

**Request by Lamont-Doherty Earth Observatory
for an Incidental Harassment Authorization
to Allow the Incidental Take of Marine Mammals
during Marine Geophysical Surveys by the
R/V *Marcus G. Langseth* in the North Pacific Ocean,
2018/2019**

submitted by

Lamont-Doherty Earth Observatory

61 Route 9W, P.O. Box 1000
Palisades, NY 10964-8000

to

National Marine Fisheries Service

Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

Application Prepared by

LGL Limited, environmental research associates

22 Fisher St., POB 280
King City, Ont. L7B 1A6

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Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by the *R/V Marcus G. Langseth* in the North Pacific Ocean, 2018/2019

SUMMARY

Researchers from Lamont-Doherty Earth Observatory (L-DEO) and University of Hawaii, with funding from the U.S. National Science Foundation (NSF), in collaboration with researchers from United States Geological Survey (USGS), Oxford University, and GEOMAR Helmholtz Centre for Ocean Research Kiel (GEOMAR), propose to conduct two high-energy seismic surveys from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) in the North Pacific Ocean during 2018/2019. The NSF-owned *Langseth* is operated by Columbia University's L-DEO under an existing Cooperative Agreement. One proposed seismic survey would occur at the Main Hawaiian Islands in 2018, and another survey would take place at the Emperor Seamounts in the western North Pacific in 2019. The proposed timing for the Hawaii survey is summer/early fall 2018; the timing for the Emperor Seamounts survey would likely be spring/early summer. Both surveys would use a 36-airgun towed array with a total discharge volume of ~6600 in³. The survey at the Emperor Seamounts would take place in International Waters where water depths are 1500–6000 m. The Hawaii survey would occur within the U.S. Exclusive Economic Zone (EEZ), in water ~700 to >5000 m deep. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals could occur in the proposed survey areas in the North Pacific. Several of these species are listed as *endangered* under the ESA: the North Pacific right, sei, fin, blue, and sperm whales, the Western North Pacific Distinct Population Segments (DPS) of humpback whale and gray whales, the Hawaiian Islands Insular DPS of false killer whale, the Western DPS of Steller sea lion, and the Hawaiian monk seal. ESA-listed sea turtle species that could occur in the Hawaii survey area include the *endangered* hawksbill, leatherback, and loggerhead (North Pacific Ocean DPS) turtles, and the *threatened* green (Central North Pacific DPS) and olive ridley turtles. Listed seabirds that could be encountered in the survey areas include the *endangered* Hawaiian petrel, short-tailed albatross, and band-rumped storm petrel; and the *threatened* Newell's shearwater (USFWS 2017). ESA-listed fish species that could occur in the Hawaii survey area include the *threatened* oceanic white tip shark and the Giant manta ray, and the *endangered* Sakhalin sturgeon could occur in the Emperor Seamounts survey area.

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

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

The proposed study consists of two seismic surveys in the North Pacific Ocean—one at the Main Hawaiian Islands in the Central North Pacific (Fig. 1) and the other at the Emperor Seamounts in the western North Pacific (Fig. 2). The proposed Hawaii survey would occur within ~18–24°N, ~153–160°W, and the proposed Emperor Seamounts survey would occur within ~43–48°N, ~166–173°E.

Representative survey tracklines are shown in Figures 1 and 2. As described further in this document, however, some deviation in actual track lines, including order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, for the Emperor Seamounts survey, the tracklines could occur anywhere within the coordinates noted above and illustrated by the box in the inset map on Figure 2. The tracklines for the Hawaii survey could shift slightly, but would stay within the coordinates noted above and general vicinity of representative lines depicted in Figure 1. Water depths in the proposed Hawaii survey area range from ~700 to more than 5000 m. The water depths in the Emperor Seamounts survey area range from 1500–6000 m. The proposed Hawaii seismic survey would be conducted within the EEZ of Hawaii; the Emperor Seamounts survey would take place only within International Waters.

The Hawaii survey would be expected to last for 36 days, including ~19 days of seismic operations, 11 days of equipment deployment/retrieval, ~3 days of operational contingency time (e.g., weather delays, etc.), and ~3 days of transit. The *Langseth* would leave out of and return to port in Honolulu during summer/early fall (likely mid-August) 2018. The Emperor Seamounts survey would be expected to last 42 days, including ~13 days of seismic operations, ~11 days of equipment deployment/retrieval, ~5.5 days of operational contingency time, and 12.5 days of transit. The *Langseth* would leave Honolulu and return to port likely in Adak or Dutch Harbor. The most likely timing for this cruise would be late spring/early summer 2019.

The main goal of the surveys proposed by L-DEO and the University of Hawaii is to gain fundamental insight into the formation and evolution of Hawaiian-Emperor Seamount chain, and inform a more comprehensive assessment of geohazards for the Hawaiian Islands region. The Hawaii-Emperor Seamount Chain is the most well-known example on Earth of hotspot magmatism, where volcanoes form far from the boundaries between tectonic plates above hot regions in the underlying mantle. Seismic data acquired during the proposed study would image faults within the volcanic edifice and in the surrounding oceanic crust that could be used to evaluate earthquake, tsunami, and submarine landslide hazards.

To achieve the project goals, the Principal Investigators (PI) Drs. D. Shillington (L-DEO), T. Watts (Oxford University, L-DEO), and R. Dunn, G. Ito, and P. Wessel (University of Hawaii), propose to collect 2-D deep-penetration seismic reflection and wide-angle seismic refraction data on a series of long transects across the Hawaii-Emperor Seamount Chain to constrain the thickness of new crust created by magmatism and the way that the oceanic plate bends and deforms because of the addition of new crust. Although not funded through NSF, collaborators Dr. I. Grevenmeyer (GEOMAR) would work with the PIs to achieve the research goals, providing assistance, such as through logistical support (e.g., Ocean Bottom Seismometers or OBSs) and data acquisition and exchange. Likewise, personnel from the USGS, Drs. U. Brink and N. Miller, would collaborate on the program without receiving NSF funding; USGS would participate in planning, acquiring and analyzing data and using the results to inform hazards for Hawaii.

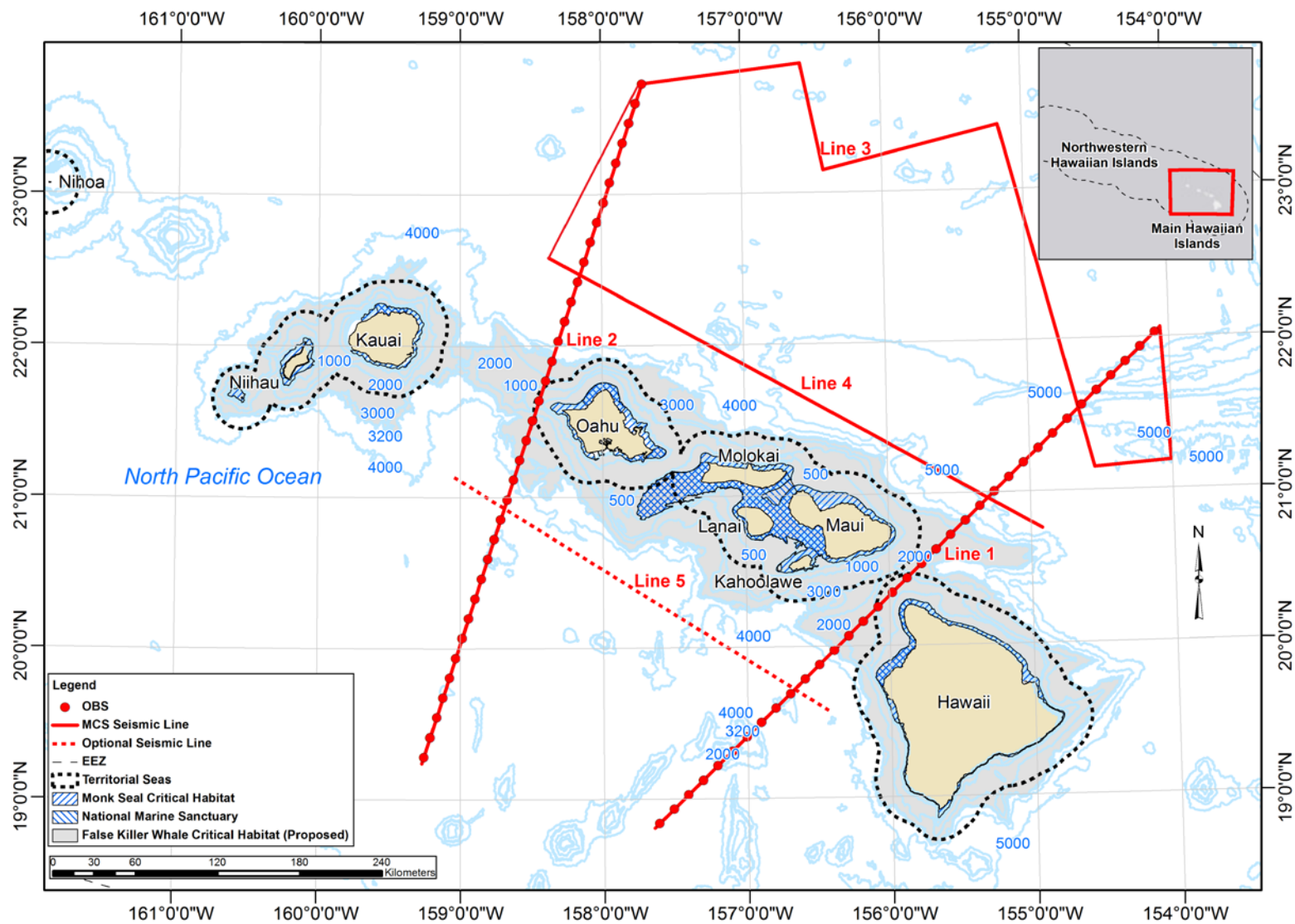


FIGURE 1. Location of the proposed 2018 seismic survey at the Main Hawaiian Islands, and proposed locations of ocean bottom seismometers (OBSs). The National Marine Sanctuary is the Hawaii Islands Humpback Whale National Marine Sanctuary.

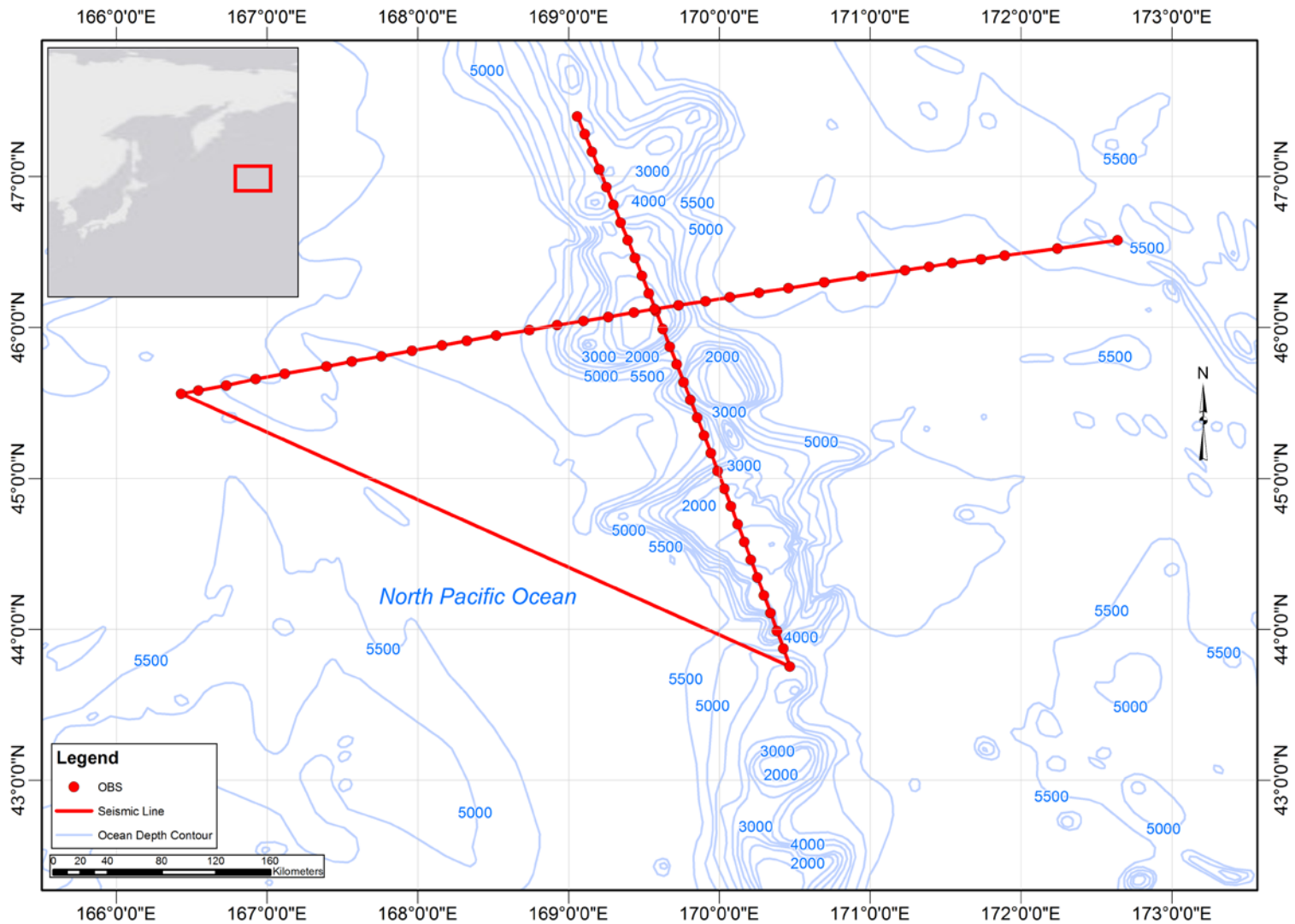


FIGURE 2. Location of the proposed 2019 seismic survey at the Emperor Seamounts in the western North Pacific Ocean, and the proposed locations of ocean bottom seismometers (OBSs). OBSs would be deployed and recovered along one line at a time.

There would be a total of four seismic transects for the Hawaii survey – two North (N)-South (S) tracklines (Lines 1 and 2), and two East (E)-West (W) tracklines (Lines 3 and 4). An optional trackline (Line 5) could be acquired instead of Line 4 (Fig. 1). Lines 1 and 2 would be acquired twice – seismic refraction data would be acquired first, followed by MCS reflection data. Only MCS reflection profiling would occur along Lines 3, 4, or 5. The location of the E-W tracklines (Lines 3, 4, or 5) could shift from what is currently depicted in Figure 1 depending on the science objectives; however, the E-W lines would remain in water >3200 m deep, outside of the proposed critical habitat for false killer whales.

The *Langseth* would first deploy all 70 OBSs required for the refraction profiling – the vessel would transit from Honolulu to the north end of Line 2, deploy 35 OBSs along Line 2, ~15 km apart, and then transit to the south end of Line 1 to deploy 35 OBSs (~15 km apart) along Line 1. The streamer and airgun array would then be deployed. Refraction data would then be acquired from north to south on Line 1 followed by MCS profiling along the same line. If Lines 3 and 4 are to be surveyed (preferred option), MCS profiles would then be acquired along Line 3, followed by refraction data acquisition in a north-south direction along Line 2, followed by MCS profiles along Line 2 from south to north. The vessel would then acquire MCS profiles from the north end of Line 2 to the west end of Line 4, and along Line 4. After seismic acquisition ceases, the streamer, airgun source, and all OBSs would be recovered by the *Langseth*.

There would be three seismic transects for the Emperor Seamounts survey (Fig. 2). Data would be acquired twice along the two OBS lines – once for seismic refraction data and once for MCS reflection profiling. Only MCS reflection profiling would occur along the third transect that connects the two OBS lines. The *Langseth* would first acquire MCS reflection data for all three lines – from north to south, then along the connecting transect, and from west to east. After recovering the streamer and airgun array, the *Langseth* would deploy 32 OBSs required for the refraction profiling from east to west along the first line. After seismic acquisition along the first OBS line from west to east, the OBSs would be recovered and re-deployed along the second OBS line, which would then be surveyed from north to south. The *Langseth* would then recover all OBSs, the streamer, and the airgun array.

A total of ~5657 km of transect lines would be surveyed in the North Pacific Ocean: ~3455 km during the Hawaii survey and ~2202 km during the Emperor Seamounts survey. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. During the Hawaii survey, 1.5% of line km would take place in intermediate (100–1000 m) water depths; the rest would occur in deep (>1000 m) water. All of the Emperor Seamounts survey would take place in deep (>1000 m) water.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from the *Langseth* continuously during the seismic surveys, but not during transit to and from the survey areas. All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

Source Vessel Specifications

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

Airgun Description

During the two surveys, the *Langseth* would tow the full array, consisting of four strings with 36 airguns (plus 4 spares) and a total volume of ~6600 in³. The airgun array is described in § 2.2.3.1 of the PEIS, and the airgun configurations are illustrated in Figures 2-11 to 2-13 of the PEIS. The 4-string array would be towed at a depth of 12 m, and the shot intervals would range from 50 m for MCS acquisition and 150 m for OBS acquisition.

Predicted Sound Levels

Mitigation zones for the proposed marine seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and safety zones (160 dB re 1μPa_{rms}) for Level B takes. The background information and methodology for this are provided in Appendix A.

The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 36-airgun array and 40-in³ airgun at a 12-m tow depth in deep water (>1000 m) down to a maximum water depth of 2000 m. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. Table 1 shows the distances at which the 160-dB re 1μPa_{rms} sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

TABLE 1. Level B. Predicted distances to which sound levels ≥160-dB re 1 μPa_{rms} could be received during the proposed surveys in the North Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level
Single Bolt airgun, 40 in ³	12	>1000 m	431 ¹
		100–1000 m	647 ²
4 strings, 36 airguns, 6600 in ³	12	>1000 m	6,733 ¹
		100–1000 m	10,100 ²

¹ Distance is based on L-DEO model results.

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

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

TABLE 2. Level A threshold distances for different marine mammal hearing groups. As required by NMFS (2016a), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances.

Level A Threshold Distances (m) for Various Hearing Groups					
36-airgun array; 6600 in ³	Low- Frequency Cetaceans	Mid- Frequency Cetaceans	High- Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL_{cum}	320.2	0	1.0	10.4	0
PTS Peak	38.9	13.6	268.3	43.7	10.6

Table 3 shows the distances at which the 175- and 195-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the 36-airgun array and a single airgun, based on L-DEO modeling; the 195-dB distance would be used as the EZ for sea turtles, as required by NMFS, and the 175-dB level is used by NMFS, as well as USN (2017), to determine behavioral disturbance for turtles.

This document has been prepared in accordance with the current NOAA acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). At the time of preparation of this document, how the technical guidance would be implemented operationally remains somewhat uncertain. For a previous high-energy seismic survey conducted by L-DEO, NMFS (2017a) required protected species observers (PSOs) to establish and monitor a 500-m EZ for power downs and to monitor an additional 500-m buffer zone beyond the EZ. A power down required the reduction of the full array to a single 40-in³ airgun; a 100-m EZ was established and monitored for shut downs of the single airgun. Enforcement of mitigation zones via power and shut downs would be implemented as described in § XI.

TABLE 3. Sea turtle thresholds recommended by NMFS. Predicted distances to which sound levels ≥ 195 - and 175-dB re $1\mu Pa_{rms}$ could be received during the proposed surveys in the North Pacific Ocean.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to Received Sound Levels	
			195 dB	175 dB
Single Bolt airgun, 40 in ³	12	>1000 m	8 ¹ (100 ³)	77 ¹
		100–1000 m	11 ² (100 ³)	116 ²
4 strings, 36 airguns, 6600 in ³	12	>1000 m	181 ¹	1864 ¹
		100–1000 m	272 ¹	2796 ²

¹ Distance is based on L-DEO model results.

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

³ An EZ of 100 m would be used as the shut-down distance for sea turtles, as specified for low-energy sources in the PEIS.

OBS Description and Deployment

For the Hawaii survey, the *Langseth* would first deploy all 70 OBSs required for the refraction profiling – the vessel would transit from Honolulu to the north end of Line 2, deploy 35 OBSs along Line 2, ~15 km apart, and then transit to the south end of Line 1 to deploy 35 OBSs (~15 km apart) along Line 1. The streamer and airgun array would then be deployed. After seismic acquisition ceases, the streamer, airgun array, and all OBSs would be recovered by the *Langseth*. For the Emperor Seamounts survey, the *Langseth* would deploy 32 OBS required for the refraction profiling after MCS reflection data has been acquired. After seismic acquisition along the first OBS line, the OBSs would be recovered and re-deployed along the second OBS line. The *Langseth* would then recover all OBSs, the streamer, and the airgun array.

The Hawaii survey would use US Ocean Bottom Seismograph Instrument Pool (OBSIP) OBSs, and the Emperor Seamounts survey would use 7 OBSIP and 25 GEOMAR OBSs. The US OBSIP OBSs would be from Scripps Institution of Oceanography (SIO) or Woods Hole Oceanographic Institute (WHOI). The WHOI D2 OBSs have a height of ~1 m and a maximum diameter of 50 cm. The anchor is made of hot-rolled steel, weighs 23 kg, with dimension $2.5 \times 30.5 \times 38.1$ cm. The SIO L-Cheapo OBSs have a height of ~1 m and a maximum diameter of ~1 m. The anchors are 36-kg iron grates with dimensions $7 \times 91 \times 91.5$ cm. The 25 GEOMAR OBSs would consist of Longterm OBSs for Tsunami and Earthquake Research or LOBSTERS; 15 LOBSTER-6000 and 10 LOBSTER-ultradeep OBSs would likely be used. These OBSs are 165 cm long, 130 cm wide, and 72 cm high, with a titanium frame that weighs ~335 kg; they have a steel anchor. To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor which is not retrieved.

Description of Operations

The procedures to be used for the proposed surveys would be similar to those used during previous seismic surveys by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, the *Langseth*, which is owned by NSF and operated on its behalf by Columbia University's L-DEO. The *Langseth* would deploy an array of 36 airguns as an energy source with a total volume of ~6600 in³. The receiving system would consist of OBSs and a single hydrophone streamer 15 km in length and OBSs. As the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system, and the OBSs would receive and store the returning acoustic signals internally for later analysis.

A total of ~5657 km of transect lines would be surveyed in the North Pacific Ocean: ~3455 km during the Hawaii survey and ~2202 km during the Emperor Seamounts survey. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the 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, the ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The proposed Hawaii survey would occur within ~18–24°N, ~153–160°W, and the proposed Emperor Seamounts survey would occur within ~43–48°N, ~166–173°E. Representative survey tracklines are shown in Figures 1 and 2. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, for the Emperor Seamounts survey, the tracklines could occur anywhere in the box as indicated in the inset map on Figure 2. The tracklines for the Hawaii survey could shift slightly but would stay within the general vicinity of representative lines depicted in Figure 1. The proposed Hawaii seismic survey would be conducted within the EEZ of Hawaii; the Emperor Seamounts survey would take place only within International Waters.

The Hawaii survey would be expected to last for 36 days, including ~19 days of seismic operations, 11 days of equipment deployment/retrieval, ~3 days of operational contingency time (e.g., weather delays, etc.), and ~3 days of transit. The *Langseth* would leave out of and return to port in Honolulu during summer (likely mid-August) 2018. The Emperor Seamounts survey would be expected to last 42 days, including ~13 days of seismic operations, ~11 days of equipment deployment/retrieval, ~5.5 days of operational contingency time, and 12.5 days of transit. The *Langseth* would leave Honolulu and return to port likely in Adak or Dutch Harbor. The dates for this cruise have not yet been determined, although late spring 2019 seems the most likely time.

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. As higher densities of baleen whales would be encountered in the Emperor Seamounts survey area during the summer, we have used the highest densities available for the area (i.e., July–September) to determine conservative take estimates for baleen whales for a potential survey at any time of the year. Humpback whales are known to occur in Hawaii during the winter (December–April); thus, more individuals would be encountered if the proposed survey would occur at that time.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Twenty-eight cetacean species, including 21 odontocetes (dolphins and small- and large-toothed whales) and seven mysticetes (baleen whales), and one pinniped species, could occur in the proposed Hawaii survey area (Table 4). In the Emperor Seamounts survey area, 27 marine mammal species could occur, including 15 odontocetes (dolphins and small- and large-toothed whales), eight mysticetes (baleen whales), and four pinniped species (Table 4).

Baird et al. (2015) described numerous Biologically Important Areas (BIAs) for cetaceans for the Hawaii region. Twenty BIAs were identified for resident populations of cetaceans based on sighting data, photo-identification, genetics, satellite tagging, and expert opinion, and one reproductive area for humpbacks was identified as a BIA; these are described in the following section for each marine mammal species. The BIAs range from ~700–23,500 km² in area (Baird et al. 2015).

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

TABLE 4. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey areas in the North Pacific Ocean.

Species	Occurrence in Area at Time of Survey		Habitat	Abundance in Hawaii ¹	Abundance in Hawaii ²	Abundance in North Pacific or ETP	ESA ₃	IUCN ₄	CITES ₅
	Hawaii	Emperor Seamounts							
<i>Mysticetes</i>									
Gray whale	Absent	Rare	Mainly coastal	N.A.	N.A.	140 ⁶	EN ⁷	CR ⁸	I
North Pacific right whale	Rare	Un-common	Pelagic, coastal	N.A.	N.A.	400-500 ⁹	EN	EN	I
Humpback whale	Rare	Un-common	Mainly nearshore, banks	7120-10,425 ¹⁰	N.A.	21,063 ¹¹	EN ¹²	LC	I
Minke whale	Rare	Un-common	Pelagic, coastal	N.A.	N.A.	>22,000 ¹³	NL	LC	I
Bryde's whale	Un-common	Rare	Pelagic, coastal	798	1751	28,447 ¹⁴	NL	DD	I
Sei whale	Rare	Un-common	Mostly pelagic	178	391	27,197 ¹⁵	EN	EN	I
Fin whale	Rare	Un-common	Pelagic, slope	58	154	13,620-18,680 ¹⁶	EN	EN	I
Blue whale	Rare	Un-common	Pelagic, coastal	81	133	1647 ¹⁷ 958 ¹⁸	EN	EN	I
<i>Odontocetes</i>									
Sperm whale	Un-common	Un-common	Pelagic, steep topography	3354	4559	29,674 ¹⁹ 26,300 ²⁰	EN	VU	I
Pygmy sperm whale	Un-common	Rare	Deep, off shelf	7138 ²¹	N.A.	N.A.	NL	DD	II
Dwarf sperm whale	Common	Rare	Deep, shelf, slope	17,519 ²¹	N.A.	11,200 ²²	NL	DD	II
Cuvier's beaked whale	Common	Un-common	Slope, pelagic	1941	723	20,000 ²³	NL	LC	II
Longman's beaked whale	Un-common	Absent	Pelagic	4571	7619	291 ²⁴	NL	DD	II
Blainville's beaked whale	Un-common	Absent	Pelagic	2338	2105	25,300 ²⁵	NL	DD	II
Stejneger's beaked whale	Absent	Un-common	Pelagic	N.A.	N.A.	25,300 ²⁵	NL	DD	II
Ginkgo-toothed beaked whale	Rare	Absent	Pelagic	N.A.	N.A.	25,300 ²⁵	NL	DD	II
Deraniyagala's beaked whale	Rare	Absent	Pelagic	N.A.	N.A.	25,300 ²⁵	NL	DD	II
Hubb's beaked whale	Rare	Absent	Pelagic	N.A.	N.A.	25,300 ²⁵	NL	DD	II
Baird's beaked whale	Absent	Un-common	Pelagic	N.A.	N.A.	25,300 ²⁵ 5029 ²⁶ 10,190 ²⁷	NL	DD	I
Rough-toothed dolphin	Common	Absent	Mainly pelagic	6288	72,528	107,633 ²⁸	NL	LC	II
Common bottlenose dolphin	Common	Absent	Coastal, shelf, deep	5950 ²⁹	21,815	335,834 ²⁸ 168,792 ³⁰	NL	LC	II

Species	Occurrence in Area at Time of Survey		Habitat	Abundance in Hawaii ¹	Abundance in Hawaii ²	Abundance in North Pacific or ETP	ESA ³	IUCN ⁴	CITES ⁵
	Hawaii	Emperor Seamounts							
Short-beaked common dolphin	Absent	Rare	Shelf and pelagic,	N.A.	N.A.	2,963,000 ³¹	NL	LC	II
Pantropical spotted dolphin	Common	Absent	Coastal, pelagic	15,917 ²⁹	55,795	1,297,092 ³² 438,064 ³⁰	NL	LC	II
Spinner dolphin	Common	Absent	Coastal, pelagic	3351 ²⁹	N.A.	1,797,716 ³⁴	NL	DD	II
Striped dolphin	Un-common	Un-common	Off shelf	20,650 ²⁹	61,201	964,362 ²⁸ 570,038 ³⁰	NL	LC	II
Fraser's dolphin	Un-common	Absent	Pelagic	16,992	51,491	289,300 ²³	NL	LC	II
Pacific white-sided dolphin	Absent	Common	Continental slope and	N.A.	N.A.	988,333 ³⁵	NL	LC	II
Northern right whale dolphin	Absent	Un-common	Pelagic	N.A.	N.A.	307,784 ³⁵	NL	LC	II
Risso's dolphin	Un-common	Rare	Shelf, slope, mounts	7256	11,613	110,457 ²⁸ 83,289 ³⁰	NL	LC	II
Melon-headed whale	Un-common	Absent	Pelagic	5794 ³⁶	8666	45,400 ²³	NL	LC	II
Pygmy killer whale	Un-common	Absent	Pelagic, coastal	3433	10,640	38,900 ²³	NL	DD	II
False killer whale	Un-common	Rare	Pelagic	1540 ³⁷	N.A.	16,668 ³⁰	EN ³³	DD	II
Killer whale	Rare	Un-common	Widely distributed	101	146	8500 ³⁸	NL	DD	II
Short-finned pilot whale	Common	Rare	Pelagic, high-relief	12,422	19,503	53,608 ³⁰	NL	DD	II
Dall's porpoise	Absent	Common	Deep water	N.A.	N.A.	1,186,000 ³⁹	NL	LC	II
<i>Pinnipeds</i>									
Hawaiian monk seal	Un-common	Absent	Coastal	1,272	N.A.	N.A.	EN	EN	N.A.
Northern fur seal	Absent	Un-common	Coastal and pelagic	N.A.	N.A.	1.1 million ⁴⁰ 626,734 ⁴¹	NL	VU	N.A.
Steller sea lion	Absent	Rare	Coastal and pelagic	N.A.	N.A.	143,000 ⁴⁰ 50,883 ⁴² 41,638 ⁴³	E ⁴⁶	E ⁴⁷	N.A.
Northern elephant seal	Absent	Un-common	Coastal and pelagic	N.A.	N.A.	210,000- 239,000 ⁴⁴	NL	LC	N.A.
Ribbon seal	Absent	Rare	Coastal and pelagic	N.A.	N.A.	240,000 ⁴⁰ 184,000 ⁴⁵	NL	LC	N.A.

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

¹ Estimates presented in Carretta et al. (2017), unless otherwise noted. Most of the estimates provided by Carretta et al. (2017) were derived from summer-fall shipboard surveys in 2010 by Bradford et al. (2013).

² Based on summer-fall shipboard surveys in 2010 (Bradford et al. 2017).

³ U.S. ESA (NMFS 2018): EN = Endangered, NL = Not listed.

⁴ Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2018): 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 2017): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

⁶ Weller et al. (2013).

⁷ Only the Western North Pacific DPS is listed as endangered.

- ⁸ The western subpopulation is listed as critically endangered; the global population is designated as least concern.
- ⁹ North Pacific (Jefferson et al. 2015).
- ¹⁰ Hawaii wintering area, 2004–2006 (Calambokidis et al. 2008).
- ¹¹ North Pacific, 2004–2006 (Barlow et al. 2011).
- ¹² Out of the 14 distinct population segments (DPS) of humpbacks, only the Western Pacific DPS is listed as endangered; the Hawaii DPS is not listed under the ESA (NMFS 2016b).
- ¹³ North West Pacific and Okhotsk Sea (IWC 2018a).
- ¹⁴ Western North Pacific (Hakamada et al. 2017).
- ¹⁵ Central and Eastern North Pacific (Hakamada and Matsuoka 2015a).
- ¹⁶ Ohsumi and Wada (1974).
- ¹⁷ Eastern North Pacific Stock (Calambokidis 2013).
- ¹⁸ Western Pacific Ocean (Hakamada and Matsuoka 2015b).
- ¹⁹ Western North Pacific (Whitehead 2002).
- ²⁰ Northeastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
- ²¹ Barlow (2006).
- ²² Wade and Gerrodette (1993); estimate for ETP mostly for *K. sima* but may also include *K. breviceps*.
- ²³ ETP (Wade and Gerrodette 1993).
- ²⁴ ETP (Ferguson and Barlow 2003).
- ²⁵ This estimate includes all species of the genus *Mesoplodon* in the ETP (Wade and Gerrodette 1993).
- ²⁶ Pacific coast of Japan (Kasuya 2009).
- ²⁷ Western Pacific Ocean (Okamura et al. 2012).
- ²⁸ ETP for 2006 (Gerrodette et al. 2008).
- ²⁹ Pelagic stock.
- ³⁰ Western North Pacific (Miyashita 1993a).
- ³¹ ETP (Gerrodette and Forcada 2002 in Hammond et al. 2008b).
- ³² ETP for 2006 for the two offshore spotted dolphin stocks (Gerrodette et al. 2008).
- ³³ Only the Main Hawaiian Islands Insular DPS is listed as endangered.
- ³⁴ ETP for 2006 for the eastern and white belly spinner dolphin, stocks (Gerrodette et al. 2008).
- ³⁵ North Pacific (Miyashita 1993b).
- ³⁶ Hawaiian Islands Stock (Aschettino 2010).
- ³⁷ Hawaii pelagic stock (Bradford et al. 2015).
- ³⁸ ETP (Ford 2009).
- ³⁹ North Pacific (Buckland et al. 1993).
- ⁴⁰ North Pacific (Jefferson et al. 2015).
- ⁴¹ Eastern Pacific stock (Muto et al. 2017).
- ⁴² Estimate for the Western U.S. Stock, including Russia and Japan (Muto et al. 2017).
- ⁴³ Estimate for the Eastern U.S. Stock; not corrected for animals at sea (Muto et al. 2017).
- ⁴⁴ U.S. and Mexico (Lowry et al. 2014).
- ⁴⁵ Alaska stock (Muto et al. 2017).
- ⁴⁶ The Western U.S. stock or DPS is listed as endangered; the Eastern U.S. stock (DPS) is not listed.
- ⁴⁷ The Western Steller sea lion (*Eumetopias jubatus jubatus*) is listed as endangered under the IUCN Red List; globally, *E. jubatus* is considered near threatened.

