

**Request by Lamont-Doherty Earth Observatory  
for an Incidental Harassment Authorization to Allow the  
Incidental Take of Marine Mammals during Marine  
Geophysical Surveys by R/V *Marcus G. Langseth* of the  
Queen Charlotte Fault in the Northeast Pacific Ocean,  
Summer 2021**

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

2 December 2019  
revised 16 December 2020

LGL Report FA0186-00B



# TABLE OF CONTENTS

	Page
SUMMARY .....	1
I. OPERATIONS TO BE CONDUCTED .....	1
Overview of the Activity .....	1
Source Vessel Specifications .....	4
Airgun Description .....	4
Predicted Sound Levels .....	4
OBS Description and Deployment .....	5
Description of Operations .....	6
II. DATES, DURATION, AND REGION OF ACTIVITY .....	7
III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA .....	7
IV. STATUS, DISTRIBUTION AND SEASONAL DISTRIBUTION OF AFFECTED SPECIES OR STOCKS OF MARINE MAMMALS .....	8
Mysticetes .....	8
Odontocetes .....	18
Pinnipeds .....	24
Fissipeds .....	29
V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED .....	30
VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN .....	31
VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS .....	31
Summary of Potential Effects of Airgun Sounds .....	31
Tolerance .....	32
Masking .....	32
Disturbance Reactions .....	33
Hearing Impairment and Other Physical Effects .....	39
Possible Effects of Other Acoustic Sources .....	42
Other Possible Effects of Seismic Surveys .....	44
Numbers of Marine Mammals that could be “Taken by Harassment” .....	46
Basis for Estimating “Takes” .....	46
Conclusions .....	51
VIII. ANTICIPATED IMPACT ON SUBSISTENCE .....	51
IX. ANTICIPATED IMPACT ON HABITAT .....	52
X. ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS .....	52
XI. MITIGATION MEASURES .....	52
Planning Phase .....	53
Mitigation During Operations .....	54

Shut-down/Power-down Procedures .....	54
Ramp-up Procedures .....	54
XII. PLAN OF COOPERATION .....	55
XIII. MONITORING AND REPORTING PLAN .....	55
Vessel-based Visual Monitoring .....	56
Passive Acoustic Monitoring.....	56
PSO Data and Documentation .....	57
XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE .....	58
XV. LITERATURE CITED.....	58
LIST OF APPENDICES: .....	94
APPENDIX A: DETERMINATION OF MITIGATION ZONES .....	A-1
APPENDIX B: MARINE MAMMAL DENSITIES .....	B-1
APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS .....	C-1
APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS .....	D-1

# Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Queen Charlotte Fault in the Northeast Pacific Ocean, Summer 2021

## SUMMARY

Researchers from the University of New Mexico and Western Washington University, with funding from the U.S. National Science Foundation (NSF), and in collaboration with researchers from the United States Geological Survey (USGS), Dalhousie University, and the Geological Survey of Canada, propose to conduct high-energy seismic surveys from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) at the Queen Charlotte Fault (QCF) in the Northeast Pacific Ocean during summer 2021. The NSF-owned *Langseth* is operated by L-DEO under an existing Cooperative Agreement. The proposed 2-D seismic surveys would occur within Exclusive Economic Zones (EEZ) of Canada and the U.S., including U.S. state waters and Canadian Territorial Waters. This request prepared pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5), was originally submitted to the National Marine Fisheries Service (NMFS) on 3 December 2019. However, it has been revised due to a number of factors including: (1) to address comments from NMFS, (2) a schedule change from summer 2020 to summer 2021 due to COVID-19 impacts, and (3) a change in the mitigation zones which are now based on both modeling for the Level A and Level B thresholds and using empirical measurements from Crone et al. (2014) from the Cascadia Margin, which were then used to revise the take estimates, and (4) a change in location tracklines. Although the location of some tracklines has changed from what was originally proposed, the original trackline locations were used to generate take estimates, because they are still adequately representative of the proposed survey plan.

Numerous species of marine mammals inhabit the proposed survey area in the northeastern Pacific Ocean. Under the U.S. ESA, several of these are listed as ***endangered***, including the North Pacific right, sei, fin, blue, and sperm whales; the Western North Pacific Distinct Population Segment (DPS) of gray whales and the Western DPS of Steller sea lions may also occasionally occur in the area. The ***threatened*** Mexico DPS of the humpback whale could also occur in the proposed survey area, but it is unlikely that humpbacks from the ***endangered*** Central America DPS or killer whales from the ***endangered*** Southern Resident DPS would occur in the project area at the time of the surveys. The North Pacific right whale, Pacific populations of the sei and blue whales, and Southern Resident killer whales are also listed as ***endangered*** under Canada's *Species at Risk Act* (SARA); the Pacific population of fin whale, and all other populations of killer whales in the Pacific Ocean are listed as ***threatened***. The northern sea otter is the one marine mammal species mentioned in this document that, in the U.S., is managed by the U.S. Fish and Wildlife Service (USFWS); all others are managed by NMFS. A separate request for an Incidental Harassment Authorization (IHA) was submitted to USFWS for the sea otter.

ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback turtle and ***threatened*** green turtle; the leatherback turtle is also listed as ***endangered*** under SARA, but the green turtle is not listed. ESA-listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross (also ***endangered*** under SARA) and Hawaiian petrel (not listed under SARA).

Although Alaskan fish populations are not listed under the ESA, there are several ESA-listed fish species that spawn on the west coast of the Lower 48 U.S. and may occur in Alaskan and B.C. waters during the marine phases of their life cycles, including the *threatened* green sturgeon (Southern DPS) and several DPSs of steelhead trout; and various *endangered* and *threatened* evolutionary significant units (ESUs) of chinook, chum, coho, and sockeye salmon. None of these species are listed under SARA, but the basking shark and northern abalone are listed as *endangered*.

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

## I. OPERATIONS TO BE CONDUCTED

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

### Overview of the Activity

The proposed study would use 2-D seismic surveying to characterize crustal and uppermost mantle velocity structure, fault zone architecture and rheology, and seismicity of the QCF. The proposed surveys would occur within ~52–57°N, ~131–137°W; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above. However, deviations in tracklines are expected to be limited and would not be expected to substantially affect the ensuing analysis. The surveys are proposed to occur within the EEZs of the U.S. and Canada, including U.S. state waters and Canadian Territorial Waters, ranging in 50–2800 m in depth. The proposed surveys would be expected to last for 36 days, including ~27 days of seismic operations, ~2 days of transit to and from the survey area, 3 days for equipment deployment/recovery, and 4 days of contingency. R/V *Langseth* would likely leave out of and return to port in Ketchikan, AK, during summer (July–August) 2021.

The QCF system is a ~1200 km-long onshore-offshore transform system connecting the Cascadia and Alaska-Aleutian subduction zones; the QCF is the ~900 km-long offshore component of the transform system. The primary objective of the proposed study is to characterize ~450-km segment of the fault that encompasses systematic variations in key parameters in space and time: 1) changes in fault obliquity relative to Pacific-North American plate motion leading to increased convergence from north to south; 2) Pacific plate age and theoretical mechanical thickness decrease from north to south; and 3) a shift in Pacific plate motion at ~12-6 Ma that may have increased convergence along the entire length of the fault, possibly initiating underthrusting in the southern portion of the study area. Current understanding of how these variations are expressed through seismicity, crustal-scale deformation, and lithospheric structure and dynamics is limited due to lack of instrumentation and modern seismic imaging.

To achieve the project goals, the Principal Investigators (PI) Drs. L. Worthington (University of New Mexico) and E. Roland (Western Washington University) propose to utilize long-offset 2-D seismic reflection and wide-angle reflection-refraction capabilities of R/V *Langseth* and a combined U.S.-Canadian broadband Ocean Bottom Seismometer (OBS) array. Although not funded through NSF, collaborators Dr. M. Nedimovic (Dalhousie University) and the Geological Survey of Canada, as well as the USGS (Dr.

