Biol. Mar. Mamm., 9–13 December 2013, Dunedin, New Zealand. 233 p.

Bröker, K., G. Gailey, J. Muir, and R. Racca. 2015. Monitoring and impact mitigation during a 4D seismic survey near a population of gray whales off Sakhalin Island, Russia. **Endang. Species Res.** 28:187-208.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press, Inc., New York, NY. 432 p.

Calambokidis, J. 2013. Updated abundance estimates of blue and humpback whales off the US west coast incorporating photo-identifications from 2010 to 2011. Document PSRG-2013-13 presented tp the Pacific Scientific Review Group, April 2013. 7 p. Accessed in January 2016 at http://www.cascadiaresearch.org//Rep-Mn-Bm-2011-Rev.pdf.

Calambokidis, J., G.H. Steiger, J.C. Cubbage, K.C. Balcomb, C. Ewald, S. Kruse, R. Wells, and R. Sears. 1990. Sightings and movements of blue whales off central California 1986–88 from photo-identification of individuals. **Rep. Int. Whal. Comm. Spec. Iss.** 12:343-348.

Calambokidis, J., G.H Steiger, K. Rasmussen, J. Urbán R., K.C. Balcomb, P. Ladrón De Guevara, M. Salinas Z., J.K. Jacobsen, C.S. Baker, L.M. Herman, S. Cerchio, and J.D. Darling. 2000. Migratory destinations of humpback whales from the California, Oregon and Washington feeding ground. **Mar. Ecol. Prog. Ser.** 192:295-304.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urbán R., J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabrielle, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P.L. de Guevara, M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow, and T.J. Quinn II. 2001. Movements and population structure of humpback whales in the North Pacific. **Mar. Mamm. Sci.** 17(4):769-794.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urban R., D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: structure of populations, levels of abundance and status of humpback whales in the North Pacific. Rep. AB133F-03-RP-0078 for U.S. Dept. of Comm., Seattle, WA. Accessed in January 2016 at https://swfsc.noaa.gov//Divisions/PRD/Projects/Research_Cruises/Hawaii_and_Alaska/SPLASH/SPLASH-contract-Report-May08.pdf.

Campana, I., R. Crosti, D. Angeletti, L. Carosso, L. Davis, N. Di-Méglio, A. Moulins, M. Rosso, P. Tepsich, and A. Arcangeli. 2015. Cetacean response to summer maritime traffic in the western Mediterranean Sea. **Mar. Environ. Res.** 109:1-8.

Carretta, J.V., E.M. Oleson, D.W. Weller, A.R. Lang, K.A. Forney, J. Baker, M.M. Muto, B. Hanson, A.J. Orr, H. Huber, M.S. Lowry, J. Barlow, J.E. Moore, D. Lynch, L. Carswell, and R.L Brownell Jr. 2015. U.S. Pacific marine mammal stock assessments: 2014. NOAA Tech. Memo. NMFS-SWFSC-549. Nat. Mar. Fish. Service, Southwest Fish. Sci. Center, La Jolla, CA. 414 p.

Carroll, A.G., R. Przeslawski, A. Duncan, M. Gunning, and B. Bruce. 2016. A review of the potential impacts of marine seismic surveys on fish & invertebrates. **Mar. Poll. Bull.** https://doi.org/10.1016/j.marpolbul.2016.11.038.

Castellote, M. and C. Llorens. 2016. Review of the effects of offshore seismic surveys in cetaceans: Are mass strandings a possibility? p. 133-143 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

Castellote, M., C.W. Clark, and M.O. Lammers. 2012. Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. **Biol. Conserv.** 147(1):115-122.

Cerchio, S., S. Strindberg, T. Collins, C. Bennett, and H. Rosenbaum. 2014. Seismic surveys negatively affect humpback whale singing activity off northern Angola. **PLoS ONE** 9(3):e86464. https://doi.org/.1371/journal.pone.0086464.

Chivers, S.J., R.W. Baird, K.M. Martien, B.L. Taylor, E. Archer, A.M. Gorgone, B.L. Hancock, N.M. Hedrick, D. Matilla, D.J. McSweeney, E.M. Oleson, C.L. Palmer, V. Pease, K.M. Robertson, J. Robbins, J.C. Salinas, G.S. Schorr, M. Schultz, J.L. Thieleking, and D.L. Webster. 2010. Evidence of genetic differentiation for Hawai'i insular false killer whales (*Pseudorca crassidens*). NOAA Tech. Memo. NMFS-SWFSC-458. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 44 p.

Clapham, P.J. 2009. Humpback whale *Megaptera novaeangliae*. p. 582-585 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Clark, C.W. and G.C. Gagnon. 2006. Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. Working Pap. SC/58/E9. Int. Whal. Comm., Cambridge, U.K. 9 p.

Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel, and D. Ponirakis. 2009. Acoustic masking in marine ecosystems: Intuitions, analysis, and implication. **Mar. Ecol. Prog. Ser.** 395:201-222.

Dahlheim, M. and M. Castellote. 2016. Changes in the acoustic behavior of gray whales *Eschrichtius robustus* in response to noise. **Endang. Species Res.** 31:227-242.

Darling, J.D. and S. Cerchio. 1993. Movement of a humpback whale (*Megaptera novaeangliae*) between Japan and Hawaii. **Mar. Mamm. Sci.** 9(1):84-89.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. **Mar. Mamm. Sci.** 14(3):490-507.

Deng, Z.D., B.L. Southall, T.J. Carlson, J. Xu, J.J. Martinez, M.A. Weiland, and J.M. Ingraham. 2014. 200-kHz commercial sonar systems generate lower frequency side lobes audible to some marine mammals. **PLoS ONE** 9(4):e95315. http://dx.doi.org/10.1371/journal.pone.0095315.

DeRuiter, S.L., I.L. Boyd, D.E. Claridge, C.W. Clark, C. Gagnon, B.L. Southall, and P.L. Tyack. 2013a. Delphinid whistle production and call matching during playback of simulated military sonar. **Mar. Mamm. Sci.** 29(2):E46-E59.

DeRuiter, S.L., B.L. Southall, J. Calambokidis, W.M.X. Zimmer, D. Sadykova, E.A. Falcone, A.S. Friedlaender, J.E. Joseph, D. Moretti, G.S. Schorr, L. Thomas, and P.L. Tyack. 2013b. First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. **Biol. Lett.** 9:20130223. http://dx.doi.org/10.1098/rsbl.2013.0223.

Diebold, J.B., M. Tolstoy, L. Doermann, S.L. Nooner, S.C. Webb, and T.J. Crone. 2010. R/V *Marcus G. Langseth* seismic source: modeling and calibration. **Geochem. Geophys. Geosyst.** 11(12):Q12012. doi:10.1029/2010GC003126. 20 p.

Di Iorio, L. and C.W. Clark. 2010. Exposure to seismic survey alters blue whale acoustic communication. **Biol. Lett.** 6(1):51-54.

Dizon, A.E., W.F. Perrin, and P.A. Akin. 1994. Stocks of dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific: a phylogeographic classification. NOAA Tech. Rep. NMFS 119. 20 p.

Dolar, M.L.L. 2009. Fraser's dolphin *Lagenodelphis hosei*. *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA. 1316 p.

DoN (U.S. Department of the Navy). 2005. Marine resources assessment for the Hawaiian Islands Operating Area. Pacific Division, Naval Facilities Engineering Command, Pearl Harbor, HI. Contract No. N62470-02-D-9997, CTO 0026. Prepared by Geo-Marine, Inc., Plano, TX.

Donahue, M.A. and W.L. Perryman. 2009. Pygmy killer whale, *Feresa attenuata*. p. 938-939 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Duffield, D.A., S.H. Ridgway, and L.H. Cornell. 1983. Hematology distinguishes coastal and offshore forms of dolphins (*Tursiops*). **Can. J. Zool.** 61(4):930-933.

Dunlop, R.A. 2015. The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. **Animal Behav.** 111:13-21.

Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, D. Paton, and D.H. Cato. 2015. The behavioural response of humpback whales (*Megaptera novaeangliae*) to a 20 cubic inch air gun. **Aquatic Mamm.** 41(4):412-433.

Dunlop, R.A., M.J. Noad, and D.H. Douglas. 2016b. A spatially explicit model of the movement of humpback whales relative to a source. Proceedings of Meetings on Acoutstics 4ENAL 27(1):010026. doi:10.1121/2.0000296.

Dunlop, R. A., M. J. Noad, R. D. McCauley, E. Kniest, R. Slade, D. Paton, and D. H. Cato. 2016a. Response of humpback whales (*Megaptera novaeangliae*) to ramp-up of a small experimental air gun array. **Mar. Poll. Bull**. 103:72-83.

Dunlop, R., M.J. Noad, R. McCauley, and D. Cato. 2016c. The behavioral response of humpback whales to seismic air gun noise. **J. Acoust. Soc. Am.** 140(4):3412.

Edwards, E.F., C. Hall, T.J. Moore, C. Sheredy, J.V. Redfern. 2015. Global distribution of fin whales *Balaenoptera physalus* in the post-whaling era (1980–2012). **Mamm. Rev.** 45:197-214.

Ellison, W.T., B.L. Southall, C.W. Clark, and A.S. Frankel. 2012. A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. **Conserv. Biol.** 26(1):21-28.