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 marine mammal species/populations that may occur within or near the survey areas in the North Pacific Ocean, 10 are listed under the U.S. ESA as **endangered**: the North Pacific right, sei, fin, blue, and sperm whales, the Western North Pacific DPSs of humpback and gray whales, the Hawaiian Islands Insular DPS of false killer whale, the Western DPS of Steller sea lion, and the Hawaiian monk seal.

Although the harbor porpoise (*Phocoena phocoena*) and sea otter (*Enhydra lutris*) were considered for inclusion in this analysis, these species generally occur in nearshore areas and are not expected to occur in the offshore waters of the Emperor Seamounts survey area. Also, the ringed seal (*Pusa hispida*), spotted seal (*Phoca largha*), harbor seal (*Phoca vitulina*), walrus (*Odobenus rosmarus*), and bowhead whale (*Balaena mysticetus*) are not expected to occur in the Emperor Seamounts survey area.

Mysticetes

Gray Whale (*Eschrichtius robustus*)

Two separate populations of gray whales have been recognized in the North Pacific (LeDuc et al. 2002): the eastern North Pacific and western North Pacific (or Korean-Okhotsk) stocks. However, the distinction between these two populations has been recently debated owing to evidence that whales from the western feeding area also travel to breeding areas in the eastern North Pacific (Weller et al. 2012, 2013; Mate et al. 2015). Thus, it is possible that whales from both the *endangered* Western North Pacific and the delisted Eastern North Pacific DPS could occur in the proposed survey area in the western North Pacific.

The western population is known to feed in the Okhotsk Sea along the northeast coast of Sakhalin Island (Weller et al. 1999, 2002a, 2008), eastern Kamchatka, and the northern Okhotsk Sea in the summer and autumn (Vladimirov et al. 2008). Winter breeding grounds are not known; however, it has been postulated that wintering areas occur along the south coast of the Korean Peninsula, but it is more likely that they are located in the South China Sea, along the coast of Guangdong province and Hainan (Wang 1984 and Zhu 1998 in Weller et al. 2002a; Rice 1998). Winter records exist for Japan, North Korea, and South Korea (Weller et al. 2002a,b). Migration into the Okhotsk Sea may occur through the Sea of Japan via the Tatar Strait and/or La Perouse Strait (see Reeves et al. 2008). If migration timing is similar to that of the better-known eastern gray whale, southbound migration probably occurs mainly in December–January and northbound migration mainly in February–April, with northbound migration of newborn calves and their mothers probably concentrated at the end of that period. The eastern North Pacific gray whale breeds and winters in Baja, California, and migrates north to summer feeding grounds in the northern Bering Sea, Chukchi Sea, and western Beaufort Sea (Rice and Wolman 1971; Jefferson et al. 2015).

In the western North Pacific, gray whales migrate along the coast of Japan (Weller et al. 2008), and records have been reported there from November through August, with the majority for March through May (Weller et al. 2012). Although the offshore limit of this route is not well documented, gray whales are known to prefer nearshore coastal waters. However, some exchange between populations in the eastern and western North Pacific has been reported (Weller et al. 2012, 2013; Mate et al. 2015); thus, migration routes could include pelagic waters of the Pacific Ocean, including the proposed Emperor Seamounts survey area. Nonetheless, given their small population size and preference for nearshore waters, it is highly unlikely that any gray whales would be encountered during the proposed Emperor Seamounts survey during any time of the year. Additionally, during summer, most gray whales would be feeding near Sakhalin Island. The gray whale does not occur in Hawaiian waters.

North Pacific Right Whale (*Eubalaena japonica*)

North Pacific right whales summer in the northern North Pacific, primarily in the Okhotsk Sea (Brownell et al. 2001) and in the Bering Sea (Shelden et al. 2005; Wade et al. 2006). The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011), and critical habitat has been designated in the eastern Bering Sea and in the Gulf of Alaska, south of Kodiak Island (NMFS 2017b). Wintering and breeding areas are unknown, but have been suggested to include the Hawaiian Islands, Ryukyu Islands, and Sea of Japan (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980; Omura 1986). The Hawaiian Islands were not a major calving ground for right whales in the last 200 years, but mid-ocean whaling records of right whales during winter suggest that right whales may have wintered and calved far offshore in the Pacific Ocean (Scarff 1986, 1991;

Clapham et al. 2004). In April 1996, a right whale was sighted off Maui, the first documented sighting of a right whale in Hawaiian waters since 1979 (Salden and Mickelsen 1999).

Whaling records indicate that right whales once ranged across the entire North Pacific Ocean north of 35°N and occasionally occurred as far south as 20°N (e.g., Scarff 1986, 1991). In the western Pacific, most sightings in the 1900s were reported from Japanese waters, followed by the Kuril Islands, and the Okhotsk Sea (Brownell et al. 2001). Significant numbers of right whales have been seen in the Okhotsk Sea during the 1990s, suggesting that the adjacent Kuril Islands and Kamchatka coast are a major feeding ground (Brownell et al. 2001). Right whales were also seen near Chichi-jima Island (Bonin Islands), Japan, in the 1990s (Mori et al. 1998). During 1994–2014, right whale sightings were reported off northern Japan, the Kuril Islands, and Kamchatka during April through August, with highest densities in May and August (Matsuoka et al. 2015). All sightings were north of 38°N, and in July–August, the main distribution was north of 42°N (Matsuoka et al. 2015). Right whale sightings were made within the Emperor Seamounts survey area during August, and adjacent to the survey area during May and July (Matsuoka et al. 2015). Ovsyanikova et al. (2015) also reported right whale sightings in the western Pacific Ocean during 1977–2014; although they also reported sightings off eastern Japan, the Kuril Islands, and southeast Kamchatka, including sightings to the west of the proposed Emperor Seamounts survey area, no sightings were reported within the proposed survey area. Sekiguchi et al. (2014) reported several sightings just to the north and west of the proposed survey area during June 2012.

Although there are a few historical records of North Pacific right whales in Hawaiian waters (Brownell et al. 2001), they are very unlikely to occur in the Hawaiian survey area, especially during the summer. However, right whales could be encountered in the Emperor Seamounts survey area during spring and summer, and likely fall. Individuals that could occur there would likely be from a western North Pacific stock rather than the eastern North Pacific stock.

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). The Western Pacific DPS is listed as **endangered**, whereas the Hawaii DPS is not listed (NMFS 2016b). Calambokidis et al. (2008) estimated the Hawaii population at ~10,000 individuals and the Western Pacific population at ~1000 humpbacks.

There is potential for the mixing of the western and eastern North Pacific humpback populations, as several individuals have been seen in the wintering areas of Japan and Hawaii in separate years (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001, 2008). Whales from these wintering areas have been shown to travel to summer feeding areas in British Columbia, Canada, and

Kodiak Island, Alaska (Darling et al. 1996; Calambokidis et al. 2001), but feeding areas in Russian waters may be most important (Calambokidis et al. 2008). There appears to be a very low level of interchange between wintering and feeding areas in Asia and those in the eastern and central Pacific (Calambokidis et al. 2008; Baker et al. 2013).

In U.S. Pacific waters, four stocks are currently recognized: (1) California/Oregon/Washington, (2) Central North Pacific (feeding areas occur from Southeast Alaska to the Alaska Peninsula), (3) Western North Pacific (feeding occurs from the Aleutians, to the Bering Sea, and Russia), and (4) American Samoa (Carretta et al. 2017). 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 just north of the Big Island (Barlow et al. 2004). Another sighting was made during summer–fall 2010 surveys, but the date and location of that sighting were not reported (Bradford et al. 2017).

The Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS) was established in 1992 by the U.S. Congress to protect humpback whales and their habitat in Hawaii (NOAA 2018a). The sanctuary provides essential breeding, calving, and nursing areas necessary for the long-term recovery of the North Pacific humpback whale population. The HIHWNMS provides protection to humpbacks in the shallow waters (from the shoreline to a depth of 100 fathoms or 183 m) around the four islands area of Maui, Penguin Bank; off the north shore of Kauai, the north and south shores of Oahu, and the north Kona and Koahala coast of the Big Island (NOAA 2018a). These areas, as well as some of the waters surrounding them, are also considered BIAs (Baird et al. 2015). The proposed seismic lines are located at least 10 km from the HIHWNMS (Fig. 1). However, humpback whales are not expected to be encountered in the Hawaiian survey area during the summer.

During Japanese surveys in the western North Pacific from 1994–2014, humpbacks were seen off northern Japan, the Kuril Islands, and Kamchatka (Miyashita 2006; Matsuoka et al. 2015). Sightings were reported for the months of April through September, with lowest densities in April and September (Matsuoka et al. 2015). In May and June, sightings were concentrated east of northern Japan between 37° and 43°N; concentrations moved north of 45°N during July and August, off the Kuril Islands and Kamchatka (Matsuoka et al. 2015). Humpback whales were encountered within the proposed Emperor Seamount study area in May, July, and August (Matsuoka et al. 2015).

Thus, humpbacks could be encountered in the Emperor Seamounts survey area during spring and summer, as individuals are migrating to northern feeding grounds at that time. They could also be encountered in the survey area during fall, on their southbound migration. Humpback whales are not expected to occur in the Hawaiian survey area during the time of the proposed survey.

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. 2015).

In the Pacific U.S., a Hawaii and an Eastern Tropical Pacific stock are recognized (Carretta et al. 2017). 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 reported during 2010 (Bradford et al. 2017). 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 the proposed survey area (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013; Forney et al. 2015; Carretta et al. 2017).

Bryde's whales have been regularly seen during Japanese summer sighting surveys in the western North Pacific, south of 43°S (Hakamada et al. 2009, 2017), and individual movements have been tracked with satellite tags in offshore waters off Japan (Murase et al. 2016). No recent sightings have been made in the proposed Emperor Seamounts survey area, but commercial catches have been reported there (IWC 2007a).

Bryde's whale is likely to be rare in the Emperor Seamounts survey area, as its distributional range is generally to the south of this region. However, it could occur in the Hawaiian survey area at any time of the year.

Common Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, minke whales are usually seen in coastal areas, but can also be seen in pelagic waters during northward migrations in spring and summer, and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range extends to the Chukchi Sea; in the winter, minke whales move further south to within 2° of the Equator (Perrin and Brownell 2009). The International Whaling Commission (IWC) recognizes three stocks in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180°N, and the remainder of the Pacific (Donovan 1991).

In U.S. Pacific waters, three stocks are recognized: Alaska, Hawaii, and California/Oregon/Washington stocks (Carretta et al. 2017). In Hawaii, the minke whale is thought to occur seasonally from November through March (Rankin and Barlow 2005). It 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). 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 the ALOHA station (22.75°N, 158°W) from October–May for decades (Oswald et al. 2011).

A lack of sightings is likely related to misidentification or low detection capability in poor sighting conditions (Rankin et al. 2007). 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. 2017). Numerous additional sightings in the EEZ were made by observers on Hawaii-based longline fishing vessels, including four near the proposed survey area to the north and south of the Main Hawaiian Islands (Carretta et al. 2017).

Minke whales have been seen regularly during Japanese sighting surveys in the western North Pacific during summer (Miyashita 2006; Hakamada et al. 2009), and one sighting was made in August 2010 in offshore waters off Japan during the Shatsky Rise cruise (Holst and Beland 2010). Minke whales were sighted within the Emperor Seamounts survey area in the greatest numbers in August, with the lowest numbers occurring during May and June (Hakamada et al. 2009).

Thus, minke whales could be encountered in the Emperor Seamounts survey area during spring and summer, and likely fall, but they are unlikely to be encountered in the Hawaiian survey area during the summer.

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. 2015). 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 the U.S. Pacific, an Eastern North Pacific and a Hawaii stock are recognized (Carretta et al. 2017). In Hawaii, the occurrence of sei whales is considered rare (DoN 2005). However, six sightings were made during surveys in the Hawaiian Islands EEZ in July–December 2002 (Barlow 2006), including several along the north coasts of the Main Hawaiian Islands (Barlow et al. 2004). All sightings occurred in November, with one sighting reported near proposed seismic Line 3 north of the Big Island (Barlow et al. 2004). Bradford et al. (2017) reported two sightings in the northwestern portion of the Hawaiian Islands EEZ during summer–fall surveys in 2010. Hopkins et al. (2009) sighted one group of three subadult sei whales northeast of Oahu in November 2007. Sei whale vocalizations were also detected near Hawaii during November 2002 (Rankin and Barlow 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).

Sei whales have been regularly seen during Japanese surveys during the summer in the western North Pacific (Miyashita 2006; Hakamada et al. 2009; Sasaki et al. 2013). Sei whales have been sighted in and near the Emperor Seamounts survey area, with the greatest numbers reported for July and August; few sightings were made during May and June (Hakamada et al. 2009).

Thus, sei whales could be encountered in the Emperor Seamounts survey area during spring and summer, and likely fall, but they are unlikely to be encountered in the Hawaiian survey area at any time of the year, especially during summer.

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. 2015). A recent review of fin whale distribution in the North Pacific noted the lack of sightings across the pelagic waters between eastern and western winter areas (Mizroch et al. 2009). 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 (Jefferson et al. 2015). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985). In the U.S., three stocks are recognized in the North Pacific: California/Oregon/Washington, Hawaii, and Alaska (Northeast Pacific) (Carretta et al. 2017). 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, including near the Emperor Seamounts survey area (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). In the central North Pacific, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b).

Sightings of fin whales have been made in Hawaiian waters during fall and winter (Edwards et al. 2015), but fin whales are generally considered uncommon at that time (DoN 2005). During spring and summer, their occurrence in Hawaii is considered rare (DoN 2005; see Edwards et al. 2015). There were five sightings of fin whales during summer–fall surveys in 2002, with sightings during every month except August (Barlow et al. 2004). Most sightings were made to the northwest of the Main Hawaiian Islands; one sighting was made during October southeast of Ohau (Barlow et al. 2004). Two sightings were made in the Northwestern Hawaiian Islands during summer–fall 2010 (Carretta et al. 2017; Bradford et al. 2017). Two additional sightings in the EEZ were made by observers on Hawaii-based longline fishing vessels, including one near proposed seismic Line 3 north of Maui (Carretta et al. 2017). Fin whale vocalizations have also been detected in Hawaiian waters, mainly during winter (Oleson et al. 2014, 2016).

In the western Pacific, fin whales are seen off northern Japan, the Kuril Islands, and Kamchatka during the summer (Miyashita 2006; Matsuoka et al. 2015). During Japanese sightings surveys in the western North Pacific from 1994–2014, the fin whale was sighted more frequently than the blue, humpback, or right whale (Matsuoka et al. 2015). During May–June, main distribution areas occurred from 35–40°N and moved north of 40°N during July and August; high densities were reported north of 45°N (Matsuoka et al. 2015). During these surveys, fin whales were seen in the proposed Emperor Seamounts survey area from May through September, with most sightings during August (Matsuoka et al. 2015). Summer sightings in the survey area during 1958–2000 were also reported by Mizroch et al. (2009) and during July–September 2005 (Miyashita 2006). Edwards et al. (2015) reported fin whale sightings within or near the Emperor Seamounts survey area from spring through fall.

Thus, fin whales could be encountered in the Emperor Seamounts survey area from spring through fall, but they are unlikely to be encountered in the Hawaiian survey area during summer.

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). 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 detected year-round (Stafford et al. 2001, 2009; Moore et al. 2002, 2006; Monnahan et al. 2014). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections in the 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) suggests that there are two separate populations: one in the eastern and one in the central North Pacific (Carretta et al. 2017). The Eastern North Pacific Stock includes whales that feed primarily off California from June–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. 2017). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016).

Blue whales are considered rare in Hawaii (DoN 2005). However, call types from both stocks have been recorded near Hawaii during August–April, although eastern calls were more prevalent; 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). 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 offshore waters north of Maui (Carretta et al. 2017).

In the western North Pacific, blue whale calls have been detected throughout the year, but are more prevalent from July–December (Stafford et al. 2001). Numerous blue whale sightings have also been made in the western North Pacific during Japanese surveys during 1994–2014 (Miyashita 2006; Matsuoka et al. 2015). A northward migration pattern was evident, with the main distribution occurring from 35–40°N during May and June, and north of 40°N during July and August (Matsuoka et al. 2015). High densities were reported north of 45°N (Matsuoka et al. 2015). Blue whales were seen in the proposed Emperor Seamounts survey area during August and September and adjacent to the area during May and July (Matsuoka et al. 2015).

Thus, blue whales could be encountered in the Emperor Seamounts and Hawaii survey areas at any time of the year, but are more likely to occur in the Emperor Seamounts area during summer, and in the Hawaii survey area during winter.

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 $\sim 40^\circ$ (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 whale vocalizations have been recorded throughout the Central and Western Pacific Ocean (Merkens et al. 2016). Sperm whales are widely distributed in Hawaiian waters throughout the year (Mobley et al. 2000) and are considered a separate stock from the Oregon/Washington/California stock in U.S. waters (Carretta et al. 2017). Higher densities occur in deep, offshore waters (Forney et al. 2015). 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 near the proposed survey area (Barlow et al. 2004; Barlow 2006; Bradford et al. 2017). All sightings during surveys of the Main Hawaiian Islands in 2000–2012 were made in water >1000 m in depth, with most sightings in areas >3000 m deep (Baird et al. 2013). Sightings were made during surveys of the Big Island during all seasons, including near proposed seismic Line 1; no sightings were made off Oahu (Baird et al. 2013). Sperm whales were also detected acoustically off the west coast of the Big Island year-round (Klinck et al. 2012; Giorli et al. 2016).

Sperm whales have been regularly seen in the western North Pacific during Japanese surveys during summer (Miyashita 2006; Hakamada et al. 2009), and sightings were also made in offshore waters east of Japan and on the Shatsky Rise during a summer survey in 2010 (Holst and Beland 2010). During winter, few sperm whales are observed off the east coast of Japan (Kato and Miyashita 1998). Sperm whales have been sighted in and near the Emperor Seamounts survey area from May through August, with the greatest numbers occurring there during June–August (Miyashita 2006; Hakamada et al. 2009).

Thus, sperm whales could be encountered in the Emperor Seamounts and Hawaii survey areas at any time of the year, but are more likely to occur in the Emperor Seamounts area during summer.

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). It has been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the Eastern Tropical Pacific or ETP (Wade and Gerrodette 1993). *Kogia* spp. are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). 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.

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). However, 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). On the other hand, McAlpine (2009) and Barros et al. (1998) suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales.

Vocalizations of *Kogia* spp. have been recorded in the North Pacific Ocean (Merkens et al. 2016). An insular resident population of dwarf sperm whales occurs within ~20 km from the Main Hawaiian Islands throughout the year (Baird et al. 2013; Oleson et al. 2013). During small-boat surveys 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). Of a total of 74 sightings during those surveys, most sightings were made off the Big Island, including near proposed seismic Line 1 (Baird et al. 2013). The area off the west coast of the Big Island is considered a BIA for dwarf sperm whales (Baird et al. 2015). Only one sighting was made off Oahu (Baird et al. 2013).

Only five sightings of pygmy sperm whales were made during the surveys, including several off the west coast of the Big Island; the majority of sightings were made in water >3000 m deep (Baird et al. 2013). The dwarf sperm whale was one of the most abundant species during a summer–fall survey of the Hawaiian EEZ in 2002 (Barlow 2006); during that survey, two sightings of pygmy sperm whales, five sightings of dwarf sperm whales, and one 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 EEZ in 2010, one dwarf sperm whale and one unidentified *Kogia* sp. were sighted (Bradford et al. 2017); no sightings were made in or near the proposed survey area (Carretta et al. 2017).

Although *Kogia* spp. have been seen during Japanese sighting surveys in the western North Pacific in August–September (Kato et al. 2005), to the best of our knowledge, there are no direct data available for the Emperor Seamounts survey area with respect to *Kogia* spp. Based on their distributional ranges, the pygmy sperm whale is more likely to occur in the proposed Emperor Seamounts survey area than the dwarf sperm whale.

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. 2015).

Cuvier’s beaked whale has been sighted during surveys in Hawaii (Barlow 2006; Baird et al. 2013; Bradford et al. 2017). Resighting and telemetry data suggest that a resident insular population of Cuvier’s beaked whale may exist in Hawaii, distinct from offshore, pelagic whales (e.g. McSweeney et al. 2007; Baird et al. 2013; Oleson et al. 2013). During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made in water depths of 500–4000 m off the west coast of the Big Island during all seasons (Baird et al. 2013). The waters around the Big Island are considered a BIA for Cuvier’s beaked whale (Baird et al. 2015); proposed seismic Line 1 would traverse this area.

During summer–fall surveys of the Hawaiian Islands EEZ, three 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). It was one of the most abundant cetacean species sighted in 2002 (Barlow 2006). In 2010, most sightings were made in nearshore waters of the Northwestern Hawaiian Islands, but one was made on the west coast of the Big Island, and another was made far offshore and to the southwest of Kauai (Carretta et al. 2017). Cuvier’s beaked whales were also reported near proposed

seismic line 1 during November 2009 (Klinck et al. 2012). They have also been detected acoustically at hydrophones deployed near the Main Hawaiian Islands during spring and fall (Baumann-Pickering et al. 2014, 2016), including off the west coast of the Big Island (Klinck et al. 2012). Probable acoustic detections were also made at Cross Seamount, south of the Main Hawaiian Islands, at 18.72°N, 158.25°W (Johnston 2008).

Cuvier's beaked whale has been seen during Japanese sighting surveys in August–September in the western North Pacific (Kato et al. 2005). It has also been detected acoustically in the Aleutian Islands (Baumann-Pickering et al. 2014). There is very little information on this species for the Emperor Seamounts survey area, but what is known of its distribution and habitat preferences suggests that it could occur there.

Longman's Beaked Whale (*Indopacetus pacificus*)

Longman's beaked whale, also known Indo-Pacific beaked whale, used to be one of the least known cetacean species, but it is now one of the more frequently sighted beaked whales (Pitman 2009a). Longman's beaked whale occurs in tropical waters throughout the Indo-Pacific, with records from 30°S to 40°N (Pitman 2009a). Longman's beaked whale is most often sighted in waters with temperatures $\geq 26^{\circ}\text{C}$ and depth >2000 m, and sightings have also been reported along the continental slope (Anderson et al. 2006; Pitman 2009a).

During small-boat surveys around the Hawaiian Islands in 2000–2012, a single sighting of Longman's beaked whale was made off the west coast of the Big Island during summer (Baird et al. 2013). During summer–fall surveys of the Hawaiian Islands EEZ, one sighting was made in 2002 and three were made in 2010; one sighting was made in offshore waters southwest of Oahu, and another was made at the edge of the EEZ southwest of the Big Island (Barlow et al. 2004; Barlow 2006; Bradford et al. 2013). Acoustic detections have been made at the Palmyra Atoll and the Pearl and Hermes Reef (Baumann-Pickering et al. 2014).

Longman's beaked whale has been seen during Japanese sighting surveys in August–September in the western North Pacific (Kato et al. 2005). However, what is known about its distribution and habitat preferences suggests that it does not occur in the Emperor Seamounts survey area.

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2009b). It has the widest distribution throughout the world of all mesoplodont species and appears to be common (Pitman 2009b). It is commonly sighted in some areas of Hawaii (Jefferson et al. 2015).

McSweeney et al. (2007), Schorr et al. (2009), Baird et al. (2013), and Oleson et al. (2013) have suggested the existence of separate insular and offshore Blainville's beaked whales in Hawaiian waters. During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made in shelf as well as deep water, with the highest sighting rates in water 3500–4000 m deep, followed by water 500–1000 m deep (Baird et al. 2013). Sightings were made during all seasons off the Big Island, as well as off Oahu (Baird et al. 2013). The area off the west coast of the Big Island is considered a BIA for Blainville's beaked whale (Baird et al. 2015); proposed seismic Line 1 would traverse this BIA. During summer–fall shipboard surveys of the Hawaiian Islands EEZ, three sightings were made in 2002 and two 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 four sightings of unidentified *Mesoplodon* there in 2002 (Barlow et al. 2004; Barlow 2006) and 10 in 2010 (Bradford et al. 2013).

Blainville's beaked whales have also been detected acoustically at hydrophones deployed near the Main Hawaiian Islands throughout the year (Baumann-Pickering et al. 2014, 2016; Henderson et al. 2016; Manzano-Roth et al. 2016), including off the west coast of the Big Island, near proposed seismic Line 1, during October–November 2009 (Klinck et al. 2012). Probable acoustic detections were also made at Cross Seamount, south of the Main Hawaiian Islands, at 18.72°N, 158.25°W (Johnston 2008). Blainville's beaked whale is expected to be absent from the Emperor Seamounts survey area.

Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). Most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989). In the western Pacific Ocean, Stejneger's beaked whale has been seen during Japanese sighting surveys during August–September (Kato et al. 2005). Seasonal peaks in strandings along the western coast of Japan suggest that this species may migrate north in the summer from the Sea of Japan (Mead 1989). They have also been detected acoustically in the Aleutian Islands during summer, fall, and winter (Baumann-Pickering et al. 2014).

Given its distributional range (see Jefferson et al. 2015), Stejneger's beaked whale could occur in the Emperor Seamounts survey area. It does not occur in the Hawaiian survey area.

Ginkgo-toothed Beaked Whale (*Mesoplodon ginkgodens*)

Ginkgo-toothed beaked whale is only known from stranding and capture records (Mead 1989; Jefferson et al. 2015). It is hypothesized to occupy tropical and warm temperate waters of the Indian and Pacific oceans (Pitman 2009b). Its distributional range in the North Pacific extends from Japan to the Galapagos Islands, and there are also records for the South Pacific as far south as Australia and New Zealand (Jefferson et al. 2015). Although its distributional range is thought to be south of Hawaii (Jefferson et al. 2015), vocalizations likely from this species have been detected acoustically at hydrophones deployed near the Main Hawaiian Islands and just to the south at Cross Seamount (18.72°N, 158.25°W), as well as at the Wake Atoll and Mariana Islands (Baumann-Pickering et al. 2014, 2016). However, no sightings have been made in Hawaiian waters (Barlow 2006; Baird et al. 2013; Bradford et al. 2017).

The ginkgo-toothed beaked whale could occur in the southern parts of the Hawaiian survey area, but it is not expected to occur in the Emperor Seamounts survey area.

Deraniyagala's Beaked Whale (*Mesoplodon hotaula*)

Deraniyagala's beaked whale is a newly recognized species of whale that recently has been described for the tropical Indo-Pacific, where it is thought to occur between ~15°N and ~10°S (Dalebout et al. 2014). Strandings have been reported for the Maldives, Sri Lanka, the Seychelles, Kiribati, and Palmyra Atoll (Dalebout et al. 2014), and acoustic detections have been made at Palmyra Atoll and Kingman Reef in the Line Islands (Baumann-Pickering et al. 2014). It is closely related to ginkgo-toothed beaked whale, but DNA and morphological data have shown that the two are separate species (Dalebout et al. 2014).

Although possible, Deraniyagala's beaked whale is unlikely to occur in the Hawaiian survey area, and its range does not include the Emperor Seamounts survey area.

Hubb's Beaked Whale (*Mesoplodon carlhubbsi*)

Hubb's beaked whale occurs in temperate waters of the North Pacific (Mead 1989). Most of the stranding records are from California (Willis and Baird 1998). Its distribution appears to be correlated

with the deep subarctic current (Mead et al. 1982). Its range is believed to be continuous across the North Pacific (Macleod et al. 2006), although this has yet to be substantiated because very few direct at-sea observations exist.

Hubb's beaked whale was seen during Japanese sighting surveys in the western North Pacific during August–September (Kato et al. 2005). However, there is very little information on this species for the Emperor Seamounts survey area, but what is known of its distribution suggests that it is unlikely to occur there. Although not expected to occur in warm waters, possible vocalizations have been detected acoustically in the Hawaiian Islands and Wake Atoll, but no detections were made in the Aleutians (Baumann-Pickering et al. 2014). Although possible, Hubb's beaked whale is unlikely to occur in the Hawaiian survey area.

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30°N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). Two forms of Baird's beaked whales have been recognized – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, in the Aleutians, and on the west coast of North America, whereas the black form has been reported for northern Japan and the Aleutians (Morin et al. 2017). Recent genetic studies suggest that the black form could be a separate species (Morin et al. 2017).

Baird's beaked whale is currently divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). The whales occur year-round in the Okhotsk Sea and Sea of Japan (Kasuya 2009). Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 1993; Kasuya and Ohsumi 1984; Kasuya 2009).

Off Japan's Pacific coast, Baird's beaked whales start to appear in May, numbers increase over the summer, and decrease toward October (Kasuya 2009). During this time, they are nearly absent in offshore waters (Kasuya 2009). Kato et al. (2005) also reported the presence of Baird's beaked whales in the western North Pacific in August–September. They have also been detected acoustically in the Aleutian Islands (Baumann-Pickering et al. 2014).

Baird's beaked whale could be encountered at the Emperor Seamounts survey area, but its distribution does not include Hawaiian waters.

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. 2015).

The rough-toothed dolphin is expected to be one of the most abundant cetaceans in the Hawaiian survey area, based on previous surveys in the area (Barlow et al. 2004; Barlow 2006; Baird et al. 2013; Bradford et al. 2017). Higher densities are expected to occur in deeper waters around the Hawaiian Islands than in far offshore waters of the Hawaiian EEZ (Forney et al. 2015). 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, throughout the year (Baird et al. 2013). Sightings were made off the Big Island as well as Oahu (Baird et al. 2013). The area west of the Big Island is considered BIA (Baird et al. 2015); proposed seismic Line 1 would traverse this area. During summer–fall surveys of the Hawaiian Islands EEZ, rough-toothed dolphins were observed throughout the EEZ, including near the proposed survey area to the north and south of the Main Hawaiian Islands; in total, there were 18

sightings in 2002 and 24 sightings in 2010 (Barlow 2006; Barlow et al. 2004; Bradford et al. 2017). Acoustic detections have also been made in Hawaiian waters (Rankin et al. 2015).

In the western North Pacific Ocean, rough-toothed dolphins have been seen during Japanese sighting surveys during August–September (Kato et al. 2005). However, there is very little information on this species for the Emperor Seamounts survey area, but what is known of its distribution suggests that it is unlikely to occur there.

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).

The bottlenose dolphin is expected to be one of the most abundant cetaceans in the Hawaiian survey area, based on previous surveys in the region (Barlow 2006; Baird et al. 2013; Bradford et al. 2017). Higher densities are expected to occur around the Hawaiian Islands than in far offshore waters of the Hawaiian EEZ (Forney et al. 2015). Photo-identification studies have shown that there are distinct resident populations at the four island groups in Hawaii (Kuai & Niihau, Oahu, the 4-island region, and the Big Island); the 1000-m isobath serves as the boundary between these resident insular stocks and the Hawaii pelagic stock (Martien et al. 2012). The areas where the insular stocks are found are also considered BIAs (Baird et al. 2015). Proposed seismic Lines 1 and 2 would traverse the BIAS to the west of Oahu and west of the Big Island.

During small-boat surveys around the Hawaiian Islands in 2000–2012, the bottlenose dolphin was sighted in water as deep as 4500 m, but the highest sighting rates occurred in water <500 m deep (Baird et al. 2013). Sightings were made during all seasons off the Big Island, including near proposed seismic Line 1, and off Oahu (Baird et al. 2013). Common bottlenose dolphins were also observed during summer–fall surveys of the Hawaiian EEZ, mostly in nearshore waters but also in offshore waters, including in and near the proposed survey area among the Main Hawaiian Islands, and to the north and south of the islands (see map in Carretta et al. 2017). Fifteen sightings were made in 2002 (Barlow 2006), and 19 sightings were made in 2010 (Bradford et al. 2017).

In the western North Pacific Ocean, common bottlenose dolphins have been sighted off the east coast of Japan during summer surveys in 1983–1991 (Miyashita 1993a). Although only part of the proposed Emperor Seamounts survey area was surveyed during the month of August, no sightings were made within or near the survey area (Miyashita 1993a). Offshore sightings to the south of the proposed survey area were made during September (Miyashita 1993a), and there is also a record just to the southwest of the survey area during summer (Kanaji et al. 2017). The distributional range of the common bottlenose dolphin does not appear to extend north to the Emperor Seamounts survey area; thus, it is not expected to be encountered during the survey.