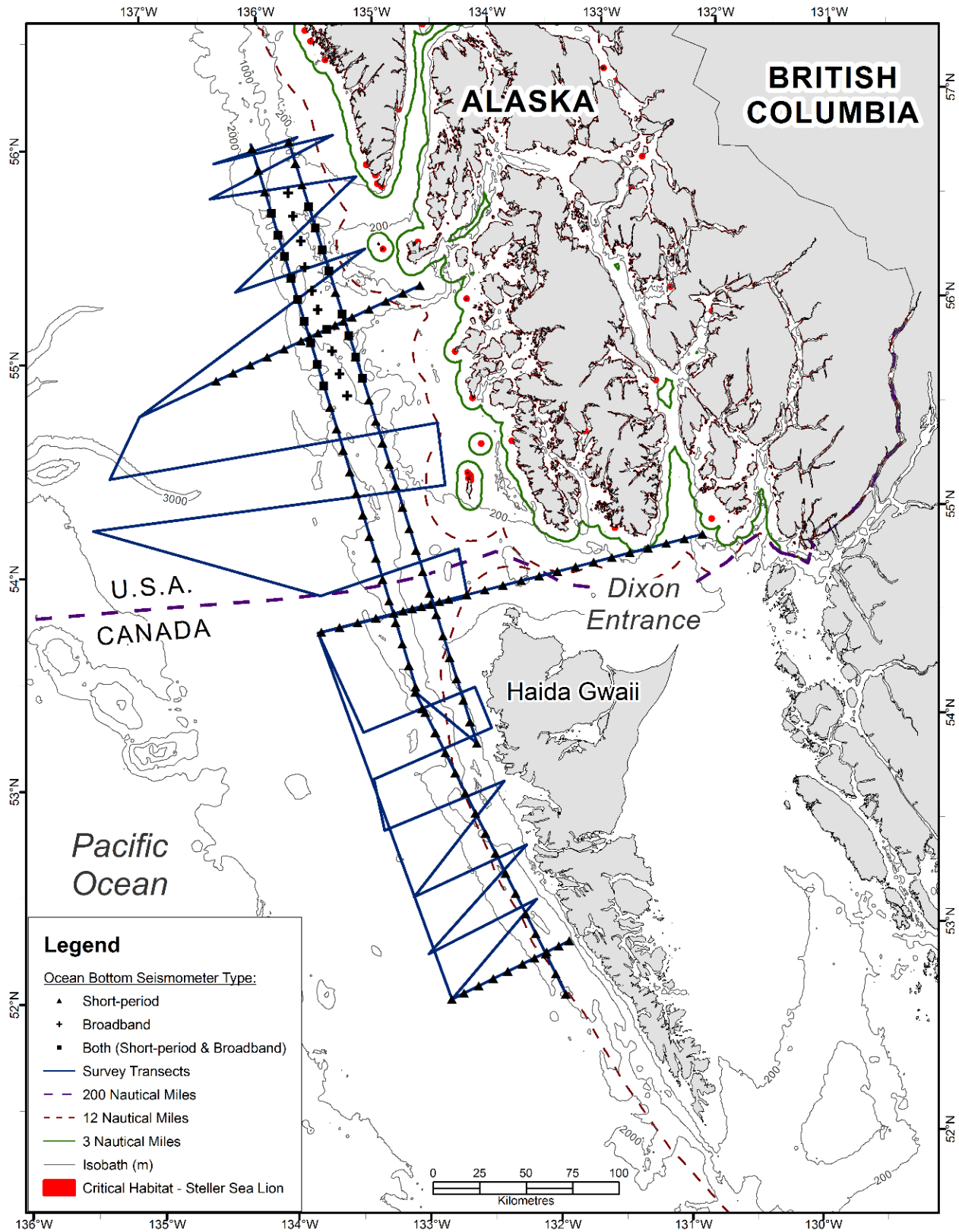


FIGURE 1. Location of the proposed seismic surveys and OBS deployments in the Northeast Pacific Ocean and marine mammal critical habitat in the U.S.

M. Walton and collaborators), would work with the PIs to achieve the research goals, providing assistance, such as through logistical support (e.g., OBSs and land seismometers), partial funding for a support vessel, and data acquisition, processing, and exchange. The land-based seismometers would capitalize on the proposed R/V *Langseth* marine-based activities and would vastly expand the geophysical dataset available for analysis for the region.

To achieve the project goals, the Principal Investigators (PI) Drs. L. Worthington (University of New Mexico) and E. Roland (Western Washington University) propose to utilize long-offset 2-D seismic reflection and wide-angle reflection-refraction capabilities of R/V *Langseth* and a combined U.S.-Canadian broadband Ocean Bottom Seismometer (OBS) array. Although not funded through NSF, collaborators Dr. M. Nedimovic (Dalhousie University) and the Geological Survey of Canada, as well as the USGS (Dr. M. Walton and collaborators), would work with the PIs to achieve the research goals, providing assistance, such as through logistical support (e.g., OBSs and land seismometers), partial funding for a support vessel, and data acquisition, processing, and exchange. The land-based seismometers would capitalize on the proposed R/V *Langseth* marine-based activities and would vastly expand the geophysical dataset available for analysis for the region.

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume of ~6600 in<sup>3</sup> at a depth of 12 m. The receiving system would consist of a 15-km long hydrophone streamer and ~60 short-period OBSs, which would be deployed at a total of 123 sites in multiple phases from a second vessel, the Canadian Coast Guard ship (CCGS) *John P. Tully* (*Tully*). In the event CCGS *Tully* is unavailable to assist with OBS deployments (e.g., scheduling and/or COVID issues), another vessel would be retained to deploy the OBSs. Twenty-eight broadband OBS instruments would also collect data during the survey and would be deployed prior to the active-source seismic survey, depending on logistical constraints.

Short-period OBSs would be deployed first along five OBS refraction lines by CCGS *Tully*. Two OBS lines run parallel to the coast, and three are perpendicular to the coast; one perpendicular line is located off Southeast Alaska, one is off Haida Gwaii, and another is located in Dixon Entrance (Fig. 1). Following refraction shooting of a single line, short-period instruments on that line would be recovered, serviced, and redeployed on a subsequent refraction line while MCS data would be acquired by the *Langseth*. MCS lines would be acquired off Southeast Alaska, Haida Gwaii, and Dixon Entrance (Fig. 1). The coast-parallel OBS refraction transect nearest to shore (Fig. 1) would only be surveyed once at OBS shot spacing. The other coast-parallel OBS refraction transect (on the ocean side; Fig. 1) would be acquired twice, once during refraction and once during reflection surveys. In addition, portions of the three coast-perpendicular OBS refraction lines would also be surveyed twice, once for OBS shot spacing and once for MCS shot spacing. The coincident reflection/refraction profiles that run parallel to the coast would be acquired in multiple segments to ensure straight-line geometry. Sawtooth transits during which seismic data would be acquired would take place between transect lines when possible; otherwise boxcar turns would be performed to save time. Both reflection and refraction surveys would use the same airgun array with the same discharge volume. As previously noted, the location of the survey lines could shift from what is currently depicted in Figure 1 depending on factors such as science drivers, poor data quality, weather, etc.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys, but not during transit to and from the survey area or when the airguns are not operational. CCGS *Tully* is also equipped with a Knudsen Chirp system. All planned



geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

## Vessel Specifications

R/V *Marcus G. Langseth* is described in § 2.2.2.1 of the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. The vessel speed during seismic operations would be ~4.2 kt (~7.8 km/h) during the survey.

CCGS *Tully* would be used to deploy OBSs. The vessel has a length of 69 m, a beam of 14.5 m, and a draft of 4.5 m. The ship is powered by two Deutz 628 geared diesel engines, producing 3697 hp, which drives the controllable-pitch propeller. The vessel also has stern and bow thrusters. The cruising speed is 10 kts, and the range is ~22,224 n.mi. with an endurance of 50 days. In the event CCGS *Tully* is unavailable to assist with OBS deployments (e.g., scheduling and/or COVID issues), another vessel would be retained to deploy the OBSs.

Other details of CCGS *Tully* include the following:

Owner:	Canadian Coast Guard
Operator:	Canadian Coast Guard
Flag:	Canada
Date Built:	1985
Gross Tonnage:	2021
Accommodation Capacity:	41 including ~20 scientists

## Airgun Description

During the surveys, R/V *Langseth* would tow four strings with 36 airguns (plus 4 spares). During the surveys, all four strings, totaling 36 active airguns with a total discharge volume of 6600 in<sup>3</sup>, would be used. The airgun array is described in § 2.2.3.1 of the PEIS, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. The array would be towed at a depth of 12 m. The airguns would fire at a shot interval of 50 m (~23 s) during multi-channel seismic (MCS) surveys with the hydrophone streamer (~42% of survey), at a 150-m (~69 s) interval during refraction surveys to OBSs (~29% of survey), and at a shot interval of ~1 min (~130 m) during turns (~29% of survey).

## Predicted Sound Levels

Mitigation zones for the proposed marine seismic surveys using the 36-airgun array were not derived from the farfield signature but based on modeling by L-DEO for the exclusion zones (EZ) for Level A takes, and a combination of empirical data and modeling for the Level B (160 dB re 1µPa<sub>rms</sub>) threshold. 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<sub>rms</sub> radius for the 36-airgun array and 40-in<sup>3</sup> airgun (mitigation airgun) at a 12-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). For the 36-airgun array, radii for intermediate-water depths (100–1000 m) and shallow water (<100 m) are derived from empirical data from Crone et al. (2014) with a scaling factor applied to account for differences in tow depth (see Appendix A). As Crone et al. (2014) did not collect empirical data for the 40-in<sup>3</sup> airgun, the radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. For

shallow water (<100 m), radii are based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth (see Appendix A). Table 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.

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 ( $\text{SEL}_{\text{cum}}$  over 24 hours) and peak sound pressure levels ( $\text{SPL}_{\text{flat}}$ ). 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., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2016a, 2018). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria ( $\text{SEL}_{\text{cum}}$  or Peak  $\text{SPL}_{\text{flat}}$ ) was used to calculate Level A takes and threshold distances for marine mammals. Here,  $\text{SEL}_{\text{cum}}$  is used for LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups (Table 2).

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for 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-in<sup>3</sup> airgun; a 100-m EZ was established and monitored for shut downs of the single airgun. However, based on recent direction from NMFS, power downs would not be allowable under the IHA, and shut downs would be implemented for marine mammals within the designated EZ; a power down (or if necessary shut down) would be implanted for sea turtles and ESA-listed diving birds. Enforcement of mitigation zones via power and shut downs would be implemented as described in § XI.

## OBS Description and Deployment

The seismometers would consist of ~60 short-period OBSs and 28 broadband instruments that would be deployed prior to or during the survey. Along OBS refraction lines, short-period OBSs would be deployed by CCGS *Tully* at ~10 km intervals, with a spacing of ~5 km over the central ~40 km of the fault zone for fault-normal crossings. Following refraction shooting of a single line, short-period instruments on that line would be recovered, serviced, and redeployed on a subsequent refraction line while MCS data are acquired. The OBSs have a height and diameter of ~1 m and an anchor weighing ~80 kg.