Engel, M.H., M.C.C. Marcondes, C.C.A. Martins, F.O. Luna, R.P. Lima, and A. Campos. 2004. Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult humpback whales in Abrolhos Bank, northeastern coast of Brazil. Working Pap. SC/56/E28. Int. Whal. Comm., Cambridge, U.K. 8 p.

Erbe, C. 2012. The effects of underwater noise on marine mammals. p. 17-22 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Erbe, C., C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling. 2016. Communication masking in marine mammals: a review and research strategy. **Mar. Poll. Bull.** 103:15-38. https://doi.org/10.1016/j.marpolbul.2015.12.007.

Evans, P.G.H. 1987. The natural history of whales and dolphins. Christopher Helm, Bromley, Kent, U.K. 343 p.

Fay, R.R. and A.N. Popper. 2012. Fish hearing: new perspectives from two senior bioacousticians. **Brain Behav. Evol.** 79(4):215-217.

Ferguson, M.C. and J. Barlow. 2003. Addendum: Spatial distribution and density of cetaceans in the Eastern Tropical Pacific Ocean based on summer/fall research vessel surveys in 1986–96. Admin. Rep. LJ-01-04. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 120 p.

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

Finneran, J.J. 2012. Auditory effects of underwater noise in odontocetes. p. 197-202 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Finneran, J.J. 2015. Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. **J. Acoust. Soc. Am.** 138(3):1702-1726.

Finneran, J.J. and B.K. Branstetter. 2013. Effects of noise on sound perception in marine mammals. p. 273-308 *In*: H. Brumm (ed.), Animal communication and noise. Springer Berlin, Heidelberg, Germany. 453 p.

Finneran, J.J. and C.E. Schlundt. 2010. Frequency-dependent and longitudinal changes in noise-induced hearing loss in a bottlenose dolphin (*Tursiops truncatus*) (L). **J. Acoust. Soc. Am.** 128(2):567-570.

Finneran, J.J. and C.E. Schlundt. 2011. Noise-induced temporary threshold shift in marine mammals. **J. Acoust. Soc. Am.** 129(4):2432. [Supplemented by oral presentation at the ASA meeting, Seattle, WA, May 2011].

Finneran, J.J. and C.E. Schlundt. 2013. Effects of fatiguing tone frequency on temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 133(3):1819-1826.

Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin, and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. **J. Acoust. Soc. Am.** 108(1):417-431.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder, and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. **J. Acoust. Soc. Am.** 111(6):2929-2940.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. **J. Acoust. Soc. Am.** 118(4):2696-2705.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and R.L. Dear. 2010a. Growth and recovery of temporary threshold shift (TTS) at 3 kHz in bottlenose dolphins (*Tursiops truncatus*). **J. Acoust. Soc. Am.** 127(5):3256-3266.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and R.L. Dear. 2010b. Temporary threshold shift in a bottlenose dolphin (*Tursiops truncatus*) exposed to intermittent tones. **J. Acoust. Soc. Am.** 127(5):3267-3272.

Finneran, J.J., C.E. Schlundt, B.K. Branstetter, J.S. Trickey, V. Bowman, and K. Jenkins. 2015. Effects of multiple impulses from a seismic air gun on bottlenose dolphin hearing and behavior. **J. Acoust. Soc. Am.** 137(4):1634-1646.

Fleming, A., and J. Jackson. 2011. Global review of humpback whales (*Megaptera novaeangliae*). NOAA Tech. Memo. NMFS-SWFSC-474. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 206 p.

Ford, J.K.B. 2009. Killer whale. p. 650-657 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Frankel A.S., C.W. Clark, L.M. Herman, and C.M. Gabriele. 1995. Spatial distribution, habitat utilization, and social interactions of humpback whales (*Megaptera novaeangliae*), off Hawai'i, determined using acoustic and visual techniques. **Can. J. Zool.** 73(6):1134-1146.

Friedlaender, A.S., E.L. Hazen, J.A. Goldbogen, A.K. Stimpert, J. Calambokidis, and B.L. Southall. 2016. Prey-mediated behavioral responses of feeding blue whales in controlled sound exposure experiments. **Ecol. Appl.** doi:10.1002/15-0783.

Gailey, G., B. Würsig, and T.L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, northeast Sakhalin Island, Russia. **Environ. Monit. Assessm.** 134(1-3):75-91.

Gailey, G., O. Sychenko, T. McDonald, R. Racca, A. Rutenko, and K. Bröker. 2016. Behavioural responses of western gray whales to a 4-D seismic survey off northeastern Sakhalin Island, Russia. **Endang. Species Res.** 30:53-71.

Gambell, R. 1985. Fin whale *Balaenoptera physalus* (Linnaeus, 1758). p. 171-192 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, U.K. 362 p.

Gannier, A. 2002. Cetaceans of the Marquesas Islands (French Polynesia): distribution and relative abundance as obtained from a small boat dedicated survey. **Aquat. Mamm.** 28(2):198-210.

Garrigue, C., P.J. Clapham, Y. Geyer, A.S. Kennedy, and A.N. Zerbini. 2015. Satellite tracking reveals novel migratory patterns and the importance of seamounts for endangered South Pacific humpback whales. **R. Soc. Open Sci.** 2:150489. http://dx.doi.org/10.1098/rsos.150489.

Gedamke, J. 2011. Ocean basin scale loss of whale communication space: Potential impacts of a distant seismic survey. p. 105-106 *In*: Abstr. 19th Bienn. Conf. Biol. Mar. Mamm., 27 Nov.–2 Dec. 2011, Tampa, FL. 344 p.

Gedamke, J., N. Gales, and S. Frydman. 2011. Assessing risk of baleen whale hearing loss from seismic surveys: The effects of uncertainty and individual variation. **J. Acoust. Soc. Am.** 129(1):496-506.

Gerrodette, T. and J. Forcada. 2002. Estimates of abundance of western/southern spotted, whitebelly spinner, striped and common dolphins, and pilot, sperm and Bryde's whales in the eastern tropical Pacific Ocean. Admin. Rep. LJ-02-20. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 24 p.

Gerrodette, T., G. Watters, W. Perryman, and L. Balance. 2008. Estimates of 2006 dolphin abundance in the eastern tropical Pacific, with revised estimates from 1986–2003. NOAA Tech. Memo. NMFS-SWFSC-422. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 39 p.

Gervaise, C., N. Roy, Y. Simard, B. Kinda, and N. Menard. 2012. Shipping noise in whale habitat: Characteristics, sources, budget, and impact on belugas in Saguenay-St. Lawrence Marine Park hub. **J. Acoust. Soc. Am.** 132(1):76-89.

Goldbogen, J.A., B.L. Southall, S.L. DeRuiter, J. Calambokidis, A.S. Friedlaender, E.L. Hazen, E. Falcone, G. Schorr, A. Douglas, D.J. Moretti, C. Kyburg, M.F. McKenna, and P.L. Tyack. 2013. Blue whales respond to simulated mid-frequency military sonar. **Proc. R. Soc. B.** 280(1765):20130657. http://dx.doi.org/10.1098/rspb.2013.0657.

Gomez, C., J. Lawson, A.D. Wright, A. Buren, D. Tollit, and V. Lesage. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. **Can. J. Zool.** 94:801-819.

Gong, Z., A.D. Jain, D. Tran, D.H. Yi, F. Wu, A. Zorn, P. Ratilal, and N.C. Makris. 2014. Ecosystem scale acoustic sensing reveals humpback whale behavior synchronous with herring spawning processes and re-evaluation finds no effect of sonar on humpback song occurrence in the Gulf of Maine in fall 2006. **PLoS ONE** 9(10):e104733. http://dx.doi.org/10.1371/journal.pone.0104733.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift, and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. **Mar. Technol. Soc. J.** 37(4):16-34.

Gospić, N.R. and M. Picciulin. 2016. Changes in whistle structure of resident bottlenose dolphins in relations to underwater noise and boat traffic. **Mar. Poll. Bull.** 105:193-198.

Gray, H. and K. Van Waerebeek. 2011. Postural instability and akinesia in a pantropical spotted dolphin, *Stenella attenuata*, in proximity to operating airguns of a geophysical seismic vessel. **J. Nature Conserv.** 19(6):363-367.

Greene, C.R., Jr. 1997. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Gregr, E.J. and A.W. Trites. 2001. Predictions of critical habitat of five whale species in the waters of coastal British Columbia. **Can. J. Fish. Aquat. Sci.** 58(7):1265-1285.

Guan, S., J.F. Vignola, J.A. Judge, D. Turo, and T.J. Ryan. 2015. Inter-pulse noise field during an arctic shallow-water seismic survey. **J. Acoust. Soc. Am.** 137(4):2212.

Guerra, M., A.M. Thode, S.B. Blackwell, and M. Macrander. 2011. Quantifying seismic survey reverberation off the Alaskan North Slope. **J. Acoust. Soc. Am.** 130(5):3046-3058.

Guerra, M., P.J. Dugan, D.W. Ponirakis, M. Popescu, Y. Shiu, and C.W. Clark. 2016. High-resolution analysis of seismic airgun impulses and their reverberant field as contributors to an acoustic environment. p. 371-379 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Hain, J.H.W., W.A.M. Hyman, R.D. Kenney, and H.E. Winn. 1985. The role of cetaceans in the shelf-edge region of the U.S. **Mar. Fish. Rev.** 47(1):13-17.