Short-beaked Common Dolphin (*Delphinus delphis*)

The common dolphin is found in tropical and warm temperate oceans around the World (Perrin 2009a). It ranges as far south as 40°S in the Pacific Ocean, is common in coastal waters 200–300 m deep, and is also associated with prominent underwater topography, such as seamounts (Evans 1994). There are two species of common dolphins: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*). The short-beaked common dolphin is

mainly found in offshore waters, and the long-beaked common dolphin is more prominent in coastal areas.

During Japanese sighting surveys in the western North Pacific in August–September, both long- and short-beaked common dolphins have been seen (Kato et al. 2005). Kanaji et al. (2017) reported one record to the southwest of the proposed survey area during summer. There are also bycatch records of short-beaked common dolphins near the Emperor Seamounts survey area during summer and winter (Hobbs and Jones 1993). Based on information regarding the distribution and habitat preferences, only the short-beaked common dolphin could occur in the region.

Neither the short-beaked nor long-beaked common dolphin are expected to occur in the Hawaiian survey area. No sightings of either species have been made during surveys of the Hawaii Islands (Barlow 2006; Baird et al. 2013; Bradford et al. 2017).

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 2009b), between ~40°N and 40°S (Jefferson et al. 2015). It is found primarily in deeper waters, but can also be found in coastal, shelf, and slope waters (Perrin 2009b). 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 2009b). 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 Hawaiian survey area based on previous surveys in the region (Baird et al. 2013; Barlow 2006; Bradford et al. 2017). Higher densities are expected to occur around the Main Hawaiian Islands than elsewhere in the Hawaiian EEZ (Forney et al. 2015). The Main Hawaiian Islands insular spotted dolphin stock consists of two separate stocks at Oahu and 4-Islands (which extend 20 km seaward), and one stock off the Big Island, up to 65 km from shore (Carretta et al. 2017). Spotted dolphins outside of these insular stocks are part of the Hawaii pelagic stock (Carretta et al. 2017).

During small-boat surveys around the Hawaiian Islands in 2000–2012, the pantropical spotted dolphin was sighted in all water depth categories, with the lowest sighting rate in water <500 m (Baird et al. 2013). It was observed during all seasons, including off the Big Island and Oahu (Baird et al. 2013). It was also seen during summer–fall surveys of the Hawaiian Islands EEZ including in the proposed survey area, with sightings to the north, south, and around the Main Hawaiian Islands (see map in Carretta et al. 2017); 14 sightings were made in 2002 (Barlow 2006), and 12 sightings were made in 2010 (Bradford et al. 2017). The areas off southwest Oahu, south of Lanai, and west of the Big Island are considered BIAs (Baird et al. 2015); proposed seismic Line 1 traverses the BIA west of the Big Island. One sighting was made in July 2010 in the northwestern portion of the Hawaiian EEZ during the Shatsky Rise cruise (Holst and Beland 2010).

In the western Pacific, pantropical spotted dolphins occur from Japan south to Australia; they have been hunted in drive fisheries off Japan for decades (Kasuya 2007). A sighting of three individuals was made in offshore waters east of Japan in August 2010 during the Shatsky Rise cruise (Holst and Beland 2010). Pantropical spotted dolphins were also sighted off the east coast of Japan during summer surveys in 1983–1991, with the highest densities in offshore waters between 30°N and 37°N (Miyashita 1993a). Although only part of the proposed Emperor Seamounts survey area was surveyed

during the month of August, no sightings were made within or near the survey area; offshore sightings to the south of the proposed survey area were made during August and September (Miyashita 1993a). The distributional range of the pantropical spotted dolphin does not appear to extend north to the Emperor Seamounts survey area; thus, it is not expected to be encountered during the survey.

Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, including oceanic tropical and sub-tropical waters between 40°N and 40°S (Jefferson et al. 2015). It is generally considered a pelagic species (Perrin 2009b), but can also be found in coastal waters and around oceanic islands (Rice 1998). In Hawaii, spinner dolphins belong to the offshore stock (*S.l. longirostris*; Gray's spinner) that is separate from animals in the ETP (Dizon et al. 1991).

The spinner dolphin is expected to be one of the most abundant cetaceans in the Hawaiian survey area, based on previous surveys in the region (Barlow 2006; Baird et al. 2013; Bradford et al. 2017). Higher densities are expected to occur around in offshore waters south of the Hawaiian Islands (Forney et al. 2015). There are six separate stocks managed within the Hawaiian EEZ – the Hawaii Island (Big Island), Oahu/4-islands, Kauai/Niihau, Pearl & Hermes Reef, Midway Atoll/Kure, and Hawaiian pelagic stocks (Carretta et al. 2017); individuals from three of these stocks (Hawaii pelagic, Hawaii Island, Oahu/4-Islands) are expected to overlap with the proposed survey area. The boundaries of these stocks are out to 10 n.mi. from shore; these regions are also considered BIAs (Baird et al. 2015). Proposed seismic Line 1 traverses the BIA west of the Big Island of Hawaii.

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). It was seen during all months, including off the west coast of the Big Island and off Oahu (Baird et al. 2013). Spinner dolphins were also sighted in the proposed survey area during summer–fall surveys of the Hawaiian Islands EEZ, including south of Oahu (see map in Carretta et al. 2017); eight sightings were made in 2002 (Barlow 2006) and four were made in 2010 (Bradford et al. 2013).

Kato et al. (2005) noted that spinner dolphins were seen during Japanese sighting surveys in the western North Pacific in August–September. To the best of our knowledge, there are no data on the occurrence of spinner dolphins near the Emperor Seamounts survey area. However, the survey area is located to the north of the known range of the spinner dolphins.

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994a; Jefferson et al. 2015). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling (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. 2015).

The striped dolphin is expected to be one of the most abundant cetaceans in the proposed Hawaiian survey area, based on previous surveys in the region (Barlow 2006; Baird et al. 2013; Bradford et al. 2017). Higher densities are expected to occur around in offshore waters of the Hawaiian EEZ (Forney et al. 2015). 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). Sightings were made during all seasons, including near proposed seismic Line 1 off the Big Island (Baird et al. 2013). It was also sighted within the proposed survey area during summer–fall shipboard surveys of the Hawaii Islands EEZ, including north and south of the Main Hawaiian Islands

(see map in Carretta et al. 2017); 15 sightings were made in 2002 (Barlow 2006) and 25 sightings were made in 2010 (Bradford et al. 2013).

In the western North Pacific, the striped dolphin was one of the most common dolphin species seen during Japanese summer sighting surveys (Miyashita 1993a). During these surveys, densities were highest in offshore areas between 35°N and 40°N, and in coastal waters of southeastern Japan (Miyashita 1993a). Although only part of the proposed Emperor Seamounts survey area was surveyed during the month of August, no sightings were made within the survey area; sightings near the proposed survey area, south of 41°N, were made during August (Miyashita 1993a). Kanaji et al. (2017) reported on another record during summer to the southwest of the survey area. One winter bycatch record was reported just to the south of the survey area for October 1990 to May 1991 (Hobbs and Jones 1993). Based on its distributional range and habitat preferences, the striped dolphin could be encountered in the Emperor Seamounts survey area.

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, it was 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 offshore waters of the Hawaiian Islands EEZ (Barlow 2006; Bradford et al. 2017). Summer–fall shipboard surveys of the EEZ resulted in two sightings of Fraser's dolphin in 2002 and four in 2010, all in the western portion of the EEZ (Barlow 2006; Bradford et al. 2013; Carretta et al. 2017). During small-boat surveys around the Hawaiian Islands in 2000–2012, only two sightings were made off the west coast of the Big Island, one during winter and one during spring in water deeper than 1000 m.

Fraser's dolphin was seen during Japanese sighting surveys in the western North Pacific during August–September (Kato et al. 2005). However, its range does not extend as far north as the Emperor Seamounts survey area. Thus, Fraser's dolphin is not expected to occur in the Emperor Seamounts survey area, but it could be encountered in deep water of the Hawaii survey area.

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found throughout the temperate North Pacific, in a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). It is common both on the high seas and along the continental margins (Leatherwood et al. 1984; Dahlheim and Towell 1994; Ferrero and Walker 1996). Pacific white-sided dolphins often associate with other species, including cetaceans (especially Risso's and northern right whale dolphins; Green et al. 1993), pinnipeds, and seabirds.

Pacific white-sided dolphins were seen throughout the North Pacific during surveys conducted during 1983–1990 (Buckland et al. 1993; Miyashita 1993b). Sightings were made in the western Pacific during the summer (Buckland et al. 1993; Miyashita 1993b), as well as during spring and fall (Buckland et al. 1993). Pacific white-sided dolphins were observed in the southern portion of the Emperor Seamounts survey area, south of 45°S, as well as at higher latitudes just to the east (Buckland et al. 1993; Miyashita 1993b). Bycatch in the squid driftnet fishery has also been reported for the Emperor Seamounts survey area (Hobbs and Jones 1993; Yatsu et al. 1993). Thus, Pacific white-sided dolphins could be encountered in the Emperor Seamounts survey area, but they are not known to occur as far south as Hawaii.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, ranging from 34–55°N (Lipsky 2009). It occurs from the Kuril Islands south to Japan and eastward to the Gulf of Alaska and southern California (Rice 1998). The northern right whale dolphin is one of the most common marine mammal species in the North Pacific, occurring primarily on the outer continental shelf, slope waters, and oceanic regions, where water depths are >100 m (see Green et al. 1993; Barlow 2003; Carretta et al. 2017). The northern right whale dolphin does, however, come closer to shore where there is deep water, such as over submarine canyons (Jefferson et al. 2015).

Northern right whale dolphins were seen throughout the North Pacific during surveys conducted during 1983–1990, with sightings made in the western Pacific primarily during the summer (Buckland et al. 1993; Miyashita 1993b). Northern right whale dolphins were observed in the southern portion of the Emperor Seamounts survey area, south of 45°S (Buckland et al. 1993; Miyashita 1993b). Bycatch records for the Emperor Seamounts survey area have also been reported (Hobbs and Jones 1993; Yatsu et al. 1993). One sighting was made just to the east of the survey area, at a more northerly latitude (Miyashita 1993b). Thus, northern right whale dolphins could be encountered in the Emperor Seamounts survey area, but their distribution does not range as far south as the Hawaiian Islands.

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 60°N and 60°S, where surface water temperatures are at least 10°C (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). Sightings were made during all seasons off the west coast of the Big Island, including near proposed seismic Line 1; no sightings were made off Oahu (Baird et al. 2013). During summer–fall surveys of the Hawaiian Islands EEZ, seven sightings were made in 2002 (Barlow 2006) and 10 were made in 2010 (Bradford et al. 2017); several sightings occurred within the proposed survey area south of the Main Hawaiian Islands (see map in Carretta et al. 2017).

Risso's dolphins were regularly seen during Japanese summer sighting surveys in the western North Pacific (Miyashita 1993a), and one individual was seen in the offshore waters east of Japan on 18 August 2010 during the Shatksy Rise cruise (Holst and Beland 2010). Occurrence in the western North Pacific appears to be patchy, but high densities were observed in coastal waters, between 148°E–157°E, and east of 162°E (Miyashita 1993a). Although only part of the proposed Emperor Seamounts survey area was surveyed during the month of August, no sightings were made within the survey area; however, sightings were made south of 41°N (Miyashita 1993a). As its regular northern range extends to the southernmost portion of the Emperor Seamounts survey area, and one record has been reported outside of its range in the Aleutian Islands (Jefferson et al. 2014), the occurrence of Risso's dolphin is expected to be rare in the Emperor Seamounts survey area.

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is an oceanic species found worldwide in tropical and subtropical waters from ~40°N to 35°S (Jefferson et al. 2015). It is commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997; 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). In the

North Pacific, it is distributed south of central Japan and southern California, as well as across the Pacific, including Hawaii.

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 the Kohala resident stock associated with the west coast of the Big Island (Aschettino et al. 2012; Oleson et al. 2013; Carretta et al. 2017). During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made during all seasons in all water depths up to 5000 m, including sightings off the west coasts of the Big Island and Oahu (Baird et al. 2013). There are numerous records near the proposed seismic transect off the west coast of the Big Island (Carretta et al. 2017); this area is considered a BIA (Baird et al. 2015). 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. 2017). Satellite telemetry data revealed distant pelagic movements, associated with feeding, nearly to the edge of the Hawaiian Islands EEZ (Oleson et al. 2013).

Melon-headed whales have been seen during Japanese sighting surveys in the western North Pacific in August–September (Kato et al. 2005). However, their distributional range does not extend to the Emperor Seamounts survey area. Thus, melon-headed whale is expected to occur in the proposed Hawaiian survey area, but not in the Emperor Seamounts survey area.

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. 2015). In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. In the North Pacific, it occurs from Japan and Baja, California, southward and across the Pacific Ocean, including Hawaii.

A small resident population inhabits the waters around the Main Hawaiian Islands (Oleson et al. 2013), where it generally occurs within ~20 km from shore (Baird et al. 2011). During small-boat surveys around the Hawaiian Islands in 2000–2012, sightings were made during all seasons in water up to 3000 m deep, off the west coasts of Oahu and the Big Island (Baird et al. 2013), including near proposed seismic Lines 1 and 2. The waters off the west and southeast coasts of the Big Island are considered a BIA (Baird et al. 2015). Pygmy killer whales were also recorded during summer–fall surveys of the Hawaiian Islands EEZ: three sightings in 2002 (Barlow et al. 2004; Barlow 2006) and five in 2010 (Bradford et al. 2017), including some within the study area to the north and south of the Main Hawaiian Islands (Carretta et al. 2017).

Kato et al. (2005) reported the occurrence of this species during Japanese sighting surveys in the western North Pacific in August–September. However, its distributional range indicates that the pygmy killer whale is unlikely to occur in the Emperor Seamounts survey area.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50°N and 50°S (Odell and McClune 1999). It is widely distributed, but 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). In the North Pacific, it occurs from Japan and southern California, southward and across the Pacific, including Hawaii.

Telemetry, photo-identification, and genetic studies have identified three independent populations of false killer whales in Hawaiian waters: Main Hawaiian Islands Insular, Northwestern Hawaiian Islands, and Hawaii pelagic stocks (Chivers et al. 2010; Baird et al. 2010, 2013; Bradford et al. 2014; Carretta et al. 2017). The population 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). Higher densities likely occur in the western-most areas of the Hawaiian EEZ (Forney et al. 2015).

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, and 22 of those were assessed as seriously injured; locations of false killer whale and unidentified blackfish takes observed included the proposed survey area (Bradford and Forney 2014). Critical habitat has been proposed for the endangered insular population of the false killer whale in Hawaii; in general, this includes waters between the 45- and 3200-m isobaths in the Main Hawaiian Islands (NNMFS 2017c). The final rule is expected to be published ~1 July 2018 (NMFS 2017c).

High-use areas in Hawaii include the north half of the Big Island, the northern areas of Maui and Molokai, and southwest of Lanai (Baird et al. 2012). These areas are considered BIAs (Baird et al. 2015), and proposed seismic Line 1 to the west of the Big Island traverses the BIA. Individuals are found up to 122 km from shore (Baird et al. 2012). Satellite-tagged false killer whales were also recorded using the areas off the western Big Island and west of Oahu during summer 2008 and fall 2009 (Baird et al. 2012). 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). Sightings were made during all seasons, including off the west coast of the Big Island and Oahu (Baird et al. 2013). During summer–fall surveys of the Hawaiian Islands EEZ, two sightings were made in 2002 (Barlow et al. 2004; Barlow 2006) and 14 were made in 2010 (Bradford et al. 2017), including two within the study area, south of the Main Hawaiian Islands (see map in Carretta et al. 2017). False killer whales were also detected acoustically off the west coast of the Big Island and off Kauai (Baumann-Pickering et al. 2015).

False killer whales have been seen during Japanese summer sighting surveys in the western Pacific Ocean (Miyashita 1993a), and a sighting of four individuals was made in offshore waters east of Japan in August 2010 during the Shatksy Rise cruise (Holst and Beland 2010). The distribution in the western Pacific was patchy, with several high-density areas in offshore waters (Miyashita 1993a). Although only part of the proposed Emperor Seamounts survey area was surveyed during the month of August, no sightings were made within the survey area; however, one sighting was made just to the southeast of the survey area (Miyashita 1993a). Jefferson et al. (2015) did not show its distributional range to include the Emperor Seamounts region.

False killer whale is expected to occur in the proposed Hawaiian survey area, but it is likely rare, if present at all, in the Emperor Seamounts survey area.

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 small-boat surveys around the Hawaiian Islands in

2000–2012, a single sighting was made during spring in water <2000 m deep off the west coast of the Big Island (Baird et al. 2013). During summer–fall surveys of the Hawaiian Islands EEZ, two sightings were made in 2002 (Barlow et al. 2004; Barlow 2006) and one was made in 2010 (Bradford et al. 2017); none was made within the proposed survey area (Barlow et al. 2004; Bradford et al. 2017; Carretta et al. 2017). Numerous additional sightings in and north of the EEZ have been made by observers on longliners, some at the edge of the EEZ north of the Main Hawaiian Islands (Carretta et al. 2017).

Very little is known about killer whale abundance and distribution in the western Pacific Ocean outside of Kamchatka. However, they are common along the coast of Russia, Sea of Okhotsk, and Sea of Japan, Sakhalin Island, and Kuril Islands (Forney and Wade 2006). Kato et al. (2005) reported sightings of this species during Japanese sighting surveys in the western North Pacific in August–September. However, there is very little information on killer whales for the Emperor Seamounts survey area, but based on information regarding the distribution and habitat preferences, they are likely to occur there (see Forney and Wade 2006).

Killer whales are expected to occur in both the proposed Hawaiian and Emperor survey areas.

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 ~40°S and as far north as 50°N (Jefferson et al. 2015). 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). Based on genetic data, Van Cise et al. (2017) suggested that two types of short-finned pilot whales occur in the Pacific – one in the western and central Pacific, and one in the Eastern Pacific; they hypothesized that prey distribution rather than sea surface temperature determine their latitudinal ranges.

During surveys of the Main Hawaiian Islands during 2000–2012, short-finned pilot whales were the most frequently sighted cetacean (Baird et al. 2013). Higher densities are expected to occur around the Hawaiian Islands rather than in far offshore waters of the Hawaiian EEZ (Forney et al. 2015). Photo-identification and telemetry studies indicate that there may be insular and pelagic populations of short-finned pilot whales in Hawaii (Mahaffy 2012; Oleson et al. 2013). Genetic research is also underway to assist in delimiting population stocks for management (Carretta et al. 2017). During small-boat surveys around the Hawaiian Islands in 2000–2012, pilot whales were sighted in water as deep as 5000 m, with the highest sighting rates in water depths of 500–2500 m (Baird et al. 2013). Sightings were made during all seasons, mainly off the west coasts of the Big Island and Oahu (Baird et al. 2013). The waters off the west coast of the Big Island are considered a BIA (Baird et al. 2015); proposed seismic tLine 1 traverses the BIA. 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. 2017), including within the proposed survey area, north, south, and between the Main Hawaiian Islands (see Carretta et al. 2017). Short-finned pilot whales were also detected acoustically off the west coast of the Big Island and off Kauai (Baumann-Pickering et al. 2015).

Stock structure of short-finned pilot whales has not been adequately studied in the North Pacific, except in Japanese waters, where two stocks have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). The southern stock of short-finned pilot whales has been observed during Japanese summer sightings surveys (Miyashita 1993a) and is morphologically similar to pilot whales found in Hawaiian waters (Carretta et al. 2017). Distribution of short-finned pilot whales in the western North Pacific appears to be patchy, but high densities were observed in coastal waters of central and southern Japan and in some areas offshore (Miyashita 1993a). A sighting of three individuals was made in offshore waters east of Japan in August 2010 during the Shatksy

Rise cruise (Holst and Beland 2010). Although only part of the proposed Emperor Seamounts survey area was surveyed during the month of August, no sightings were made within or near the survey area; offshore sightings to the south of the proposed survey area were made during the month of September (Miyashita 1993a). Although Jefferson et al. (2015) did not include the Emperor Seamounts region in its distributional range, Olson (2009) did.

Short-finned pilot whales are expected to occur in the proposed Hawaiian survey area; their occurrence in the Emperor Seamounts survey area is expected to be rare.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is only found in the North Pacific and adjacent seas. It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979), ranging from ~30–62°N (Jefferson et al. 2015). In general, this species is common throughout its range (Buckland et al. 1993). It is known to approach vessels to bowride (Jefferson 2009b).

In the western North Pacific, there are two different color morphs which are also considered sub-species: the *truei*-type (*P. d. truei*) and the *dalli*-type (*P. d. dalli*) (Jefferson et al. 2015). They can be distinguished from each other by the extent of their white thoracic patches—the *truei*-type has a much broader patch, which extends nearly the length of the body. Both types could be encountered in the proposed Emperor Seamounts survey area.

Dall's porpoise was one of the most common cetaceans in the bycatch of the central and western North Pacific high-seas driftnet fisheries, but that source of mortality is not thought to have substantially depleted their abundance in the region (Hobbs and Jones 1993). Dall's porpoises were seen throughout the North Pacific during surveys conducted during 1987–1990 (Buckland et al. 1993), including in the western Pacific during the summer (Buckland et al. 1993; Kato et al. 2005). The observed range included the entire Emperor Seamounts survey area (Buckland et al. 1993). Records of both types within the Emperor Seamounts survey area, in particular for April–July, have also been reported by Kasuya (1982), and bycatch records in the proposed survey area have also been reported (Hobbs and Jones 1993; Yatsu et al. 1993). Thus, Dall's porpoise could be encountered in the Emperor Seamounts survey area, but its distribution does not range as far south as the Hawaiian Islands.

Pinnipeds

Hawaiian Monk Seal (*Neomonachus schauinslandi*)

The Hawaiian monk seal only occurs in the Central North Pacific. It is distributed throughout the Hawaiian Island chain, with most of the population occurring in the Northwestern Hawaiian Islands (within the PMNM), and a small but increasing number residing in the Main Hawaiian Islands (Baker et al. 2011). Six main breeding subpopulations are located at the Kure Atoll, Midway Islands, Pearl and Hermes Reef, Lisianski Island, Laysan Island, and French Frigate Shoals (Baker et al. 2011). Most births occur from February to August, with a peak in April to June, but births have been reported any time of the year (Gilmartin and Forcada 2009). Hawaiian monk seals show high site fidelity to natal islands (Gilmartin and Forcada 2009; Wilson et al. 2017). They mainly occur within 50 km of atolls/islands (Parrish et al. 2000; Stewart et al. 2006; Wilson et al. 2017) and within the 500-m isobath (e.g., Parrish et al. 2002; Wilson et al. 2017). Secondary occurrence may occur in water as deep as 1000 m, but occurrence beyond the 1000-m isobath is rare (DoN 2005). Nonetheless, tagged monk seals have been tracked in water >1000 m deep (Wilson et al. 2017).

Hawaiian monk seals are benthic foragers that feed on marine terraces of atolls and banks; most foraging occurs in water depths <100 m deep but occasionally to depths up to 500 m (Parrish et al. 2002;

Stewart et al. 2006). Stewart et al. (2006) used satellite tracking to examine the foraging behavior of monk seals at the six main breeding colonies in the Northwestern Hawaiian Islands. Foraging trips varied by sex and by age and ranged from <1 km up to 322 km from haul-out sites. Wilson et al. (2017) reported foraging trips of up to 100 km. Satellite tracking of Hawaiian monk seals revealed that home ranges in Main Hawaiian Islands were much smaller than those in the Northwestern Hawaiian Islands (NMFS 2007, 2014); home ranges for most seals were <2000 km² (Wilson et al. 2017).

Critical habitat has been designated based on preferred pupping and nursing areas, significant haul-out areas, and marine foraging areas out to a depth of 200 m (NMFS 2017b). In the Main Hawaiian Islands, critical habitat generally includes marine habitat from the seafloor to 10 m above the seafloor, from the 200-m isobath to the shoreline and 5 m inland, with some exceptions for specific areas (NMFS 2017b). For the Big Island of Hawaii, Maui, and Oahu (islands adjacent to the proposed transects), all marine habitat and inland habitat is included as critical habitat (NMFS 2017b). The seismic transects are located at least 10 km from monk seal critical habitat (Fig. 1).

Hawaiian monk seals have been reported throughout the Main Hawaiian Islands, including the west coast of Oahu, the east coast of Maui, and the north coast of the Big Island (Baker and Johanos 2004; DoN 2005). Tagged seals showed movements among the Main Hawaiian Islands, and were reported to occur near and crossing proposed seismic Lines 1 and 2 off the west coast of Oahu and the Big Island (Wilson et al. 2017). However, the core area of occurrence around Oahu was reported to be off the south coast, not the west coast (Wilson et al. 2017). Thus, monk seals could be encountered during the proposed survey, especially in nearshore portions (<1000 m deep), as well as areas near the islands where water depth is greater than >1000 m.

Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean and occurs from southern California to the Bering Sea, Okhotsk Sea, and Honshu Island, Japan (Muto et al. 2017). During the breeding season, most of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering Sea (Lee et al. 2014; Muto et al. 2017). The rest of the population occurs at rookeries on Bogoslof Island in the Bering Sea, in Russia (Commander Islands, Robben Island, Kuril Islands), on San Miguel Island in southern California (NMFS 1993; Lee et al. 2014), and on the Farallon Islands off central California (Muto et al. 2017). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2017). The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to California during winter (Muto et al. 2017).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2017). During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November; adult females are found ashore from June–November (Carretta et al. 2017; Muto et al. 2017). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Once weaned, juveniles spend 2–3 years at sea before returning to rookeries. Animals may migrate to the Gulf of Alaska, off Japan, and the west coast of the U.S. (Muto et al. 2017); in particular, adult males from the Pribilof Islands have been shown to migrate to the Kuril Islands in the western Pacific (Loughlin et al. 1999). The southern extent of the migration is ~35°N.

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990, including in the western Pacific during the summer (Buckland et al. 1993). The observed range included the entire Emperor Seamounts survey area (Buckland et al. 1993). They have also been reported as bycatch in squid and large-mesh fisheries during summer in the Emperor Seamounts survey area (Hobbs and Jones 1993; Yatsu et al. 1993). Tracked adult male fur seals that were tagged on St. Paul

Island in the Bering Sea in October 2009, wintered in the Bering Sea or northern North Pacific Ocean, and approached near the eastern-most extent of the Emperor Seamounts survey area; females migrated to the Gulf of Alaska and the California Current (Sterling et al. 2014). Tagged pups also approached the eastern portion of the Emperor Seamounts survey area during November (Lea et al. 2009). Thus, northern fur seals could be encountered in the Emperor Seamounts survey area; only juveniles would be expected to occur there during the summer. Their distribution does not range as far south as the Hawaiian Islands.

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion occurs along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). They are distributed around the coasts to the outer shelf from northern Japan through the Kuril Islands and Okhotsk Sea, through the Aleutian Islands, central Bering Sea, southern Alaska, and south to California (NMFS 2016c). There are two stocks or DPSs of Steller sea lions – the Western and the Eastern DPS which are divided at the 144°W longitude (NMFS 2016c). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (NMFS 2016c; Muto et al. 2017); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Critical habitat has been designated 20 n.mi. around all major haul-outs and rookeries, as well as three large foraging areas (NMFS 2017b); there is no critical habitat within the proposed survey area. Only individuals from the Western DPS are expected to occur in the proposed survey area. It is uncertain whether individuals that breed in Asia are genetically different enough to warrant a separate stock of Steller sea lion (Muto et al. 2017).

Rookeries of Steller sea lions from the Western DPS are located on the Aleutian Islands and along the Gulf of Alaska, as well as the east coast of Kamchatka, Commander Islands, and Kuril Islands (Burkanov and Loughlin 2005; Fritz et al. 2016; Muto et al. 2017). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008). Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). Territorial males fast and remain on land during the breeding season (NMFS 2008). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005). Loughlin et al. (2003) reported that most (88%) at-sea movements of juvenile Steller sea lions in the Aleutian Islands were short (<15 km) foraging trips. The mean distance of juvenile sea lion trips at sea was 16.6 km and the maximum trip distance recorded was 447 km. Long-range trips represented 6% of all trips at sea, and trip distance and duration increase with age (Loughlin et al. 2003; Call et al. 2007). Although Steller sea lions are not considered migratory, foraging animals can travel long distances outside of the breeding season (Loughlin et al. 2003; Raum-Suryan et al. 2002).

There is little information available on at-sea occurrence of Steller sea lions in the northwestern Pacific Ocean. Even though Steller sea lions are unlikely to occur in the proposed offshore survey area based on their known distributional range and habitat preference, it is possible that they could be encountered during the Emperor Seamounts survey area.

Northern Elephant Seal (*Mirounga angustirostris*)

Northern elephant seals breed in California and Baja California, primarily on offshore islands (Stewart et al. 1994), from December–March (Stewart and Huber 1993). Adult elephant seals engage in two long northward migrations per year, one following the breeding season, and another following the annual molt, with females returning earlier to molt (March–April) than males (July–August) (Stewart and

DeLong 1995). Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Hindell (2009) noted that traveling likely takes place in water depths >200 m.

When not breeding, elephant seals feed at sea far from the rookeries, ranging as far north as 60°N, into the Gulf of Alaska and along the Aleutian Islands (Le Boeuf et al. 2000). Some seals that were tracked via satellite-tags for no more than 224 days traveled distances in excess of 10,000 km during that time (Le Boeuf et al. 2000). Northern elephant seals that were satellite-tagged at a California rookery have been recorded traveling as far west as ~166.5–172.5°E, including the proposed Emperor Seamount survey area (Le Boeuf et al. 2000; Robinson et al. 2012; Robinson 2016 *in* OBIS 2018; Costa 2017 *in* OBIS 2018). Occurrence in the survey area was documented during August and September; during July and October, northern elephant seals were tracked just to the east of the survey area (Robinson et al. 2012). Post-molting seals traveled longer and farther than post-breeding seals (Robinson et al. 2012).

Thus, northern elephant seals could be encountered in the Emperor Seamounts survey area during summer and fall. Although there are rare records of northern elephant seals in Hawaiian waters, they are unlikely to occur in the proposed survey area.

Ribbon Seal (*Histiophoca fasciata*)

Ribbon seals occur in the North Pacific and adjacent Arctic Ocean, ranging from the Okhotsk Sea, to the Aleutian Islands and the Bering, Chukchi, and western Beaufort seas. Ribbon seals inhabit the Bering Sea ice front from late-March to early-May and are abundant in the northern parts of the ice front in the central and western parts of the Bering Sea (Burns 1970; Burns 1981). In May to mid-July, when the ice recedes, some of the seals move farther north (Burns 1970; Burns 1981) to the Chukchi Sea (Kelly 1988c). However, most likely become pelagic and remain in the Bering Sea during the open-water season, and some occur on the Pacific Ocean side of the Aleutian Islands (Boveng et al. 2008). Of 10 seals that were tagged along the coast of the Kamchatka Peninsula in 2005, most stayed in the central and eastern Bering Sea, but two were tracked along the south side of the Aleutian Islands; 8 of 26 seals that were tagged in the central Bering Sea in 2007 traveled to the Bering Strait, Chukchi Sea, and Arctic Basin (Boveng et al. 2008). Although unlikely ribbon seals could be encountered in the proposed Emperor Seamounts survey area.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

L-DEO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys in the North Pacific Ocean in 2018/2019. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. “Takes” by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of “Level B Harassment” for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. However, per NMFS requirement, L-DEO and NSF are also requesting small numbers of Level A takes 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. However, during the Emperor Seamounts survey where they could be present, Dall’s porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as it is known to approach vessels to bowride.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the North 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 surveys, 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.

Summary of Potential Effects of Airgun Sounds

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

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

Tolerance

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

Masking

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

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

and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016).

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

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

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

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

Dunlop et al. (2015) reported that migrating humpback whales in Austrian waters responded to a vessel operating a 20 in³ airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in³, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in³) within 3 km and received levels of at least 140 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$ (Dunlop et al. 20171). Responses to ramp up and use of a large 3130 in³ array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks reduced their southbound migration, or deviated from their path thereby avoiding the active array, when they were within 4 km of the active large airgun source, where received levels were >135 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$ (Dunlop et al. 2017b). These results are consistent with earlier studies (e.g., McCauley et al. 2000).

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

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

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

whales corroborates earlier evidence that, during the summer feeding season, bowheads are less responsive to seismic sources (e.g., Miller et al. 2005; Robertson et al. 2013).

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 μ Pa; at SPLs <108 dB re 1 μ Pa, 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-min} (cumulative SEL over a 10-min period) of ~94 dB re 1 μ Pa²·s, decreased at CSEL_{10-min} >127 dB re 1 μ Pa²·s, and whales were nearly silent at CSEL_{10-min} >160 dB re 1 μ Pa²·s. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The 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 μ Pa_{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. Gray whales in British Columbia exposed to seismic survey sound levels up to ~170 dB re 1 μ Pa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the

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

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

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

Toothed Whales.— Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing

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

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

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

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

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

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

individual fitness. Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

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

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

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 $\mu\text{Pa}_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in³ airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB $\mu\text{Pa}^2 \cdot \text{s}$. One porpoise moved away from the sound source but returned to natural movement patterns within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥ 170 dB disturbance criterion (rather than ≥ 160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is currently developing new guidance for predicting behavioral 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.