OBS sample rates would be set at 100 Hz and 200 Hz for the broadband and short-period OBSs, respectively, so that all instruments can be used for refraction imaging and earthquake analysis. The lower sample rate for the broadband OBSs is desirable, as the instruments would be deployed for an extended period of time. All OBSs would be recovered upon conclusion of the survey; however, the broadband OBSs would be deployed for ~12 months before recovery.

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.

TABLE 1. Level B. Predicted distances to which sound levels  $\geq 160$ -dB and  $\geq 175$ -dB re 1  $\mu\text{Pa}_{\text{rms}}$  could be received during the proposed surveys in the Northeast Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Single Bolt airgun, 40 in <sup>3</sup>	12	>1000 m	431 <sup>1</sup>	77 <sup>1*</sup>
		100–1000 m	647 <sup>2</sup>	116 <sup>2</sup>
		<100 m	1,041 <sup>3</sup>	170 <sup>3</sup>
4 strings, 36 airguns, 6600 in <sup>3</sup>	12	>1000 m	6,733 <sup>1</sup>	1,864 <sup>1</sup>
		100–1000 m	9,468 <sup>4</sup>	2,542 <sup>4</sup>
		<100 m	12,650 <sup>4</sup>	3,924 <sup>4</sup>

<sup>1</sup> Distance is based on L-DEO model results.

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

<sup>3</sup> Distance is based on empirically derived measurements in the GOM with scaling applied to account for differences in tow depth.

<sup>4</sup> Based on empirical data from Crone et al. (2014); see Appendix A for details.

\* An EZ of 100 m would be used as the shut-down distance for sea turtles in all water depths.

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

Level A Threshold Distances (m) for Various Hearing Groups						
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
<b>PTS SEL<sub>cum</sub></b>	<b>320.2</b>	0	1.0	10.4	0	<b>15.4</b>
<b>PTS Peak</b>	38.9	<b>13.6</b>	<b>268.3</b>	<b>43.7</b>	<b>10.6</b>	10.6

<sup>1</sup> Using the 50-m shot interval provides more conservative distances than the 150-m shot interval, so these distances would be used for all seismic transects.

## Description of Operations

The procedures to be used for the proposed surveys would be similar to those used during previous seismic surveys by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Langseth*, which is owned by NSF and operated on its behalf by L-DEO. R/V *Langseth* would deploy an array of 36 airguns as an energy source with a total volume of  $\sim 6600$  in<sup>3</sup>. The receiving system would consist of a 15-km long hydrophone streamer and  $\sim 60$  short-period OBSs, which would be deployed from the *Tully*.

As the airgun arrays are towed along the survey lines, the OBSs would receive and store the returning acoustic signals internally for later analysis, and the hydrophone streamer would transfer the data to the on-board processing system. Approximately 4250 km of transect lines would be surveyed. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where

initial data quality is sub-standard. In the take calculations, 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. Most of the survey (69%) would occur in deep water (>1000 m), 30% would occur in intermediate water (100–1000 m deep), and 1% would take place in shallow water <100 m deep. Approximately 13% of the transect lines (548 km) would be undertaken in Canadian Territorial Waters. In addition to the operations of the airgun array, the ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. These sources are described in § 2.2.3.1 of the PEIS.

## II. DATES, DURATION, AND REGION OF ACTIVITY

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

The proposed surveys would occur within ~52–57°N, ~131–137°W; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within the EEZ of the U.S. and Canada, as well as in U.S. state waters and Canadian Territorial Waters, ranging in depth 50–2800 m. The proposed surveys would be expected to last for 36 days, including ~27 days of seismic operations, ~2 days of transit to and from the survey area, 3 days for equipment deployment/recovery, and 4 days of contingency. R/V *Langseth* would likely leave out of and return to port in Ketchikan, AK, during late summer (July–August) 2021. The ensuing analysis focuses on the time of the survey (summer); the best available species densities for that time of year have been used.

## III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Twenty-three marine mammal species could occur in or near the proposed survey area, including 7 mysticetes (baleen whales), 10 odontocetes (toothed whales, such as dolphins), 5 pinnipeds (seals and sea lions), and the northern sea otter (Table 3). Seven of the species that could occur in the proposed survey area are listed under the U.S. ESA as **endangered**, including the sperm, sei, fin, blue, and North Pacific right whales, the Western North Pacific DPS of gray whales, and the Western DPS of Steller sea lions. The **threatened** Mexico DPS of the humpback whale could also occur in the proposed survey area, but it is unlikely that killer whales from the Southern Resident DPS or humpback whales from the Central America DPS would occur in the proposed survey area, both of which are **endangered**.

Blainville's beaked whale (*Mesoplodon densirostris*), pygmy sperm whale (*Kogia breviceps*), dwarf sperm whale (*K. sima*), Hubbs' beaked whale (*Mesoplodon caelhubbsi*), false killer whale (*Pseudorca crassidens*), short-finned pilot whale (*Globicephala macrorhynchus*), common bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), long-beaked common dolphin (*D. capensis*), striped dolphin (*Stenella coeruleoalba*), and rough-toothed dolphin (*Steno bredanensis*) are distributed farther to the south, and belugas (*Delphinapterus leucas*) occur farther to the north, with a population in Yakutat Bay, Southeast Alaska. Based on the known distribution ranges and information provided in Ford (2014), the aforementioned species are unlikely to be seen in the proposed survey area and are not addressed in the summaries below. To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

## IV. STATUS, DISTRIBUTION AND SEASONAL DISTRIBUTION OF AFFECTED SPECIES OR STOCKS OF MARINE MAMMALS

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

Sections III and IV are integrated here to minimize repetition. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. One of the qualitative analysis areas (QAAs) defined in the PEIS, the B.C. Coast (specifically the Queen Charlotte Basin), is located just to the south of the proposed survey area. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters off the B.C. Coast is discussed in § 3.6.3.2, § 3.7.3.2, § 3.8.3.2, and § 3.9.3.1 of the PEIS, respectively. In B.C., systematic surveys have been conducted in coastal and inland waters (e.g., Williams and Thomas 2007; Ford et al. 2010a; Best et al. 2015; Harvey et al. 2017). Surveys in coastal as well as offshore waters were conducted by the Canadian Department of Fisheries and Oceans (DFO) during 2002 to 2008 (Ford et al. 2010a).

The western GOA was chosen as a detailed analysis area (DAA) in the PEIS. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters in the western GOA is discussed in § 3.6.2.4, § 3.7.2.4, § 3.8.2.4, and § 3.9.2.3 of the PEIS, respectively. Few systematic surveys have been conducted in Southeast Alaska, especially in offshore waters. However, Dahlheim et al. (2008, 2009) conducted surveys in inland waters of Southeast Alaska and presented abundance estimates for the region. The rest of this section deals specifically with species distribution in the proposed survey area.

### Mysticetes

#### 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). This species is divided into western and eastern North Pacific stocks. The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011a), and critical habitat has been designated in the eastern Bering Sea and in the GOA, south of Kodiak Island (NOAA 2019b). 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).

Since the 1960s, North Pacific right whale sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). However, starting in 1996, right whales have been seen regularly in the southeast Bering Sea, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002a; Wade et al. 2006; Zerbini et al. 2009); they have also been detected there acoustically (McDonald and Moore 2002; Munger et al. 2003; 2005, 2008; Berchok et al. 2009). They are known to occur in the southeastern Bering Sea from May–December (e.g., Tynan et al. 2001; Hildebrand and Munger 2005; Munger et al. 2005, 2008).

In March 1979, a group of four right whales was seen in Yakutat Bay (Waite et al. 2003), but there were no further reports of right whale sightings in the GOA until July 1998, when a single whale was seen southeast of Kodiak Island (Waite et al. 2003). Since 2000, several other sightings and acoustic detections have been made in the western GOA during summer (Waite et al. 2003; Mellinger et al. 2004; RPS 2011; Wade et al. 2011a,b; Rone et al. 2014). A biologically important area (BIA) for feeding for North Pacific right whales was designated east of the Kodiak Archipelago, encompassing the GOA critical habitat and extending south of 56°N and north of 58°N and beyond the shelf edge (Ferguson et al. 2015).

TABLE 3. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area in the Northeast Pacific Ocean.