Hansen, L.J., K.D. Mullin, and C.L. Roden. 1994. Preliminary estimates of cetacean abundance in the northern Gulf of Mexico, and selected species in the U.S. Atlantic exclusive economic zone from vessel surveys. Miami Lab Contrib. No. MIA-93/94-58. Nat. Mar. Fish. Serv., Southeast Fish. Sci. Center, Miami, FL. 14 p.

Harwood, J. and B. Wilson. 2001. The implications of developments on the Atlantic Frontier for marine mammals. **Cont. Shelf Res.** 21(8-10):1073-1093.

Hatch, L.T., C.W. Clark, S.M. Van Parijs, A.S. Frankel, and D.W. Ponirakis. 2012. Quantifying loss of acoustic communication space for right whales in and around a U.S. National Marine Sanctuary. **Conserv. Biol.** 26(6):983-994.

Hawkins, A.D., A.E. Pembroke, and A.N. Popper. 2015. Information gaps in understanding the effects of noise on fishes and invertebrates. **Rev. Fish Biol. Fisher.** 25(1):39-64. https://doi.org/10.1007/s11160-014-9369-3.

Heide-Jørgensen, M.P., R.G. Hansen, S. Fossette, N.J. Nielsen, M.V. Jensen, and P. Hegelund. 2013a. Monitoring abundance and hunting of narwhals in Melville Bay during seismic surveys. September 2013. Greenland Institute of Natural Resources. 56 p. Accessed in December 2015 at http://www.natur.gl/fileadmin/user_files/Dokumenter/PAFU/Monitoring_abundance_and_hunting_of_narwhals_in_Melville_Bay.pdf.

Heide-Jørgensen, M.P., R.G. Hansen, K. Westdal, R.R. Reeves, and A. Mosbech. 2013b. Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments? **Biol. Conserv.** 158:50-54.

Heiler, J., S.H. Elwen, H.J. Kriesell, and T. Gridley. 2016. Changes in bottlenose dolphin whistle parameters related to vessel presence, surface behaviour and group composition. **Animal Behav.** 117:167-177.

Hermannsen, L., J. Tougaard, K. Beedholm, J. Nabe-Nielsen, and P.T. Madsen. 2014. High frequency components of ship noise in shallow water with a discussion of implications for harbor porpoises (*Phocoena phocoena*). **J. Acoust. Soc. Am.** 136(4):1640-1653.

Heyning, J.E. and M.E. Dahlheim. 1988. *Orcinus orca*. **Mammal. Spec.** 304:1-9.

Heyning, J.E. and J.G. Mead. 2009. Cuvier's beaked whale *Ziphius cavitostris*. p. 294-295 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Hoelzel, A.R., C.W. Potter, and P.B. Best. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. **Proc. R. Soc. Lond. B** 265:1177-1183.

Holt, M.M., D.P. Noren, R.C. Dunkin, and T.M. Williams. 2015. Vocal performance affects metabolic rate in dolphins: Implications for animals communicating in noisy environments. **J. Exp. Biol.** 218(11):1647-1654.

Hopkins, J.L., M.A. Smultea, T.A. Jefferson, and A.M. Zoidis. 2009. Rare sightings of a Bryde's whale (*Balaenoptera brydei/edeni*) and subadult sei whales (*B. borealis*) (Cetacea: Balaenopteridae) northeast of Oahu in November 2007. p. 115 *In*: Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Canada, October 2009. 306 p.

Horwood, J. 2009. Sei whale *Balaenoptera borealis*. p. 1001-1003 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Houghton, J., M.M. Holt, D.A. Giles, M.B. Hanson, C.K. Emmons, J.T. Hogan, T.A. Branch, and G.R. VanBlaricom. 2015. The relationship between vessel traffic and noise levels received by killer whales (*Orcinus orca*). **PLoS ONE** 10(12): e0140119. doi:10.1371/journal.pone.0140119Huggins, J.L., R.W. Baird, D.L. Webster, D.J. McSweeney, G.S. Schorr, and A.D. Ligon. 2005. Inter-island movements and re-sightings of melon-headed whales within the Hawaiian archipelago. p. 133-134 *In*: Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., San Diego, CA. 12–16 Dec. 2005.

Houser, D.S., C.D. Champagne, D.E. Crocker. N.M. Kellar, J. Cockrem, T. Romano, R.K. Booth, and S.K. Wasser. 2016. Natural variation in stress hormones, comparisons across matrices, and impacts resulting from induced stress in the bottlenose dolphin. p. 467-471 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Isojunno, S., C. Curé, P.H. Kvadsheim, F.-P.A. Lam, P.L. Tyack, P.J. Wensveen, and P.J.O. Miller. 2016. Sperm whales reduce foraging effort during exposure to 1–2 kHz sonar and killer whale sounds. **Ecol. Appl.** 26(1), 77-93.

IUCN (The World Conservation Union). 2015. The IUCN Red List of Threatened Species. Version 2015-4. Accessed in January 2016 at http://www.iucnredlist.org.

IWC (International Whaling Commission). 2007. Report of the standing working group on environmental concerns. Annex K to Report of the Scientific Committee. **J. Cetac. Res. Manage.** 9(Suppl.):227-260.

IWC (International Whaling Commission). 2015. Whale population estimates. Accessed in December 2015 at https://iwc.int/estimate.

Jackson, A., T. Gerrodette, S. Chivers, M. Lynn, S. Rankin, and S. Mesnick. 2008. Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard NOAA ships *David Starr Jordan* and *McArthur II*, July 28–December 7, 2006. NOAA Tech. Memo. NMFS-SWFSC-421. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 45 p.

Jackson, J.A., D.J. Steel, P. Beerli, B.C. Congdon, C. Olavarria, M.S. Leslie, C. Pomilla, H. Rosenbaum, and C.S. Baker. 2014. Global diversity and oceanic divergence of humpback whales (*Megaptera novaeangliae*). **Proc. R. Soc. B** 281(1786):20133222. http://dx.doi.org/10.1098/rspb.2013.3222.

Jaquet, N. and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. **Mar. Ecol. Prog. Ser.** 135(1-3):1-9.

Jefferson, T.A. 2009. Rough-toothed dolphin *Steno bredanensis*. p. 990-992 *In*: W.F Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, New York, NY. 1316 p.

Jefferson, T.A. and N.B. Barros. 1997. *Peponocephala electra*. **Mammal. Spec.** 553:1-6.

Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2008. Marine mammals of the world: a comprehensive guide to their identification. Academic Press, New York, NY. 573 p.

Jefferson, T.A., C.R. Weir, R.C. Anderson, L.T. Ballance, R.D. Kenney, J.J. Kiszka. 2014. Global distribution of Risso's dolphin *Grampus griseus*: A review and critical evaluation. **Mamm. Rev.** 44(1):56-68.

Jensen, F.H., L. Bejder, M. Wahlberg, N. Aguilar Soto, M. Johnson, and P.T. Madsen. 2009. Vessel noise effects on delphinid communication. **Mar. Ecol. Prog. Ser.** 395:161-175.

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin, and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. **Environ. Monit. Assess.** 134(1-3):1-19.

Kastak, D. and C. Reichmuth. 2007. Onset, growth, and recovery of in-air temporary threshold shift in a California sea lion (*Zalophus californianus*). **J. Acoust. Soc. Am.** 122(5):2916-2924.

Kastak, D., J. Mulsow, A. Ghoul, and C. Reichmuth. 2008. Noise-induced permanent threshold shift in a harbor seal. **J. Acoust. Soc. Am.** 123(5):2986.

Kastelein, R., R. Gransier, L. Hoek, and J. Olthuis. 2012a. Temporary threshold shifts and recovery in a harbor porpoise (*Phocoena phocoena*) after octave-band noise at 4 kHz. **J. Acoust. Soc. Am.** 132(5):3525-3537.

Kastelein, R.A., R. Gransier, L. Hoek, A. Macleod, and J.M. Terhune. 2012b. Hearing threshold shifts and recovery in harbor seals (*Phoca vitulina*) after octave-band noise exposure at 4 kHz. **J. Acoust. Soc. Am.** 132(4):2745-2761.

Kastelein, R.A., R. Gransier, L. Hoek, and C.A.F. de Jong. 2012c. The hearing threshold of a harbor porpoise (*Phocoena phocoena*) for impulsive sounds (L). **J. Acoust. Soc. Am.** 132(2):607-610.

Kastelein, R.A., N. Steen, R. Gransier, and C.A.F. de Jong. 2013a. Brief behavioral response threshold level of a harbor porpoise (*Phocoean phocoena*) to an impulsive sound. **Aquat. Mamm.** 39(4):315-323.

Kastelein, R.A., R. Gransier, and L. Hoek, and M. Rambags. 2013b. Hearing frequency thresholds of a harbour porpoise (*Phocoena phocoena*) temporarily affected by a continuous 1.5-kHz tone. **J. Acoust. Soc. Am.** 134(3):2286-2292.

Kastelein, R., R. Gransier, and L. Hoek. 2013c. Comparative temporary threshold shifts in a harbour porpoise and harbour seal, and severe shift in a seal. **J. Acoust. Soc. Am.** 134(1):13-16.