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed

that the detection rate for grey seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in³ airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Hearing Impairment and Other Physical Effects

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

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017; 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 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 $\mu\text{Pa}^2 \cdot \text{s}$ (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015; Schlundt et al. 2016).

Recent studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed

to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL_{cum} of 188 and 191 $\mu Pa^2 \cdot s$, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

Popov et al. (2016) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016, 2017).

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

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

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

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136,

and 148 dB re 1 μ Pa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 μ Pa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 μ Pa for 1 h induced a 44 dB TTS. For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 μ Pa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 μ Pa; no low-frequency TTS was observed.

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

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 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 as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat} . Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat} . Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur

in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale stranding along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2106). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 64 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NMFS 2017d). In a hearing to examine the Bureau of Ocean Energy Management's 2017-2022 OCS Oil and Gas Leasing Program (<http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=110E5E8F-3A65-4BEC-9D25-5D843A0284D3>), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico.

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

Possible Effects of Other Acoustic Sources

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

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales (*Peponocephala electra*; Southall et al. 2013) off Madagascar. During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated

that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

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

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on the *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, “all ranges are multiplied by a factor of 4” (Lurton 2016:209).

There is 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; Samarra and Miller 2016), mid-frequency active sonars (e.g., Tyack et al. 2011; Melcón et al. 2012; Miller et al. 2012, 2014b; 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. 2012d, 2015a; Wensveen et al. 2015; Friedlaender et al. 2016; Isojunno et al. 2016; Samarra and Miller 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 μ Pa. In contrast, Gong et al. (2014) reported no effect of the OAWRS signals on humpback whale vocalizations in the Gulf of Maine. Range to the source, ambient noise, and/or behavioral state may have differentially influenced the behavioral responses of humpbacks in the two areas (Risch et al. 2014).

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by grey seals to echosounders with frequencies of 200 and 375 kHz. Short-finned

pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2016).

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

Other Possible Effects of Seismic Surveys

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

Vessel noise from the *Langseth* could affect marine animals in the proposed survey areas. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20 to 300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018); Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2015; Jones et al. 2017; Putland et al. 2017). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016). Harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016).

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey area during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance

(Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986). Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016). Fin whale sightings in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

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

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

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

Another concern with vessel traffic is the potential for striking marine mammals. Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels (McKenna et al. 2015). The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with the R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

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

All takes would be anticipated to be Level B “takes by harassment” as described in § I, involving temporary changes in behavior. As required by NMFS, Level A takes have been requested; given the small exclusion zones and the proposed mitigation measures to be applied, injurious takes would not be expected for most species. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A “takes” would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level B and Level A sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys in the North Pacific Ocean.

The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

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

Basis for Estimating “Takes”

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥ 160 dB re $1 \mu\text{Pa}_{\text{rms}}$ 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, i.e., the 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 the proposed Hawaii survey, we used densities from Bradford et al. (2017), as required by NMFS. For cetacean species not included by Bradford et al. (2017), including *Kogia* spp. and spinner dolphin, we used the NOAA CetSound website to estimate exposures (NOAA 2018e). CetMap (<https://cetsound.noaa.gov/cda>), a mapping tool on the CetSound website, presents habitat-based density models for cetaceans in Hawaiian waters which were based on all appropriate surveys conducted within the Hawaiian EEZ. Details of the determination of the density for the Hawaiian monk seal are provided in Appendix B. Density estimates were not available for humpback and minke whales and were assumed to be zero, because these species are unlikely to occur in the survey area during the temporal scope of the study. As North Pacific right whales are extremely rare and very unlikely to occur in Hawaiian waters, they were not considered further.

For the proposed Emperor Seamounts survey, there are few published data, so we used mostly gray literature available from IWC scientific reports to compute densities based on parts of surveys that occurred within or adjacent to the survey area (e.g., Buckland et al. 1993; Miyashita 1993a; Hakamada et al. 2009; Matsuoka et al. 2009; Hakamada and Matsuoka 2015). It was necessary to use different densities for the Hawaii and Emperor Seamounts surveys, as there are major differences in the distribution and abundance of marine mammals in the two areas due to different oceanographic conditions. Details of the density calculations for each species or species group that could occur in the Emperor Seamounts survey area can be found in Appendix B. Densities for gray and Bryde’s whales were assumed to be zero in the Emperor Seamounts survey area, because these species are unlikely to occur there; gray whales generally do not occur that far offshore, and the distribution of Bryde’s whale does not extend as far north as the survey area.

All densities were corrected for trackline detection probability bias [$f(0)$] and availability [$g(0)$] bias by the authors, or in the case of the gray literature data, by using values provided either by the

authors, or if those were not provided, from comparable surveys conducted by NMFS. For the Hawaiian EEZ survey area, 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. 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 surveys.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 $\mu\text{Pa}_{\text{rms}}$ criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered “taken by harassment”. Tables 5 and 6 show 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 $\mu\text{Pa}_{\text{rms}}$ during the proposed seismic surveys in the North Pacific if no animals moved away from the survey vessel (see Appendix C for more details). The *Requested Take Authorization* is given in the right-most column of Tables 5 and 6. For all species, including those for which densities were not available or expected to be low, we have included a *Requested Take Authorization* for at least the mean group size for species where that number was higher than the calculated take.

For the proposed Hawaii survey, species (and relevant sources) for which the *Requested Take Authorization* was increased to mean group size include the minke whale (Jackson et al. 2008), humpback whale (Mobley et al. 2001), and killer whale (Bradford et al. 2017). For the proposed Emperor Seamounts survey, species (and relevant sources) for which the *Requested Take Authorization* was increased to mean group size include the pygmy sperm, dwarf sperm, and false killer whales (Barlow 2006); Risso’s dolphin, short-finned pilot whale, and Bryde’s whale (Bradford et al. 2017); and short-beaked common dolphin (Barlow 2016). For Stejneger’s and Baird’s beaked whales, the *Requested Take Authorization* was increased to the upper end of group sizes that could be encountered (Jefferson et al. 2015). For species that are very unlikely to occur in the survey area, the *Requested Take Authorization* was increased to 1 individual for the gray whale and 5 individuals for the Steller sea lion and ribbon seal.

It should be noted that the exposure estimates assume that the proposed surveys 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 $\mu\text{Pa}_{\text{rms}}$ are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the PEIS and §4.1.1.1 of this document. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of “takes by harassment” of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as “taken” to sound levels <160 dB (NMFS 2013b). 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 2013b).

The number of marine mammals that could be exposed to airgun sounds with received levels ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ (Level B) for marine mammals 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

TABLE 5. Densities and estimates of the possible numbers of marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed Hawaii seismic survey.

Species	Estimated Density ¹ (#/1000 km ²)	Calculated Take, NMFS Daily Method ²		Level A + Level B as % of Pop. ⁵	Requested Level B 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 ⁸	3	61	0.23	64
<i>Sei whale</i>	0.22 ⁸	1	13	0.05	14
<i>Fin whale</i>	0.06	0	4	0.02	4
<i>Blue whale</i>	0.05	0	3	0.13	3
MF Cetaceans					
<i>Sperm whale</i>	1.86	0	122	0.47	122
Cuvier's beaked whale	0.30	0	20	0.10	20
Blainville's beaked whale	0.86	0	57	0.22	57
Ginkgo-toothed beaked whale	0.63 ⁹	0	41	0.16	41
Deraniygala's beaked whale	0.63 ⁹	0	41	0.16	41
Hubbs beaked whale	0.63 ⁹	0	41	0.16	41
Longman's beaked whale	3.11	0	205	4.48	205
Rough-toothed dolphin	29.63	3	1946	1.81	1949
Common bottlenose dolphin	8.99	1	590	0.18	591
Pantropical spotted dolphin	23.32	3	1531	0.12	1534
Spinner dolphin	6.99 ¹⁰	1	459	0.03	460
Striped dolphin	25.0	3	1641	0.17	1644
Fraser's dolphin	21.04	2	1382	0.48	1384
Risso's dolphin	4.74	1	311	0.28	312
Melon-headed whale	3.54	0	233	0.51	233
Pygmy killer whale	4.35	1	285	0.74	286
<i>False killer whale</i>	0.60	0	39	0.24	39 ¹¹
Killer whale	0.06	0	4	0.05	5 ⁷
Short-finned pilot whale	7.97	1	523	0.98	524
HF Cetaceans					
Pygmy sperm whale	2.91 ¹⁰	7	184	2.68	191
Dwarf sperm whale	7.14 ¹⁰	16	454	2.68	470
Phocid Seals					
<i>Hawaiian Monk Seal</i>	0.05	0	3	0.27	3

Species in italics are listed under the ESA as endangered.

¹ Most densities from Bradford et al. (2017), except for the monk seal (see Appendix B for details), and otherwise as noted.

² Take using NMFS daily method for calculating ensouffled area: estimated density multiplied by the daily ensouffled area to levels ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ on one selected day (see text) multiplied by the number of survey days (12 days for mixed-depth lines; 7 days for deep lines), times 1.25; daily ensouffled area = full 160-dB area minus ensouffled area for the appropriate PTS thresholds.

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 4).

⁶ Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.

⁷ Requested take authorization (Level B only) increased to mean group size (see text and Appendix B for sources).

⁸ From Bradford et al. (2017), but added proportion for 'Sei or Bryde's whale' density.

⁹ From Bradford et al. (2017) for 'Unidentified Mesoplodon' proportioned equally among *Mesoplodon* spp., except *M. densirostris*.

¹⁰ From CetMap.

¹¹ Includes 6 individuals from the endangered Main Hawaiian Islands insular stock (population size estimated at 151) and 33 from the Hawaiian pelagic stock (population size estimated 906) (see Carretta et al. 2017).

TABLE 6. 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 Emperor Seamounts seismic survey in the northwest Pacific Ocean during 2019.

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					
Gray whale	0	0	0	0	1 ⁷
North Pacific right whale	0.54	1	22	5.11	23
Humpback whale	0.41	1	16	0.08	17
Minke whale	2.48	5	99	0.47	104
Bryde's whale	0	0	0	0	2 ⁸
Sei whale	2.93	5	117	0.45	122
Fin whale	0.93	2	37	0.24	39
Blue whale	0.13	0	5	0.19	50 ⁹
MF Cetaceans					
Sperm whale	10.97	1	456	1.54	457
Cuvier's beaked whale	6.80	1	283	1.42	284
Stejneger's beaked whale	N.A.	-	-	-	15 ¹⁰
Baird's beaked whale	N.A.	-	-	-	20 ¹⁰
Short-beaked common dolphin	N.A.	-	-	-	180 ⁸
Striped dolphin	9.21	1	383	0.04	384
Pacific white-sided dolphin	68.81	5	2865	0.29	2870
Northern right whale dolphin	3.37	0	141	0.05	141
Risso's dolphin	N.A.	-	-	-	27 ⁸
False killer whale	N.A.	-	-	-	10 ⁸
Killer whale	3.00	0	125	1.47	125
Short-finned pilot whale	N.A.	-	-	-	41 ⁸
HF Cetaceans					
Pygmy sperm whale	N.A.	-	-	-	1 ⁸
Dwarf sperm whale	N.A.	-	-	-	2 ⁸
Dall's porpoise	35.46	56	1443	0.12	1479
Otariids					
Northern fur seal	3.56	0	149	0.01	149
Steller sea lion	N.A.	-	-	-	5 ⁷
Phocid Seals					
Northern elephant seal	8.31	2	345	0.15	347
Ribbon seal	N.A.	-	-	-	5 ⁷

Species in italics are listed under the ESA as endangered. N.A. (-) is not available

¹ See text and Appendix B 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 $\mu\text{Pa}_{\text{rms}}$ on one selected day (see text) multiplied by the number of survey days (13), times 1.25; daily ensonified area = full 160-dB area minus ensonified area for the appropriate PTS threshold.

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 4).

⁶ Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.

⁷ Requested take authorization (Level B only) increased to 1 for cetaceans and 5 for pinnipeds.

⁸ Requested take authorization (Level B only) increased to mean group size (see text and Appendix B for sources).

⁹ Requested take authorization is based on feeding aggregation size given in Sears and Perrin (2009).

¹⁰ Requested take authorization increased to upper end of group size that could be encountered (Jefferson et al. 2008).

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 (180 km) with a proportion of depth intervals (100–1000 m and >1000 m) and associated radii that is roughly similar to that of the entire survey. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by “drawing” the applicable 160-dB (Table 1) and PTS threshold buffers (Table 2) around each line. The ensonified areas were then multiplied by the number of survey days (19 days for Hawaii, 13 days for Emperor Seamounts) increased by 25%; this is equivalent to adding an additional 25% to the proposed line km (see Appendix D for more details). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as the *Langseth* approaches.

Per NMFS requirement, estimates of the numbers of cetaceans and pinnipeds that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (power downs or shut downs when PSOs observed animals approaching or inside the EZs), are also given in Tables 5 and 6. Those numbers likely overestimate actual Level A takes because the predicted Level A EZ is small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Dall’s porpoise, which could be present during the Emperor Seamounts survey, could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as it is known to approach vessels to bowride. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey areas.

Hawaii Survey

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ in the Hawaii survey area is 10,233 cetaceans and 3 pinnipeds (Table 5). That total includes 152 marine mammals listed as *endangered* under the ESA: 122 sperm whales, 14 sei whales, 4 fin whales, 3 blue whales, and 6 false killer whales (Main Hawaiian Islands insular stock) representing 0.47%, 0.05%, 0.02%, 0.13%, and 0.24% of their regional populations, respectively, and 3 Hawaiian monk seals or 0.3% of the population. In addition, 405 beaked whales could be exposed. Most (88%) of the cetaceans potentially exposed would be delphinids; the rough-toothed dolphin, striped, pantropical spotted, and Fraser’s dolphins are expected to be the most common delphinid species in the area, with estimates of 1949, 1644, 1534, and 1384 exposed to ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$, respectively (0.12–1.81% of their regional populations).

Emperor Seamounts Survey

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ in the Emperor Seamounts survey area is 6180 cetaceans and 496 pinnipeds (Table 6). That total includes 663 cetaceans listed as *endangered* under the ESA: 457 sperm whales, 122 sei whales, 39 fin whales, 23 North Pacific right whales, 17 humpback whales (Western North Pacific DPS), and 5 blue whales, representing 1.54%, 0.45%, 0.24%, 5.11%, 0.08%, and 0.19%, of their regional populations, respectively. We have also requested additional takes for *endangered* species that are unlikely to occur in the survey area, including 1 gray whale and 5 Steller sea lions. In addition, 284 beaked whales, 1479 Dall’s porpoise, and 3 *Kogia* spp. could be exposed. More than half (59%) of the cetaceans potentially exposed would be delphinids; the Pacific white-sided is expected to be the most common delphinid species in the area, with an estimate of 2870 exposed to ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$, respectively

(0.29% of the regional populations). After the Pacific white-sided dolphin, the Dall's porpoise is expected to be the most commonly encountered species with an estimated 1479 individuals or 0.12% individuals exposed. In addition to the cetaceans, 149 northern fur seals and 347 northern elephant seals, or 0.01% and 0.15%, respectively, of their populations might be exposed to seismic sounds with received levels ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$.

Conclusions

The proposed seismic project would involve towing a 36-airgun array that introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". In §3.6.7, §3.7.7, and §3.8.7, the PEIS concluded that 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, odontocete, and pinniped species and that Level A effects were highly unlikely. Nonetheless, NMFS required the calculation of and request for potential Level A takes for the Proposed Action (following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys). For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2015, 2016d,e, 2017a,e).

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

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

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

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

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic surveys would not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above.

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations.

X. ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS

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

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

XI. MITIGATION MEASURES

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

Marine mammals and sea turtles are known to occur in the proposed survey areas. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental ‘take’ of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS). The proposed activities would take place in the Hawaiian EEZ in the central Pacific Ocean, and in International Waters at the Emperor Seamounts in the western Pacific Ocean.

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

Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. The scientific objectives for the proposed surveys could not be met using smaller sources, as the primary aim of the project is deep imaging of the crust and upper-most mantle, for which a large, low-frequency airgun array is required.
2. *Survey Location and Timing*—The PIs worked with L-DEO and NSF to identify specific locations where seismic activities would not take place, such as in critical habitat and marine protected areas, in order to avoid sensitive species and concentrations of marine mammals and still meet the research goals. For example, for the proposed Hawaii survey, the seismic transect lines were moved farther from shore to avoid exposing Hawaiian monk seal critical habitat and the HIHWNMS to Level A and B source levels. When considering potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the *Langseth*.

Most marine mammal species are expected to occur in Hawaiian waters year-round, except for baleen whales that occur in the area on a seasonal basis. In particular, humpback whales use Hawaiian waters extensively during the winter (December–April). Thus, the likely timing (i.e., summer/early fall) for the proposed survey is advantageous for minimizing potential impacts on baleen whales. At the Emperor Seamounts survey area, it is expected that a greater number of baleen whales would occur there during the summer (July–September, with peak numbers during August). However, a summer timeframe for the surveys has more ideal weather conditions resulting in calmer waters than other times of the year, which is necessary for quality data collection. The likely timing of the Emperor Seamounts survey would be spring/early summer given key factors.

3. *Mitigation Zones*—During the planning phase, mitigation zones for the proposed surveys were calculated based on modeling by L-DEO for both the EZ and the safety zone. The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve. A more detailed description of the modeling process used to develop the mitigation zones can be found in Appendix A.

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 modeled by L-DEO. Enforcement of mitigation zones via power and shut downs would be implemented during operations, as noted below.

Mitigation During Operations

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

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the threshold zone is decreased to the extent that marine mammals or turtles are no longer in or about to enter the EZ. The acoustic source would also be powered down in the event an ESA-listed seabird were observed diving or foraging within the designated 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 40-in³ airgun would be operated. If a marine mammal or turtle is detected within or near the smaller EZ around that single airgun, 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 zone for 15 min in the case of small odontocetes, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales, or
- the vessel has moved outside the EZ for turtles, e.g., if a turtle is sighted close to the vessel and the ship speed is 7.6 km/h, it would take the vessel ~15 min to leave the turtle behind in deep water.

The airgun array would be ramped up gradually after a power down or shut down for a marine mammal or sea turtle. 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.

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. The operating airgun(s) would also be shut down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ.

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, or (3) if a power-down has exceeded 30 min. 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 30 min,

as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal or sea turtle has not cleared the EZ as described earlier.

Ramp up would begin with the smallest airgun in the array (40 in³). Ramp-up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals or turtles are sighted, a power down or shut down would be implemented as though the full array were operational. Ramp up would not commence at night or during poor visibility unless the EZ has been monitored visually and PAM has occurred for 30 min prior to the start of operations and no marine mammal or sea turtle detections occurred during that period.

XII. PLAN OF COOPERATION

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

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

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

XIII. MONITORING AND REPORTING PLAN

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

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan would be subject to review by NMFS and that refinements may be required.

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

Vessel-based Visual Monitoring

Observations by PSOs would take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations would be suspended when marine mammals, turtles, or diving ESA-listed seabirds are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals and sea 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 *Langseth* is underway without seismic operations, such as during transits. PSOs would also watch for any potential impacts of the acoustic sources on fish.

During seismic operations, five PSOs would be based aboard the *Langseth*. All PSOs would be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals and sea turtles around the seismic vessel; these observers may be referred to as the visual PSOs or “PSVOs”. Use of two simultaneous observers would increase the effectiveness of detecting animals around the source vessel. However, during meal times, only one PSVO may be on duty. PSVO(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 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 *Langseth* is a suitable platform for marine mammal and turtle observations. When stationed on the observation platform, the eye level would be ~21.5 m above sea level, and the observer would have a good view around the entire vessel. During daytime, the PSVO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.

Passive Acoustic Monitoring

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

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

conditioning, and processing system would be located. The acoustic signals received by the hydrophones are amplified, digitized, and then processed by the Pamguard software. The system can detect marine mammal vocalizations at frequencies up to 250 kHz.

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when the *Langseth* 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 PSO would monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSO monitoring the acoustical data referred to as the PSAO, would be on shift for 1–6 h at a time. All observers would be expected to rotate through the PAM position, although the most experienced with acoustics would be on PAM duty more frequently.

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

PSO Data and Documentation

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

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

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

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

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

Results from the vessel-based observations would provide

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

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

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

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

XV. LITERATURE CITED

- Aarts, G., A.M. von Benda-Beckmann, K. Lucke, H.Ozkan Sertlek, R. van Bemmelen, S.C. V. Geelhoed, S. Brasseur, M. Scheidat, F.P.A. Lam, H. Slabbekoorn, and R. Kirkwood. 2016. Harbour porpoise movement strategy affects cumulative number of animals acoustically exposed to underwater explosions. **Mar. Ecol. Prog. Ser.** 557:261-275.
- Acosta, A., N. Nino-Rodriguez, M.C. Yepes, and O. Boisseau. 2017. Mitigation provisions to be implemented for marine seismic surveying in Latin America: a review based on fish and cetaceans. **Aquat. Biol.** 199-216.
- 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 edit. Academic Press, San Diego, CA. 1316 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.
- Allen, G.M. 1942. Extinct and vanishing mammals of the Western Hemisphere with the marine species of all oceans. **Spec. Publ. Am. Comm. Intern. Wildl. Protection** No.11. 620 p.
- 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.
- Applied Physics Laboratory-University of Washington. 2006. North Pacific Acoustics Laboratory. Accessed 15 February 2017 at <http://www.apl.washington.edu/projects/npal/index.php>.
- 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** 185:463-486.
- 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 Zahren, 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.
- Bain, D.E. and R. Williams. 2006. Long-range effects of airgun noise on marine mammals: responses as a function of received sound level and distance. Paper SC/58/E35 presented to the IWC Sci. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.
- Baird, R.W. 2009b. 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., G.S. Schorr, D.L. Webster, D.J. McSweeney, M.B. Hanson, and R.D. Andrews. 2011. Movements of two satellite-tagged pygmy killer whales (*Feresa attenuata*) off the island of Hawai'i. **Mar. Mamm. Sci.** 27(4):E332-E337.
- Baird, R.W., M.B. Hanson, G.S. Schorr, D.L. Webster, D.J. McSweeney, A.M. Gorgone, S.D. Mahaffy, D.M. Holzer, E.M. Oleson, and R.D. Andrews. 2012. Range and primary habitats of Hawaiian insular false killer whales: informing determination of critical habitat. **Endang. Species Res.** 18:47-61.
- 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., D. Cholewiak, D.L. Webster, G.S. Schorr, S.D. Mahaffy, C. Curtice, J. Harrison, and S.M. Van Parijs. 2015. 5. Biologically important areas for cetaceans within U.S. waters – Hawai'i Region. **Aquatic Mamm.** 41(1):54-64.
- 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, J.D. and T.C. Johanos. 2004. Abundance of the Hawaiian monk seal in the main Hawaiian Islands. **Biol. Conserv.** 116(1):103-110.
- 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. Natl. 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.
- Balcomb, K.C. 1989. Baird's beaked whales *Berardius bairdii* Stejneger, 1883; Arnoux's beaked whale *Berardius arnuxii* Duvernoy, 1851. p. 261-288 In: Ridgway, S.H. and S.R. Harrison (eds.), Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, London, U.K. 442 p.
- 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. 2016. Cetacean abundance in the California Current estimated from ship-based line-transect surveys in 1991-2014. National Oceanic and Atmospheric Administration (NOAA) Administrative Rep. LJ-16-01. 31 p. + appendix.
- 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. Appller. 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.** 27(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. Pages 273-276 In: A.N. Popper and A. Hawkins (eds.) The effects of noise on aquatic life. Springer, New York, NY. 695 p.
- Baumann-Pickering, S., M.A. Roch, R.L. Brownell Jr., A.E. Simonis, M.A. McDonald, A. Solsona-Berga, E.M. Oleson, S.M. Wiggins, and J.A. Hildebrand. 2014. Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific. **PLoS One** 9(1):e86072. doi:10.1371/journal.pone.0086072.

- Baumann-Pickering, S., A.E. Simonis, E.M. Oleson, R.W. Baird, M.A. Roch, and S.M. Wiggins. 2015. False killer whale and short-finned pilot whale acoustic identification. **Endang. Spec. Res.** 28:97-108.
- Baumann-Pickering, S., A.E. Simonis, J.S. Trickey, M.A. Roch, and E.M. Oleson. 2016. Beaked whale species occurrence in the central Pacific and their relation to oceanographic features. **J. Acoust. Soc. Am.** 140(4):3017-3017.
- 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 April 2017 at https://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?utm_term=.db43ada63ee0
- 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.
- Bittencourt, L., I.M.S. Lima, L.G. Andrade, R.R. Carvalho, T.L. Bisi, J. Lailson-Brito, Jr., and A.F. Azevedo. 2016. Underwater noise in an impacted environment can affect Guiana dolphin communication. **Mar. Poll. Bull.** <https://doi.org/10.1016/j.marpolbul.2016.10.037>.
- 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.** <https://doi.org/10.1111/mms.12001>.
- 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. doi:10.1371/journal.pone.0125720.
- Blair, H.B., N.D. Merchant, A.S. Friedlaender, D.N. Wiley, and S.E. Parks. 2016. Evidence for ship noise impacts on humpback whale foraging behaviour. **Biol. Lett.** 12:20160005.
- Boveng, P.L., J.L. Bengtson, M.F. Cameron, S.P. Dahle, E.A. Logerwell, J.M. London, J.E. Overland, J.T. Sterling, D.E. Stevenson, B.L. Taylor, and H.L. Ziel. 2008. Status review of the ribbon seal (*Histiophoca fasciata*). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-255. 174 p.
- 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 Hawaiian 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. doi: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., K.A. Forney, E.M. Oleson, and J. Barlow. 2017. Abundance estimates of cetaceans from a line-transect survey within the U.S. Hawaiian Islands Exclusive Economic Zone. **Fish. Bull.** 115(2):129-142.
- 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 et al. 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.

- Branch, T.A., D.P. Palacios, and C.C. Monnahan. 2016. Overview of North Pacific blue whale distribution, and the need for an assessment of the western and central Pacific. Paper SC/66b/IA 15 presented to the International Whaling Commission. 12 p.
- 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.
- Briggs, H.B., D.G. Calkins, R.W. Davis, and R. Thorne. 2005. Habitat associations and diving activity of subadult Steller sea lions (*Eumetopias jubatus*) during the winter and spring in the north-central Gulf of Alaska. Abstr. 16th Bienn. Conf. Biol. Mar. Mamm., 12–16 Dec. 2005, San Diego, CA.
- 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 Greenland, 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.
- Brownell, R.L., W.A. Walker, and K.A. Forney. 1999. Pacific white-sided dolphin - *Lagenorhynchus obliquidens* (Gray, 1828). p. 57-84 *In*: S.H. Ridgway and S.R. Harrison (eds.), *Handbook of marine mammals*, Vol. 6: The second book of dolphins and porpoises. Academic Press, San Diego, CA. 486 p.
- Brownell, R.L., Jr., P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. **J. Cetac. Res. Manage. Spec. Iss.** 2:269-286.
- Buckland, S.T., K.L. Cattanch, and R.C. Hobbs. 1993. Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987-1990. **Int. North Pacific Fish. Comm. Bull.** 53(3):387-407.
- Burkanov, V. and T.R. Loughlin. 2005. Distribution and abundance of Steller sea lions on the Asian coast, 1720's–2005. **Mar. Fish. Rev.** 67(2):1-62.
- Burns, J. J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. **J. Mammal.** 51:445-454.
- Burns, J. J. 1981. Ribbon seal-*Phoca fasciata*. p. 895-109, *In* S. H. Ridgway and R. J. Harrison (eds.), *Handbook of Marine Mammals*. Vol. 2. Seals. Academic Press, New York.
- 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 to the Pacific Scientific Review Group, April 2013. 7 p. Accessed in January 2016 at <http://www.cascadiaresearch.org/reports/Rep-Mn-Bm-2011-Rev.pdf>.
- 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/uploadedFiles/Divisions/PRD/Projects/Research_Cruises/Hawaii_and_Alaska/SPLASH/SPLASH-contract-Report-May08.pdf.
- Call, K.A., B.S. Fadely, A. Grieg, and M.J. Rehberg. 2007. At-sea and on-shore cycles of juvenile Steller sea lions (*Eumetopias jubatus*) derived from satellite dive recorders: A comparison between declining and increasing populations. **Deep-Sea Res. Pt. II** 54: 298-300.
- 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., K.A. Forney, E.M. Oleson, D.W. Weller, A.R. Lang, 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. Brownwell Jr. 2017. U.S. Pacific marine mammal stock assessments: 2016. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-577. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 407 p.
- 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. doi:10.1371/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.
- Cholewiak, D., A. Izzi, D. Palka, P. Corkeron, and S. Van Parijs. 2017. Beaked whales demonstrate a marked acoustic response to the use of shipboard echosounders. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, Nova Scotia, Canada.
- Clapham, P.J. 2009. Humpback whale. p. 582-595 In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. Academic Press, San Diego, CA. 1316 p.
- Clapham, P.J., C. Good, S.E. Quinn, R.R. Reeves, J.E. Scarff, and R.L. Brownell, Jr. 2004. Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. **J. Cetac. Res. Manage.** 6(1):1-6.
- 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.
- Costa, D.P., L. Schwarz, P. Robinson, R. Schick, P.A. Morris, R. Condit, D.E. Crocker, and A.M. Kilpatrick. 2016a. A bioenergetics approach to understanding the population consequences of disturbance: elephant seals as a model system. p. 161-169 In: A.N. Popper and A. Hawkins (eds.), The Effects of Noise on Aquatic Life II. Springer, New York, NY. 1292 p.

- Costa, D.P., L.A. Hückstädt, L.K. Schwarz, A.S. Friedlaender, B.R. Mate, A.N. Zerbini, A. Kennedy, and N.J. Gales. 2016b. Assessing the exposure of animals to acoustic disturbance: towards an understanding of the population consequences of disturbance. *Proceedings of Meetings on Acoustics* **4ENAL** 27(1):010027. doi:10.1121/2.0000298.
- Crone, T.J., M. Tolstoy, and H. Carton. 2014. Estimating shallow water sound power levels and mitigation radii for the R/V *Marcus G. Langseth* using an 8 km long MCS streamer. **Geochem., Geophys., Geosyst.** 15(10):3793-3807.
- Culloch, R.M., P. Anderwald, A. Brandecker, D. Haberlin, B. McGovern, R. Pinfield, F. Visser, M. Jessopp, and M. Cronin. 2016. Effect of construction-related activities and vessel traffic on marine mammals. **Mar. Ecol. Prog. Ser.** 549:231-242.
- 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.
- Dahlheim, M.E. and R.G. Towell. 1994. Occurrence and distribution of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in southeastern Alaska, with notes on an attack by killer whales (*Orcinus orca*). **Mar. Mamm. Sci.** 10(4):458-464.
- Dalebout, M.L., C.S. Baker, D. Steel, K. Thompson, K.M. Robertson, S.J. Chivers, W.F. Perrin, M. Gonnatilake, R.C. Anderson, J.G. Mead, C.W. Potter, L. Thompson, D. Jupiter, and T.K. Yamada. 2014. Resurrection of *Mesoplodon hotaula* Deraniyagala 1963: a new species of beaked whale in the tropical Indo-Pacific. **Mar. Mamm. Sci.** 30(3):1081-1108.
- 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.
- Darling, J.D., J. Calambokidis, K.C. Balcomb, P. Bloedel, K. Flynn, A. Mochizuki, K. Mori, F. Sato, H. Suganuma, and M. Yamaguchi. 1996. Movement of a humpback whale (*Megaptera novaeangliae*) from Japan to British Columbia and return. **Mar. Mamm. Sci.** 12(2):281-287.
- 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. doi:10.1371/journal.pone.0095315.
- Diebold, J.B., M. Tolstoy, P.J. Barton, and S.P. Gulick. 2006. Propagation of exploration seismic sources in shallow water. **Eos Trans. Amer. Geophys. Union** 87(36), Joint Assembly Suppl., Abstr. OS41A-03. 23-26 May, Baltimore, MD.
- 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., S.O. Southern, and W.F. Perrin. 1991. Molecular analysis of mtDNA types in exploited populations of spinner dolphins (*Stenella longirostris*). **Rep. Int. Whal. Comm. Spec. Iss.** 15:355-363.
- 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.
- Dolman, S.J., and M. Jasny. 2015. Evolution of marine noise pollution management. **Aquatic Mamm.** 41(4):357-374.
- 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.
- Donovan, G.P. 1991. A review of IWC stock boundaries. **Rep. Int. Whal. Comm. Spec. Iss.** 13:39–63.
- Donovan, C.R., C.M. Harris, L. Milazzo, J. Harwood, L. Marshall, and R. Williams. 2017. A simulation approach to assessing environmental risk of sound exposure to marine mammals. **Ecol. Evol.** 7:2101-2111.
- 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, 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.A., M.J. Noad, and D.H. Cato. 2016b. A spatially explicit model of the movement of humpback whales relative to a source. Proceedings of Meetings on Acoustics **4ENAL** 27(1):010026. doi:10.1121/2.0000296.
- 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.
- Dunlop, R.A., M.J. Noad, R.D. McCauley, L. Scott-Hayward, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2017a. Determining the behavioural dose–response relationship of marine mammals to air gun noise and source proximity. **J. Exp. Biol.** 220:2878–2886.
- Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2017b. The behavioural response of migrating humpback whales to a full seismic airgun array. **Proc. R. Soc. B.** 284:20171901. <http://dx.doi.org/10.1098/rspb.2017/1901>.
- Dyndo, M., D.M. Wisniewska, L. Rojano-Doñate, and P.T. Madsen. 2015. Harbour porpoises react to low levels of high frequency vessel noise. **Sci. Rep.** 5:11083. <http://dx.doi.org/doi:10.1038/srep11083>.
- 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.
- Ellison, W.T., R. Racca, C.W. Clark, B. Streever, A.S. Frankel, E. Fleishman, R. Angliss, J. Berger, D. Ketten, M. Guerra, M. Leu, M. McKenna, T. Sformo, B. Southall, R. Suydam, and L. Thomas. 2016. Modeling the aggregated exposure and responses of bowhead whales *Balaena mysticetus* to multiple sources of anthropogenic underwater sound. **Endang. Spec. Res.** 30:95-108.
- 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.
- 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. 2015. Communication masking in marine mammals: a review and research strategy. **Mar. Poll. Bull.** doi:10.1016/j.marpolbul.2015.12.007.
- 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.
- Evans, P.G.H. 1987. The natural history of whales and dolphins. Christopher Helm, Bromley, Kent, U.K. 343 p.