Species	Occurrence in Area <sup>1</sup>	Habitat	Abund- ance <sup>2</sup>	U.S. ESA <sup>3</sup>	Canada		IUCN <sup>6</sup>	CITES <sup>7</sup>
					COSEWIC <sup>4</sup>	SARA <sup>5</sup>		
<b>Mysticetes</b>								
North Pacific right whale	Rare	Coastal, shelf, offshore	400-500 <sup>8</sup>	EN	EN	EN	CR <sup>9</sup>	I
Gray whale	Uncommon	Coastal, shelf	26,960 <sup>10</sup>	EN/DL <sup>11</sup>	EN <sup>12</sup>	NS	LC <sup>13</sup>	I
Humpback whale	Common	Mainly nearshore	10,103 <sup>14</sup>	EN/T <sup>15</sup>	SC	SC	LC	I
Common minke whale	Uncommon	Nearshore,	28,000 <sup>16</sup>	NL	NAR	NS	LC	I
Sei whale	Rare	Mostly pelagic	27,197 <sup>17</sup>	EN	EN	EN	EN	I
Fin whale	Common	Slope, pelagic	13,620-18,680 <sup>18</sup>	EN	SC	T	VU	I
Blue whale	Rare	Pelagic and coastal	1647 <sup>19</sup>	EN	EN	EN	EN	I
<b>Odontocetes</b>								
Sperm whale	Common	Pelagic, steep topography	26,300 <sup>20</sup>	EN	NAR	NS	VU	I
Cuvier's beaked whale	Uncommon	Pelagic	3274 <sup>21</sup>	NL	NAR	NS	LC	II
Baird's beaked whale	Uncommon	Pelagic	2697 <sup>21</sup>	NL	NAR	NS	DD	I
Stejneger's beaked	Uncommon	Slope, offshore	3044 <sup>21,22</sup>	NL	NAR	NS	DD	II
Pacific white-sided dolphin	Common	Offshore, slope	26,880 <sup>23</sup>	NL	NAR	NS	LC	II
Northern right whale dolphin	Uncommon	Slope, offshore waters	26,556 <sup>21</sup>	NL	NAR	NS	LC	II
Risso's dolphin	Uncommon	Shelf, slope, mounts	6336 <sup>21</sup>	NL	NAR	NS	LC	II
Killer whale	Common	Widely distributed	77 <sup>24</sup> 243 <sup>25</sup> 2347 <sup>26</sup> 261 <sup>27</sup> 587 <sup>28</sup> 300 <sup>29</sup>	EN <sup>30</sup>	EN/T <sup>31</sup>	EN/T <sup>31</sup>	DD	II
Harbor porpoise	Common	Shelf	11,146 <sup>32</sup>	NL	SC	SC	LC	II
Dall's porpoise	Common	Shelf, slope, offshore	83,400 <sup>33</sup>	NL	NAR	NS	LC	II
<b>Pinnipeds</b>								
Northern fur seal	Uncommon	Pelagic, offshore	620,660 <sup>34</sup>	NL	T	NS	VU	N.A.
Northern elephant seal	Common	Coastal, pelagic in migration	179,000 <sup>35</sup>	NL	NAR	NS	LC	N.A.
Steller sea lion	Common	Coastal, offshore	41,638 <sup>36</sup>	EN/DL <sup>37</sup>	SC	SC	NT <sup>38</sup>	N.A.
California sea lion	Uncommon	Coastal	257,606 <sup>39</sup>	NL	NAR	NS	LC	N.A.
Harbor seal	Common	Coastal	81,282 <sup>40</sup> 7210 <sup>41</sup> 9478 <sup>42</sup> 14,855 <sup>43</sup> 18,105 <sup>44</sup> 31,634 <sup>45</sup>	NL	NAR	NS	LC	N.A.
<b>Fissiped</b>								
Northern Sea Otter	Rare	Coastal	25,712 <sup>46</sup>	NL <sup>47</sup>	SC	SC	EN	II

N.A. means not available.

<sup>1</sup> Occurrence in area at the time of the survey; based on authors' professional opinion and available data.

<sup>2</sup> Abundance for the Eastern North Pacific or U.S. stock, unless otherwise stated.

<sup>3</sup> U.S. Endangered Species Act (ESA; NOAA 2019a): EN = Endangered; T = Threatened; DL = Delisted; NL = Not listed.

<sup>4</sup> Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status (Government of Canada 2019);

EN = Endangered; T = Threatened; SC = Special Concern; NAR = Not at Risk.

<sup>5</sup> Pacific Population for Canada's Species at Risk Act (SARA) Schedule 1 species, unless otherwise noted (Government of Canada 2019); EN = endangered; T = Threatened; SC = Special Concern; NS = No Status.

- <sup>6</sup> Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2019); CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; NT = Near Threatened; DD = Data Deficient.
- <sup>7</sup> Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; 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.
- <sup>8</sup> North Pacific (Jefferson et al. 2015).
- <sup>9</sup> The Northeast Pacific subpopulation is listed as critically endangered; globally, the North Pacific right whale is considered endangered.
- <sup>10</sup> Eastern North Pacific population (Durban et al. 2017 *in* Carretta et al. 2019).
- <sup>11</sup> Although the Eastern North Pacific DPS was delisted under the ESA, the Western North Pacific DPS is listed as endangered.
- <sup>12</sup> Pacific Coast Feeding Aggregation and Western Pacific populations are listed as endangered; the Northern Pacific Migratory population is not at risk.
- <sup>13</sup> Globally considered as least concern; western population listed as endangered.
- <sup>14</sup> Central North Pacific stock (Muto et al. 2019).
- <sup>15</sup> The Central America DPS is endangered, and the Mexico DPS is threatened; the Hawaii DPS was delisted in 2016 (81 FR 62260, 8 September 2016).
- <sup>16</sup> Northwest Pacific and Okhotsk Sea (IWC 2019).
- <sup>17</sup> Central and Eastern North Pacific (Hakamada and Matsuoka 2015).
- <sup>18</sup> North Pacific (Ohsumi and Wada 1974).
- <sup>19</sup> Eastern North Pacific Stock (Calambokidis and Barlow 2013).
- <sup>20</sup> Eastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
- <sup>21</sup> California/Oregon/Washington stock (Carretta et al. 2019).
- <sup>22</sup> All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2019).
- <sup>23</sup> North Pacific stock (Muto et al. 2019).
- <sup>24</sup> Eastern North Pacific Southern Resident stock (Carretta et al. 2019).
- <sup>25</sup> West Coast Transient stock; minimum estimate (Muto et al. 2019).
- <sup>26</sup> Alaska Resident stock (Muto et al. 2019).
- <sup>27</sup> Northern Resident stock (Muto et al. 2019).
- <sup>28</sup> Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock (Muto et al. 2019).
- <sup>29</sup> North Pacific Offshore stock (Carretta et al. 2019).
- <sup>30</sup> The Southern Resident DPS is listed as endangered; no other stocks are listed.
- <sup>31</sup> Southern resident population is listed as endangered; the northern resident, offshore, and transient populations are listed as threatened.
- <sup>32</sup> Southeast Alaska stock (Hobbs and Waite 2010).
- <sup>33</sup> Alaska stock (Muto et al. 2019).
- <sup>34</sup> Eastern Pacific stock (Muto et al. 2019).
- <sup>35</sup> California breeding stock (Carretta et al. 2019).
- <sup>36</sup> Eastern U.S. stock (Muto et al. 2019).
- <sup>37</sup> The Eastern DPS was delisted in 2013 (NMFS 2013); the Western DPS is listed as endangered.
- <sup>38</sup> Globally considered as near threatened; western population listed as endangered.
- <sup>39</sup> U.S. stock (Carretta et al. 2019).
- <sup>40</sup> Total of all harbor seal stocks in Southeast Alaska is 81,282 (Muto et al. 2019).
- <sup>41</sup> Glacier Bay/Icy Strait stock (Muto et al. 2019).
- <sup>42</sup> Lynn Canal/Stephens Passage stock (Muto et al. 2019).
- <sup>43</sup> Sitka/Chatham Strait stock (Muto et al. 2019).
- <sup>44</sup> Dixon/Cape Decision stock (Muto et al. 2019).
- <sup>45</sup> Clarence Strait stock (Muto et al. 2019).
- <sup>46</sup> Southeast Alaska stock (Muto et al. 2019).
- <sup>47</sup> Southwest Alaska DP is listed as threatened.

South of 50°N in the eastern North Pacific, only 29 reliable sightings were recorded from 1900–1994 (Scarff 1986, 1991; Carretta et al. 1994). Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of California/Oregon/Washington over the years, only seven documented sightings of right whales were made from 1990–2000 (Waite et al. 2003). Two North Pacific right whale calls were detected on a bottom-mounted hydrophone off the Washington coast on 29 June 2013 (Širović et al. 2014).

Right whales have been scarce in B.C. since 1900 (Ford 2014). In the 1900s, there were only six records of right whales for B.C., all of which were catches by whalers (Ford et al. 2016); five occurred to the west of Haida Gwaii (Ford 2014). Since 1951, there have only been three confirmed records. A sighting of one individual 15 km off the west coast of Haida Gwaii was made on 9 June 2013 and another sighting occurred on 25 October 2013 on Swiftsure Bank near the entrance to the Strait of Juan de Fuca (Ford 2014; Ford et al. 2016; DFO 2017). The third and most recent sighting was made off Haida Gwaii in June 2018 (CBC 2018). There have been two additional unconfirmed records for B.C., including one off Haida Gwaii in 1970 and another for the Strait of Juan de Fuca in 1983 (Brownell et al. 2001; DFO 2011; Ford 2014).

Based on the very low abundance of this species, its rarity off the coasts of B.C. and Southeast Alaska in recent decades, and the likelihood that animals would be feeding in the Bering Sea and western GOA at the time of the survey, it is possible although unlikely that a North Pacific right whale could be encountered in the proposed survey area during the period of operations.

#### **Gray Whale (*Eschrichtius robustus*)**

Two separate populations of gray whales have been recognized in the North Pacific: the eastern North Pacific and western North Pacific (or Korean-Okhotsk) stocks (LeDuc et al. 2002; Weller et al. 2013). 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 either the U.S. ESA-listed *endangered* Western North Pacific DPS or the delisted Eastern North Pacific DPS could occur in the proposed survey area.