Kastelein, R.A., L. Hoek, R. Gransier, M. Rambags, and N. Clayes. 2014. Effect of level, duration, and inter-pulse interval of 1–2 kHz sonar signal exposures on harbor porpoise hearing. **J. Acoust. Soc. Am.** 136:412-422.

Kastelein, R.A., R. Gransier, J. Schop, and L. Hoek. 2015a. Effects of exposure to intermittent and continuous 6-7 kHz sonar sweeps on harbor porpoise (*Phocoena phocoena*) hearing. **J. Acoust. Soc. Am.** 137(4):1623-1633.

Kastelein, R.A., R. Gransier, M.A.T. Marijt, and L Hoek. 2015b. Hearing frequency thresholds of harbor porpoises (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds. **J. Acoust. Soc. Am.** 137(2):556-564.

Kastelein, R.A., I. van den Belt, R. Gransier, and T. Johansson. 2015c. Behavioral responses of a harbor porpoise (*Phocoena phocoena*) to 25.5- to 24.5-kHz sonar down-sweeps with and without side bands. **Aquatic Mamm.** 41(4):400-411.

Kastelein, R.A., L. Helder-Hoek, G. Janssens, R. Gransier, and T. Johansson. 2015d. Behavioral responses of harbor seals (*Phoca vitulina*) to sonar signals in the 25-kHz range. **Aquatic Mamm.** 41(4):388-399.

Kastelein, R.A., R. Gransier, and L. Hoek. 2016. Cumulative effects of exposure to continuous and intermittent sounds on temporary hearing threshold shifts induced in a harbor porpoise (*Phocoena phocoena*). p. 523-528 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

Kasuya, T. 1986. Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. **Sci. Rep. Whales Res. Inst.** 37:61-83.

Kato, H. and W.F. Perrin. 2009. Bryde's whales *Balaenoptera edeni/brydei.* p. 158-163 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Kenney, R.D. and H.E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. **Continent. Shelf Res.** 7(2):107-114.

Ketten, D.R. 2012. Marine mammal auditory system noise impacts: evidence and incidence. p. 207-212 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Klatsky, L.J. 2004. Movement and dive behavior of bottlenose dolphins (*Tursiops truncatus*) near the Bermuda Pedestal. M.Sc. Thesis. San Diego State University, CA. 31 p.

Klinck, H., S.L. Nieukirk, D.K. Mellinger, K. Klinck, H. Matsumoto, and R.P. Dziak. 2012. Seasonal presence of cetaceans and ambient noise levels in polar waters of the North Atlantic. **J. Acoust. Soc. Am.** 132(3):EL176-EL181.

Krieger, K.J. and B.L. Wing. 1984. Hydroacoustic surveys and identification of humpback whale forage in Glacier Bay, Stephens Passage, and Frederick Sound, southeastern Alaska, summer 1983. NOAA Tech. Memo. NMFS F/NWC-66. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 60 p. NTIS PB85-183887.

Krieger, K.J. and B.L. Wing. 1986. Hydroacoustic monitoring of prey to determine humpback whale movements. NOAA Tech. Memo. NMFS F/NWC-98. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 63 p. NTIS PB86-204054.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). p. 183-212 *In*: S.H. Ridgway and R. Harrison (eds.) Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Kujawa, S.G. and M.C. Liberman. 2009. Adding insult to injury: cochlear nerve degeneration after "temporary" noise-induced hearing loss. **J. Neurosci.** 29(45):14077-14085.

Laws, R. 2012. Cetacean hearing-damage zones around a seismic source. p. 473-476 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Le Prell, C.G. 2012. Noise-induced hearing loss: From animal models to human trials. p. 191-195 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Liberman, C. 2016. Noise-induced hearing loss: permanent versus temporary threshold shifts and the effects of hair cell versus neuronal degeneration. p. 1-7 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Lockyer, C.H. and S.G. Brown. 1981. The migration of whales. p. 105-137 *In*: D.J. Aidley (ed.), Animal migration. Soc. Exp. Biol. Seminar Ser. 13, Cambridge University Press, U.K.

Luís, A.R., M.N. Couchinho, and M.E. Dos Santos. 2014. Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. **Mar. Mamm. Sci.** 30(4):1417-1426.

Lurton, X. 2016. Modelling of the sound field radiated by multibeam echosounders for acoustical impact assessment. **Appl. Acoust.** 101:201-216.

Lusseau, D. and L. Bejder. 2007. The long-term consequences of short-term responses to disturbance experience from whale watching impact assessment. **Int. J. Comp. Psych.** 20(2-3):228-236.

Lyamin, O.I., S.M. Korneva, V.V. Rozhnov, and L.M. Mukhametov. 2016. Cardiorespiratory responses to acoustic noise in belugas. p. 665-672 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

MacGillivray, A.O., R. Racca, and Z. Li. 2014. Marine mammal audibility of selected shallow-water survey sources. **J. Acoust. Soc. Am.** 135(1):EL35-EL40.

MacLeod, C.D., N. Hauser, and H. Peckham. 2004. Diversity, relative density and structure of the cetacean community in summer months east of Great Abaco, Bahamas. **J. Mar. Biol. Assoc. U.K.** 84(2):469-474.

MacLeod, C.D., W.F. Perrin, R. Pitman, J. Barlow, L.T. Ballance, A. D'Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). **J. Cetac. Res. Manage.** 7(3):271-286.

Mahaffy, S.D. 2012. Site fidelity, associations and long-term bonds of short-finned pilot whales off the island of Hawaii. M.Sc. Thesis, Portland State University. 151 p. Accessed in November 2015 at: http://www.cascadiaresearch.org/Hawaii/Mahaffy_MScThesis_2012.pdf

Malme, C.I. and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. p. 253-280 *In*: G.D. Greene, F.R. Engelhard, and R.J. Paterson (eds.), Proc. Workshop on Effects of Explosives Use in the Marine Environment, Jan. 1985, Halifax, NS. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Canada. 398 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for MMS, Alaska OCS Region, Anchorage, AK. NTIS PB86-218377.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark, and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Rep. 5851. OCS Study MMS 85-0019. Rep. from BBN Labs Inc., Cambridge, MA, for MMS, Anchorage, AK. NTIS PB86-218385.

Malme, C.I., B. Würsig, J.E. Bird, and P. Tyack. 1986. Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling. BBN Rep. 6265. OCS Study MMS 88-0048. Outer Contin. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK. 56(1988):393-600. NTIS PB88-249008.

Malme, C.I., B. Würsig, B., J.E. Bird, and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. p. 55-73 *In*: W.M. Sackinger, M.O. Jeffries, J.L. Imm, and S.D. Treacy (eds.), Port and Ocean Engineering Under Arctic Conditions, Vol. II: Symposium on noise and marine mammals. Univ. Alaska Fairbanks, Fairbanks, AK. 111 p.

Marques, F.F.C. and S.T. Buckland. 2004. Covariate models for the detection function. p. 31-47 *In*: S.T. Buckland, D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas (eds.), Advanced distance sampling. Oxford University Press, Oxford, UK. 434 p.

Martien, K.K., R.W. Baird, N.M. Hedrick, A.M. Gorgone, J.L. Thieleking, D.J. McSweeney, K. Robertson, and D.L. Webster. 2012. Population structure of island-associated dolphins: evidence from mitochondrial and microsatellite markers for common bottlenose dolphins (*Tursiops truncatus*) around the main Hawaiian Islands. **Mar. Mamm. Sci.** 28(3):E208-E332.

Martin, S.W., T.A. Marques, L. Thomas, R.P. Morrissey, S. Jarvis, N. DiMarzio, D. Moretti, and D.K. Mellinger. 2012. Estimating minke whale (*Balaenoptera acutorostrata*) boing sound density using passive acoustic sensors. **Mar. Mamm. Sci.** 29(1):142-158.

Martins, D.T.L., M.R. Rossi-Santos, and F.J.D.L. Silva. 2016. Effects of anthropogenic noise on the acoustic behaviour of *Sotalia guianensis* (Van Bénéden, 1864) in Pipa, North-eastern Brazil. **J. Mar. Biol. Assoc. U.K.** https://doi.org/10.1017/S0025315416001338.

Mate, B.R., B.A. Lagerquist, and J. Calambokidis. 1999. Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. **Mar. Mamm. Sci.** 15(4):1246-1257.

McAlpine, D.F. 2009. Pygmy and dwarf sperm whales *Kogia breviceps* and *K. sima*. p. 936-938 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe, and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: Preliminary results of observations about a working seismic vessel and experimental exposures. **APPEA J.** 38:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188 p.

McDonald, T.L., W.J. Richardson, K.H. Kim, and S.B. Blackwell. 2010. Distribution of calling bowhead whales exposed to underwater sounds from Northstar and distant seismic surveys, 2009. p. 6-1 to 6-38 *In*: W.J. Richardson (ed.), Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea: Comprehensive report for 2005–2009. LGL Rep. P1133-6. Rep. by LGL Alaska Res. Assoc. Inc., Anchorage, AK, Greeneridge Sciences Inc., Santa Barbara, CA, WEST Inc., Cheyenne, WY, and Applied Sociocult. Res., Anchorage, AK, for BP Explor. (Alaska) Inc., Anchorage, AK. 265 p.