- Evans, W.E. 1994. Common dolphin, white-bellied porpoise *Delphinus delphis* Linnaeus, 1758. p. 191-224 In: S.H. Ridgway and R. Harrison (eds.) Handbook of marine mammals, Vol. 5. The first book of dolphins. Academic Press, San Diego, CA. 416 p.
- Farmer, N., K. Baker, D. Zeddies, M. Zykov, D. Noren, L. Garrison, E. Fougères, and A. Machernis. 2017. Population consequences of disturbance for endangered sperm whales (*Physeter macrocephalus*) exposed to seismic surveys in the Gulf of Mexico, USA. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, Nova Scotia, Canada.
- 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.
- Ferrero, R.C. and W.A. Walker. 1996. Age, growth and reproductive patterns of the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) taken in high seas driftnets in the central North Pacific Ocean. **Can. J. Zool.** 74(9):1673-1687.
- 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. 2016. Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise. Technical Report 3026. SSC Pacific, San Diego, CA.
- 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., J.F. Pilkington, B. Gisborne, T.R. Frasier, R.M. Abernethy, and G.M. Ellis. 2016. Recent observations of critically endangered North Pacific right whales (*Eubalaena japonica*) off the west coast of Canada. *Marine Biodiversity Records*, 9(1), p.50.
- Forney, K.A. and P.R. Wade. 2006. Worldwide distribution and abundance of killer whales. Pages 145-162 In: J.A. Estes, D.P. DeMaster, D.F. Doak, T.M. Williams, and R.L. Brownell, Jr. (eds.) *Whales, Whaling and Ocean Ecosystems*. University of California Press, Berkeley.
- Forney, K.A., E.A. Becker, D.G. Foley, J. Barlow, and E.M. Oleson. 2015. Habitat-based models of cetacean density and distribution in the central North Pacific. **Endang. Species Res.** 27:1-20.
- Forney, K.A., B.L. Southall, E. Slooten, S. Dawson, A.J. Read, R.W. Baird, and R.L. Brownell, Jr. 2017. Nowhere to go: noise impact assessments for marine mammal populations with high site fidelity. **Endang. Species Res.** 32:391-413.
- 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.
- Fritz, L., K. Sweeney, R. Towell, and T. Gelatt. 2016. Aerial and ship-based surveys of Steller sea lions (*Eumetopias jubatus*) conducted in Alaska in June-July 2013 through 2015, and an update on the status and trend of the western distinct population segment in Alaska.
- 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. Assess.** 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.
- Gailey, G., O. Sychenko, A. Rutenko, and R. Racca. 2017. Western gray whale behavioral response to extensive seismic surveys conducted near their feeding grounds. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, Nova Scotia, Canada.
- 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., Tampa, FL, 27 Nov.–2 Dec. 2011. 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.
- Gilmartin, W.G. and J. Forcada. 2009. Monk seals *Monachus monachus*, *M. tropicalis*, and *M. schauinslandi*. p. 741-744 In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. Academic Press, San Diego, CA. 1316 p.
- Gilmore, R.M. 1978. Right whale. In: D. Haley (ed.) Marine mammals of eastern North Pacific and arctic waters. Pacific Search Press, Seattle, WA.
- Giorli, G., A. Neuheimer, A. Copeland, and W.W. Au. 2016. Temporal and spatial variation of beaked and sperm whales foraging activity in Hawai'i, as determined with passive acoustics. **J. Acoust. Soc. Am.** 140(4):2333-2343.
- 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. doi: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.
- Green, G.A., R.A. Grotefendt, M.A. Smultea, C.E. Bowlby, and R.A. Rowlett. 1993. Delphinid aerial surveys in Oregon and Washington offshore waters. Rep. by Ebasco Environmental, Bellevue, WA, for National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, WA. Contract #50ABNF200058. 35 p.
- Gregg, 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.
- Gridley, T., S.H. Elwen, G. Rashley, A.B. Krakauer, and J. Heiler. 2016. Bottlenose dolphins change their whistling characteristics in relation to vessel presence, surface behavior and group composition. Proceedings of Meetings on Acoustics **4ENAL** 27(1):010030. <https://doi.org/10.1121/2.0000312>.
- Guan, S., J. Vignola, J. Judge, and D. Turo. 2015. Airgun inter-pulse noise field during a seismic survey in an Arctic ultra shallow marine environment. **J. Acoust. Soc. Am.** 138(6):3447-3457.
- 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.
- Hakamada, T. and K. Matsuoka. 2015a. Abundance estimate for sei whales in the North Pacific based on sighting data obtained during IWC-POWER surveys in 2010-2012. Paper SC/66a/IA12 presented to the IWC Scientific Committee, May 2015, San Diego, USA (unpublished). 12 p.

- Hakamada, T. and K. Matsuoka. 2015b. The number of blue, fin, humpback, and North Pacific right whales in the western North Pacific in the JARPNII offshore survey area. Paper SC/F16/JR13 presented to the IWC Scientific Committee, May 2015, San Diego, USA (unpublished). 12 p.
- Hakamada, T., K. Matsuoka, and T. Miyashita. 2009. Distribution and the number of western North Pacific common minke, Bryde's, sei and sperm whales distributed in JARPN II Offshore component survey area. Paper SC/J09/JR15 presented to the expert workshop to review the ongoing JARPN II Programme, Yokohama, Japan, 26-30, January 2009. 18 p. (unpublished).
- Hakamada, T., M. Takahashi, K. Matsuoka, and T. Miyashita. 2017. Abundance estimate for western North Pacific Bryde's whale by sub-areas based on IWC-POWER and JARPNII sighting surveys. Paper SC/MAR17/RMP/02 presented to the RMP Bryde's whale workshop, March 2017, Tokyo, Japan. 12 p. (unpublished).
- Hall, J. 1979. A survey of cetaceans of Prince William Sound and adjacent waters – their numbers and seasonal movements. Unpubl. Rep. to Alaska Outer Continental Shelf Environmental Assessment Programs. NOAA OSCEAP Juneau Project Office, Juneau, AK.
- Halliday, W.D., S.J. Insley, R.C. Hilliard, T. de Jong, and M.K. Pine. 2017. Potential impacts of shipping noise on marine mammals in the western Canadian Arctic. **Mar. Poll. Bull.** 123:73–82.
- Hammond, P.S., G. Bearzi, A. Bjørge, K. Forney, L. Karczmarski, T. Kasuya, W.F. Perrin, M.D. Scott, J.Y. Wang, R.S. Wells, and B. Wilson. 2008b. *Delphinus delphis*. In: IUCN 2009: IUCN Red List of Threatened Species. Version 2009.2. Accessed on 7 January 2010 at <http://www.iucnredlist.org/apps/redlist/details/6336/0>.
- 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.
- Harris, C.M., L. Thomas, E.A. Falcone, J. Hildebrand, D. Houser, P.H. Kvadsheim, F.-P.A. Lam, P.J.O. Miller, D.J. Moretti, A.J. Read, H. Slabbekoorn, B.L. Southall, P.L. Tyack, D. Wartzok, and V.M. Janik. 2017. Marine mammals and sonar: dose–response studies, the risk-disturbance hypothesis and the role of exposure context. **J. Appl. Ecol.** <http://dx.doi.org/doi:10.1111/1365-2566.12955>.
- 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.
- Harwood, J.S., S. King, C. Booth, C. Donovan, R. Schick, L. Thomas, and L. New. 2016. Understanding the population consequences of acoustic disturbance for marine mammals. p. 417-423 In: A.N. Popper and A. Hawkins (eds.), *The Effects of Noise on Aquatic Life II*. Springer, New York, NY. 1292 p.
- Hastie, G.D., C. Donovan, T. Götz, and V.M. Janik. 2014. Behavioral responses of grey seals (*Halichoerus grypus*) to high frequency sonar. **Mar. Poll. Bull.** 79(1-2):205-210.
- 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.
- 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. Prelim. Rep. from the Greenland Institute of Natural Resources. 59 p.
- 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.

- Henderson, E.E., S.W. Martin, R. Manzano-Roth, and B.M. Matsuyama. 2016. Occurrence and habitat use of foraging Blainville's beaked whales (*Mesoplodon densirostris*) on a US Navy range in Hawaii. **Aquatic Mamm.** 42(4):549.
- Herman, L.M., C.S. Baker, P.H. Forestell, and R.C. Antinaja. 1980. Right whale, *Balaena glacialis*, sightings nears Hawaii: a clue to the wintering grounds? **Mar. Ecol. Prog. Ser.** 2(4):271-275.
- Hermanssen, 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.
- Hermanssen, L., J. Tougaard, K. Beedholm, J. Nabe-Nielsen, and P.T. Madsen. 2015. Characteristics and propagation of airgun pulses in shallow water with implications for effects on small marine mammals. **PLoS ONE** 10(7):e0133436. doi:10.1371/journal.pone.0133436.
- Heyning, J.E. and M.E. Dalheim. 1988. *Orcinus orca*. **Mammal. Spec.** 304:1-9.
- Heyning, J.E. and J.G. Mead. 2009. Cuvier's beaked whale *Ziphius cavirostris*. 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.
- Hindell, M.A. and W.F. Perrin. 2009. Elephant seals. p. 990-992 In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. Academic Press, New York, NY. 1316 p.
- Hobbs, R. C. and L.L. Jones. 1993. Impacts of high seas driftnet fisheries on marine mammal populations in the North Pacific. **International North Pacific Fisheries Commission Bulletin** 53(3):409-434.
- 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.
- Holst, M. and J. Beland. 2010. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's Shatsky Rise marine seismic program in the Northwest Pacific Ocean, July–September 2010. LGL Rep. TA4873-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 70 p.
- 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.** 218:1647-1654.
- 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 edit. 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.0140119.
- 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.
- Houser, D.S., W. Yost, R. Burkhard, J.J. Finneran, C. Reichmuth, and J. Mulsow. 2017. A review of the history, development and application of auditory weighting functions in humans and marine mammals. **J. Acoust. Soc. Am.** 141(1371). <http://dx.doi.org/doi:10.1121/1.4976086>.
- Huggins, 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., 12–16 December 2005, San Diego, CA.

- IUCN (The World Conservation Union). 2018. The IUCN Red List of Threatened Species. Version 2017-3. Accessed in February 2018 at <http://www.iucnredlist.org/>
- IWC (International Whaling Commission). 2007a. Western North Pacific Bryde's Whale Implementation: Report of the First Intersessional Workshop. **J. Cetac. Res. Manage.** 9(Suppl.):407-427.
- IWC. 2007b. 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. 2018. Whale population estimates. Accessed on 1 March 2018 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. <https://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. 2009a. Rough-toothed dolphin *Steno bredanensis*. p. 990-992 In: W.F. Perrin, B. Würsig, and J.G.M. Theewissen (eds.), Encyclopedia of marine mammals. Academic Press, New York, NY. 1316 p.
- Jefferson, T.A. 2009b. Dall's porpoise *Phocoenoides dalli*. p. 296-298 In: W.F. Perrin, B. Würsig, and J.G.M. Theewissen (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., S. Leatherwood, and M.A. Webber. 1993. FAO Species identification guide. Marine mammals of the world. UNEP/FAO, Rome, Italy.
- 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, and J.J. Kiszka. 2014. Global distribution of Risso's dolphin *Grampus griseus*: a review and critical evaluation. **Mamm. Rev.** 44(1):56-68.
- Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2015. Marine mammals of the world: a comprehensive guide to their identification, 2nd edit. Academic Press, London, U.K.. 608 p.
- 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.
- Johnston, D.W., M. McDonald, J. Polovina, R. Domokos, S. Wiggins, and J. Hildebrand. 2008. Temporal patterns in the acoustic signals of beaked whales at Cross Seamount. **Biol. Lett.** 4:208-211.
- Jones, E.L., G.D. Hastie, S. Smout, J. Onoufriou, N.D. Merchant, K.L. Brookes, and D. Thompson. 2017. Seals and shipping: quantifying population risk and individual exposure to vessel noise. **J. Appl. Ecol.** [dx.doi.org/doi:10.1111/1365-2664.12911](https://doi.org/10.1111/1365-2664.12911).
- Kanaji, Y., H. Yoshida, and M. Okazaki. 2017. Spatiotemporal variations in habitat utilization patterns of four Delphinidae species in the western North Pacific, inferred from carbon and nitrogen stable isotope ratios. **Mar. Biol.** 164(4):65. doi:10.1007/s00227-017-3107-z.
- 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., R.L. Schusterman, B.L. Southall, and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinnipeds. **J. Acoust. Soc. Am.** 106(2):1142-1148.
- Kastak, D., B.L. Southall, R.J. Schusterman, and C. Reichmuth. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. **J. Acoust. Soc. Am.** 118(5):3154-3163.
- 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 (*Phocoena phocoena*) to an impulsive sound. **Aquat. Mamm.** 39(4):315-323.
- Kastelein, R.A., R. Gransier, 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., R. Gransier, and L. Hoek. 2016a. 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.
- Kastelein, R.A., L. Helder-Hoek, J. Covi, and R. Gransier. 2016b. Pile driving playback sounds and temporary threshold shift in harbor porpoises (*Phocoena phocoena*): effect of exposure duration. **J. Acoust. Soc. Am.** 139(5):2842-2851.
- Kastelein, R.A., L. Helder-Hoek, S. Van de Voorde, A.M. von Benda-Beckmann, F.P.A. Lam, E. Jansen, C.A.F. de Jong, and M.A. Ainslie. 2017. Temporary hearing threshold shift in a harbor porpoise (*Phocoena phocoena*) after exposure to multiple airgun sounds. **J. Acoust. Soc. Am.** 142(4):2430-2442.
- Kasuya, T. 1982. Preliminary report of the biology, catch and populations of *Phocoenoides* in the western Pacific. p. 3-20 *In*: Mammals in the seas, Volume 4, Small cetaceans, Seals, Sirenians and otters. FAO Advisory Committee on Marine Resources Research.
- 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.
- Kasuya, T. 2007. Japanese whaling and other fisheries. **Env. Sci. Pollut. Res.** 14:39-48.
- Kasuya, T. 2009. Giant beaked whales. p. 498-500 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. Academic Press, San Diego, California. 1316 p.

- Kasuya, T. and S. Ohsumi. 1984. Further analysis of Baird's beaked whales in the waters adjacent to Japan. **Rep. Int. Whal. Comm.** 33:633-641.
- Kasuya, T., T. Miyashita, and F. Kasamatsu. 1988. Segregation of two forms of short-finned pilot whales off the Pacific Coast of Japan. **Sci. Rep. Whales Res. Inst. Tokyo** 39:77-90.
- Kato, H. and T. Miyashita. 1998. Current status of the North Pacific sperm whales and its preliminary abundance estimates. Paper SC/50/CAWS2 presented to the Scientific Committee of the International Whaling Commission. 6 p.
- 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.
- Kato, H., M. Yoshioka, and S. Ohsumi. 2005. Current status of cetaceans and other marine mammals in the North Pacific, with a review of advanced research activities on cetacean biology in Japan. **Mammal Study** 30:S113-S124.
- Kelly, B.P. 1988c. Ribbon seal, *Phoca fasciata*. p. 96-106 In: J. W. Lentfer (ed.), Selected marine mammals of Alaska. Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.
- Kenney, R.D. and H.E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. **Continental 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.
- Ketten, D.R., J. O'Malley, P.W.B. Moore, S. Ridgway, and C. Merigo. 2001. Aging, injury, disease, and noise in marine mammal ears. **J. Acoust. Soc. Am.** 110(5, Pt. 2):2721.
- King, S.L., R.S. Schick, C. Donovan, C.G. Booth, M. Burgman, L. Thomas, and J. Harwood. 2015. An interim framework for assessing the population consequences of disturbance. **Meth. Ecol. Evol.** 6(1):1150-1158.
- 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., D.K. Mellinger, K. Klinck, N.M. Bogue, J.C. Luby, W.A. Jump, G.B. Shilling, T. Litchendorf, A.S. Wood, G.S. Schorr, and R.W. Baird. 2012. Near-real-time acoustic monitoring of beaked whales and other cetaceans using a SeagliderTM. **PLoS ONE** 7(5):e36128. doi:10.1371/journal.pone.0036128.
- 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. Nat. 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. Nat. 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.
- Kunc, H.P., K.E. McLaughlin, and R. Schmidt. 2016. Aquatic noise pollution: implications for individuals, populations, and ecosystems. **Proc. R. Soc. B.** 283:20160839. <http://dx.doi.org/doi:10.1098/rspb.2016.0839>.
- Lalas, C. and H. McConnell. 2015. Effects of seismic surveys on New Zealand fur seals during daylight hours: do fur seals respond to obstacles rather than airgun noise? **Mar. Mamm. Sci.** 32(2):643-663.
- 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.

- Lea, M.A., D. Johnson, R. Ream, J. Sterling, S. Melin, and T. Gelatt. 2009. Extreme weather events influence dispersal of naïve northern fur seals. **Biol. Lett.** 5:252-257.
- Leatherwood, S., R.R. Reeves, A.E. Bowles, B.S. Stewart, and K.R. Goodrich. 1984. Distribution, seasonal movements, and abundance of Pacific white-sided dolphins in the eastern North Pacific. **Sci. Rep. Whales Res. Inst. Tokyo** 35:129-157.
- LeBeouf, B.J., D.E. Crocker, D.P. Costa, S.B. Blackwell, P.M. Webb, and D.S. Houser. 2000. Foraging ecology of northern elephant seals. **Ecol. Monographs** 70(3):353-382.
- LeDuc, R.G., D.W. Weller, J. Hyde, A.M. Burdin, P.E. Rosel, R.L. Brownell Jr, B. Würsig, and A.E. Dizon. 2002. Genetic differences between western and eastern gray whales (*Eschrichtius robustus*). **J. Cetacean Res. Manage.** 4(1):1-5.
- Lee, O.A., V. Burkanov, and W.H. Neill. 2014. Population trends of northern fur seals (*Callorhinus ursinus*) from a metapopulation perspective. **J. Exp. Mar. Biol. Ecol.** 451:25-34.
- 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.
- Lesage, V., A. Omrane, T. Doniol-Valccroze, and A. Mosnier. 2017. Increased proximity of vessels reduces feeding opportunities of blue whales in St. Lawrence Estuary, Canada. **Endang. Species Res.** 32:351–361.
- Liberman, M.C., M.J. Epstein, S.S. Cleveland, H. Wang, and S.F. Maison. 2016. Toward a differential diagnosis of hidden hearing loss in humans. **PLoS ONE** 11(9):e0162726. doi:10.1371/journal.pone.0162726.
- Lipsky, J.D. 2009. Right whale dolphins *Lissodelphis borealis*, *L. peronii*. p. 958-962 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. Academic Press, San Diego, CA. 1316 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.
- Loughlin, T.R., D.J. Rugh, and C.H. Fiscus. 1984. Northern sea lion distribution and abundance: 1956–1980. **J. Wildl. Manage.** 48:729-740.
- Loughlin T.R., J.T. Sterling, R.L. Merrick, J.L. Sease, and A.E. York. 2003. Diving behavior of immature Steller sea lions (*Eumetopias jubatus*). **Fish. Bull.** 101:566-582
- Loughlin, T.R., W.J. Ingraham, Jr., N. Baba, and B.W. Robson. 1999. Use of a surface-current model and satellite telemetry to assess marine mammal movements in the Bering Sea. p. 615-630 *In*: T.R. Loughlin, and K. Ohtani (eds.) Dynamics of the Bering Sea. University of Alaska Sea Grant Press, AK-SG-99-03, Fairbanks, AK.
- Lowry, M.S., R. Condit, B. Hatfield, S.G. Allen, R. Berger, P.A. Morris, B.J. Le Boeuf, and J. Reiter. 2014. Abundance, distribution, and population growth of the northern elephant seal (*Mirounga angustirostris*) in the United States from 1991 to 2010. **Aquatic Mamm.** 40(1):20-31.
- Lucke, K., U. Siebert, P.A. Lepper, and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. **J. Acoust. Soc. Am.** 125(6):4060-4070.
- Luís, A.R., M.N. Couchinho, and M.E. Dos Santos. 2014. Changes in the acoustic behavior of resident bottlenose dolphins near operating vessels. 2014. **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 whalewatching 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. Balance, A. D'Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D.L. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whales species (Cetacean: 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 February 2018 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, Ont. 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.
- Manzano-Roth, R., E.E. Henderson, S.W. Martin, C. Martin, and B.M. Matsuyama. 2016. Impacts of U.S. Navy training events on Blainville's beaked whale (*Mesoplodon densirostris*) foraging dives in Hawaiian waters. **Aquatic Mamm.** 42(4):507-518.
- 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.
- 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 Bénédén, 1864) in Pipa, North-eastern Brazil. **J. Mar. Biol. Assoc. U.K.** doi: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.
- Mate, B.R., V.Y. Ilyashenko, A.L. Bradford, V.V. Vetyankin, G.A. Tsidulko, V.V. Rozhnov, and L.M. Irvine. 2015. Critically endangered western gray whales migrate to the eastern North Pacific. **Biol. Lett.** 11:20150071. doi:10.1098/rsbl.2015.0071.
- Matthews, L. 2017. Harbor seal (*Phoca vitulina*) reproductive advertisement behavior and the effects of vessel noise. Ph.D. Thesis, Syracuse University. 139 p.
- Matos, F. 2015. Distribution of cetaceans in Vestfjorden, Norway, and possible impacts of seismic surveys. MSc. Thesis, University of Nordland, Norway. 45 p.
- Matsuoka, K., H. Kiwada, Y. Fujise, and T. Miyashita. 2009. Distribution of blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*) and North Pacific right (*Eubalaena japonica*) whales in the

- western North Pacific based on JARPN and JARPN II sighting surveys (1994 to 2007). Paper SC/J09/JR35 presented to the Int. Whal. Comm., Cambridge, U.K.
- Matsuoka, K., T. Hakamada, and T. Miyashita. 2015. Distribution of blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*) and North Pacific right (*Eubalaena japonica*) whales in the western North Pacific based on JARPN and JARPNII (1994 to 2014). Paper SC/F16/JR9 presented to the Int. Whal. Comm., Cambridge, U.K.
- McAlpine, D.F. 2009. Pygmy and dwarf sperm whales *Kogia breviceps* and *K. sima*. p. 936-939 In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. 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 (Austral. Petrol. Product. Explor. Assoc.) 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. from 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., Tampa, FL, 27 Nov.–2 Dec. 2011. 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. doi:10.1121/2.0000281.
- McKenna, M.F., J. Calambokidis, E.M. Oleson, D.W. Laist, J.A. Goldbogen. 2015. Simultaneous tracking of blue whales and large ships demonstrate limited behavioral responses for avoiding collision. **Endang. Species. Res.** 27:219-232.
- 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. 1989b. Beaked whales of the genus *Mesoplodon*. p. 349-430 In: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.
- 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.
- Mead, J.G., W.A. Walker, and W.J. Jouck. 1982. Biological observations on *Mesoplodon carlhubbsi* (Cetacea: Ziphiidae). **Smithson. Contrib. Zool.** 344.
- 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 response to anthropogenic noise. **PLoS ONE** 7(2):e32681. doi:10.1371/journal.pone.0032681.

- Merkens, K., A. Simonis, and E. Oleson. 2016. Long-term monitoring of Physeteroidea (sperm whales, dwarf, and pygmy sperm whales) in the Central and Western Pacific. **J. Acoust. Soc. Am.** 139(4):2062-2062.
- 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. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. 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.
- 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.** 56(7):1168-1181.
- Miyashita, T. 1993a. Abundance of dolphin stocks in the western North Pacific taken by the Japanese drive fishery. **Rep. Int. Whal. Comm.** 43:417-437.
- Miyashita, T. 1993b. Distribution and abundance of some dolphins taken in the North Pacific driftnet fisheries. **Internat. North Pacific Fish. Comm. Bull.** 53(3):435-449.
- Miyashita, T. 2006. Cruise report of the sighting survey in the waters east of the Kuril Islands and the Kamchatka Peninsula in 2005. Unpublished report SC/58/NPM5 to the International Whaling Commission. 9 p.
- 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.
- Mizroch, S.A., D.W. Rice, D. Zwiefelhofer, J. Waite, and W.L. Perryman. 2009. Distribution and movements of fin whales in the North Pacific Ocean. **Mammal. Rev.** 39(3):193-227.
- 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.
- 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 Hawaii Department of Land and Natural Resources. 16 p. Accessed in January 2016 at http://hawaiihumpbackwhale.noaa.gov/documents/_science/HHWNMS_Research_Mobley.pdf.
- 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. doi:10.4401/ag-7089.
- Monnahan, C.C., T.A. Branch, K.M. Stafford, Y.V. Ivashchenko, and E.M. Oleson. 2014. Estimating historical eastern North Pacific blue whale catches using spatial calling patterns. **PLoS ONE** 9(6). doi:10.1371/journal.pone.0098974.
- 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.

- Morell, M., A. Brownlow, B. McGovern, S.A. Raverty, R.E. Shadwick, and M. André. 2017. Implementation of a method to visualize noise-induced hearing loss in mass stranded cetaceans. **Sci. Rep.** 7:41848 doi:10.1038/srep41848.
- Mori, K., F. Sato, and A. Mochizuki. 1998. recent observation records on the northern right whale in the waters of Ogasawara (Bonin Islands), Japan. Abstract p. 93-94 In: The World Marine Mammal Science Conference, Monaco, January 1998.
- Morin, P.A., C.S. Baker, R.S. Brewer, A.M. Burdin, M.L. Dalebout, J.P. Dines, I. Fedutin, O. Filatova, E. Hoyt, J.L. Jung, and M. Lauf. 2017. Genetic structure of the beaked whale genus *Berardius* in the North Pacific, with genetic evidence for a new species. **Mar. Mamm. Sci.** 33(1):96-111.
- 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, Nfld. 28 p. Accessed in November 2014 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. Bröker. 2016. Gray whale densities during a seismic survey off Sakhalin Island, Russia. **Endang. Species Res.** 29(3):211-227.
- Mulsow, J., C.E. Schlundt, L. Brandt, and J.J. Finneran. 2015. Equal latency contours for bottlenose dolphins (*Tursiops truncatus*) and California sea lions (*Zalophus californianus*). **J. Acoust. Soc. Am.** 138(5):2678-2691.
- Murase, H., T. Tamura, S. Otani, and S. Nishiwaki. 2016. Satellite tracking of Bryde's whales *Balaenoptera edeni* in the offshore western North Pacific in summer 2006 and 2008. **Fish. Sci.** 82(1):35-45.
- Muto, M.M., V.T. Helker, R.P. Angliss, B.A. Allen, P.L. Boveng, J.M. Breiwick, M.F. Cameron, P.J. Clapham, S.P. Dahle, M.E. Dahlheim, B.S. Fadely, M.C. Ferguson, L.W. Fritz, R.C. Hobbs, Y.V. Ivashchenko, A.S. Kennedy, J.M. London, S.A. Mizroch, R.R. Ream, E.L. Richmond, K.E.W. Shelden, R.G. Towell, P.R. Wade, J.M. Waite, and A.N. Zerbini. 2017. Alaska marine mammal stock assessments, 2016. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-355. 366 p.
- 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.** 216:3062-3070.
- 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 predicts a loud sound in the false killer whale (*Pseudorca 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.
- Nachtigall, P.E., A.Y. Supin, A.F. Pacini, and R.A. Kastelein. 2017. Four odontocete species change hearing levels when warned of impending loud sound. **Integrative Zool.** doi:10.1111/1749-4877.12286.
- National Academies of Sciences, Engineering, and Medicine. 2017. Approaches to understanding the cumulative effects of stressors on marine mammals. The National Academies Press. Washington, DC. 134 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. 2013a. Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. **Function. Ecol.** 27:314-322.
- New, L.F., D. Moretti, S.K. Hooker, D.P. Costa, and S.E. Simmons. 2013b. Using energetic models to investigate the survival and reproduction of beaked whales (family Ziphiidae). **PLoS ONE** 8(7):e68725. doi:10.1371/journal.pone.0068725.

- 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.
- Nitta, E. and J.R. Henderson. 1993. A review of interactions between Hawaii's fisheries and protected species. **Mar. Rish. Rev.** 55(2):83-92.
- NMFS (NMFS (National Marine Fisheries Service). 1993. Final conservation plan for the northern fur seal (*Callorhinus ursinus*). Prepared by the National Marine Mammal Laboratory, Alaska Fisheries Science Center, Seattle, WA, and the Office of Protected Resources, National Marine Fisheries Service, Silver Spring, MD. 80 p.
- NMFS. 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. Reg.** 66(26, 7 Feb.):9291-9298.
- NMFS. 2007. Recovery plan for the Hawaiian monk seal (*Monachus schauinslandi*). 2nd rev. Nat. Mar. Fish. Serv., Silver Spring, MD. 165 p.
- NMFS. 2008. Recovery plan for the Steller Sea Lion (*Eumetopias jubatus*). Revision. Nat. Mar. Fish. Serv., Silver Spring, MD. 325 p.
- NMFS. 2013a. Endangered and threatened species; delisting of the eastern distinct population segment of Steller sea lion under the Endangered Species Act; amendment to special protection measures for endangered marine mammals. **Fed. Regist.** 78(213, 4 Nov.):66140-66199.
- NMFS. 2013b. 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 April 2017 at <http://www.nmfs.noaa.gov/pr/permits/eis/arctic.htm>.
- NMFS. 2014. Programmatic environmental impact statement; Final PEIS for Hawaiiin monk seal recovery actions. (*Neomonachus schauinslandi*). U.S. Dept. Comm., NOAA Fisheries, Silver Springs, MD. Available at <http://www.nmfs.noaa.gov/pr/permits/eis/hawaiianmonksealeis.htm>
- NMFS. 2015. Environmental assessment: proposed issuance of an incidental authorization to Lamont-Doherty Earth Observatory to take marine mammals by harassment incidental to a marine geophysical survey in the eastern Mediterranean Sea, Mid-November –December 2015. U.S. Department of Commerce, 38 p.
- NMFS. 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. 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. 2016c. Steller sea lion (*Eumetopias jubatus*). Accessed in March 2018 at <http://www.nmfs.noaa.gov/pr/species/mammals/sealions/steller-sea-lion.html>.
- NMFS. 2016d. Environmental assessment: proposed issuance of an incidental authorization to Lamont-Doherty Earth Observatory to take marine mammals by harassment incidental to a marine geophysical survey over the Mid-Atlantic Ridge in the South Atlantic Ocean, January – March, 2016. U.S. Department of Commerce. 39 p.
- NMFS. 2016e. Final environmental assessment: proposed issuance of an incidental authorization to Lamont-Doherty Earth Observatory to take marine mammals by harassment incidental to a marine geophysical survey over the southeast Pacific Ocean, 2016-2017. U.S. Department of Commerce. 38 p.
- NMFS. 2017a. Environmental assessment: proposed issuance of an incidental authorization to Lamont-Doherty Earth Observatory to take marine mammals by harassment incidental to a marine geophysical survey in the Southwest Pacific Ocean, 2017/2018. U.S. Department of Commerce, 83 p.
- NMFS. 2017b. Critical habitat. Accessed on 2 February 2018 at <http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm>

- NMFS. 2017c. Endangered and threatened wildlife and plants: proposed rulemaking to designate critical habitat for the Main Hawaiian Islands insular false killer whale distinct population segment. **Fed. Reg.** 82(212, 3 Nov.):51186-51209.
- NMFS. 2017d. Marine mammal unusual mortality events. Accessed on 20 February 2018 at <http://www.nmfs.noaa.gov/pr/health/mmume/events.html>.
- NMFS. 2017e. Environmental assessment: proposed issuance of an incidental authorization to the Scripps Institution of Oceanography to take marine mammals by harassment incidental to a low-energy geophysical survey in the northeastern Pacific Ocean, fall 2017. U.S. Department of Commerce, 73 p.
- NMFS. 2018. Endangered and threatened marine species. Accessed on 20 February 2017 at <http://www.nmfs.noaa.gov/pr/species/esa/>
- NOAA (National Oceanic & Atmospheric Administration). 2018a. Hawaiian Islands Humpback Whale National Marine Sanctuary. Accessed on 22 February 2018 at <https://hawaiihumpbackwhale.noaa.gov>
- NOAA. 2018b. Cetacean data availability. Accessed in February 2018 at <https://cetsound.noaa.gov/cda>.
- Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. **Mamm. 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. **Aquatic 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.
- Nowacek, D.P., F. Christiansen, L. Bejder, J.A. Goldbogen, and A.S. Friedlaender. 2016. Studying cetacean behaviour: new technological approaches and conservation applications. **Animal Behav.** doi:10.1016/j.anbehav.2016.07.019.
- NRC (National Research Council). 2005. Marine mammal populations and ocean noise/Determining when noise causes biologically significant effects. U.S. Nat. Res. Council, Ocean Studies Board, Committee on characterizing biologically significant marine mammal behavior (Wartzok, D.W., J. Altmann, W. Au, K. Ralls, A. Starfield, and P.L. Tyack). Nat. Acad. Press, Washington, DC. 126 p.
- NSF (National Science Foundation). 2012. Record of Decision for marine seismic research funded by the National Science Foundation. June 2012. Accessed on 18 November 2014 at <http://www.nsf.gov/geo/oce/envcomp/rod-marine-seismic-research-june2012.pdf>.
- NSF and USGS (National Science Foundation and U.S. Geological Survey). 2011. Final Programmatic Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) for marine seismic research funded by the National Science Foundation or conducted by the U.S. Geological Survey. June 2011. Prepared for NSF and USGS.
- O'Brien, J.M., S. Beck, S.D. Berrow, M. Andre, M. van der 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.