Gray whale populations were severely reduced by whaling, and the western population has remained highly depleted, but the eastern North Pacific population is considered to have recovered. Punt and Wade (2012) estimated the eastern North Pacific population to be at 85% of its carrying capacity in 2009. 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; Rice 1998; Jefferson et al. 2015). The migration northward occurs from late February to June (Rice and Wolman 1971), with a peak into the GOA during mid-April (Braham 1984). Most gray whales follow the coast during migration and stay within 2 km of the shoreline, except when crossing major bays, straits, and inlets from Southeast Alaska to the eastern Bering Sea (Braham 1984).

Gray whales are regularly seen and detected acoustically in the western GOA during the summer (e.g., Wade et al. 2003; Calambokidis et al. 2004; Calambokidis 2007; Moore et al. 2007; Rice et al. 2015; Rone et al. 2017). A BIA for feeding gray whales has been identified in Southeast Alaska (in the waters surrounding Sitka, north of the survey area) and along the eastern coast of Kodiak Island; the Southeast Alaska BIA is used by ~100 whales from May through November (Ferguson et al. 2015). Additionally, a gray whale migratory corridor BIA has been established extending from Unimak Pass in the western GOA to the Canadian border in the eastern GOA (Ferguson et al. 2015). Gray whales occur in this area in high densities from November through January (southbound) and March through May (northbound).



Instead of migrating to arctic and subarctic waters, some individuals spend the summer months scattered along the coast from California to Southeast Alaska (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Calambokidis and Quan 1999; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002, 2015, 2017). There is recent genetic evidence indicating the existence of this Pacific Coast Feeding Group (PCFG) as a distinct local subpopulation (Frasier et al. 2011; Lang et al. 2014); however, the status of the PCFG as a separate stock is currently unresolved (Weller et al. 2013). In Canada, three designatable units (DUs) are recognized including the Northern Pacific Migratory, PCFG, and Western Pacific populations (COSEWIC 2017). For the purposes of abundance estimates, it is defined to occur between 41°N to 52°N from 1 June to 30 November (IWC 2012); the 2015 abundance estimate was 243 whales (Calambokidis et al. 2017). Approximately 100 of those may occur in BC during summer (Ford 2014). In B.C., most summer resident gray whales are found in Clayoquot Sound, Barkley Sound, and along the southwestern shore of Vancouver Island, and near Cape Caution, on mainland B.C. off the northeastern tip of Vancouver Island; other summer residents are scattered along the mainland coast, including off Dundas Island (east of the northern tip of Haida Gwaii), and Porcher and Aristazabal islands (Ford 2014).

Gray whales are common off Haida Gwaii and western Vancouver Island (Williams and Thomas 2007), in particular during the migration. Whales travel southbound along the coast of B.C. during their migration to Baja California between November and January, with a peak off Vancouver Island during late December; during the northbound migration, whales start appearing off Vancouver Island during late February, with a peak in late March, with fewer whales occurring during April and May (Ford 2014). Northbound migrants typically travel within ~5 km from shore (Ford 2014), although some individuals have been sighted more than 10 km from shore (Ford et al. 2010a, 2013). Based on acoustic detections described by Meyer (2017 in COSEWIC 2017), the southward migration also takes place in shallow shelf waters. During surveys in B.C. waters during summer, most sightings were made within 10 km from the coast in water shallower than 100 m (Ford et al. 2010a).

After leaving the waters off Vancouver Island, gray whales typically use Hecate Strait and Dixon Entrance as opposed to the west coast of Haida Gwaii as their main migratory corridor through Southeast Alaska during the northbound migration (Ford et al. 2013); during the southbound migration, gray whales likely migrate past the outer coast of Haida Gwaii (Ford 2014; Mate et al. 2015; COSEWIC 2017). A female gray whale was reported off Haida Gwaii after traveling across the Pacific Ocean from Sakhalin Island (Ford 2014). Other sightings have also been made off the coast of Haida Gwaii, including in Dixon Entrance, Hecate Strait, and along the west coast of Haida Gwaii, including in or near the survey area during the month of August (Williams and Thomas 2007; Ford et al. 2010a; Ford 2014). Calambokidis et al. (2002) reported the results of a collaborative study to photo-identify a feeding aggregation of gray whales from California to Southeast Alaska in 1998. They completed one survey near Sitka in November 1998 and identified four individual gray whales, one of which had been identified in previous years off Washington.

The proposed surveys would occur during the summer feeding season; at this time, most individuals from the eastern North Pacific stock occur farther north; however, some individuals from the PCFG are feeding further south, and some individuals are feeding in the Southeast Alaska BIA to the north. Nonetheless, some individuals could be encountered in nearshore waters of the proposed project area; few are expected to be seen more than 10 km from shore. NOAA (2019c) has declared an unusual mortality event (UME) for gray whales in 2019, as an elevated number of strandings have occurred along the coast of the Pacific Northwest since January. As of 30 September 2019, a total of 212 dead gray whales have been reported, including 121 in the U.S. (14 in Washington; 6 in Oregon), 81 in Mexico, and 10 in B.C.; some of the whales were emaciated. UMEs for gray whales were also declared in 1999 and 2000 (NOAA 2019c).

### Humpback Whale (*Megaptera novaeangliae*)

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

North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008; Bettridge et al. 2015). Humpbacks winter in four different breeding areas: (1) the coast of Mexico; (2) the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). There is potential for mixing of the western and eastern North Pacific humpback populations on their summer feeding grounds, but several sources suggest that this occurs to a limited extent (Muto et al. 2019). NMFS is currently reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (NMFS 2016b). Individuals encountered in the proposed survey area would likely be from the Hawaii DPS, followed by the Mexico DPS; individuals from the Central America DPS are unlikely to feed in northern B.C. and Southeast Alaska (Calambokidis et al. 2008; Ford 2014). According to Wade (2017), ~3.8% of humpbacks occurring in Southeast Alaska and northern B.C. are likely to be from the Mexico DPS; the rest would be from the Hawaii DPS.

During summer, most eastern North Pacific humpback whales are on feeding grounds in Alaska, with smaller numbers summering off the U.S. west coast and B.C. (Calambokidis et al. 2001, 2008). Currently, two stocks of humpback whales are recognized as occurring in Alaskan waters. The Central North Pacific Stock occurs from Southeast Alaska to the Alaska Peninsula, and the Western North Pacific stock occurs from the Aleutians to the Bering Sea and Russia. These two stocks overlap on feeding grounds in the eastern Bering Sea and the western GOA (Muto et al. 2019). Numerous feeding BIAs have been designated in the GOA, including in Southeast Alaska, where the BIAs change on a seasonal basis (Ferguson et al. 2015). During summer, the northern-most portion of the survey area occurs in a portion of the BIA.

On 9 October 2019, NMFS issued a proposed rule to designate critical habitat in nearshore waters of the North Pacific Ocean for the *endangered* Central America DPS and the *threatened* Mexico DPS of humpback whale (NMFS 2019a). Critical habitat for the Mexico DPS would include a total of ~175,812 n.mi.<sup>2</sup> in Alaska and off the coasts California, Oregon, and Washington. Critical habitat for the Central America DPS would include ~43,798 n.mi.<sup>2</sup> off the coasts California, Oregon, and Washington. Off Southeast Alaska, the critical habitat would extend out to the 2000-m isobath and would encompass BIAs (NMFS 2019a).

Peak abundance in Southeast Alaska occurs during September and October (Dahlheim et al. 2009; Straley et al. 2018), but humpback whales occur in the GOA year-round (Straley 1990; Zerbini et al. 2006; Stafford et al. 2007). Hendrix et al. (2012) reported an abundance estimate of 1585 humpbacks for Southeast Alaska in 2008 based on photographic studies. Calambokidis et al. (2008) estimated the

Southeast Alaska/northern B.C. feeding aggregation to number 6000 individuals, where they feed on herring and euphausiids (Moran et al. 2018; Straley et al. 2018). Dahlheim et al. (2009) encountered concentrations in Icy Strait, Lynn Canal, Stephens Passage, Chatham Strait, and Frederick Sound; sightings were also made around Prince of Wales Island. MacLean and Koski (2005) reported concentrations of humpbacks in Sitka Sound, Icy Strait, and Lynn Canal during surveys of Southeast Alaska in August–September 2004; sightings were also made off Baranof Island and Prince of Wales Island, including in Dixon Entrance and Cordova Bay. During an L-DEO cruise from Oregon to Alaska, humpback whales were seen within the proposed survey area off Southeast Alaska during September (Hauser and Holst 2009). Humpbacks typically move between Glacier Bay/Icy Strait and other areas of Southeast Alaska (Baker 1986; Baker et al. 1990; Straley 1994; Straley et al. 1995). During a vessel transit to a survey area in the western GOA during June 2013, humpbacks were seen just outside of Sitka (Rone et al. 2017).

Humpback whales are common in the waters of B.C., where they occur in inshore, outer coastal, continental shelf waters, as well as offshore (Ford 2014). Williams and Thomas (2007) estimated an abundance of 1310 humpback whales in inshore coastal waters of B.C. based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 1029 humpbacks based on surveys during 2004–2008. In B.C., humpbacks are typically seen within 20 km from the coast, in water <500 m deep (Ford et al. 2010a). They were the most frequently sighted cetacean during DFO surveys in 2002–2008 (Ford et al. 2010a). The highest densities occur off Haida Gwaii, especially the eastern coast of Moresby Island and around Langara Island in Dixon Entrance (Ford et al. 2010a; Ford 2014; Harvey et al. 2017); humpbacks are also commonly seen along the west coast of Haida Gwaii (Ford et al. 2010a; Ford 2014). Eastern Moresby Island and the waters around Langara Island have been designated as critical habitat (DFO 2013). During an L-DEO surveys, humpback whales were seen off the west coast of Haida Gwaii during September (MacLean and Koski 2005; Hauser and Holst 2009).