McDonald, T.L., W.J. Richardson, K.H. Kim, S.B. Blackwell, and B. Streever. 2011. Distribution of calling bowhead whales exposed to multiple anthropogenic sound sources and comments on analytical methods. p. 199 *In*: Abstr. 19th Bienn. Conf. Biol. Mar. Mamm., 27 Nov.–2 Dec. 2011, Tampa, FL. 344 p.

McGeady, R., B.J. McMahon, and S. Berrow. 2016. The effects of surveying and environmental variables on deep diving odontocete stranding rates along Ireland's coast. **Proceedings of Meetings on Acoustics 4ENAL** 27(1):040006. https://doi.org/10.1121/2.0000281.

McSweeney, D.J., R.W. Baird, and S.D. Mahaffy. 2007. Site fidelity, associations, and movements of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales off the island of Hawai'i. **Mar. Mamm. Sci.** 23(3):666-687.

Mead, J.G. and C.W. Potter. 1995. Recognizing two populations of the bottlenose dolphins (*Tursiops truncatus*) off the Atlantic coast of North America: morphological and ecological considerations. **IBI Reports** 5:31-44.

Meier, S.K., S.B. Yazvenko, S.A. Blokhin, P. Wainwright, M.K. Maminov, Y.M. Yakovlev, and M.W. Newcomer. 2007. Distribution and abundance of western gray whales off northeastern Sakhalin Island, Russia, 2001-2003. **Environ. Monit. Assess.** 134(1-3):107-136.

Melcón, M.L., A.J. Cummins, S.M. Kerosky, L.K. Roche, S.M. Wiggins, and J.A. Hildebrand. 2012. Blue whales respond to anthropogenic noise. **PLoS ONE** 7(2):e32681. http://dx.doi.org/10.1371/journal.pone.0032681.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton, and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. by LGL Ltd., King City, ON, and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray, and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001–2002. p. 511-542 *In*: S.L. Armsworthy, P.J. Cranford, and K. Lee (eds.), Offshore oil and gas environmental effects monitoring/approaches and technologies. Battelle Press, Columbus, OH. 631 p.

Miller, P.J.O., M.P. Johnson, P.T. Madsen, N. Biassoni, M. Quero, and P.L. Tyack. 2009. Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. **Deep-Sea Res.** I 56(7):1168-1181.

Miller, P.J.O., P.H. Kvadsheim, F.P.A. Lam, P.J. Wensveen, R. Antunes, A.C. Alves, F. Visser, L. Kleivane, P.L. Tyack, and L.D. Sivle. 2012. The severity of behavioral changes observed during experimental exposures of killer (*Orcinus orca*), long-finned pilot (*Globicephala melas*), and sperm whales (*Physeter macrocephalus*) to naval sonar. **Aquat. Mamm.** 38(4):362-401.

Miller, P.J.O., R.N. Antunes, P.J. Wensveen, F.I.P. Samarra, A.C. Alves, P.L. Tyack, P.H. Kvadsheim, L. Kleivane, F.-P.A. Lam, M.A. Ainslie, and L. Thomas. 2014. Dose-response relationships for the onset of avoidance of sonar by free-ranging killer whales. **J. Acoust. Soc. Am.** 135(2):975-993.

Miyazaki, N. and W.F. Perrin. 1994. Rough-toothed dolphin *Steno bredanensis* (Lesson, 1828). p. 1-21 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Mobley, J., Jr., S. Spitz, and R. Grotefendt. 2001. Abundance of humpback whales in Hawaiian waters: results of 1993–2000 aerial surveys. Prepared for the Hawaiian Islands Humpback Whale National Marine Sanctuary, NOAA, U.S. Department of Commerce, and the Hawaiii Department of Land and Natural Resources. 16 p. Accessed in January 2016 at http://hawaiihumpbackwhale.noaa.gov/documents/_science/ HIHWNMS_Research_Mobley.pdf.

Mobley, J.R., Jr., S.S. Spitz, K.A. Forney, R. Grotefendt, and P.H. Forestell. 2000. Distribution and abundance of odontocete species in Hawaiian waters: preliminary results of 1993-98 aerial surveys. Southwest Fish. Sci. Cen. Admin. Rep. LJ-00-14C. 26 p.

Monaco, C., J.M. Ibáñez, F. Carrión, and L.M. Tringali. 2016. Cetacean behavioral responses to noise exposure generated by seismic surveys: how to mitigate better? **Annals of Geoph.** 59(4)S0436. https://doi.org/10.4401/ag-7089.

Moore, S.E., K.M. Stafford, M.E. Dahlheim, C.G. Fox, H.W. Braham, J.J. Polovina, and D.E. Bain. 1998. Seasonal variation in reception of fin whale calls at five geographic areas in the North Pacific. **Mar. Mamm. Sci.** 14(3):617-627.

Moore, S.E., W.A. Watkins, M.A. Daher, J.R. Davies, and M.E. Dahlheim. 2002. Blue whale habitat associations in the Northwest Pacific: analysis of remotely-sensed data using a Geographic Information System. **Oceanography** 15(3):20-25.

Moore, S.E., K.M. Stafford, D.K. Mellinger, and C.G. Hildebrand. 2006. Listening for large whales in the offshore waters of Alaska. BioScience 56(1):49-55.

Moulton, V.D. and M. Holst. 2010. Effects of seismic survey sound on cetaceans in the Northwest Atlantic. Environ. Stud. Res. Funds Rep. 182. St. John's, NL. 28 p. Accessed in December 2015 at http://www.esrfunds.org/pdf/182.pdf.

Muir, J.E., L. Ainsworth, R. Joy, R. Racca, Y. Bychkov, G. Gailey, V. Vladimirov, S. Starodymov, and K. Bröker. 2015. Distance from shore as an indicator of disturbance of gray whales during a seismic survey off Sakhalin Island, Russia. **Endang. Species Res.** 29(2):161-178.

Muir, J.E., L. Ainsworth, R. Racca, Y. Bychkov, G. Gailey, V. Vladimirov, S. Starodymov, and K. Broker. 2016. Gray whale densities during a seismic survey off Sakhalin Island, Russia. **Endang. Species Res.** 29(2):211-227.

Nachtigall, P.E. and A.Y. Supin. 2013. A false killer whale reduces its hearing sensitivity when a loud sound is preceded by a warning. **J. Exp. Biol.** 216(16):3062-3070.

Nachtigall, P.E. and A.Y. Supin. 2014. Conditioned hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). **J. Exp. Biol.** 217(15):2806-2813.

Nachtigall, P.E. and A.Y. Supin. 2015. Conditioned frequency-dependent hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). **J. Exp. Biol.** 218(7):999-1005.

Nachtigall, P.E. and A.Y. Supin. 2016. Hearing sensation changes when a warning predict a loud sound in the false killer whale (*Pseurorca crassidens*). p. 743-746 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

New, L.F., J. Harwood, L. Thomas, C. Donovan, J.S. Clark, G. Hastie, P.M. Thompson, B. Cheney, L. Scott-Hayward, and D. Lusseau. 2013. Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. **Funct. Ecol.** 27(2):314-322.

Nieukirk, S.L., D.K. Mellinger, S.E. Moore, K. Klinck, R.P. Dziak, and J. Goslin. 2012. Sounds from airguns and fin whales recorded in the mid Atlantic Ocean, 1999–2009. **J. Acoust. Soc. Am.** 131(2):1102-1112.

NMFS (National Marine Fisheries Service). 2000. Small takes of marine mammals incidental to specified activities: Marine seismic-reflection data collection in southern California/Notice of receipt of application. **Fed. Regist.** 65(60, 28 Mar.):16374-16379.

NMFS (National Marine Fisheries Service). 2001. Small takes of marine mammals incidental to specified activities: Oil and gas exploration drilling activities in the Beaufort Sea/Notice of issuance of an incidental harassment authorization. **Fed. Regist.** 66(26, 7 Feb.):9291-9298.

NMFS (National Marine Fisheries Service). 2013a. Takes of marine mammals incidental to specified activities; marine geophysical survey on the Mid-Atlantic Ridge in the Atlantic Ocean, April 2013, through June 2013. Notice; issuance of an incidental harassment authorization. **Fed. Regist.** 78(72, 15 Apr.):22239-22251.

NMFS (National Marine Fisheries Service). 2013b. Takes of marine mammals incidental to specified activities; marine geophysical survey in the northeast Atlantic Ocean, June to July 2013. Notice; issuance of an incidental harassment authorization. **Fed. Regist.** 78(109, 6 Jun.):34069-34083.

NMFS (National Marine Fisheries Service). 2013c. Effects of oil and gas activities in the Arctic Ocean: Supplemental draft environmental impact statement. U.S. Depart. Commerce, NOAA, NMFS, Office of Protected Resources. Accessed in June 2015 at http://www.nmfs.noaa.gov/pr/permits/eis/arctic_sdeis.pdf.

NMFS (National Marine Fisheries Service). 2014. Hawaiian monk seal recovery actions programmatic environmental impact statement. U.S. Dept. Comm., NOAA, Silver Springs, MD. 580 p.

NMFS (National Marine Fisheries Service). 2016a. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: underwater acoustic thresholds for onset of permanent and temporary threshold shifts. U.S. Dept. of Commer., NOAA. 178 p.

NMFS (National Marine Fisheries Service). 2016b. Endangered and threatened species; identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and revision of species-wide listing. Final Rule. **Fed. Regist**. 81(174, 8 Sept.):62260-62320.