- OBIS (Ocean Biogeographic Information System). 2017. Data from the Ocean Biogeographic Information System. Intergovernmental Oceanographic Commission of UNESCO. Accessed on 22 February 2017 at <http://www.iobis.org>.
- Oakley, J.A., A.T. Williams, and T. Thomas. 2017. Reactions of harbour porpoise (*Phocoena phocoena*) to vessel traffic in the coastal waters of South Wales, UK. **Ocean & Coastal Manage.** 138:158–169.
- 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.
- Okamura, H., S. Minamikawa, H.J. Skaug, and T. Kishiro. 2012. Abundance estimation of long-diving animals using line transect methods. **Biometrics** 68:504-513.
- 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.
- Oleson, E.M., A. Širović, A.R. Bayless, and J.A. Hildebrand. 2014. Synchronous seasonal change in fin whale song in the North Pacific. **PLoS ONE** 9(12):e115678. doi:10.1371/journal.pone.0115678.
- Oleson, E.M., A. Širović, A. Rice, and L.M. Varga. 2016. Fin whale occurrence and population structure in the central and western Pacific through detection and characterization of song patterns. **J. Acoust. Soc. Am.** 140(4):3296-3296.
- Olson, P.A. 2009. Pilot whales—*Globicephala melas* and *G. macrorhynchus*. p. 847-852 *In*: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopaedia of marine mammals, 2nd edit. Academic Press, Amsterdam. 1316 p.
- Omura, H. 1986. History of right whale catches in the waters around Japan. **Rep. Int. Whal. Comm. Spec. Iss.** 10:35-41.
- Oswald, J.N., W.W. Au, and F. Duennebie. 2011. Minke whale (*Balaenoptera acutorostrata*) boings detected at the Station ALOHA Cabled Observatory. **J. Acoust. Soc. Am.** 129(5):3353-3360.
- Ovsyanikova, E., I. Fedutin, O. Belonovich, A. Burdin, V. Burkanov, E. Dolgova, O. Filatova, S. Fornin, E. Hoyt, E. Mamaev, and G. Richard. 2015. Opportunistic sightings of the endangered North Pacific right whales (*Eubalaena japonica*) in Russian waters in 2003–2014. **Mar. Mamm. Sci.** 31(4):1559-1567.
- Papale, E., M. Gamba, M. Perez-Gil, V.M. Martin, and C. Giacomini. 2015. Dolphins adjust species-specific frequency parameters to compensate for increasing background noise. **PLoS ONE** 10(4):e0121711. doi: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. 2016a. 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.
- Parks, S.E., D.A. Cusano, A. Bocconcelli, and A.S. Friedlaender. 2016b. Noise impacts on social sound production by foraging humpback whales. Abstr. 4th Int. Conf. Effects of Noise on Aquatic Life, July 2016, Dublin, Ireland.
- Parrish, F.A., M.P. Craig, T.J. Ragen, G.J. Marshall, and B.M. Buhleier. 2000. Identifying diurnal foraging habitat of endangered Hawaiian monk seals using a seal-mounted video camera. **Mar. Mamm. Sci.** 16():392-412.

- Parrish, F.A., K. Abernathy, G.J. Marshall, and B.M. Buhleier. 2002. Hawaiian monk seals (*Monachus schauinslandi*) foraging in deep-water coral beds. **Mar. Mamm. Sci.** 18(1):244-258.
- Payne, R. 1978. Behavior and vocalizations of humpback whales (*Megaptera* sp.). In: K.S Norris and R.R. Reeves (eds.), Report on a workshop on 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.
- Peng, C., X. Zhao, and G. Liu. 2015. Noise in the sea and its impacts on marine organisms. **Intern. J. Environm. Res. Public Health** 12(10):12304-12323.
- Perrin, W.F. 2009a. 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. 2009b. 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. and R.L. Brownell, J. 2009. Minke whales. p. 733-735 In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2nd edit. 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., London, U.K., 23-25 June 1998.
- 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. doi: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. doi: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.
- Pirotta, E., M. Mangel, D.P. Costa, B. Mate, J.A. Goldbogen, D.M. Palacios, L.A. Hückstädt, E.A. McHuron, L. Schwartz, and L. New. 2018. A dynamic state model of migratory behavior and physiology to assess the consequence of environmental variation and anthropogenic disturbance on marine vertebrates. **Am. Nat.** 191 (2):E000-E000. doi:10.5061/dryad.md416.
- Pitcher, K.W. and D.G. Calkins. 1981. Reproductive biology of Steller sea lions in the Gulf of Alaska. **J. Mammal.** 62:599-605.
- Pitcher, K.W., V.N. Burkanov, D.G. Calkins, B.F. LeBoeuf, E.G. Mamaev, R.L. Merrick, and G.W. Pendleton. 2002. Spatial and temporal variation in the timing of births of Steller sea lions. **J. Mammal.** 82:1047-1053.
- 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. Exp. Biol.** 216:1587-1596.
- Popov, V.V., D.I. Nechaev, E.V. Sysueva, V.V. *Delphinapterus leucas* Rozhnov, and A.Y. Supin. 2015. Spectrum pattern resolution after noise exposure in a beluga whale: 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.
- 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.
- Quick, N., L. Scott-Hayward, D. Sadykova, D. Nowacek, and A.J. Read. 2017. Effects of a scientific echo sounder on the behavior of short-finned pilot whales (*Globicephala macrorhynchus*). **Can. J. Fish. Aquat. Sci.** 74:716-726.
- 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. and J. Barlow. 2007. Vocalizations of the sei whale *Balaenoptera borealis* off the Hawaiian Islands. **Bioacoustics** 16(2):137-145.
- 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.
- Rankin, S., J.N. Oswald, A.E. Simonis, and J. Barlow. 2015. Vocalizations of the rough-toothed dolphin, *Steno bredanensis*, in the Pacific Ocean. **Mar. Mamm. Sci.** 31(4):1538-1548.
- Raum-Suryan, K.L., K.W. Pitcher, D.G. Calkins, J.L. Sease, and T.R. Loughlin. 2002. Dispersal, rookery fidelity, and metapopulation structure of Steller sea lions (*Eumetopias jubatus*) in an increasing and a decreasing population in Alaska. **Mar. Mamm. Sci.** 18(3):746-764.
- 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., J.G. Mead, and S. Katona. 1978. The right whale, *Eubalaena glacialis*, in the western North Atlantic. **Rep. Int. Whal. Comm.** 28:303-12.
- 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., T.D. Smith, and E.A. Josephson. 2008. Observations of western gray whales by ship-based whalers in the 19th century. Paper SC/60/BRG7 prepared for the Int. Whal. Comm. (unpublished).
- 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.

- Reich, K.J., K.A. Bjorndal, M.G. Frick, B.E. Witherington, C. Johnson, and A.B. Bolton. 2009. Polymodal foraging in adult female loggerheads (*Caretta caretta*). **Mar. Biol.** doi:10.1007/s00227-009-1300-4.
- Reichmuth, C., A. Ghoul, J.M. Sills, A. Rouse, and B.L. Southall. 2016. Low-frequency temporary threshold shift not observed in spotted or ringed seals exposed to single air gun impulses. **J. Acoust. Soc. Am.** 140(4):2646-2658.
- 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.
- Reyes, J.C. 1991. The conservation of small cetaceans: a review. Rep. for the Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP/CMS Secretariat, Bonn, Germany.
- 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. 1986. Beaked whales. p. 102-109 *In*: Haley, D. (ed.), Marine mammals of the eastern North Pacific and Arctic waters. Pacific Search Press, Seattle, WA.
- Rice, D.W. 1989. Sperm whale *Physeter macrocephalus* Linnaeus, 1758. p. 177-233 *In*: Ridgway, S.H. and R. Harrison (eds.), Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.
- Rice, D.W. 1998. Marine mammals of the world, systematics and distribution. Spec. Publ. 4. Soc. Mar. Mammal., Allen Press, Lawrence, KS. 231 p.
- Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Soc. Mar. Mammal., Spec. Publ. 3, Allen Press, Lawrence, KS.
- 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.
- Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 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
- 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. doi:10.1371/journal.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. doi: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. Species Res.** 21:143-160.
- Robinson, P.W., D.P. Costa, D.E. Crocker, J.P. Gallo-Reynoso, C.D. Champagne, M.A. Fowler, C. Goetsch, K.T. Goetz, J.L. Hassrick, L.A. Huckstadt, C.E. Kuhn, J.L. Maresh, S.M. Maxwell, B.I. McDonald, S.H. Peterson, S.E. Simmons, N.M. Teutsschel, S. Villegas-Amtmann, and K. Yoda. 2012. Foraging behaviour and success of a mesopelagic predator in the Northeast Pacific Ocean: insights from a data-rich species, the northern elephant seal. **PLoS ONE** 7(5):e36728. doi:10.1371/journal.pone.0036728.
- 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** 279:2363-2368.
- Roppel, A.Y. 1984. Management of northern fur seals on the Pribilof Islands, Alaska, 1786-1981. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-4. 32 p.

- RPS. 2014a. Final environmental assessment for seismic reflection scientific research surveys during 2014 and 2015 in support of mapping the US Atlantic seaboard extended continental margin and investigating tsunami hazards. Rep. from RPS for United States Geological Survey, August 2014. Accessed in November 2014 at <http://www.nsf.gov/geo/oce/envcomp/usgssurveyfinalea2014.pdf>.
- RPS. 2014b. Draft protected species mitigation and monitoring report: 3-D seismic survey in the northwest Atlantic Ocean off New Jersey, 1 July 2014–23 July 2014, R/V *Marcus G. Langseth*. Rep. from RPS, Houston, TX, for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY.
- RPS. 2015. Protected species mitigation and monitoring report: East North American Margin (ENAM) 2-D seismic survey in the Atlantic Ocean off the coast of Cape Hatteras, North Carolina, 16 September–18 October 2014, R/V *Marcus G. Langseth*. Rep. from RPS, Houston, TX for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY.
- 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., Galveston, TX, Nov. 1993. 130 p.
- Salden, D.R. and J. Mickelsen. 1999. Rare sighting of a North Pacific right whale (*Eubalaena glacialis*) in Hawai'i. **Pacific Sci.** 53(4):341-345.
- 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.
- Sasaki, H., H. Murase, H. Kiwada, K. Matsuoka, Y. Mitani, and S.I. Saito. 2013. Habitat differentiation between sei (*Balaenoptera borealis*) and Bryde's whales (*B. brydei*) in the western North Pacific. **Fish. Oceanog.** 22(6):496-508.
- Scarff, J.E. 1986. Historic and present distribution of the right whale (*Eubalaena glacialis*) in the eastern North Pacific south of 50°N and east of 180°W. **Rep. Int. Whal. Comm. Spec. Iss.** 10:43-63.
- Scarff, J.E. 1991. Historic distribution and abundance of the right whale (*Eubalaena glacialis*) in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. **Rep. Int. Whal. Comm.** 41:467-489.
- Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2016. Auditory effects of multiple impulses from a seismic air gun on bottlenose dolphins (*Tursiops truncatus*). 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.
- Sciacca, V., S. Viola, S. Pulvirenti, G. Riccobene, F. Caruso, E. De Domenico, and G. Pavan. 2016. Shipping noise and seismic airgun surveys in the Ionian Sea: potential impact on Mediterranean fin whale. Proceedings of Meetings on Acoustics **4ENAL** 27(1):040010. <https://doi.org/10.1121/2.0000311>.
- Sears, R. and W.F. Perrin. 2009. Blue whale *Balaenoptera musculus*. p. 120-124 *In*: W.F. Perrin, B. Würsig, and J.G.M. Theewissen (eds.), Encyclopedia of marine mammals, 2nd ed. Academic Press, San Diego, CA. 1316 p.
- Sekiguchi, K., H. Onishi, H. Sasaki, S. Haba, Y. Iwahara, D. Mizuguchi, M. Otsuki, D. Saijo, B. Nishizawa, H. Mizuno, and N. Hoshi. 2014. Sightings of the western stock of North Pacific right whales (*Eubalaena japonica*) in the far southeast of the Kamchatka Peninsula. **Mar. Mamm. Sci.** 30(3):1199-1209.
- Sergeant, D.E. 1977. Stocks of fin whales *Balaenoptera physalus* L. in the North Atlantic Ocean. **Rep. Int. Whal. Comm.** 27:460-473.
- Shelden, K.E.W., S.E. Moore, J.M., Waite, P.R. Wade, and D.J. Rugh. 2005. Historic and current habitat use by North Pacific right whales *Eubalaena japonica* in the Bering Sea and Gulf of Alaska. **Mamm. Rev.** 35:129-155.

- 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
- 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).
- Simmonds, M.P., S.J. Dolman, M. Jasny, E.C.M Parsons, L. Weilgart, A.J. Wright, and R. Leaper. 2014. Marine noise pollution – Increasing recognition but need for more practical action. **J. Ocean Tech.** 9:71-90.
- 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.
- 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 November 2014 at <http://iwc.int/2008-mass-stranding-in-madagascar>.
- Southall, B.L., D.P. Nowacek, P.J.O. Miller, and P.L. Tyack. 2016. Experimental field studies to measure behavioral responses of cetaceans to sonar. **Endang. Species Res.** 31:293–315.
- Spalding, M.D., H.E. Fox, G.R. Allen, N. Davidson, Z.A. Ferdana, M. Finlayson, B.S. Halpern, M.A. Jorge et al. 2007. Marine Ecoregions of the World: a bioregionalization of coastal and shelf areas. **BioScience**
- 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. Nieuwirth, 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. Nieuwirth, 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.
- Stewart, B.S. and R.L. DeLong. 1995. Double migrations of the northern elephant seal, *Mirounga angustirostris*. **J. Mammal.** 76(1):196-205.
- Stewart, B.S. and H.R. Huber. 1993. *Mirounga angustirostris*. **Mammal. Species** 449:1-10.
- Stewart, B.S. and S. Leatherwood. 1985. Minke whale *Balaenoptera acutorostrata* Lacépède, 1804. p. 91-136 *In: Ridgway, S.H. and R. Harrison (eds.) Handbook of marine mammals*, Vol. 3: The sirenians and baleen whales. Academic Press, London, U.K. 362 p.
- Stewart, B.S., G.A. Antonelis, J.D. Baker, and P. Yochem. 2006. Foraging biogeography of the Hawaiian monk seal in the northwestern Hawaiian Islands. **Atoll Res. Bull.** 543:131-145.
- Stewart, B.S. and H.R. Huber. 1993. *Mirounga angustirostris*. **Mamm. Spec.** 449:1-10.
- Stewart, B.S., G.A. Antonelis, J.D. Baker, and P. Yochem. 2006. Foraging biogeography of the Hawaiian monk seal in the northwestern Hawaiian Islands. **Atoll Res. Bull.** 543:131-145.

- Stewart, B.S., B.J. LeBoeuf, P.K. Yochem, H.R. Huber, R.L. DeLong, R.J. Jameson, W. Sydeman, and S.G. Allen. 1994. History and present status of the northern elephant seal population. *In*: B.J. LeBoeuf and R.M. Laws (eds.) *Elephant seals*. Univ. Calif. Press. Los Angeles.
- Sterling, J.T., A.M. Springer, S.J. Iverson, S.P. Johnson, N.A. Pelland, D.S. Johnson, M.A. Lea, and N.A. Bond. 2014. The sun, moon, wind, and biological imperative—shaping contrasting wintertime migration and foraging strategies of adult male and female northern fur seals (*Callorhinus ursinus*). **PLoS ONE** 9(4):e93068. doi:10.1371/journal.pone.0093068.
- 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.
- Suryan, R.M., F. Sato, G.R. Balogh, K.D. Hyrenbach, P.R. Sievert, and K. Ozaki. 2006. Foraging destinations and marine habitat use of short-tailed albatrosses: a multi-scale approach using first-passage time analysis. **Deep Sea Res. Part II** 53(3-4):370-386.
- Suryan, R.M., K.S. Dietrich, E.F. Melvin, G.R. Balogh, F. Sato, and K. Ozaki. 2007. Migratory routes of short-tailed albatrosses: use of exclusive economic zones of North Pacific Rim countries and spatial overlap with commercial fisheries in Alaska. **Biol. Conserv.** 137(3):450-460.
- Sychenko, O., G. Gailey, R. Racca, A. Rutenko, L. Aerts, and R. Melton. 2017. Gray whale abundance and distribution relative to three seismic surveys near their feeding habitat in 2015. Abstract and presentation at the Society for Marine Mammalogy's 22nd Biennial Conference on the Biology of Marine Mammals, 22027 October, Halifax, Nova Scotia, Canada.
- Teilmann, J., D.M. Wisniewska, M. Johnson, L.A. Miller, U. Siebert, R. Dietz, S. Sveegaard, A. Galatius, and P.T. Madsen. 2015. Acoustic tags on wild harbour porpoises reveal context-specific reactions to ship noise. *In* 18. Danske Havforskermøde.
- 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.
- Terhune, J.M. and T. Bosker. 2016. Harp seals do not increase their call frequencies when it gets noisier. p. 1149-1153 *In*: A.N. Popper and A. Hawkins (eds.), *The effects of noise on aquatic life II*. Springer, New York, NY. 1292 p.
- 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, D., M. Sjöberg, E.B. Bryant, P. Lovell, and A. Bjørge. 1998. Behavioural and physiological responses of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals to seismic surveys. Abstr. World Mar. Mamm. Sci. Conf., Monaco.
- Thompson, P.M., K.L. Brookes, I.M. Graham, T.R. Barton, K. Needham, G. Bradbury, and N.D. Merchant. 2013b. 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.
- Tillman, M.F. 1977. Estimates of population size for the North Pacific sei whale. **Rep. Int. Whal. Comm. Spec. Iss.** 1:98-106.
- Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohnstiehl, T.J. Crone, and R.C. Holmes. 2009. Broadband calibration of R/V *Marcus G. Langseth* four-string seismic sources. **Geochem. Geophys. Geosyst.** 10:Q08011. <https://doi.org/10.1029/2009GC002451>.

- 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*: *Animal communication and noise*. Springer, Berlin, Heidelberg, Germany.
- 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 III. Accessed in January 2016 at <http://www.cites.org/eng/app/appendices.php>.
- USFWS (U.S. Fish and Wildlife Service). 2017. Endangered species. Accessed in February 2018 at <https://www.fws.gov/endangered/>
- USN (U.S. Navy). 2017. Criteria and thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical Report prepared by the U.S. Navy
- van Beest, F.M., J. Teilmann, L. Hermannsen, A. Galatius, L. Mikkelsen, S. Sveegaard, J.D. Balle, R. Dietz, J. Nabe-Nielsen. 2018. Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. **R. Soc. open sci.** 5:170110. doi:10.1098/rsos.170110.
- Van Cise, A.M., K. Martien, S.D. Mahaffy, R.W. Baird, D.L. Webster, J.H. Fowler, E.M. Oleson, and P.A. Morin. 2017. Familial social structure and socially driven genetic differentiation in Hawaiian short-finned pilot whales. **Mol. Ecol.** 26(23):6730-6741.
- Vilela, R., U. Pena, R. Esteban, and R. Koemans. 2016. Bayesian spatial modeling of cetacean sightings during a seismic acquisition survey. **Mar. Poll. Bull.** 109: 512-520.
- Vladimirov, V.A., S.P. Starodimov, A.G. Afanasyev-Grigoriyev, and J. Muir. 2008. Distribution and abundance of Korean stock gray whales in the waters of northeastern Sakhalin during June-October 2007. Final Report by the All-Russian Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia, the Institute of Marine Biology FEB RAS, Vladivostok, Russia, and LGL Limited, Sidney, Canada for Exxon Neftegaz Limited and Sakhalin Energy Investment Company, Yuzhno-Sakhalinsk.
- 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.
- Wade, P., M.P. Heide-Jørgensen, K. Shelden, J. Barlow, J. Carretta, J. Durban, R. LeDuc, L. Munger, S. Rankin, A. Sauter, and C. Stinchcomb. 2006. Acoustic detection and satellite-tracking leads to discovery of rare concentration of endangered North Pacific right whales. **Biol. Lett.** 2(3):417-419.
- Wade, P.R., A. Kennedy, R. LeDuc, J. Barlow, J. Carretta, K. Shelden, W. Perryman, R. Pitman, K. Robertson, B. Rone, J.C. Salinas, A. Zerbini, R.L. Brownell, Jr., and P. Clapham. 2011. The world's smallest whale population. **Biol. Lett.** 7:83-85.
- Wale, M.A., S.D. Simpson, and A.N. Radford. 2013a. Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. **Biol. Lett.** 9:20121194.
- Wale, M.A., S.D. Simpson, and A.N. Radford. 2013a. Noise negatively affects foraging and antipredator behaviour in shore crabs. **Anim. Behav.** 86:111-118.
- 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.** 20:159-168.
- 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.
- Weilgart, L. 2017. Din of the deep: noise in the ocean and its impacts on cetaceans. Pages 111-124 *In*: Butterworth A. (ed.) Marine Mammal Welfare Human Induced Change in the Marine Environment and its Impacts on Marine Mammal Welfare. Springer.
- 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., B. Würsig, A.L. Bradford, A.M. Burdin, S.A. Blokhin, H. Minakuchi, and R.L. Brownell, Jr. 1999. Gray whales (*Eschrichtius robustus*) off Sakhalin island, Russia: seasonal and annual patterns of occurrence. **Mar. Mamm. Sci.** 15(4):1208-1227.
- 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. Reeve, A.M. Burdin, B. Würsig, and R.L. Brownell, Jr. 2002a. A note on spatical distribution of western gray whales (*Eschrichtius robustus*) off Sakhalin island, Russia in 1998. **J. Cetacean Res. Manage.** 4(1):13-17.
- Weller, D.W., A.M. Burdin, B. Würsig, B.L. Taylor, and R.L. Brownell, Jr. 2002b. The western gray whale: a review of past exploitation, current status and potential threats. **J. Cetacean Res. Manage.** 4(1):7-12.
- 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.
- Weller, D.W., A.L. Bradford, H. Kato, T. Bando, S. Ohtani, A.M. Burdin, and R.L. Brownell, Jr. 2008. Photographic match of a western gray whale between Sakhalin Island, Russia, and Honshu, Japan: first link between feeding ground and migratory corridor. **J. Cetacean Res. Manage.** 10:89-91.
- Weller, D.W., A. Klimek, A.L. Bradford, J. Calambokidis, A.R. Lang, B. Gisborne, A.M. Burdin, W. Szaniszlo, J. Urbán, A.G.G. Unzueta, S. Swartz, and R.L. Brownell, Jr. 2012. Movements of gray whales between the western and eastern North Pacific. **Endang. Species Res.** 18:193-199.
- Weller, D.W., A.M. Burdin, and R.L. Brownell, Jr. 2013. A gray area: on the matter of gray whales in the western North Pacific. **J. Am. Cetacean Soc.** 42(1):20-33.
- 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., L.A.E. Huijser, L. Hoek, and R.A. Kastelein. 2014. Equal latency contours and auditory weighting functions for the harbour porpoise (*Phocoena phocoena*). **J. Exp. Biol.** 217(3):359-369.
- Wensveen, P.J., A.M. von Benda-Beckmann, M.A. Ainslie, F.P.A. Lam, P.H. Kvasdheim, 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. 2002. Estimates of the current global population size and historical trajectory for sperm whales. **Mar. Ecol. Prog. Ser.** 242:295-304.
- 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.
- Willis, P.M. and R.W. Baird. 1998. Sightings and strandings of beaked whales on the west coast of Canada. **Aquat. Mamm.** 24(1):21-25.
- Willis, K.L., J. Christensen-Dalsgaard, D.R. Ketten, and C.E. Carr. 2013. Middle ear cavity morphology is consistent with an aquatic origin for testudines. **PLoS One** 8(1):e54086. doi:10.1371/journal.pone.0054086.
- Wiley, D.N., C.A. Mayo, E.M. Maloney, and M.J. Moore. 2016. Vessel strike mitigation lessons from direct observations involving two collisions between noncommercial vessels and North Atlantic right whales (*Eubaleana glacialis*). **Mar. Mamm. Sci.** 32(4):1501-1509.
- Wilson, K., C. Littnan, and A.J. Read. 2017. Movements and home ranges of monk seals in the main Hawaiian Islands. **Mar. Mamm. Sci.** 33(4):1080-1096.
- 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.
- Winsor, M.H., L.M. Irvine, and B.R. Mate. 2017. Analysis of the spatial distribution of satellite-tagged sperm whales (*Physeter macrocephalus*) in close proximity to seismic surveys in the Gulf of Mexico. **Aquatic Mamm.** 43(4):439-446.
- Wisniewska, D.M., M. Johnson, J. Teilmann, U. Siebert, A. Galatius, R. Dietz, and P.T. Madsen. 2018. High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). **Proc. R. Soc. B** 285: 20172314.
- 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. 98 p. World Wildlife Fund Global Arctic Programme, Ottawa, Canada.
- 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. <https://doi.org/10.1016/j.marpolbul.2015.08.045>.
- 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. **Aquatic 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.
- Yatsu, T. 1993. Distributions of epipelagic fishes, squids, marine mammals, seabirds and sea turtles in the central North Pacific. **Int. North Pacific Fish. Comm. Bull.** 53(3):111-146.

- 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.

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APPENDIX A: DETERMINATION OF MITIGATION ZONES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

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

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

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

The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. A-1). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS). Measurements have not been reported for a 40-in³ airgun; thus, L-DEO model results are used to determine the 160-dB_{rms} radius for the 40-in³ airgun at a 12-m tow depth in deep water (Fig. A-2).

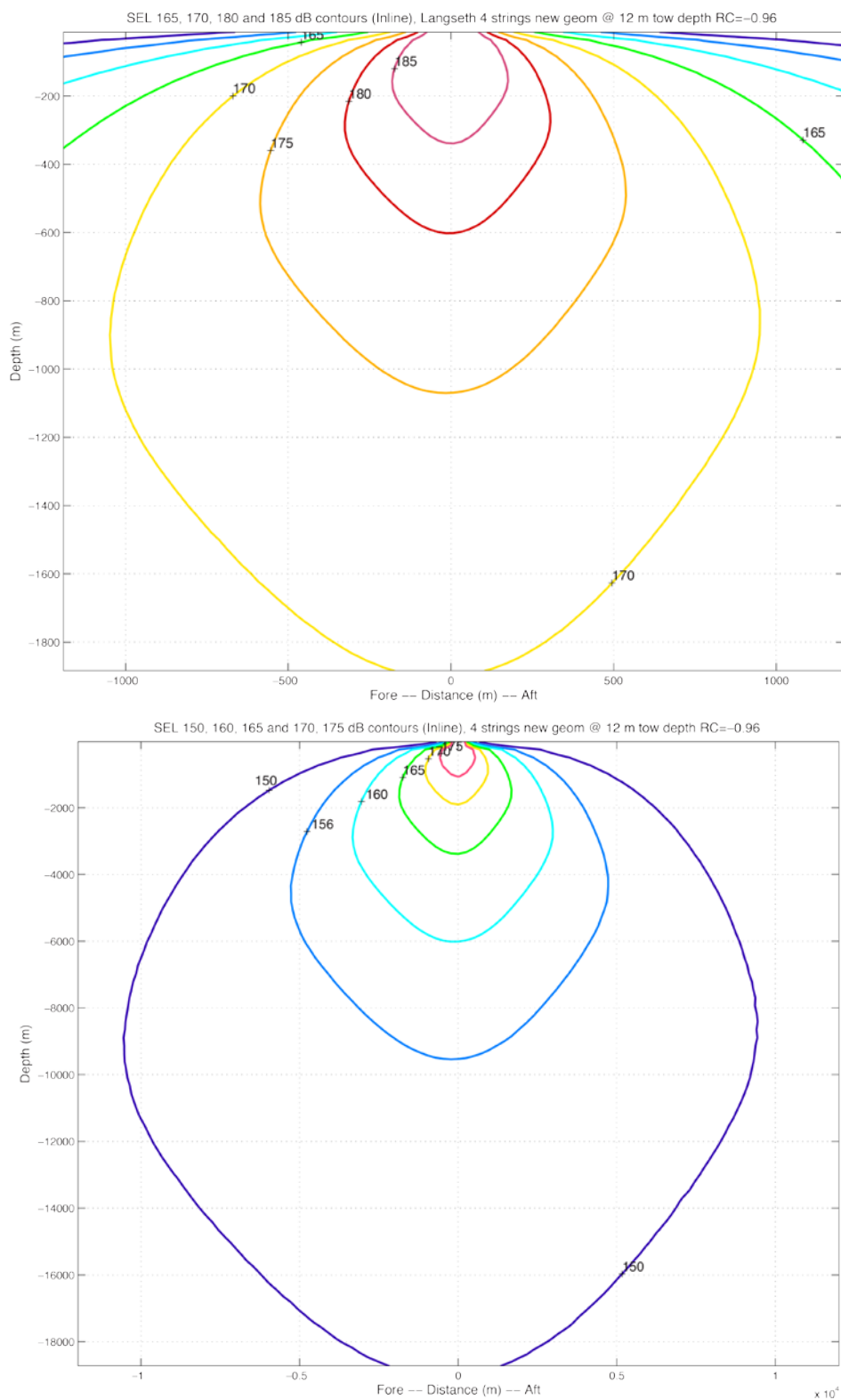


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys in the North Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is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

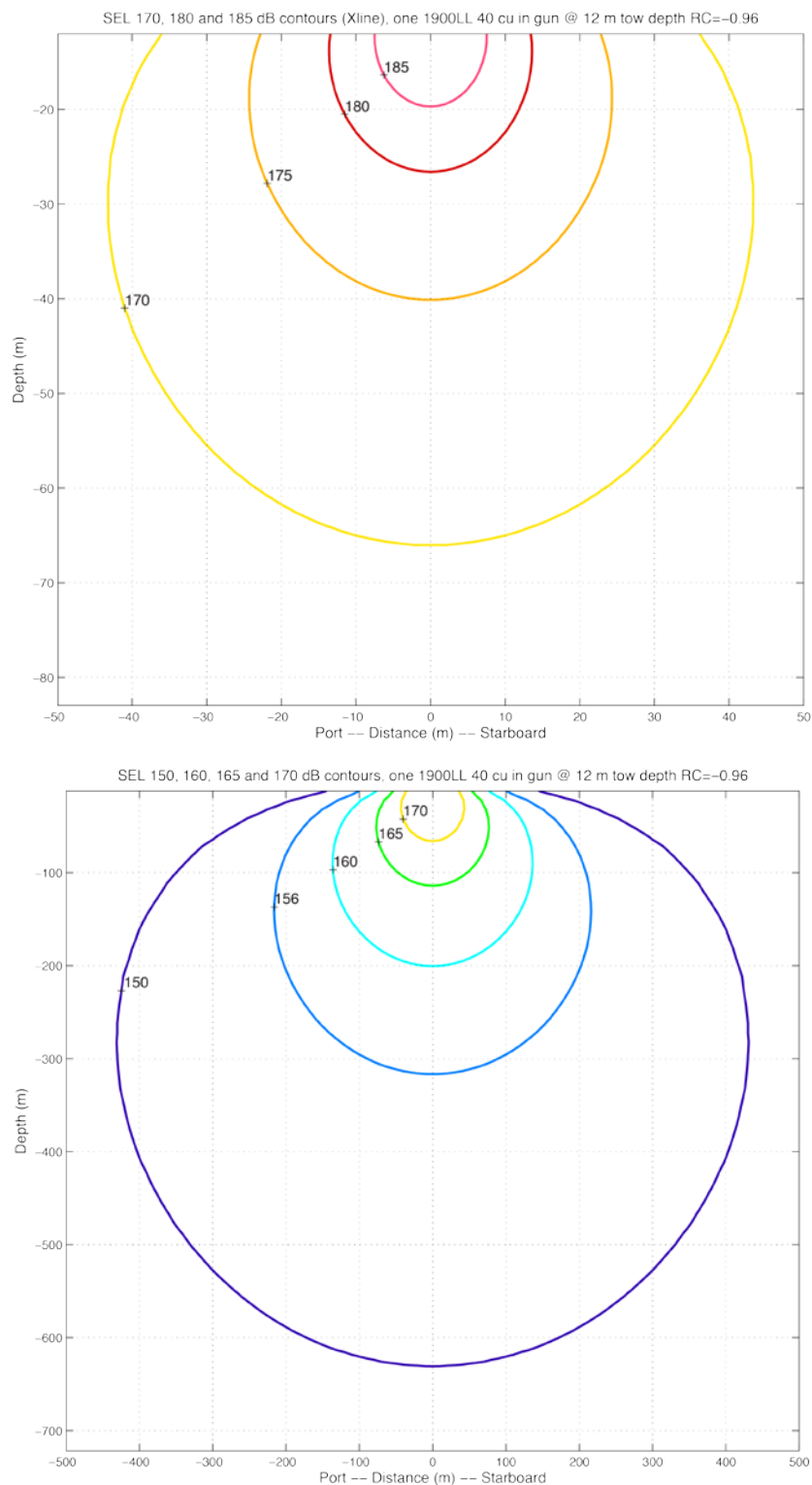


FIGURE A-2. Modeled deep-water received SELs from a single 40-in³ airgun towed at a 12-m depth, which is planned for use as a mitigation airgun during the proposed surveys in the North Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB

SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

Table A-1 shows the distances at which the 160-dB re $1\mu\text{Pa}_{\text{rms}}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. A recent retrospective analysis of acoustic propagation of *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by the *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels¹ have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released new technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016). 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, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat} , respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-3) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). As required by NMFS (2016), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances. The new guidance did not alter the current threshold, 160 dB re $1\mu\text{Pa}_{\text{rms}}$, for Level B harassment (behavior).