The greatest numbers are seen in B.C. between April and November, although humpbacks are known to occur there throughout the year (Ford et al. 2010a; Ford 2014). Gregr et al. (2000) also presented evidence of widespread winter foraging in B.C. based on whaling records. Humpback whales are thought to belong to at least two distinct feeding stocks in B.C.; those identified off southern B.C. show little interchange with those seen off northern B.C. (Calambokidis et al. 2001, 2008). However, humpback whales from northern B.C. do interchange with those from the GOA and Southeast Alaska (Calambokidis et al. 2008). Humpback whales that feed off southern and northern B.C. migrate to several wintering grounds without a clear preference, including Mexico, Hawaii, and Ogasawara off Japan (Darling et al. 1996; Urban et al. 2000; Calambokidis et al. 2001). Humpback whales are likely to be common in the proposed survey area, especially in nearshore waters.

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

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring and summer and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move south to within 2° of the Equator (Perrin et al. 2018).

The International Whaling Commission (IWC) recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180°N, and the remainder of the Pacific (Donovan 1991). Minke whales are relatively common in the Bering and Chukchi seas and in the GOA but are not considered abundant in any other part of the eastern Pacific (Brueggeman et al.

1990). In the far north, minke whales are thought to be migratory, but they are believed to be year-round residents in nearshore waters off west coast of the U.S. (Dorsey et al. 1990).

Although sightings have been made in the western GOA (Waite 2003; Zerbini et al. 2006; Rone et al. 2017), minke whales were encountered infrequently during surveys of the inland waters of Southeast Alaska; sightings were made during spring, summer, and fall, with concentrations near the entrance of Glacier Bay (Dahlheim et al. 2009). One sighting was made in eastern Dixon Entrance during summer (Dahlheim et al. 2009). During a vessel transit to a survey area in the western GOA during June 2013, a sighting was made in pelagic waters to the west of Sitka (Rone et al. 2017). Low numbers of minke whales are seen regularly around Glacier Bay in Southeast Alaska and in central Icy Strait (Gabriele and Lewis 2000).

Minke whales are sighted regularly in nearshore waters of B.C., but they are not abundant (COSEWIC 2006). They are most frequently sighted around the Gulf Islands and off northeastern Vancouver Island (Ford 2014). They are also regularly seen off the east coast of Moresby Island, and in Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island (Ford et al. 2010a; Ford 2014; Harvey et al. 2017); there are also several sightings off the west coast of Haida Gwaii (Ford et al. 2010a; Ford 2014). Williams and Thomas (2007) estimated minke whale abundance for inshore coastal waters of B.C. at 388 individuals based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 522 minke whales based on surveys during 2004–2008. Most sightings have been made during July and August; although most minke whales are likely to migrate south during the winter, they can be seen in B.C. waters throughout the year; however, few sightings occur from December through February (Ford 2014). Minke whales are expected to be uncommon in the proposed survey area.

#### **Sei Whale (*Balaenoptera borealis*)**

The sei whale occurs in all ocean basins (Horwood 2018), but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999a). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the GOA and down to southern California, as well as in the western Pacific from Japan to Korea. Sightings have been made in the western GOA (RPS 2011; Rone et al. 2017). Its winter distribution is concentrated at ~20°N (Rice 1998).

Off the west coast of B.C., 4002 sei whales were caught from 1908–1967; the majority were taken from 1960–1967 during April–June (Gregr et al. 2000). The pattern of seasonal abundance suggested that the whales were caught as they migrated to summer feeding grounds, with the peak of the migration in July and offshore movement in summer, from ~25 km to ~100 km from shore (Gregr et al. 2000). Historical whaling data show that sei whales used to be distributed along the continental slope of B.C. and over a large area off the northwest coast of Vancouver Island (Gregr and Trites 2001).

Sei whales are now considered rare in Pacific waters of the U.S. and Canada; in B.C., there were no sightings in the late 1900s after whaling ceased (Gregr et al. 2006). A single sei whale was seen off southeastern Moresby Island in Hecate Strait coastal surveys in the summers of 2004/2005 (Williams and Thomas 2007). Ford (2014) only reported two sightings for B.C., both of those far offshore from Haida Gwaii. Possible sei whale vocalizations were detected off the west coast of Vancouver Island during spring

and summer 2006 and 2007 (Ford et al. 2010b). Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for sei whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). The waters off western Haida Gwaii were identified as sei whale important areas by PNCIMAI (2011). Sei whales could be encountered during the proposed survey, although this species is considered rare in these waters.

### **Fin Whale (*Balaenoptera physalus*)**

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

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

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985b). 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 the GOA (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). In the central North Pacific, the GOA, and the Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009).

Sightings have also been made in the western GOA (Rice and Wolman 1982; Waite 2003; Zerbini et al. 2006). A BIA for fin whale feeding has been designated southward from the Kenai Peninsula inshore of the Kodiak Archipelago and along the Alaska Peninsula; densities of fin whales are highest in this area during June through August (Ferguson et al. 2015). Rice and Wolfman (1982) also reported sightings in the eastern GOA during June 1980. During a vessel transit to a survey area in the western GOA during June 2013, fin whales were seen just outside of Sitka (Rone et al. 2017). In Southeast Alaska, fin whales have been seen during summer near Prince of Wales Island, including northern Dixon Entrance (Dahlheim et al. 2009). Edwards et al. (2015) showed sightings off Southeast Alaska throughout the year, with most sightings reported for June to August, followed by September to November.

From 1908–1967, 7605 fin whales were caught off the west coast of B.C. by whalers; catches increased gradually from March to a peak in July, then decreased rapidly to very few in September and October (Gregr et al. 2000). Fin whales occur throughout B.C. waters near and past the continental shelf break, as well as in inshore waters (Ford 2014). Williams and Thomas (2007) estimated fin whale

abundance in inland coastal B.C. waters at 496 based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 329 whales based on surveys during 2004–2008. Although fin whale records exist throughout the year, few sightings have been made from November through March (Ford 2014; Edwards et al. 2015). Fin whales were the second most common cetacean sighted during DFO surveys in 2002–2008 (Ford et al. 2010a). They are common in Dixon Entrance and in southern Hecate Strait along the east coast of Gwaii Haanas National Park Reserve (Ford 2014); sightings have also been made in Queen Charlotte Sound and the west coast of Haida Gwaii, within the proposed project area (Ford et al. 2010a; Calambokidis et al. 2003; Williams and Thomas 2007; Ford 2014).

Acoustic detections have been made throughout the year in pelagic waters west of Vancouver Island (Edwards et al. 2015). Calls were detected from February through July 2006 at Union Seamount off northwestern Vancouver island, and from May through September at La Pérouse Bank (Ford et al. 2010b). Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for fin whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). The waters off western Haida Gwaii and Dixon Entrance were also identified as fin whale important areas by PNCIMAI (2011). Fin whales are likely to be encountered in the proposed survey area.

#### **Blue Whale (*Balaenoptera musculus*)**

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: the eastern and central (formerly western) stocks (Carretta et al. 2019). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016). Blue whales from the eastern stock winter in Mexico and Central America (Stafford et al. 1999, 2001) and feed off the U.S. West Coast, as well as the GOA (Carretta et al. 2019). The central North Pacific stock feeds off Kamchatka, south of the Aleutians and in the GOA 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. 2019).

In the North Pacific, blue whale calls are detected year-round (Stafford et al. 2001, 2009; Moore et al. 2002b, 2006; Monnahan et al. 2014), and Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections. However, no detections of blue whales had been made in the GOA since the late 1960s (NOAA 2004; Calambokidis et al. 2009) until blue whale calls were recorded in the area during 1999–2002 (Stafford 2003; Stafford and Moore 2005; Moore et al. 2006; Stafford et al. 2007). Call types from both northeastern and northwestern Pacific blue whales were recorded from July through December in the GOA, suggesting that two stocks used the area at that time (Stafford 2003; Stafford et al. 2007). Call rates peaked from August through November (Moore et al. 2006). More recent acoustic studies using fixed PAM have confirmed the presence of blue whales from both the Central and Eastern North Pacific stocks in the GOA concurrently (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). Blue whale calls were recorded in all months, at all shelf, slope, and seamount sites; and during all years (2011–2015) of those studies.

Before 2004, sightings of blue whales had not been documented in Alaska for at least 30 years. In July 2004, three blue whales were sighted in the GOA. The first blue whale was seen on 14 July ~185 km

southeast of Prince William Sound; two more blue whales were seen ~275 km southeast of Prince William Sound (NOAA 2004; Calambokidis et al. 2009). These whales were thought to be part of the California feeding population (Calambokidis et al. 2009). In August 2004, 19 sightings of more than 40 blue whales were seen during an L-DEO survey off southern Prince of Wales Island, Southeast Alaska, in Dixon Entrance and Cordova Bay (Maclean and Koski 2005). Rone et al. (2017) reported five blue whale sightings (seven animals) in 2013, and 13 blue whale sightings (13 animals) in 2015 in the U.S. Navy training area east of Kodiak.