NMFS (National Marine Fisheries Service). 2017. Endangered and threatened marine species under NMFS' jurisdiction. Accessed in March 2017 at http://www.nmfs.noaa.gov/pr/species/esa/.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. **Mammal Rev.** 37(2):81-115.

Nowacek, D.P., A.I. Vedenev, B.L. Southall, and R. Racca. 2012. Development and implementation of criteria for exposure of western gray whales to oil and gas industry noise. p. 523-528 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Nowacek, D.P., K. Bröker, G. Donovan, G. Gailey, R. Racca, R.R. Reeves, A.I. Vedenev, D.W. Weller, and B.L. Southall. 2013a. Responsible practices for minimizing and monitoring environmental impacts of marine seismic surveys with an emphasis on marine mammals. **Aquat. Mamm.** 39(4):356-377.

Nowacek, D.P., K. Bröker, G. Donovan, G. Gailey, R. Racca, R.R. Reeves, A.I. Vedenev, D.W. Weller, and B.L. Southall. 2013b. Environmental impacts of marine seismic surveys with an emphasis on marine mammals. **Aquatic Mamm.** 39(4):356-377.

Nowacek, D.P., C.W. Clark, P. Mann, P.J.O. Miller, H.C. Rosenbaum, J.S. Golden, M. Jasny, J. Kraska, and B.L. Southall. 2015. Marine seismic surveys and ocean noise: Time for coordinated and prudent planning. **Front. Ecol. Environ.** 13(7):378-386. http://dx.doi.org/10.1890/130286.

NRC (National Research Council). 2005. Marine mammal populations and ocean noise/Determining when noise causes biologically significant effects. U.S. Nat. Res. Counc., Ocean Studies Board, Committee on characterizing biologically significant marine mammal behavior (D.W. Wartzo, J. Altmann, W. Au, K. Ralls, A. Starfield, and P.L. Tyack). Nat. Acad. Press, Washington, DC. 126 p.

NSF and USGS (NSF and U.S. Geological Survey). 2011. Final programmatic environmental impact statement/Overseas environmental impact statement for marine seismic research funded by the National Science Foundation or conducted by the U.S. Geological Survey. Accessed in March 2015 at http://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/nsf-usgs-final-eis-oeis-with-appendices.pdf.

OBIS (Ocean Biogeographic Information System). 2016. Global biodiversity indices from the Ocean Biogeographic Information System. Intergovernmental Oceanographic Commission of UNESCO. Accessed in January 2016 at http://www.iobis.org.

O'Brien, J.M., S. Beck, S.D. Berrow, M. Andre, M. vand er Schaar, I. O'Connor, and E.P. McKeown. 2016. The use of deep water berths and the effects of noise on bottlenose dolphins in the Shannon Estuary cSAC. p. 775-783 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.

Odell, D.K. and K.M. McClune. 1999. False killer whale *Pseudorca crassidens* (Owen, 1846). p. 213-243 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.

Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. **Rep. Int. Whal. Comm.** 25:114-126.

Oleson, E.M., R.W. Baird, K.K. Martien, and B.L. Taylor. 2013. Island-associated stocks of odontocetes in the main Hawaiian Islands: A synthesis of available information to facilitate evaluation of stock structure. PIFSC Working WP-13-003. 41 p.

Olson, P.A. 2009. Pilot whales *Globicephala melas* and *G. macrorynchus*. p. 847-852 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Oswald, J.N., W.W.L. Au, and F. Duennebier. 2011. Minke whale (*Balaenoptera acutorostrata*) boings detected at the Station ALOHA Cabled Observatory. **J. Acoust. Soc. Am.** 129(5):3353-3360.

Papale, E., M. Gamba, M. Perez-Gil, V.M. Martin, and C. Giacoma. 2015. Dolphins adjust species-specific frequency parameters to compensate for increasing background noise. **PLoS ONE** 10(4):e0121711. https://doi.org/10.1371/journal.pone.0121711.

Parks, S.E., M. Johnson, D. Nowacek, and P.L. Tyack. 2011. Individual right whales call louder in increased environmental noise. **Biol. Lett.** 7(1):33-35.

Parks, S.E., M.P. Johnson, D.P. Nowacek, and P.L. Tyack. 2012. Changes in vocal behaviour of North Atlantic right whales in increased noise. p. 317-320 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.

Parks, S.E., K. Groch, P. Flores, R. Sousa-Lima, and I.R. Urazghildiiev. 2016. Humans, fish, and whales: How right whales modify calling behavior in response to shifting background noise conditions. p. 809-813 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

Payne, R. 1978. Behavior and vocalizations of humpback whales (*Megaptera* sp.). *In*: K.S Norris and R.R. Reeves (eds.), Rep. Worksh. problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. MCC-77/03. Rep. from Sea Life Inc., Makapuu Pt., HI, for U.S. Mar. Mamm. Comm., Washington, DC.

Perrin, W.F. 2009a. Pantropical spotted dolphin *Stenella attenuata*. p. 819-821 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Perrin, W.F. 2009b. Common dolphins *Delphinus delphis* and *D. capensis*. p. 255-259 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Perrin, W.F., C.E. Wilson, and F.I. Archer II. 1994a. Striped dolphin *Stenella coeruleoalba* (Meyen, 1833). p. 129-159 *In*: S. H. Ridgway and R. J. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, San Diego, CA. 416 p.

Perrin, W.F., S. Leatherwood, and A. Collet. 1994b. Fraser's dolphin *Lagenodelphis hosei* Fraser, 1956. p. 225-240 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 5: The first book of dolphins. Academic Press, London, U.K. 416 p.

Perryman, W.L. 2009. Melon-headed whale *Peponocephala electra*. p. 719-721 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Pierson, M.O., J.P. Wagner, V. Langford, P. Birnie, and M.L. Tasker. 1998. Protection from, and mitigation of, the potential effects of seismic exploration on marine mammals. Chapter 7 *In*: M.L. Tasker and C. Weir (eds.), Proc. Seismic Mar. Mamm. Worksh., 23–25 Jun. 1998, London, U.K.

Pike, G.C. and I.B. MacAskie. 1969. Marine mammals of British Columbia. **Bull. Fish. Res. Board Can.** 171. 54 p.

Pirotta, E., R. Milor, N. Quick, D. Moretti, N. Di Marzio, P. Tyack, I. Boyd, and G. Hastie. 2012. Vessel noise affects beaked whale behavior: Results of a dedicated acoustic response study. **PLoS ONE** 7(8):e42535. http://dx.doi.org/10.1371/journal.pone.0042535.

Pirotta, E., K.L. Brookdes, I.M. Graham, and P.M. Thompson. 2014. Variation in harbour porpoise activity in response to seismic survey noise. **Biol. Lett.** 10:20131090. http://dx.doi.org/10.1098/rsbl.2013.1090.

Pirotta, E., N.D. Merchant, P.M. Thompson, T.R. Barton, and D. Lusseau. 2015. Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. **Biol. Conserv.** 181:82-98.

Pitman, R.L. 2009a. Indo-Pacific beaked whale *Indopacetus pacificus*. p. 600-602 *In*: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Pitman, R.L. 2009b. Mesoplodont whales *Mesoplodon* spp. p. 721-726 *In*: W. F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Popov, V.V., A.Y. Supin, D. Wang, K. Wang, L. Dong, and S. Wang. 2011. Noise-induced temporary threshold shift and recovery in Yangtze finless porpoises *Neophocaena phocaenoides asiaeorientalis*. **J. Acoust. Soc. Am.** 130(1):574-584.

Popov, V.V., A.Y. Supin, V.V. Rozhnov, D.I. Nechaev, E.V. Sysuyeva, V.O. Klishin, M.G. Pletenko, and M.B. Tarakanov. 2013. Hearing threshold shifts and recovery after noise exposure in beluga whales, *Delphinapterus leucas*. **J. Exper. Biol.** 216(9):1587-1596.

Popov, V.V., D.I. Nechaev, E.V. Sysueva, V.V. Rozhnov, and A.Y. Supin. 2015. Spectrum pattern resolution after noise exposure in a beluga whale, *Delphinapterus leucas*: Evoked potential study. **J. Acoust. Soc. Am.** 138(1):377-388.

Popov, V., A. Supin, D. Nechaev, E.V. Sysueva, and V. Rozhnov. 2016. Temporary threshold shifts in naïve and experienced belugas: Can dampening of the effects of fatiguing sounds be learned? p. 853-859 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

Popper, A.N. 2009. Are we drowning out fish in a sea of noise? **Mar. Sci.** 27:18-20.

Popper, A.N. and M.C. Hastings. 2009a. The effects of human-generated sound on fish. **Integr. Zool.** 4(1):43-52.

Popper, A.N. and M.C. Hastings. 2009b. The effects of anthropogenic sources of sound on fishes. **J. Fish Biol.** 75(3):455-489.

Popper, A.N., A.D. Hawkins, R.R. Fay, D.A. Mann, S, Bartol, T.J. Carlson, S. Coombs, W.T. Ellison, R.L. Gentry, M.B. Halvorsen, S. Løkkeborg, P.H. Rogers, B.L. Southall, D.G. Zeddies, and W.N. Tavolga. 2014. Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer Briefs in Oceanography. ASA Press—ASA S3/SC1.4 TR-2014. 75 p.