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

¹ L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

TABLE A-1. Level B. Predicted distances to which sound levels ≥ 160 -dB re $1 \mu\text{Pa}_{\text{rms}}$ could be received during the proposed surveys in the North Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level
Single Bolt airgun, 40 in ³	12	>1000 m	431 ¹
		100–1000 m	647 ²
4 strings, 36 airguns, 6600 in ³	12	>1000 m	6,733 ¹
		100–1000 m	10,100 ²

¹ Distance is based on L-DEO model results.

² Distance is based on L-DEO model results with a $1.5 \times$ correction factor between deep and intermediate water depths.

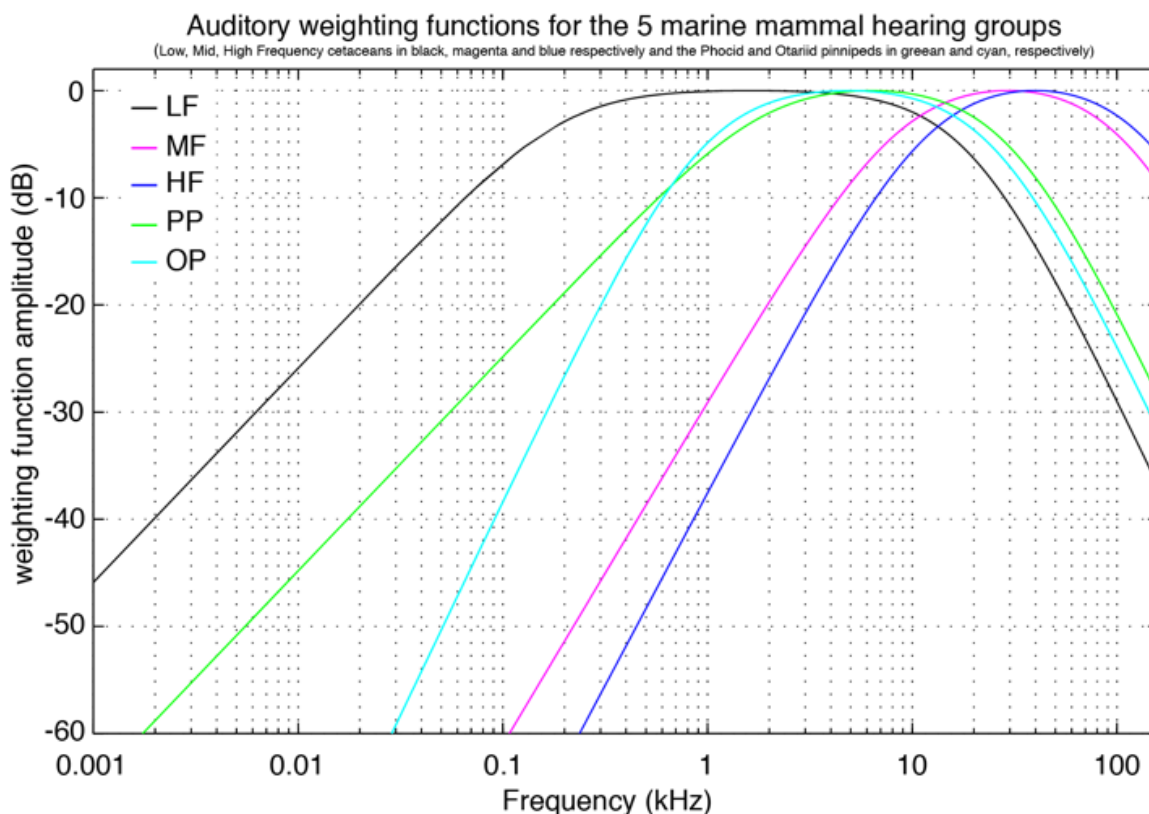


FIGURE A-3. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

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

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.109 m/s and a 1/Repetition rate of 23.7054 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the 36-airgun array and the single 40-in³ mitigation airgun.

For the LF cetaceans during operations with the 36-airgun array, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor of -12.91 dB assuming a propagation of $20\log_{10}(\text{Radial distance})$ (Table A-2).

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

For the 36-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL_{cum} , and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-4 shows the impact of weighting functions by hearing group. Figures A-5–A-7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

The thresholds for Peak SPL_{flat} for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-9–A-11 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

TABLE A-2. Results for single SEL source level modeling for the 36-airgun array with and without applying weighting functions to the five 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)	315.5691	246.4678	8033.2	246.4678	28.4413
Modified Farfield SEL	232.9819	232.8352	233.0978	232.8352	232.0790
Radial Distance (m) (with weighting function)	71.3752	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.91	N.A.	N.A.	N.A.	N.A.

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

For the single 40 in³ mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-6. The weighting function calculations, thresholds for SEL_{cum} , and the distances to the PTS thresholds for the 40 in³ airgun are shown in Table A-7. Figure A-12 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-13–A-14 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-15 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 40 in³ airgun, as well as the distances to the PTS thresholds, are shown in Table A-8. Figures A-16–A-17 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-9.

Table A-10 shows the distances at which the 175- and 195-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the 36-airgun array, and a single airgun, based on L-DEO modeling. The 195-dB distance would be used as the EZ for sea turtles, as required by NMFS. The 175-dB level is used by NMFS, based on data from the USN (2017), to determine behavioral disturbance for turtles.

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

STEP 1: GENERAL PROJECT INFORMATION						
PROJECT TITLE	R/V Langseth (PI: Shillington)					
PROJECT/SOURCE INFORMATION	source : 4 string 36 element 6600 cu.in of the R/V Langseth at a 12m towed depth. Shot interval of 50 m.					
Please include any assumptions	Source velocity of 4.1 knots					
PROJECT CONTACT						
STEP 2: WEIGHTING FACTOR ADJUSTMENT						
Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value						
Weighting Factor Adjustment (kHz) [†]	NA					
Override WFA: Using LDEO modeling						
[†] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab [‡] If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.						
STEP 3: SOURCE-SPECIFIC INFORMATION						
NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both)						
F2: ALTERNATIVE METHOD ¹ TO CALCULATE PK and SEL _{cum} (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)						
NOTE: LDEO modeling relies on Method F2						
Source Velocity (meters/second)	2.1092					
1/Repetition rate ² (seconds)	23.7054					
¹ Methodology assumes propagation of 20 log R; Activity duration (time) independent ² Time between onset of successive pulses						
Modified farfield SEL	232.9819	232.8352	233.0978	232.8352	232.079	
Source Factor	8.3819E+21	8.1035E+21	8.6086E+21	8.1035E+21	6.80852E+21	
RESULTANT ISOPLETHS*	*Impulsive sounds have dual metric thresholds (SEL _{cum} & 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)	320.2	0.0	1.0	10.4	0.0	
WEIGHTING FUNCTION CALCULATIONS						
Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.5	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) [†]	-12.91	-56.70	-66.07	-25.65	-32.62	OVERIDE Using LDEO Modeling

[†]For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of $20 \cdot \log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-4).

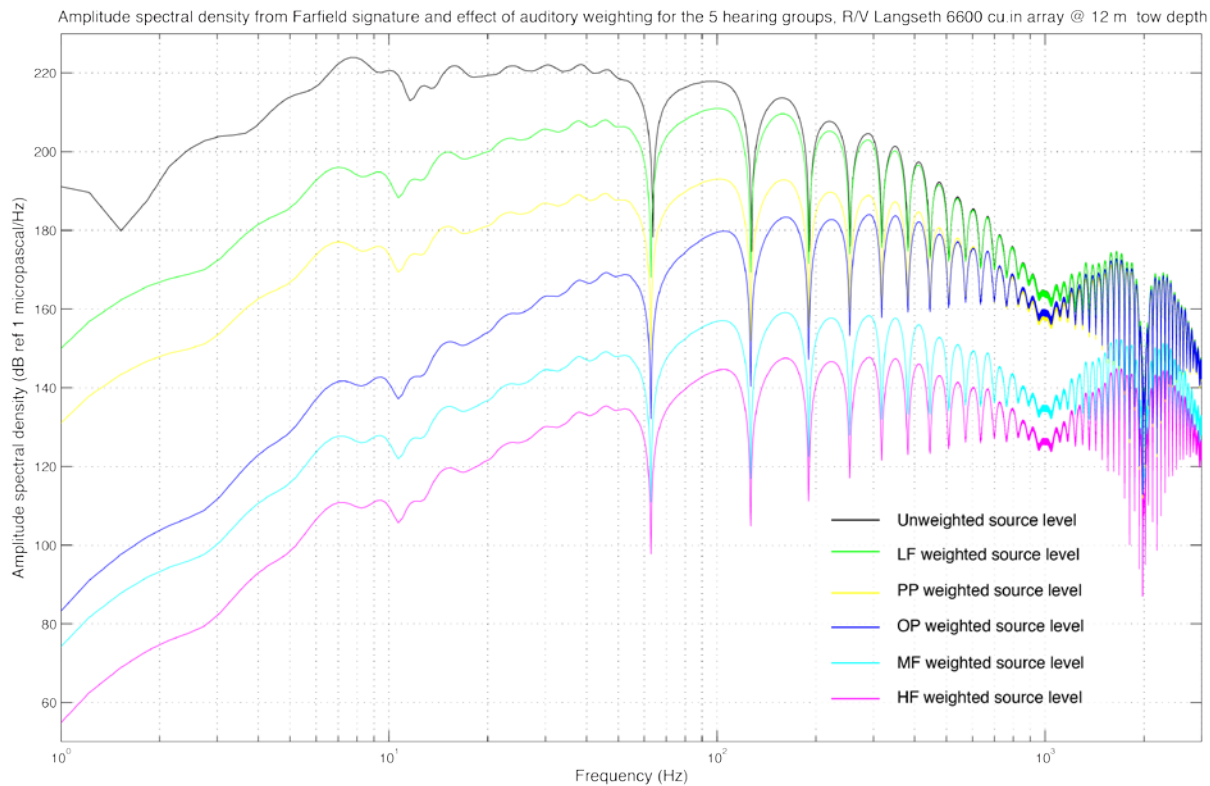


FIGURE A-4. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

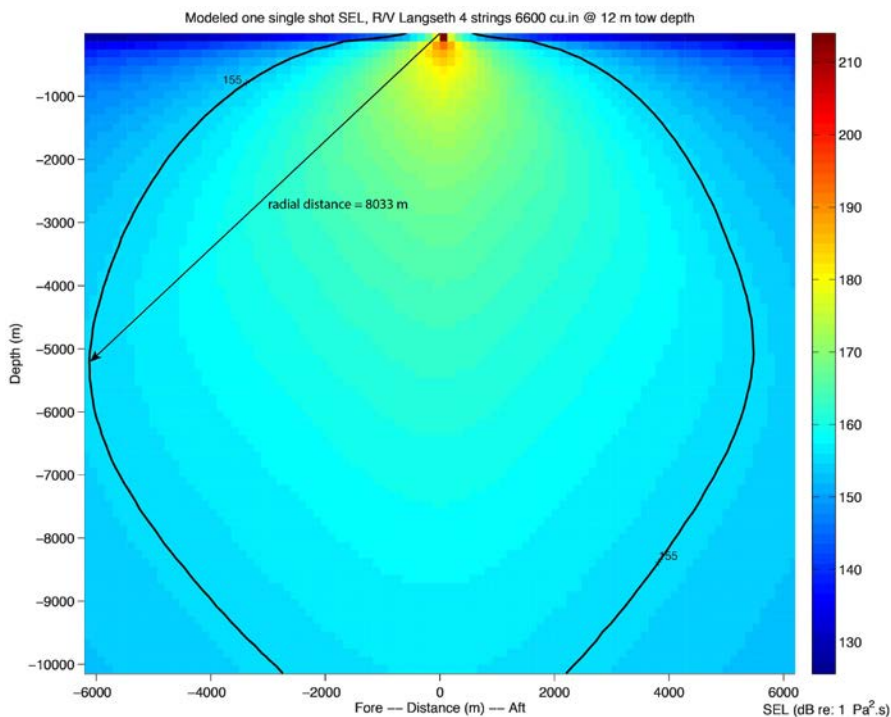


FIGURE A-5. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}(\text{radial distance})$.

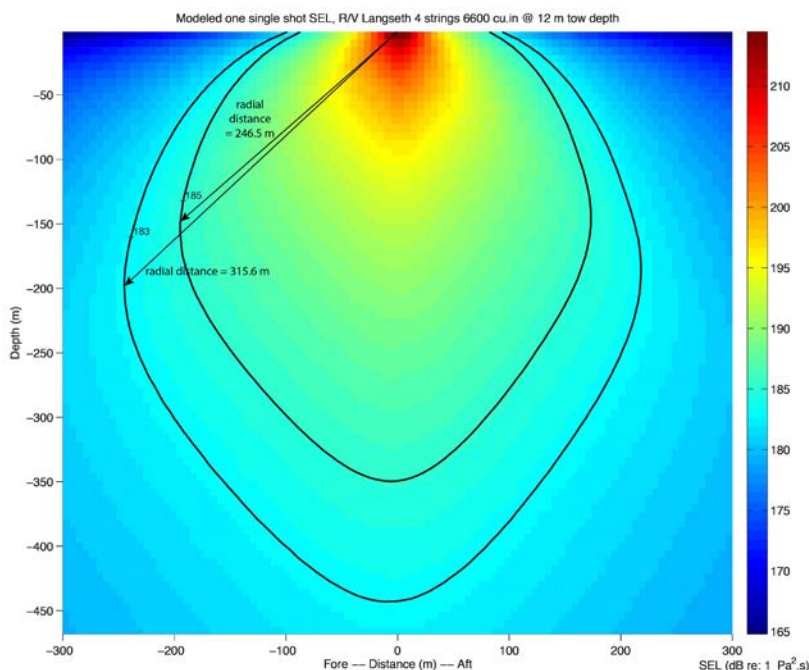


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

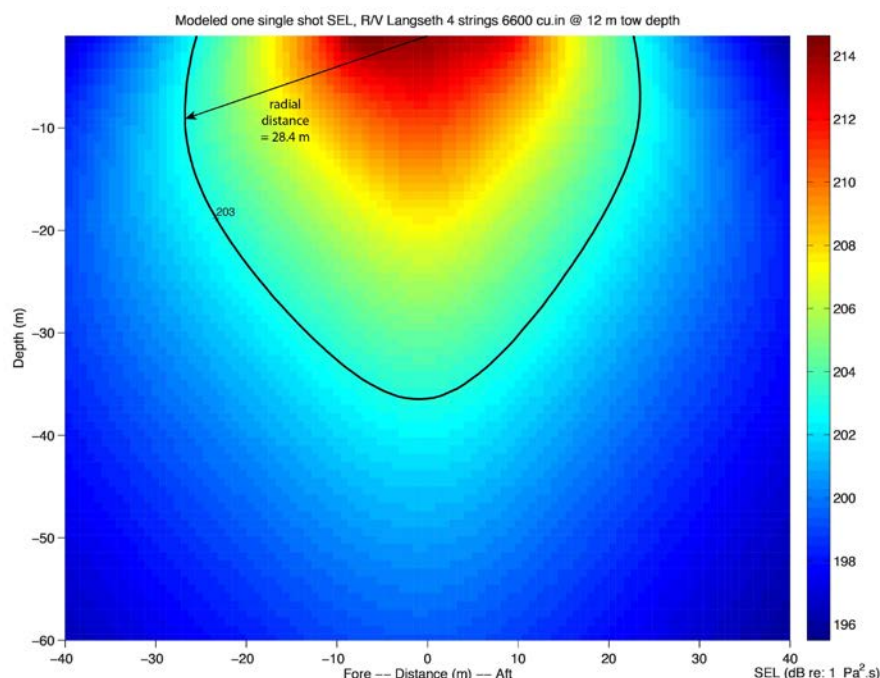


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth (28.4 m).

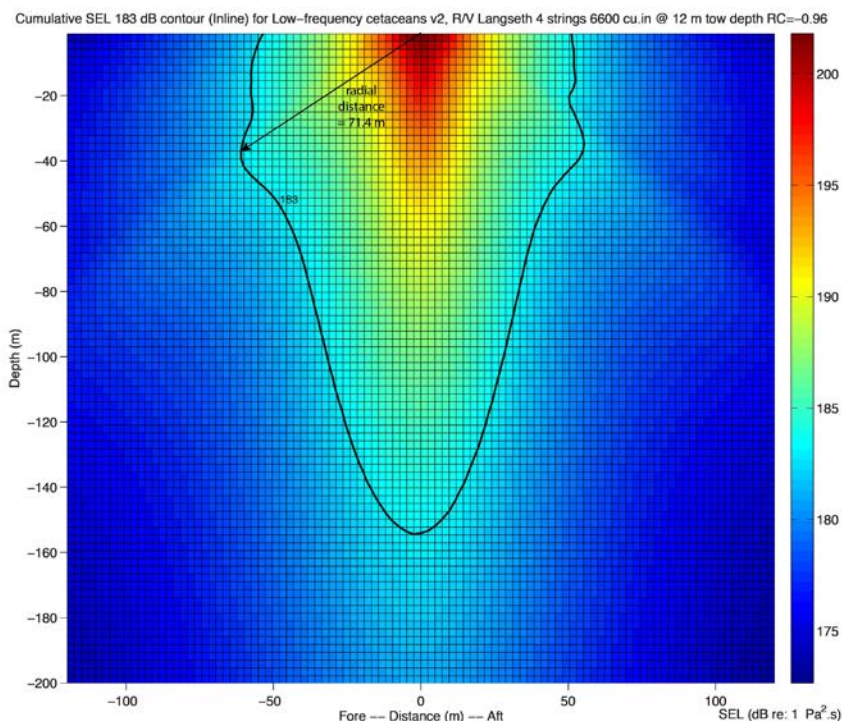


FIGURE A-8. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-6 and this figure (71.4 m) allows us to estimate the adjustment in dB.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 36-airgun array during the proposed surveys in the North 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 to Threshold (m)	45.00	13.566	364.666	51.590	10.615
Modified Farfield Peak SPL	252.06	252.65	253.24	252.25	252.52
PTS Peak Isopleth (Radius) to Threshold (m)	38.9	13.6	268.3	43.7	10.6

N.A. means not applicable or not available.

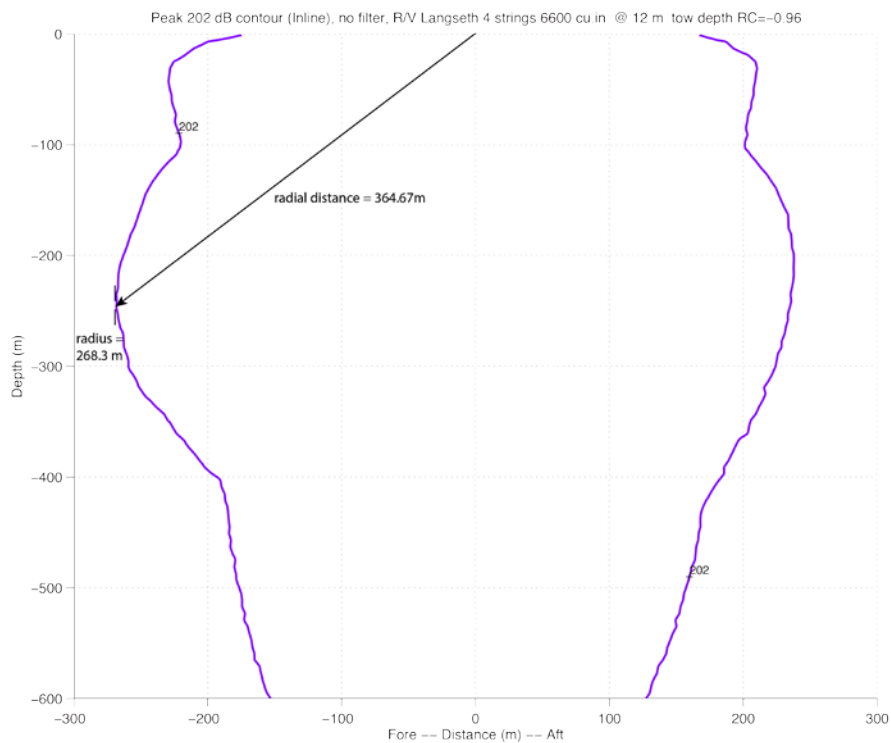


FIGURE A-9. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleths.

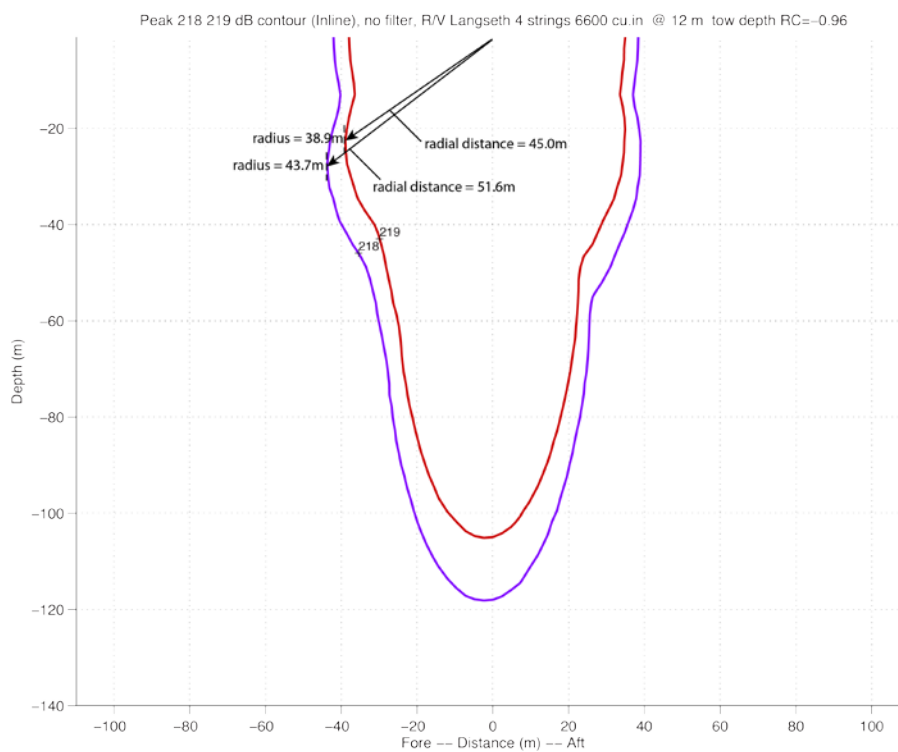


FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

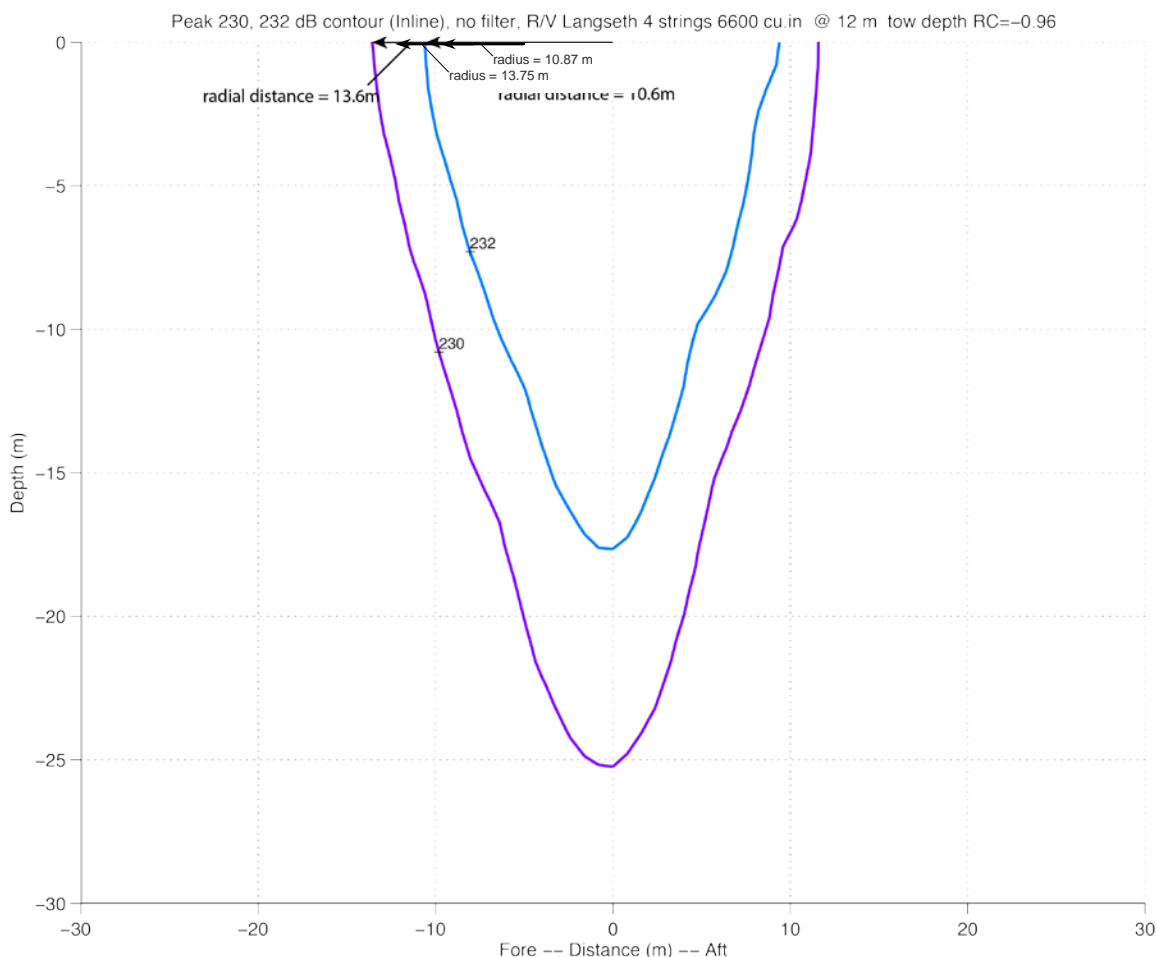


FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

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

Level A Threshold Distances (m) for Various Hearing Groups					
36-airgun array; 6600 in ³	Low- Frequency Cetaceans	Mid- Frequency Cetaceans	High- Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL_{cum}	320.2	0	1.0	10.4	0
PTS Peak	38.9	13.6	268.3	43.7	10.6

TABLE A-6. Results for single shot SEL source level modeling for the 40 in³ airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 log₁₀ (Radial distance) is used to estimate the modified farfield SEL.

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

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

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

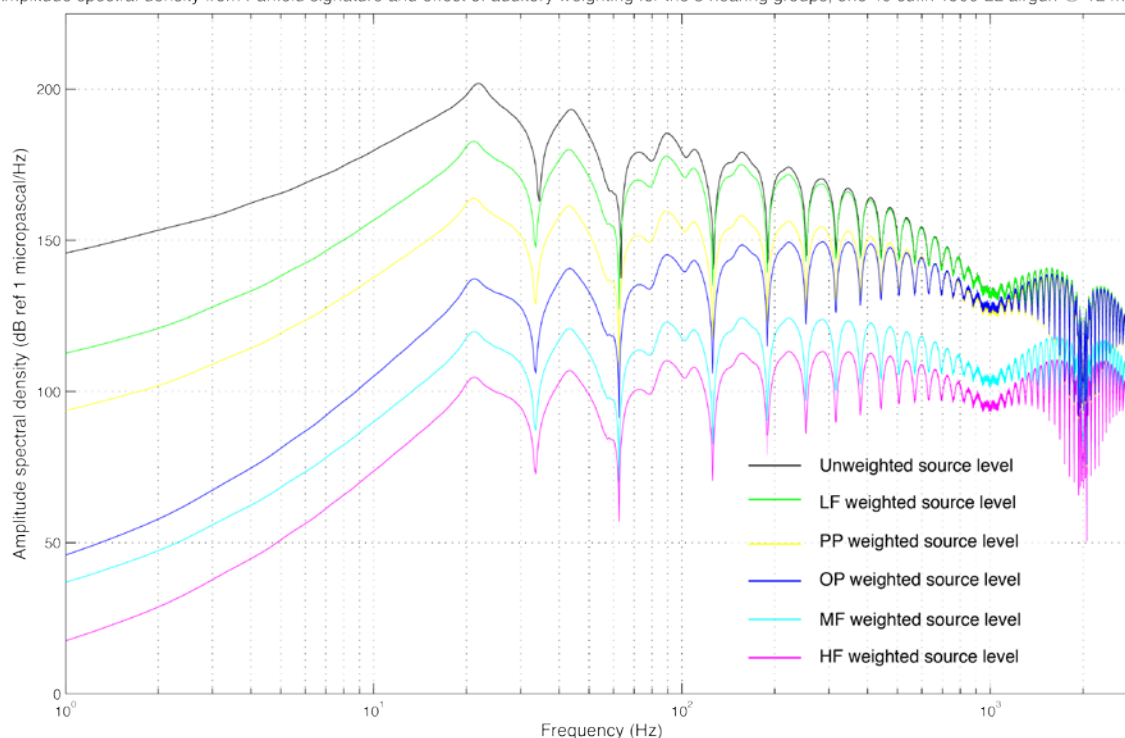


FIGURE A-12. Modeled amplitude spectral density of the 40-in³ airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-7. Results for single shot SEL source level modeling for the single 40-in³ mitigation airgun with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.

STEP 1: GENERAL PROJECT INFORMATION						
PROJECT TITLE	R/V Langseth mitigation gun					
PROJECT/SOURCE INFORMATION	one 40 cu.in 1900LL airgun @ a 12 m tow depth					
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.						
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)	2.1092	4.1 knots				
1/Repetition rate [‡] (seconds)	23.7054					
[†] Methodology assumes propagation of 20 log R; Activity duration (time) independent [‡] Time between onset of successive pulses.						
	Modified farfield SEL	202.9907	202.8948	204.368	202.8948	202.3491
	Source Factor	8.39891E+18	8.21548E+18	1.15333E+19	8.21548E+18	7.24541E+18
RESULTANT ISOPLETHS*	*Impulsive sounds have dual metric thresholds (SEL _{cum} & PK). Metric producing largest isopleth should be used.					
	Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otarid Pinnipeds
	SEL _{cum} Threshold	183	185	155	185	203
	PTS SEL _{cum} Isopleth to threshold (meters)	0.4	0.0	0.0	0.0	0.0
WEIGHTING FUNCTION CALCULATIONS						
	Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otarid Pinnipeds
	a	1	1.6	1.8	1	2
	b	2	2	2	2	2
	f ₁	0.2	8.8	12	1.9	0.94
	f ₂	19	110	140	30	25
	C	0.13	1.2	1.36	0.75	0.64
	Adjustment (dB) [†]	-12.44	-60.85	-70.00	-30.09	-36.69
OVERRIDE Using LDEO Modeling						

[†]For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of $20 \cdot \log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-12).