Whalers used to take blue whales in offshore waters of B.C.; from 1908–1967, 1398 blue whales were caught (Gregar et al. 2000). Since then, sightings have been rare (Gregar et al. 2006; Ford 2014; DFO 2017), and there is no abundance estimate for B.C. waters (Nichol and Ford 2012). During surveys of B.C. waters from 2002–2013, 16 sightings of blue whales were made, all of which occurred just to the south or west of Haida Gwaii during June, July, and August (Ford 2014). Seventeen blue whales have been photo identified off Haida Gwaii, and three were matched with whales occurring off California (Calambokidis et al. 2004b; Nichol and Ford 2012; Ford 2014). There have also been sightings off Vancouver Island during summer and fall (Calambokidis et al. 2004b; Ford 2014); the most recent sighting was reported off southwestern Haida Gwaii in July 2019 (CBC 2019). Blue whales were regularly detected on bottom-mounted hydrophones deployed off B.C. (Sears and Calambokidis 2002). Blue whale calls off Vancouver Island begin during August, increase in September and October, continue through November–February, and decline by March (Burtenshaw et al. 2004; Ford et al. 2010b; Ford 2014). They were detected on La Pérouse Bank, off southwestern Vancouver Island, during September 2007, but no calls were detected at Union Seamount, offshore from northwestern Vancouver Island (Ford et al. 2010b). The waters off western Haida Gwaii and Dixon Entrance were identified as blue whale important areas by PNCIMAI (2011). Blue whales could be encountered in the proposed survey area, but are considered rare in the region.

## **Odontocetes**

### **Sperm Whale (*Physeter macrocephalus*)**

The sperm whale is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (Whitehead 2018). In general, it is distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jaquet and Whitehead 1996). Its distribution and relative abundance can vary in response to prey availability, most notably squid (Jaquet and Gendron 2002). Females generally inhabit waters >1000 m deep at latitudes <40° where sea surface temperatures are <15°C; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds according to an unknown schedule (Whitehead 2018).

Sperm whales are distributed widely across the North Pacific (Rice 1989). Males can migrate north in the summer to feed in the GOA, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita 1988). Most of the information regarding sperm whale distribution in the GOA (especially the eastern GOA) and Southeast Alaska has come from anecdotal observations from fishermen and reports from fisheries observers aboard commercial fishing vessels (e.g., Dahlheim 1988). Fishery observers have identified interactions (e.g., depredation) between longline vessels and sperm whales in the GOA and Southeast Alaska since at least the mid-1970s (e.g., Hill et al. 1999; Straley et al. 2005; Sigler et al. 2008), with most interactions occurring in the West Yakutat and East Yakutat/Southeast regions (Perez 2006; Hanselman et al. 2008). Sigler et al. (2008) noted high depredation rates in West Yakutat, East Yakutat/Southeast region, as well as the central GOA. Sperm whales are commonly sighted during surveys in the Aleutians and the central and western GOA (e.g., Forney and Brownell 1996; Moore 2001; Waite 2003; Wade et al. 2003; Zerbini et al. 2004; Barlow and Henry 2005; Ireland et al. 2005; Straley et al. 2005; Rone

et al. 2017). In contrast, there are fewer reports on the occurrence of sperm whales in the eastern GOA (e.g., Rice and Wolman 1982; Mellinger et al. 2004a; MacLean and Koski 2005; Rone et al. 2010).

From 1908–1967, 6158 sperm whales were caught off the west coast of B.C. They were taken in large numbers in April, with a peak in May. Analysis of data on catch locations, sex of the catch, and fetus lengths indicated that males and females were both 50–80 km from shore while mating in April and May, and that by July and August, adult females had moved to waters >100 km offshore to calve), and adult males had moved to within ~25 km of shore (Gregs et al. 2000). At least in the whaling era, females did not travel north of Vancouver Island whereas males were observed in deep water off Haida Gwaii (Gregs et al. 2000). After the whaling era, sperm whales have been sighted and detected acoustically in B.C. waters throughout the year, with a peak during summer (Ford 2014). Acoustic detections at La Pérouse Bank off southwestern Vancouver Island have been recorded during spring and summer (Ford et al. 2010b). Sightings west of Vancouver Island and Haida Gwaii indicate that this species still occurs in B.C. in small numbers (Ford 2014). Based on whaling data, Gregs and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for male sperm whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). The waters off western Haida Gwaii were also identified as sperm whale important areas by PNCIMAI (2011). Sperm whales are likely to be encountered in the proposed survey area.

#### **Cuvier's Beaked Whale (*Ziphius cavirostris*)**

Cuvier's beaked whale is probably the most widespread and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 2018). It is rarely observed at sea and is known mostly from strandings; it strands more commonly than any other beaked whale (Heyning 1989). Cuvier's beaked whale is found in deep water in the open ocean and over and near the continental slope (Gannier and Epinat 2008; Baird 2018). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006).

Cuvier's beaked whale ranges north to the GOA, including Southeast Alaska, Aleutian Islands, and Commander Islands (Rice 1986, 1998). Most reported sightings have been in the Aleutian Islands (e.g., Leatherwood et al. 1983; Forney and Brownell 1996; Brueggeman et al. 1987), but several sightings have also been made in the western GOA (Waite 2003; Rone et al. 2017). Additionally, there were 34 acoustic encounters with Cuvier's beaked whales during the 2013 towed-hydrophone survey in the western GOA (Rone et al. 2014). Cuvier's beaked whales were detected occasionally at deep-water sites (900–1000 m) during the 2011–2015 fixed-PAM studies in the U.S. Navy training area. They were infrequently detected on the slope site but more commonly detected at Pratt and Quinn seamounts; detections occurred May to July 2014 at Pratt Seamount and October 2014 to March 2015 at Quinn Seamount (Rice et al. 2015).

Records of Cuvier's beaked whale in B.C. are scarce, although 20 strandings, one incidental catch, and five sightings have been reported (Ford 2014). For Haida Gwaii, strandings have been reported along the west and east coasts, as well as Dixon Entrance, and two sightings have been made in Hecate Strait; most strandings have been reported in summer (Ford 2014). Cuvier's beaked whales could be encountered during the proposed survey.

#### **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). 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. 2015).

There are numerous sighting records of Baird's beaked whale from the central GOA to the Aleutian Islands and the southern Bering Sea (Leatherwood et al. 1983; Kasuya and Ohsumi 1984; Forney and Brownell 1996; Brueggeman et al. 1987; Moore et al. 2002b; Waite 2003; Wade et al. 2003; Rone et al. 2017). Additionally, there were nine acoustic encounters with Baird's beaked whales during a 2013 towed-hydrophone survey in the GOA (Rone et al. 2014). Baird's beaked whales were detected acoustically during fixed-PAM studies in this area during 2011–2012 and 2012–2013, but not in 2014–2015 (Baumann-Pickering et al. 2012; Debich et al. 2013; Rice et al. 2015). They were detected regularly at the slope site from November through and January and at the Pratt Seamount site during most months. One sighting was made just outside of Sitka during 2013 (Rone et al. 2017).

There are whaler's reports of Baird's beaked whales off the west coast of Vancouver Island throughout the whaling season (May–September), especially in July and August (Reeves and Mitchell 1993). From 1908–1967, there was a recorded catch of 41 Baird's beaked whales, which were not favored because of their small size and low commercial value (Gregs et al. 2000). Twenty-four sightings have been made in B.C. since the whaling era, including off southwestern Haida Gwaii, near the EEZ limit west of Haida Gwaii, Queen Charlotte Sound, and off the west coast of Vancouver Island (Ford 2014). Three strandings have also been reported, including one on northeastern Haida Gwaii and two on the west coast of Vancouver Island. Baird's beaked whales could be encountered in the proposed 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; Wade et al. 2003). There have been no confirmed sightings of Stejneger's beaked whale in the GOA since 1986 (Wade et al. 2003). However, they have been detected acoustically in the Aleutian Islands during summer, fall, and winter (Baumann-Pickering et al. 2014) and were detected year-round at deep-water sites during the 2011–2015 fixed-PAM studies in the U.S. Navy training area east of Kodiak; peak detections occurred in September and October (Debich et al. 2013; Rice et al. 2015). Additionally, there were six acoustic encounters with Stejneger's beaked whales during the 2013 towed-hydrophone survey in the western GOA (Rone et al. 2014). At least five stranding records exist for B.C. (Houston 1990; Willis and Baird 1998; Ford 2014), including two strandings on the west coast of Haida Gwaii and two strandings on the west coast of Vancouver Island (Ford 2014). A possible sighting was made on the east coast of Vancouver Island (Ford 2014). Stejneger's beaked whales could be encountered during the proposed survey.

#### **Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)**

The Pacific white-sided dolphin is found in cool temperate waters of the North Pacific from the southern Gulf of California to Alaska. Across the North Pacific, it appears to have a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). In the eastern North Pacific Ocean, the Pacific white-sided dolphin is one of the most common cetacean species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003, 2010). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Pacific white-sided dolphins were seen throughout the North Pacific during surveys conducted during 1983–1990 (Buckland et al. 1993; Miyashita 1993), including in the proposed survey area. During winter, this species is most abundant in California slope and offshore areas (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). During the summer, Pacific white-sided dolphins occur north into the GOA and west to Amchitka in the Aleutian Islands; sightings have been documented in the spring and summer (Wade et al. 2003; Waite 2003; Rone et al. 2010, 2017). Sightings for Southeast Alaska have also been reported for spring, summer, and fall (Dahlheim and Towell 1994; Dalheim et al. 2009).