Psarakos, S., D.L. Herzing, and K. Marten. 2003. Mixed-species associations between pantropical spotted dolphins (*Stenella attenuata*) and Hawaiian spinner dolphins (*Stenella longirostris*) off Oahu, Hawaii. **Aquat. Mamm.** 29(3):390-395.

Radford, A.N., E. Kerridge, and S.D. Simpson. 2014. Acoustic communication in a noisy world: Can fish compete with anthropogenic noise? **Behav. Ecol.** 25(5):1022-1030.

Rankin, S. and J. Barlow. 2005. Source of the North Pacific "boing" sound attributed to minke whales. **J. Acoust. Soc. Am.** 118(5):3346-3351.

Rankin, S., T.F. Norris, M.A. Smultea, C. Oedekoven, A.M. Zoidis, E. Silva, and J. Rivers. 2007. A visual sighting and acoustic detections of minke whales, *Balaenoptera acutorostrata* (Cetacea: Balaenopteridae), in near-shore Hawaiian waters. **Pacific Sci.** 61(3):395-398.

Rankin, S., J. Barlow, J. Oswald, and L. Balance. 2008. Acoustic studies of marine mammals during seven years of combined visual and acoustic line-transect surveys for cetaceans in the eastern and central Pacific Ocean. NOAA Tech. Memo. NMFS-SWFSC-429. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 58 p.

Redfern, J.V., M.F. McKenna, T.J. Moore, J. Calambokidis, M.L. Deangelis, E.A. Becker, J. Barlow, K.A. Forney, P.C. Fiedler, and S.J. Chivers. 2013. Assessing the risk of ships striking large whales in marine spatial planning. **Conserv. Biol.** 27(2):292-302.

Reeves, R.R., P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber. 1998. Recovery plan for the blue whale (*Balaenoptera musculus*). Office of Protected Resources, NMFS, NOAA, Silver Spring, MD. 30 p.

Reeves, R.R., S. Leatherwood, and R.W. Baird. 2009. Evidence of a possible decline since 1989 in false killer whales (*Pseudorca crassidens*) around the main Hawaiian Islands. **Pacific Sci.** 63(2):253-261.

Reilly, S.B. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. **Mar. Ecol. Prog. Ser.** 66(1-2):1-11.

Reilly, S.B. and P.C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: Research vessel surveys, 1986–1990. **Fish. Bull.** 92(2):434-450.

Reilly, S.B. and V.G. Thayer. 1990. Blue whale (*Balaenoptera musculus*) distribution in the eastern tropical Pacific. **Mar. Mamm. Sci.** 6(4):265-277.

Rice, A.N., J.T. Tielens, B.J. Estabrook, C.A. Muirhead, A. Rahaman, M. Guerra, and C.W. Clark. 2014. Variation of ocean acoustic environments along the western North Atlantic coast: A case study in context of the right whale migration route. **Ecol. Inform.** 21:89-99.

Rice, D.W. 1978. The humpback whale in the North Pacific: distribution, exploitation and numbers. p. 29-44 *In*: K.S. Norris and R.R. Reeves (eds.), Report on a workshop on problems related to humpback whales (*Megaptera novaeangliae*) in Hawaii. U.S. Dept. Comm. NTIS PB 280 794.

Rice, D.W. 1998. Marine mammals of the world, systematics and distribution. Spec. Publ. 4. Soc. Mar. Mammal., Allen Press, Lawrence, KS. 231 p.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Richardson, W.J., G.W. Miller, and C.R. Greene, Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. **J. Acoust. Soc. Am.** 106(4, Pt. 2): 2281 (Abstract).

Risch, D., P.J. Corkeron, W.T. Ellison, and S.M. Van Parijs. 2012. Changes in humpback whale song occurrence in response to an acoustic source 200 km away. **PLoS One** 7:e29741. http://dx.doi.org/10.1371/.pone.0029741.

Risch, D., P.J. Corkeron, W.T. Ellison, and S.M. Van Parijs. 2014. Formal comment to Gong et al.: Ecosystem scale acoustic sensing reveals humpback whale behavior synchronous with herring spawning processes and re-evaluation finds no effect of sonar on humpback song occurrence in the Gulf of Maine in fall 2006. **PLoS One** 9(10):e109225. http://dx.doi.org/10.1371/journal.pone.0109225.

Robertson, F.C., W.R. Koski, T.A. Thomas, W.J. Richardson, B. Würsig, and A.W. Trites. 2013. Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea. **Endang. Spec. Res.** 21(2):143-160.

Rolland, R.M., S.E. Parks, K.E. Hunt, M. Castellote, P.J. Corkeron, D.P. Nowacek, S.K. Water, and S.D. Kraus. 2012. Evidence that ship noise increases stress in right whales. **Proc. R. Soc. B** 279(1737):2363-2368.

Sairanen, E.E. 2014. Weather and ship induced sounds and the effect of shipping on harbor porpoise (*Phocoena phocoena*) activity. M.Sc. Thesis, University of Helsinki. 67 p. Accessed in September 2015 at https://helda.helsinki.fi/bitstream/handle/10138/153043/Gradu_SairanenEeva(1).pdf?sequence=1.

Salden, D.R. 1993. Effects of research boat approaches on humpback whale behavior off Maui, Hawaii, 1989−1993. p. 94 *In*: Abstr. 10th Bienn. Conf. Biol. Mar. Mamm., Nov. 1993, Galveston, TX. 130 p.

Salden, D.R., L.M. Herman, M. Yamaguchik, and F. Sato. 1999. Multiple visits of individual humpback whales (*Megaptera novaeangliae*) between the Hawaiian and Japanese winter grounds. **Can. J. Zool.** 77(3):504-508.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2016. Temporary shift in masking hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. p. 987-991 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Scholik-Schlomer, A. 2015. Where the decibels hit the water: perspectives on the application of science to real-world underwater noise and marine protected species issues. **Acoustics Today** 11(3):36–44.

Schorr, G.S., R.W. Baird, M.B. Hanson, D.L. Webster, D.J. McSweeney, and R.D. Andrews. 2009. Movements of satellite-tagged Blainville's beaked whales off the island of Hawaii. **Endang. Spec. Res.** 10:203-213.

Sergeant, D.E. 1977. Stocks of fin whales *Balaenoptera physalus* L. in the North Atlantic Ocean. **Rep. Int. Whal. Comm.** 27:460-473.

Sidorovskaia, N., B. Ma, A.S. Ackleh, C. Tiemann, G.E. Ioup, and J.W. Ioup. 2014. Acoustic studies of the effects of environmental stresses on marine mammals in large ocean basins. p. 1155 *In*: AGU Fall Meeting Abstracts, Vol. 1. Accessed in December 2015 at https://agu.confex.com/agu/fm14/meetingapp.cgi#Paper/10591.

Sills, J.M., B.L. Southall, and C. Reichmuth. 2017. The influence of temporally varying noise from seismic air guns on the detection of underwater sounds by seals. **J. Acoust. Soc. Am.** 141(2):996-1008.

Simard, Y., F. Samaran, and N. Roy. 2005. Measurement of whale and seismic sounds in the Scotian Gully and adjacent canyons in July 2003. p. 97-115 *In*: K. Lee, H. Bain, and C.V. Hurley (eds.), Acoustic monitoring and marine mammal surveys in The Gully and outer Scotian Shelf before and during active seismic surveys. Environ. Stud. Res. Funds Rep. 151. 154 p. (Published 2007).

Sivle, L.D., P.H., Kvadsheim, and M.A. Ainslie. 2014. Potential for population-level disturbance by active sonar in herring. **ICES J. Mar. Sci.** 72:558-567.

Sivle, L.D., P.H. Kvadsheim, A. Fahlman, F.P.A. Lam, P.L. Tyack, and P.J.O. Miller. 2012. Changes in dive behavior during naval sonar exposure in killer whales, long-finned pilot whales, and sperm whales. **Front. Physiol.** 3(400). http://dx.doi.org/10.3389/fphys.2012.00400.

Sivle, L.D., P.H. Kvadsheim, C. Cure, S. Isojunno, P.J. Wensveen, F.-P.A. Lam, F. Visser, L. Kleivane, P.L. Tyack, C.M Harris, and P.J.O. Miller. 2015. Severity of expert-identified behavioural responses of humpback whale, minke whale, and northern bottlenose whale to naval sonar. **Aquat. Mamm.** 41(4) :469-502.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. **Aquat. Mamm.** 33(4):411-522.

Southall, B.L., T. Rowles, F. Gulland, R.W. Baird, and P.D. Jepson. 2013. Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (*Peponocephala electra*) in Antsohihy, Madagascar. Accessed in December 2015 at

Stafford, K.M. 2003. Two types of blue whale calls recorded in the Gulf of Alaska. **Mar. Mamm. Sci.** 19(4):682-693.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 1999. Low-frequency whale sounds recorded on hydrophones moored in the eastern tropical Pacific. **J. Acoust. Soc. Am.** 106(6):3687-3698.

Stafford, K.M., S.L. Nieukirk, and C.G. Fox. 2001. Geographic and seasonal variation of blue whale calls in the North Pacific. **J. Cetac. Res. Manage.** 3(1):65-76.