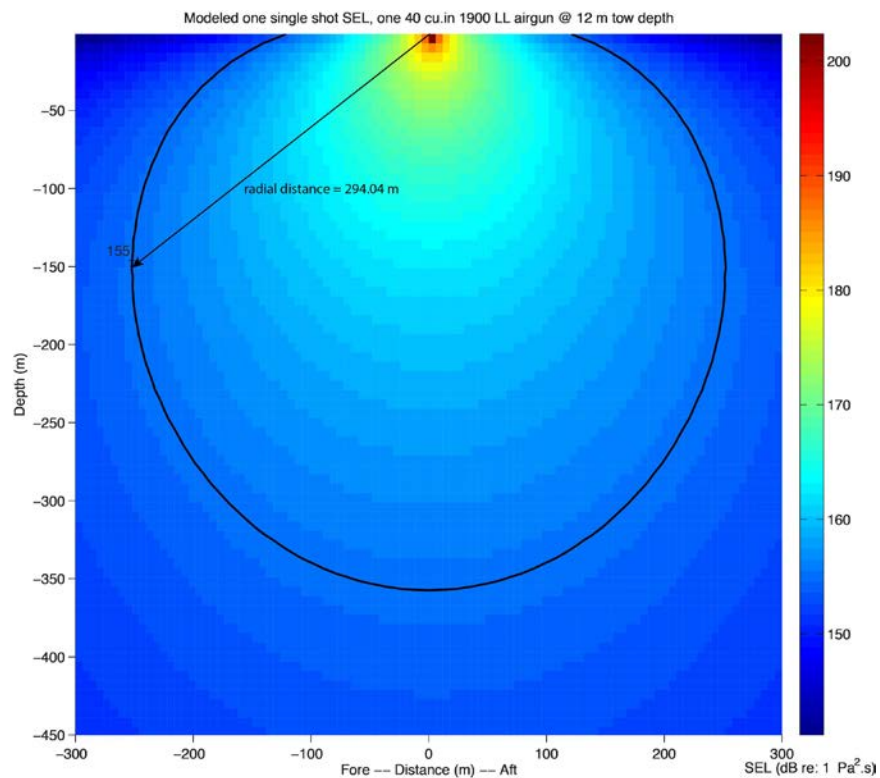


FIGURE A-13. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

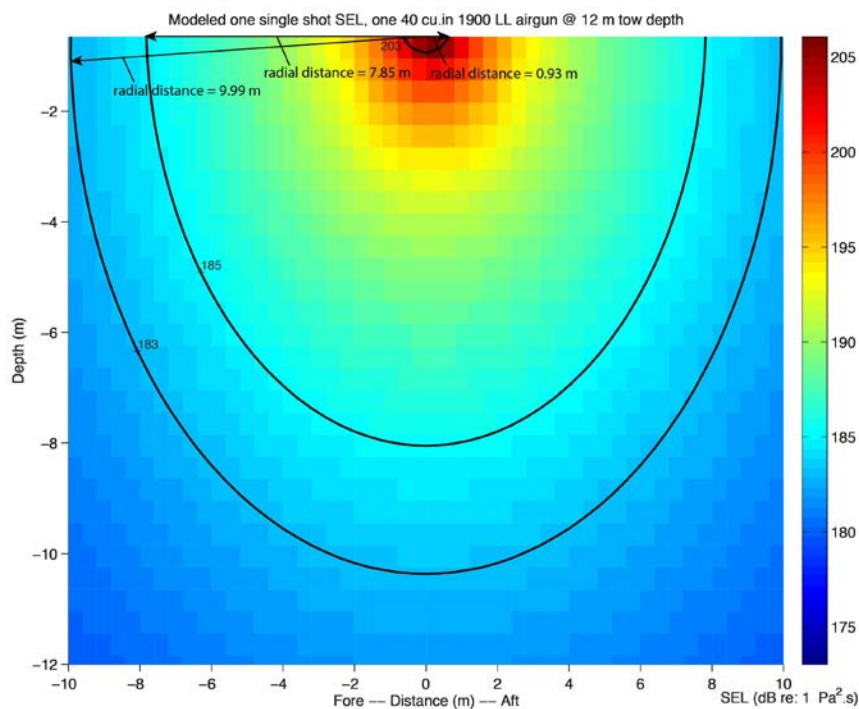


FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

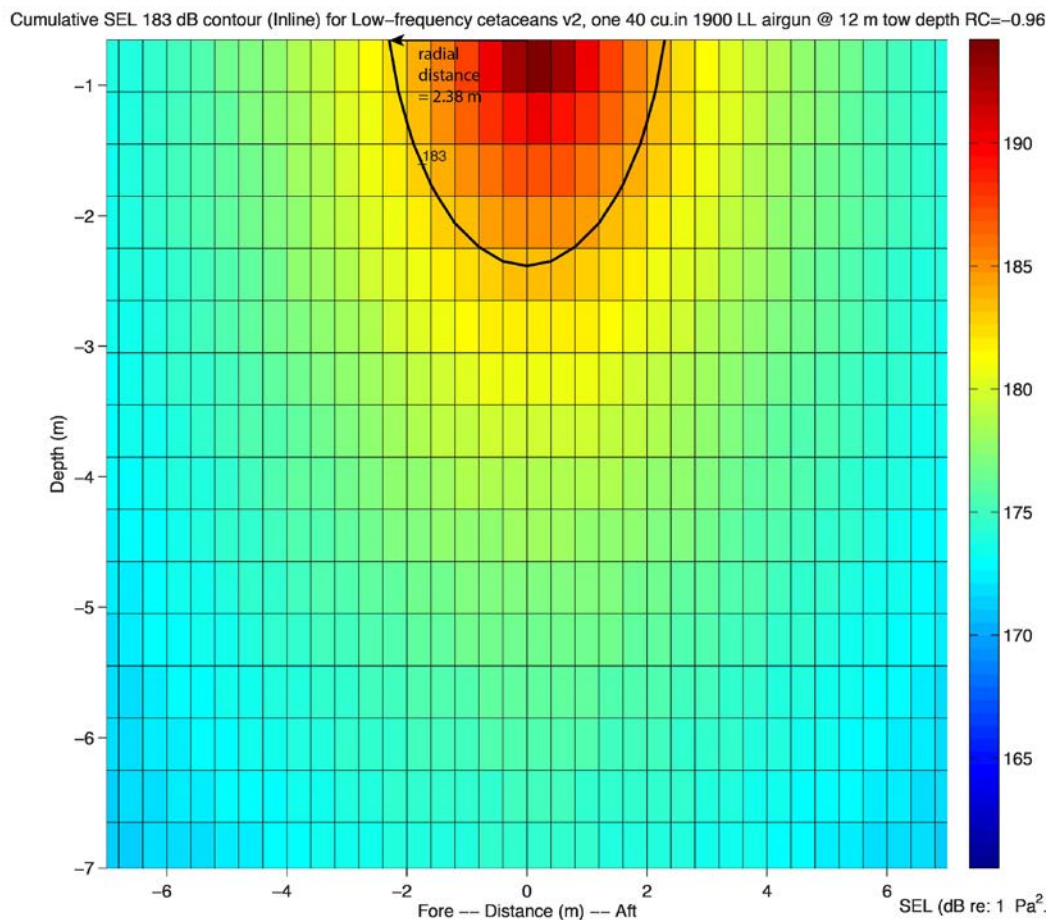


FIGURE A-15. Modeled received sound exposure levels (SELs) from one 40-in³ mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-14 and this figure allows us to estimate the adjustment in dB.

TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 40-in³ airgun during the proposed seismic surveys in the North 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 to Threshold (m)	1.764	N.A.	12.471	1.98	N.A.
Modified Farfield Peak	223.9300	N.A.	223.9185	223.9465	N.A.
PTS Peak Isopleth (Radius) to Threshold (m)	1.76	N.A.	12.5	1.98	N.A.

N.A. means not applicable or not available.

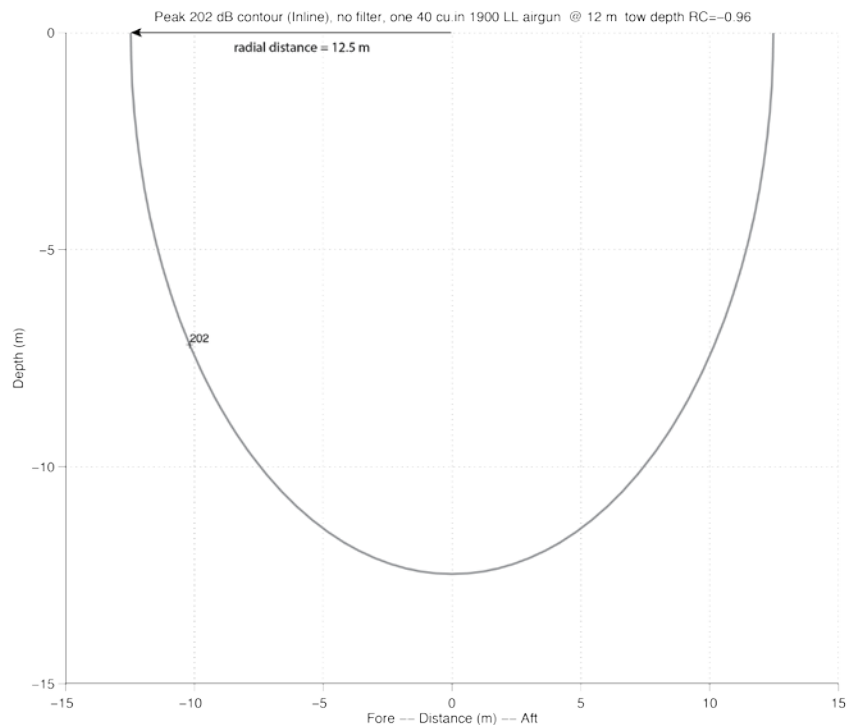


FIGURE A-16. Modeled deep-water received Peak SPL from one 40 in³ airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

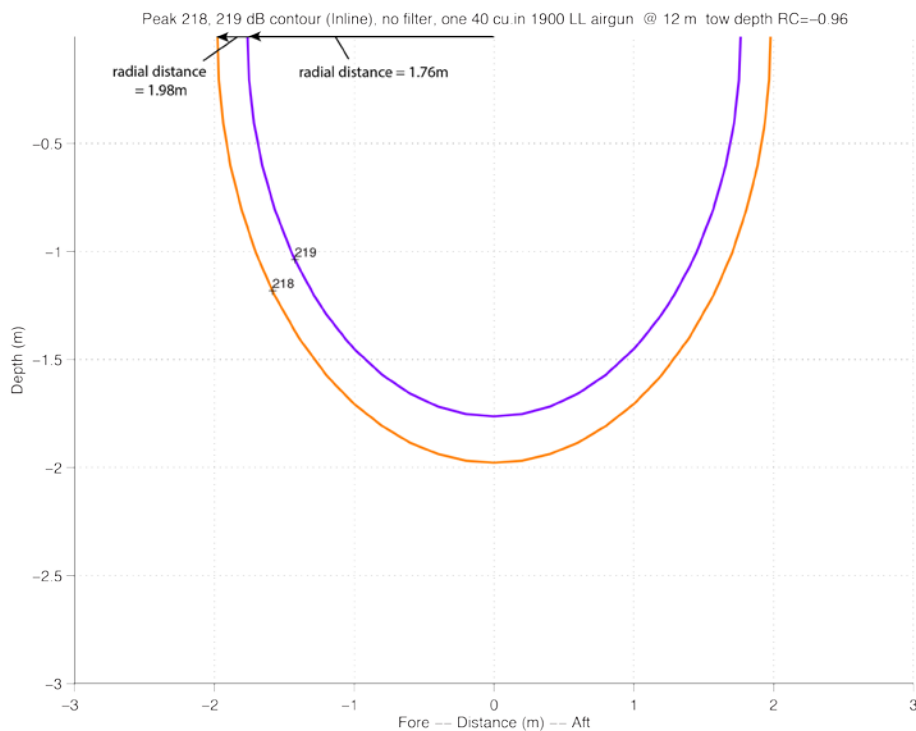


FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in³ airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

TABLE A-9. Level A threshold distances for different marine mammal hearing groups for a single airgun.

Single 40 in ³ airgun	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
PTS SEL_{cum}	0.4	0	0	0	0
PTS Peak	1.76	N/A	12.5	1.98	N/A

Note: N/A = not available.

TABLE A-10. Sea turtle thresholds recommended by NMFS. Predicted distances to which sound levels ≥ 195 - and 175-dB re 1 $\mu\text{Pa}_{\text{rms}}$ could be received during the proposed surveys in the North Pacific Ocean.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (m) to Received Sound Levels	
			195 dB	175 dB
Single Bolt airgun, 40 in ³	12	>1000 m	8 ¹ (100 ³)	77 ¹
		100–1000 m	11 ² (100 ³)	116 ²
4 strings, 36 airguns, 6600 in ³	12	>1000 m	181 ¹	1864 ¹
		100–1000 m	272 ²	2796 ²

¹ Distance is based on L-DEO model results.

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

³ An EZ of 100 m would be used as the shut-down distance, as specified for low-energy sources in the PEIS, for sea turtles.

Literature Cited

- Barton, P., J. Diebold, and S. Gulick. 2006. Balancing mitigation against impact: a case study from the 2005 Chicxulub seismic survey. **Eos Trans. Amer. Geophys. Union** 87(36), Joint Assembly Suppl., Abstr. OS41A-04. 23–26 May, Baltimore, MD.
- Crone, T.J., M. Tolstoy, and H. Carton. 2014. Estimating shallow water sound power levels and mitigation radii for the R/V *Marcus G. Langseth* using an 8 km long MCS streamer. **Geochem., Geophys., Geosyst.** 15(10):3793-3807.
- Crone, T.J., M. Tolstoy, and H. Carton. 2017. Utilizing the R/V *Marcus G. Langseth*'s streamer to measure the acoustic radiation of its seismic source in the shallow waters of New Jersey's continental shelf. **PLoS ONE** 12(8):e0183096. <http://doi.org/10.1371/journal.pone.0183096>.
- Diebold, J.B., M. Tolstoy, P.J. Barton, and S.P. Gulick. 2006. Propagation of exploration seismic sources in shallow water. **Eos Trans. Amer. Geophys. Union** 87(36), Joint Assembly Suppl., Abstr. OS41A-03. 23–26 May, Baltimore, MD.

- 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. <http://doi.org/10.1029/2010GC003126>. 20 p.
- NMFS. 2016. 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.
- 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.
- Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohnstiehl, T.J. Crone, and R.C. Holmes. 2009. Broadband calibration of R/V *Marcus G. Langseth* four-string seismic sources. **Geochem. Geophys. Geosyst.** 10:Q08011. <https://doi.org/10.1029/2009GC002451>.
- USN (U.S. Navy). 2017. Criteria and thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical Report prepared by the U.S. Navy.

APPENDIX B: MARINE MAMMAL DENSITIES

Procedures used to estimate densities of marine mammals

Hawaiian Survey Area

In the proposed survey area in the Hawaiian EEZ, densities from Bradford et al. (2017) were used, when available. For the pygmy sperm whale, dwarf sperm whale, and spinner dolphin, densities from CetMap (NOAA 2018) were used because densities were not provided by Bradford et al. (2017). For the humpback, minke, and killer whales, the calculated take was increased to mean group size, based on Bradford et al. (2017).

For Hawaiian monk seals, NMFS recommended following the methods used by the U.S. Navy (DoN 2017) to determine densities. Here, we have followed a similar method, but did not correct for hauled out animals as haul-out sites are not accessible in offshore areas. We determined density by dividing the number of animals expected to occur in the Hawaiian EEZ in water depths >200 m. According to the U.S. Navy (DoN 2017), 90% of the population may be found within the 200-m isobath; therefore 10% of the population (127 of 1272 animals; Carretta et al. 2017) is expected to occur outside of the 200-m isobath. The area within the Hawaii EEZ but outside of the 200-m isobath was estimated by the U.S. Navy to be 2,461,994 km² (DoN 2017). Thus, we estimated the average density of monk seals at sea where they could be exposed to seismic sounds as $127/2,461,994 \text{ km}^2 = 0.0000517/\text{km}^2$. No haul-out factors were used to adjust this density, as it is unlikely that animals would haul out beyond the 200-m isobath.

Emperor Seamounts Survey Area

There is a marked change in marine mammal distribution from warm-water species to temperate and sub-arctic species to the south of the proposed Emperor Seamounts survey area as illustrated in the distribution maps in Matsuoka et al. (2009, 2015), Hakamada and Matsuoka (2015), and Hakamada et al. (2017). As there are very few published data on the densities of cetaceans or pinnipeds in the area, we used mostly gray literature available from IWC scientific reports to compute densities based on parts of those surveys that were in and adjacent to the proposed seismic survey area. Had we used the overall densities provided in the reports for their entire survey area, in most cases we would have underestimated densities in the proposed survey area with the exception of warm-water species which are not usually found that far north.

For Pacific white-side dolphin, northern right whale dolphin, Dall's porpoise, and northern fur seal, we used densities from Buckland et al. (1993). Forney and Wade (2006) reported a density of 0.3/100 km² (Figure 12.1) for killer whales at latitudes 43–48°N where the proposed survey would be conducted. In the absence of other data for Cuvier's beaked whale, we used the density (whales/1000 km²) provided by Barlow (2006) for offshore areas of the Hawaiian EEZ. Although Miyashita (1993) published data on the abundance of striped, Pantropical spotted, bottlenose, and Risso's dolphins, and false killer and short-finned pilot whales in the Northwest Pacific Ocean as far north as 41°N, the distributional range of the Pantropical spotted and bottlenose dolphins does not extend as far north as the proposed survey area. For the other species, we used data from 40–41°N, 160–180°E to calculate densities and estimate the numbers of individuals that could be exposed to seismic sounds during the proposed survey. Risso's dolphin, false killer whale, and short-finned pilot whale are expected to be rare in the proposed survey area, and the calculated densities were zero. Thus, we used the mean group size from Bradford et al. (2017) for Risso's dolphin and short-finned pilot whale, and the mean group size of false killer whales from Barlow (2006), for the *Requested Take Authorization*.

The short-beaked common dolphin is expected to be rare in the Emperor Seamounts survey area; thus, there are no density estimates available. We used the mean group size (rounded up) for the California Current from Barlow (2016) for the *Requested Take Authorization*. The density of Bryde's whale in the

proposed survey area was assumed to be zero, based on information from Hakamada et al. (2009, 2017) and Forney et al. (2015); its known distribution range does not appear to extend that far north. For this species, we rounded up the mean group size from Bradford et al. (2017) for the *Requested Take Authorization*.

The densities for the remaining species were obtained from calculations using data from the papers presented to the IWC. For blue, fin, humpback, and North Pacific right whales we used a weighted mean density from Matsuoka et al. (2009) for the years 1994–2007 and Hakamada and Matsuoka (2015) for the years 2008–2014. We used Matusoka et al. (2009) instead of Matsuoka et al. (2015), as the later document did not contain all of the necessary information to calculate densities. We used densities for their Block 9N which coincides with the proposed Emperor Seamounts survey area. The density for each survey period was weighted by the number of years in the survey period; that is, 14 years for Matsuoka et al. (2009) and 7 years for Hakamada and Matsuoka (2015), to obtain a final density for the 21-year period. For minke, sei, and sperm whales we used the estimates of numbers of whales in survey blocks overlapping the Emperor Seamounts survey area from Hakamada et al. (2009); densities were estimated by dividing the number of whales in Block 9N by the area of Block 9N which are given in their Table 6. We increased the *Requested Take Authorization* for blue whales to 50 individuals (Sears and Perrin 2009), in case an aggregation would be encountered during the proposed survey.

Finally, no northern elephant seals have been reported during any of the above surveys although Buckland et al. (1993) estimated fur seal abundance during their surveys. Telemetry studies, however, indicate that elephant seals do forage as far west as the proposed Emperor Seamounts survey area. Here, we have assumed a density of 0.00831/1000 km², which is 10% of that used by LGL Limited (2017) for an area off the west coast of the U.S. However, densities fo northern elephant seals in the region are expected to be much less than densities of northern fur seals.

Table B-1 summarizes the densities for marine mammals in the Emperor Seamounts survey area and the data sources used.

TABLE B-1. Densities of marine mammals in the Emperor Seamounts survey area in the western North Pacific Ocean. Species listed as "Endangered" under the ESA are in italics.

Species	Density (#/1000 km ²)	Source
LF Cetaceans		
<i>Gray whale</i>	0	Hakamada et al. (2009); Forney et al. (2015)
<i>North Pacific right whale</i>	0.54	Matsuoka et al. (2009); Hakamada and Matsuoka (2015)
<i>Humpback whale</i>	0.41	Matsuoka et al. (2009); Hakamada and Matsuoka (2015)
Minke whale	2.48	Hakamada et al. (2009)
Bryde's whale	0	Hakamada et al. (2009, 2017); Forney et al. (2015)
<i>Sei whale</i>	2.93	Hakamada et al. (2009)
<i>Fin whale</i>	0.93	Matsuoka et al. (2009); Hakamada and Matsuoka (2015)
<i>Blue whale</i>	0.13	Matsuoka et al. (2009); Hakamada and Matsuoka (2015)
MF Cetaceans		
<i>Sperm whale</i>	10.97	Hakamada et al. (2009)
Cuvier's beaked whale	6.80	Barlow (2006)
Stejneger's beaked whale	N.A.	N.A.
Baird's beaked whale	N.A.	N.A.
Striped dolphin	9.21	Miyashita (1993)
Pacific white-sided dolphin	68.81	Buckland et al. (1993)
Northern right-whale dolphin	3.37	Buckland et al. (1993)
Risso's dolphin	0	Miyashita (1993)
False killer whale	0	Miyashita (1993)
Killer whale	3.00	Forney and Wade (2006)
Short-finned pilot whale	0	Miyashita (1993)
HF Cetaceans		
Pygmy sperm whale	N.A.	N.A.
Dwarf sperm whale	N.A.	N.A.
Dall's porpoise	35.46	Buckland et al. (1993)
Otariids		
Northern fur seal	3.56	Buckland et al. (1993)
<i>Steller sea lion</i>	N.A.	N.A.
Phocid Seals		
Northern elephant seal	8.31	LGL Limited (2017)
Ribbon seal	N.A.	N.A.

N.A. means not available.

Literature Cited

- Barlow, J. 2016. Cetacean abundance in the California Current estimated from ship-based line-transect surveys in 1991-2014. National Oceanic and Atmospheric Administration (NOAA) Administrative Rep. LJ-16-01. 31 p. + appendix.
- Bradford, A.L., K.A. Forney, E.M. Oleson, and J. Barlow. 2017. Abundance estimates of cetaceans from a line-transect survey within the U.S. Hawaiian Islands Exclusive Economic Zone. **Fish. Bull.** 115(2):129-142.
- Buckland, S.T., K.L. Cattanach, and R.C. Hobbs. 1993. Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987-1990. **Int. North Pacific Fish. Comm. Bull.** 53(3):387-407.
- Carretta, J.V., K.A. Forney, E.M. Oleson, D.W. Weller, A.R. Lang, 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. Brownwell Jr. 2017. U.S. Pacific marine mammal stock assessments: 2016. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-577. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 407 p.

- DoN (Department of the U.S. Navy). 2017. U.S. Navy marine species density database phase III for the HSTT study area. Available at https://hstteis.com/portals/hstteis/files/reports/U.S._Navy_Marine_Species_Density_Database_Phase_III_Technical_Rpt_for_HSTT_Oct2017.pdf Excerpt of the report provided by NMFS.
- Forney, K.A. and P.R. Wade. 2006. Worldwide distribution and abundance of killer whales. Pages 145-162 In: J.A. Estes, D.P. DeMaster, D.F. Doak, T.M. Williams, and R.L. Brownell, Jr. (eds.) *Whales, Whaling and Ocean Ecosystems*. University of California Press, Berkely.
- Forney, K.A., E.A. Becker, D.G. Foley, J. Barlow, and E.M. Oleson. 2015. Habitat-based models of cetacean density and distribution in the central North Pacific. **Endang. Species Res.** 27:1-20.
- Hakamada, T. and K. Matsuoka. 2015. The number of blue, fin, humpback, and North Pacific right whales in the western North Pacific in the JARPNII offshore survey area. Paper SC/F16/JR13 presented to the IWC Scientific Committee, May 2015, San Diego, USA (unpublished). 12 p.
- Hakamada, T., K. Matsuoka, and T. Miyashita. 2009. Distribution and the number of western North Pacific common minke, Bryde's, sei and sperm whales distributed in JARPN II Offshore component survey area. Paper SC/J09/JR15 presented to the expert workshop to review the ongoing JARPN II Programme, Yokohama, Japan, 26-30, January 2009. 18 p. (unpublished).
- Hakamada, T., M. Takahashi, K. Matsuoka, and T. Miyashita. 2017. Abundance estimate for western North Pacific Bryde's whale by sub-areas based on IWC-POWER and JARPNII sighting surveys. Paper SC/MAR17/RMP/02 presented to the RMP Bryde's whale workshop, March 2017, Tokyo, Japan. 12 p. (unpublished).
- LGL Limited. 2017. Final environmental assessment of a low-energy marine geophysical survey by the R/V Roger Revelle in the Northeastern Pacific Ocean, September 2017. LGL Rep. FA0114-2. Rep. by LGL Limited, St. John's, NL, for Scripps Institution of Oceanography, La Jolla, CA, and National Science Foundation, Arlington, VA.
- Matsuoka, K., H. Kiwada, Y. Fujise, and T. Miyashita. 2009. Distribution of blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*) and North Pacific right (*Eubalaena japonica*) whales in the western North Pacific based on JARPN and JARPNII sighting surveys (1994 to 2007). Paper SC/J09/JR35 presented to the Int. Whal. Comm., Cambridge, U.K.
- Matsuoka, K., T. Hakamada, and T. Miyashita. 2015. Distribution of blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*) and North Pacific right (*Eubalaena japonica*) whales in the western North Pacific based on JARPN and JARPNII (1994 to 2014). Paper SC/F16/JR9 presented to the Int. Whal. Comm., Cambridge, U.K.
- Miyashita, T. 1993. Abundance of dolphin stocks in the western North Pacific taken by the Japanese drive fishery. **Rep. Int. Whal. Comm.** 43:417-437.
- NOAA. 2018. Cetacean data availability. Accessed in February 2018 at <https://cetsound.noaa.gov/cda>.
- Sears, R. and W.F. Perrin. 2009. Blue whale *Balaenoptera musculus*. p. 120-124 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.
- Wilson, K., C. Littnan, and A.J. Read. 2017. Movements and home ranges of monk seals in the main Hawaiian Islands. **Mar. Mamm. Sci.** 33(4):1080-1096.

APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS

Table C-1. Take calculations for the Emperor Seamounts Survey

Species	Estimated Density (#/1000 km ²)	Regional Population Size	Hearing Group	NMFS		Total Takes	Level A Takes	Level B Takes	% of Pop. (Total Takes)
				Level B 160 dB Ensonified Area (km ²)	Level A Ensonified Area (km ²)				
Mysticetes									
Gray whale	0.00	140	LF	41,702.4	1,878.4	0	0	0	0
North Pacific right whale	0.54	450	LF	41,702.4	1,878.4	23	1	22	5.11
Humpback whale	0.41	21,063	LF	41,702.4	1,878.4	17	1	16	0.08
Minke whale	2.48	22,000	LF	41,702.4	1,878.4	104	5	99	0.47
Bryde's whale	0.00	28,447	LF	41,702.4	1,878.4	0	0	0	0
Sei whale	2.93	27,197	LF	41,702.4	1,878.4	122	5	117	0.45
Fin whale	0.93	16,150	LF	41,702.4	1,878.4	39	2	37	0.24
Blue whale	0.13	2,605	LF	41,702.4	1,878.4	5	0	5	0.19
Odontocetes									
Sperm whale	10.97	29,674	MF	41,702.4	79.6	457	1	456	1.54
Pygmy sperm whale	N.A.	7,138	HF	41,702.4	1,573.2	N.A.	N.A.	N.A.	N.A.
Dwarf sperm whale	N.A.	17,519	HF	41,702.4	1,573.2	N.A.	N.A.	N.A.	N.A.
Cuvier's beaked whale	6.80	20,000	MF	41,702.4	79.6	284	1	283	1.42
Stejner's beaked whale	N.A.	25,300	MF	41,702.4	79.6	N.A.	N.A.	N.A.	N.A.
Baird's beaked whale	N.A.	25,300	MF	41,702.4	79.6	N.A.	N.A.	N.A.	N.A.
Short-beaked common dolphin	N.A.	2,963,000	MF	41,702.4	79.6	N.A.	N.A.	N.A.	N.A.
Striped dolphin	9.21	964,362	MF	41,702.4	79.6	384	1	383	0.04
Pacific white-sided dolphin	68.81	988,333	MF	41,702.4	79.6	2,870	5	2,865	0.29
Northern right whale dolphin	3.37	307,784	MF	41,702.4	79.6	141	0	141	0.05
Risso's dolphin	N.A.	110,457	MF	41,702.4	79.6	N.A.	N.A.	N.A.	N.A.
False killer whale	N.A.	16,668	MF	41,702.4	79.6	N.A.	N.A.	N.A.	N.A.
Killer whale	3.00	8,500	MF	41,702.4	79.6	125	0	125	1.47
Short-finned pilot whale	N.A.	53,608	MF	41,702.4	79.6	N.A.	N.A.	N.A.	N.A.
Dall's porpoise	35.46	1,186,000	HF	41,702.4	1,573.2	1,479	56	1,423	0.12
Pinnipeds									
Northern fur seal	3.56	1,100,000	OT	41,702.4	62.0	149	0	149	0.01
Steller sea lion	N.A.	143,000	OT	41,702.4	62.0	N.A.	N.A.	N.A.	N.A.
Northern elephant seal	8.31	224,500	PW	41,702.4	255.7	347	2	345	0.15
Ribbon seal	N.A.	240,000	PW	41,702.4	255.7	N.A.	N.A.	N.A.	N.A.

N.A. means not available.

Table C-2. Take calculations for the Hawaii Survey

Species	Density (#/1000 km ²)	Regional Population Size	Hearing Group	NMFS		Total Takes	Level A Takes	Level B Takes	% of Pop. (Total Takes)
				Level B 160					
				dB Ensonified Area (km ²)	Level A Ensonified Area (km ²)				
Mysticetes									
Humpback whale	0	21,063	LF	65,778.5	2,745.4	0	0	0	0
Minke whale	0	22,000	LF	65,778.5	2,745.4	0	0	0	0
Bryde's whale	0.97	28,447	LF	65,778.5	2,745.4	64	3	61	0.23
Sei whale	0.22	27,197	LF	65,778.5	2,745.4	14	1	13	0.05
Fin whale	0.06	16,150	LF	65,778.5	2,745.4	4	0	4	0.02
Blue whale	0.05	2,605	LF	65,778.5	2,745.4	3	0	3	0.13
Odontocetes									
Sperm whale	1.86	26,300	MF	65,778.5	116.3	122	0	122	0.47
Pygmy sperm whale	2.91	7,138	HF	65,778.5	2,299.3	191	7	184	2.68
Dwarf sperm whale	7.14	17,519	HF	65,778.5	2,299.3	470	16	454	2.68
Cuvier's beaked whale	0.30	20,000	MF	65,778.5	116.3	20	0	20	0.10
Longman's beaked whale	3.11	4,571	MF	65,778.5	116.3	205	0	205	4.48
Blainville's beaked whale	0.86	25,300	MF	65,778.5	116.3	57	0	57	0.22
Ginkgo-toothed beaked whale	0.63	25,300	MF	65,778.5	116.3	41	0	41	0.16
Deraniygala's beaked whale	0.63	25,300	MF	65,778.5	116.3	41	0	41	0.16
Hubb's beaked whale	0.63	25,300	MF	65,778.5	116.3	41	0	41	0.16
Rough-toothed dolphin	29.63	107,633	MF	65,778.5	116.3	1,949	3	1,946	1.81
Common bottlenose dolphin	8.99	335,834	MF	65,778.5	116.3	591	1	590	0.18
Pantropical spotted dolphin	23.32	1,297,092	MF	65,778.5	116.3	1,534	3	1,531	0.12
Spinner dolphin	6.99	1,797,716	MF	65,778.5	116.3	460	1	459	0.03
Striped dolphin	25.00	964,362	MF	65,778.5	116.3	1,644	3	1,641	0.17
Fraser's dolphin	21.04	289,300	MF	65,778.5	116.3	1,384	2	1,382	0.48
Risso's dolphin	4.74	110,457	MF	65,778.5	116.3	312	1	311	0.28
Melon-headed whale	3.54	45,400	MF	65,778.5	116.3	233	0	233	0.51
Pygmy killer whale	4.35	38,900	MF	65,778.5	116.3	286	1	285	0.74
False killer whale	0.60	16,668	MF	65,778.5	116.3	39	0	39	0.24
Killer whale	0.06	8,500	MF	65,778.5	116.3	4	0	4	0.05
Short-finned pilot whale	7.97	53,608	MF	65,778.5	116.3	524	1	523	0.98
Pinnipeds									
Hawaiian monk seal	0.49	1,272	PW	65,778.5	373.8	32	0	32	2.55

APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

Survey	Criteria	Daily Ensonified Area (km ²)	Total Survey Days	25% Increase	Total Ensonified Area (km ²)	Relevant Isopleth (m)
Hawaii:multi-depth line (intermediate water)	160 dB	538.5	12	1.25	8076.9	10,100
Hawaii:multi-depth line (deep water)	160 dB	2349.8	12	1.25	35246.4	6,733
Hawaii:multi-depth line (total)	160 dB	2888.2	12	1.25	43323.3	6,733
Hawaii:deep-water line	160 dB	2566.3	7	1.25	22455.1	6,733
Hawaii: all lines (total)	160 dB				65778.5	
Hawaii	LF Cetacean	115.6	19	1.25	2745.4	320.2
Hawaii	MF Cetacean	4.9	19	1.25	116.3	13.6
Hawaii	HF Cetacean	96.8	19	1.25	2299.3	268.3
Hawaii	Phocid	15.7	19	1.25	373.8	43.7
Emperor Seamounts	160 dB	2566.3	13	1.25	41702.4	6,733
Emperor Seamounts	LF Cetacean	115.6	13	1.25	1878.4	320.2
Emperor Seamounts	MF Cetacean	4.9	13	1.25	79.6	13.6
Emperor Seamounts	HF Cetacean	96.8	13	1.25	1573.2	268.3
Emperor Seamounts	Phocid	15.7	13	1.25	255.7	43.7
Emperor Seamounts	Otariid	3.8	13	1.25	62.0	10.6