Stafford, K.M., D.K. Mellinger, S.E. Moore, and C.G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999–2002. **J. Acoust. Soc. Am.** 122(6):3378-3390.

Stafford, K.M., J.J. Citta, S.E. Moore, M.A. Daher, and J.E. George. 2009. Environmental correlates of blue and fin whale call detections in the North Pacific Ocean from 1997 to 2002. **Mar. Ecol. Prog. Ser.** 395:37-53.

Stone, C.J. 2015. Marine mammal observations during seismic surveys from 1994–2010. JNCC Rep. No. 463a. 64 p.

Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in U.K. waters. **J. Cetac. Res. Manage.** 8(3):255-263.

Supin, A., V. Popov, D. Nechaev, E.V. Sysueva, and V. Rozhnov. 2016. Is sound exposure level a convenient metric to characterize fatiguing sounds? A study in beluga whales. p. 1123-1129 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

Tenessen, J.B. and S.E. Parks. 2016. Acoustic propagation modeling indicates vocal compensation in noise improves communication range for North Atlantic right whales. **Endang. Species Res.** 30:225-237.

Thode, A.M., K.H. Kim, S.B. Blackwell, C.R. Greene, Jr., C.S. Nations, T.L. McDonald, and A.M. Macrander. 2012. Automated detection and localization of bowhead whale sounds in the presence of seismic airgun surveys. **J. Acoust. Soc. Am.** 131(5):3726-3747.

Thompson, P.M., K.L. Brookes, I.M. Graham, T.R. Barton, K. Needham, G. Bradbury, and N.D. Merchant. 2013. Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. **Proc. Royal Soc. B** 280:20132001. http://dx.doi.org/10.1098/rspb.2013.2001.

Thompson, P.O. and W.A. Friedl. 1982. A long term study of low frequency sound from several species of whales off Oahu, Hawaii. **Cetology** 45:1-19.

Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. **Rep. Int. Whal. Comm. Spec. Iss.** 1:98-106.

Tougaard, J., A.J. Wright, and P.T. Madsen. 2015. Cetacean noise criteria revisited in light of proposed exposure limits for harbour porpoises. **Mar. Poll. Bull.** 90(1-2):196-208.

Tougaard, J., A.J. Wright, and P.T. Madsen. 2016. Noise exposure criteria for harbor porpoises. p. 1167-1173 *In:* A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic Life II. Springer, New York, NY. 1292 p.

Tyack, P.L. and V.M. Janik. 2013. Effects of noise on acoustic signal production in marine mammals. p. 251-271 *In*: H. Brumm (ed.), Animal communication and noise. Springer, Berlin, Heidelberg, Germany. 453 p.

Tyack, P.L., W.M.X. Zimmer, D. Moretti, B.L. Southall, D.E. Claridge, J.W. Durban, C.W. Clark, A. D'Amico, N. DiMarzio, S. Jarvis, E. McCarthy, R. Morrissey, J. Ward, and I.L. Boyd. 2011. Beaked whales respond to simulated and actual navy sonar. **PLoS One** 6(e17009). http://dx.doi.org/10.1371/journal.pone.0017009.

UNEP-WCMC (United Nations Environment Programme-World Conservation Monitoring Centre). 2016. Convention on International Trade in Endangered Species of Wild Flora and Fauna. Appendices I, II, and II. Accessed in January 2016 at http://www.cites.org/eng/app/appendices.php.

USFWS (U.S. Fish and Wildlife Service). 2017. Endangered species. Accessed on 29 March 2017 at https://www.fws.gov/endangered/.

Wade, P.R. and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the eastern tropical Pacific. **Rep. Int. Whal. Comm.** 43:477-493.

Walker, J.L., C.W. Potter, and S.A. Macko. 1999. The diets of modern and historic bottlenose dolphin populations reflected through stable isotopes. **Mar. Mamm. Sci.** 15(2):335-350.

Wang, M.C., W.A. Walker, K.T. Shao, and L.S. Chou. 2002. Comparative analysis of the diets of pygmy sperm whales and dwarf sperm whales in Taiwanese waters. **Acta Zool. Taiwan** 13(2):53-62.

Wartzok, D., A.N. Popper, J. Gordon, and J. Merrill. 2004. Factors affecting the responses of marine mammals to acoustic disturbance. **Mar. Technol. Soc. J.** 37(4):6-15.

Watkins, W.A., M.A. Daher, G.M. Reppucci, J.E. George, D.L. Martin, N.A. DiMarzio, and D.P. Gannon. 2000a. Seasonality and distribution of whale calls in the North Pacific. **Oceanography** 13:62-67.

Watkins, W.A., J.E. George, M.A. Daher, K. Mullin, D.L. Martin, S.H. Haga, and N.A. DiMarzio. 2000b. Whale call data from the North Pacific, November 1995 through July 1999: occurrence of calling whales and source locations from SOSUS and other acoustic systems. Tech. Rep. WHOI-00-02. Woods Hole Oceanographic Inst., Woods Hole, MA. 160 p.

Weilgart, L.S. 2007. A brief review of known effects of noise on marine mammals. **Int. J. Comp. Psychol.** 20(2):159-168.

Weilgart, L.S. 2014. Are we mitigating underwater noise-producing activities adequately? A comparison of Level A and Level B cetacean takes. Working pap. SC/65b/E07. Int. Whal. Comm., Cambridge, U.K. 17 p.

Weir, C.R. and S.J. Dolman. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. **J. Int. Wildl. Law Policy** 10(1):1-27.

Weller, D.W., Y.V. Ivashchenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr. 2002. Influence of seismic surveys on western gray whales off Sakhalin Island, Russia in 2001. Paper SC/54/BRG14, IWC, Western Gray Whale Working Group Meet., 22-25 Oct., Ulsan, South Korea. 12 p.

Weller, D.W., S.H. Rickards, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2006a. The influence of 1997 seismic surveys on the behavior of western gray whales off Sakhalin Island, Russia. Paper SC/58/E4 presented to the IWC Scient. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.

Weller, D.W., G.A. Tsidulko, Y.V. Ivashchenko, A.M. Burdin and R.L. Brownell Jr. 2006b. A re-evaluation of the influence of 2001 seismic surveys on western gray whales off Sakhalin Island, Russia. Paper SC/58/E5 presented to the IWC Scient. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.

Wells, R.S. and M.D. Scott. 2009. Common bottlenose dolphin *Tursiops truncatus*. p. 249-255 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Wensveen, P.J., A.M. von Benda-Beckmann, M.A. Ainslie, F.P.A. Lam, P.H. Kvadsheim, P.L. Tyack, and P.J.O. Miller. 2015. How effectively do horizontal and vertical response strategies of long-finned pilot whales reduce sound exposure from naval sonar? **Mar. Environ. Res.** 106:68-81.

Whitehead, H. 2009. Sperm whale *Physeter macrocephalus*. p. 1091-1097 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.

Williams, T.M, W.A. Friedl, M.L. Fong, R.M. Yamada, P. Sideivy, and J.E. Haun. 1992. Travel at low energetic cost by swimming and wave-riding bottlenose dolphins. **Nature** 355(6363):821-823.

Winn, H.E. and N.E. Reichley. 1985. Humpback whale *Megaptera novaeangliae* (Borowski, 1781). p. 241-273 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, U.K. 362 p.

Wittekind, D., J. Tougaard, P. Stilz, M. Dähne, K. Lucke, C.W. Clark, S. von Benda-Beckmann, M. Ainslie, and U. Siebert. 2016. Development of a model to assess masking potential for marine mammals by the use of airguns in Antarctic waters. p. 1243-1249 *In:* A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

Wole, O.G. and E.F. Myade. 2014. Effect of seismic operations on cetacean sightings off-shore Akwa Ibom State, south-south, Nigeria. **Int. J. Biol. Chem. Sci.** 8(4):1570-1580.

Wright, A.J. 2014. Reducing impacts of human ocean noise on cetaceans: Knowledge gap analysis and recommendations. World Wildlife Fund Global Arctic Programme, Ottawa, ON. 98 p.

Wright, A.J. and A.M. Consentino. 2015. JNCC guidelines for minimizing the risk of injury and disturbance to marine mammals from seismic surveys: we can do better. **Mar. Poll. Bull.** 100(1):231-239.

Wright, A.J., T. Deak, and E.C.M. Parsons. 2011. Size matters: Management of stress responses and chronic stress in beaked whales and other marine mammals may require larger exclusion zones. **Mar. Poll. Bull.** 63(1-4):5-9.

Würsig, B., S.K. Lynn, T.A. Jefferson, and K.D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. **Aquat. Mamm.** 24(1):41-50.

Würsig, B.G., D.W. Weller, A.M. Burdin, S.H. Reeve, A.L Bradford, S.A. Blokhin, and R.L Brownell, Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-October 1997. A joint U.S.-Russian scientific investigation. Final Report. Rep. from Texas A&M Univ., College Station, TX, and Kamchatka Inst. Ecol. & Nature Manage., Russian Acad. Sci., Kamchatka, Russia, for Sakhalin Energy Investment Co. Ltd and Exxon Neftegaz Ltd, Yuzhno-Sakhalinsk, Russia. 101 p.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov, and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. **Environ. Monit. Assess.** 134(1-3):45-73.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton, and M.W. Newcomer. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. **Environ. Monit. Assess.** 134(1-3):93-106.