Pacific white-sided dolphins are common throughout the waters of B.C., including Dixon Entrance, Hecate Strait, Queen Charlotte Sound, the west coast of Haida Gwaii, as well as western Vancouver Island, and the mainland coast (Ford 2014). Stacey and Baird (1991) compiled 156 published and unpublished records to 1988 of the Pacific white-sided dolphin within the Canadian 320-km extended EEZ. These dolphins move inshore and offshore seasonally (Stacey and Baird 1991). There were inshore records for all months except July, and offshore records from all months except December. Offshore sightings were much more common than inshore sightings, especially in June–October; the mean water depth was ~1100 m. Ford et al. (2011b) reported that most sightings occur in water depths <500 m and within 20 km from shore. During an L-DEO cruise from Oregon to Alaska in 2008, Pacific white-sided dolphins were seen west of Haida Gwaii in mid-September during the northbound transit and in early October during the southbound transit (Hauser and Holst 2009). All sightings were made in water deeper than 1000 m (Hauser and Holst 2009). Williams and Thomas (2007) estimated an abundance of 25,900 Pacific white-sided dolphins in inshore coastal B.C. waters based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 22,160 individuals based on surveys during 2004–2008. Pacific white-sided dolphins are likely to be common in the proposed survey area.

#### **Northern Right Whale Dolphin (*Lissodelphis borealis*)**

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, from the Gulf of Alaska to near northern Baja California, ranging from 30°N to 50°N (Reeves et al. 2002). In the eastern North Pacific Ocean, the northern right whale dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters ~100 to >2000 m deep (Green et al. 1993; Barlow 2003). The northern right whale dolphin comes closer to shore where there is deep water, such as over submarine canyons (Reeves et al. 2002).

Northern right whale dolphins do not occur as far north as Alaska, but there have been 47 records for B.C., mostly in deep water off the west coast of Vancouver Island; however, sightings have also been made in deep water off the west coast of Haida Gwaii, as well as in the Gwaii Haanas National Marine Conservation Area (Ford 2014). Most sightings have occurred in water depths >900 m (Baird and Stacey 1991). One group of six northern right whale dolphins was sighted west of Vancouver Island in water deeper than 2500 m during a recent survey from Oregon to Alaska (Hauser and Holst 2009). Northern right whale dolphins could be encountered in the proposed survey area.

#### **Risso's Dolphin (*Grampus griseus*)**

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

Risso's dolphins are uncommon to rare in the GOA. Risso's dolphins have been sighted near Chirikof Island (southwest of Kodiak Island) and offshore in the GOA (Consiglieri et al. 1980; Braham 1983). They were detected acoustically once in January 2013, near Pratt Seamount during fixed-PAM studies from 2011–2015 in the U.S. Navy training area (Debich et al. 2013). The Department of the Navy (DoN 2014) considers this species as an occasional visitor to the GOA training area.

Risso's dolphin was once considered rare in B.C., but there have been numerous sightings since the 1970s (Ford 2014). In B.C., most sightings have been made in Gwaii Haanas National Park Reserve, Haida Gwaii, but there have also been sightings in Dixon Entrance, off the west coast of Haida Gwaii, Queen Charlotte Sound, as well as to the west of Vancouver Island (Ford 2014). Strandings have mainly been reported for the Strait of Georgia (Ford 2014). Risso's dolphins could be encountered in the proposed 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 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales are segregated socially, genetically, and ecologically into three distinct ecotypes: residents, transients, and offshore animals. Killer whales occur in inshore inlets, along the coast, over the continental shelf, and in offshore waters (Ford 2014).

There are eight killer whale stocks recognized in the Pacific U.S.: (1) Alaska Residents, occurring from Southeast Alaska to the Bering Sea; (2) Northern Residents, from B.C. through parts of Southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern B.C.; (4) Gulf of Alaska, Aleutians, and Bering Sea Transients, from Prince William Sound through to the Aleutians and Bering Sea; (5) AT1 Transients, from Prince William Sound through the Kenai Fjords; (6) West Coast Transients, from California through Southeast Alaska; (7) Offshore, from California through Alaska; and (8) Hawaiian (Muto et al. 2019; Carretta et al. 2019). Individuals from the Northern Resident; Alaska Resident; West Coast Transient; Offshore; and Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stocks could be encountered in the proposed project area. Although possible, it is unlikely that individuals from the *endangered* Southern Resident stock would be encountered during the proposed survey. Dalheim et al. (2009) reported sightings of killer whales during spring, summer, and fall for the inland waters of Southeast Alaska.

Alaska Resident killer whales occur in Southeast Alaska, GOA, Aleutian Islands, and the Bering Sea (Muto et al. 2019). In the past, they were considered to be the same stock as Northern Residents (Muto et al. 2019), but acoustic and genetic data confirmed that these are separate stocks (e.g., Yurk et al. 2002; Hoelzel et al. 2002). In B.C., the northern residents inhabit the central and northern Strait of Georgia, Johnstone Strait, Queen Charlotte Strait, the west coast of Vancouver Island, and the entire central and north coast of mainland B.C.; their range also extends northward to Southeast Alaska (Muto et al. 2019).

Many sightings have been made in Dixon Entrance (which is designated as critical habitat; DFO 2018) and eastern Hecate Strait, which is also considered important habitat (Ford 2014). Critical habitat for this population in B.C. also includes the waters off southwestern Vancouver Island (DFO 2018), where both northern and southern resident killer whales often forage in the summer (Ford 2014), as well as Johnstone Strait and southeastern Queen Charlotte Strait (DFO 2018).

Southern Resident killer whales primarily occur in the southern Strait of Georgia, Strait of Juan de Fuca, Puget Sound, and the southern half of the west coast of Vancouver Island (Ford et al. 1994; Baird 2001; Carretta et al. 2019); however, their range may extend into Southeast Alaska (Carretta et al. 2019). These aforementioned areas in B.C. and Washington have been designated as critical habitat either by the

U.S. or Canada. In the fall, this population is known to occur in Puget Sound, and during the winter, they occur along the outer coast and do not spend a lot of time in critical habitat areas (Ford 2014). Southern resident killer whales mainly feed on salmon, in particular Chinook, and their movements coincide with those of their prey (Ford 2014).

The main diet of transient killer whales consists of marine mammals, in particular porpoises and seals (Andersen Garcia et al. 2016). Two stocks of transient killer whales could occur in the survey area. The Gulf of Alaska, Aleutian Islands, and Bering Sea transient stock is known to occur as far east as Southeast Alaska and the west coast of Haida Gwaii. Dahlheim et al. (2009) and Dahlheim and White (2010) reported sightings throughout Southeast Alaska, including eastern Dixon Entrance and around Prince of Wales Island. West coast transient whales (also known as Bigg's killer whales) range from Southeast Alaska to California (Muto et al. 2019). The seasonal movements of transients are largely unpredictable, although there is a tendency to investigate harbor seal haulouts off Vancouver Island more frequently during the pupping season in August and September (Baird 1994; Ford 2014). Transients have been sighted throughout B.C. waters, including the waters around Haida Gwaii.

Little is known about offshore killer whales, but they occur primarily over shelf waters and feed on fish, especially sharks (Ford 2014). Dahlheim et al. (2008, 2009) reported sightings in Southeast Alaska during spring and summer. Relatively few sightings have been reported in the waters of B.C.; there have been 103 records since 1988 (Ford 2014). The number of sightings are likely influenced by the fact that these whales prefer deeper waters near the slope, where little sighting effort has taken place (Ford 2014). Most sightings are from Haida Gwaii, including Dixon Entrance and the west coast, and 15 km or more off the west coast of Vancouver Island near the continental slope (Ford et al. 1994). Offshore killer whales are mainly seen off B.C. during summer and off California during winter, but they can occur in B.C. waters year-round (Ford 2014). Based on surveys conducted during 2004–2008, Best et al. (2015) estimated that 371 killer whales (all ecotypes) occur in coastal waters of B.C. Killer whales could be encountered during the proposed surveys.

#### **Harbor Porpoise (*Phocoena phocoena*)**

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore but is occasionally sighted in deeper offshore water (Jefferson et al. 2015); abundance declines linearly as depth increases (Barlow 1988). In the eastern North Pacific, its range extends from Point Barrow, Alaska, to Point Conception, California. Their seasonal movements appear to be inshore-offshore, rather than north-south, as a response to the abundance and distribution of food resources (Dohl et al. 1983; Barlow 1988). Genetic testing has also shown that harbor porpoises along the west coast of North America are not migratory and occupy restricted home ranges (Rosel et al. 1995).

In Alaska, there are three separate stocks of harbor porpoise: Southeast Alaska, GOA, and Bering Sea. However, genetic variation shown by environmental DNA (eDNA) studies for the Southeast Alaska stock, indicates that this population could be comprised of multiple stocks (Parsons et al. 2018). Only the Southeast Alaska Stock could be encountered in the proposed survey area; it occurs from northern B.C. to Cape Suckling. Harbor porpoises are sighted regularly in the eastern and central GOA and Southeast Alaska (Dahlheim et al. 2000, 2009; MacLean and Koski 2005; Rone et al. 2010, 2017). During surveys of Southeast Alaska, harbor porpoise distribution was concentrated in Icy Strait/Glacier Bay, Wrangell area, and Zarembo Island (Dahlheim et al. 2009, 2015). The highest density (0.18 animals/km<sup>2</sup>) occurred in the region of Sumner Strait/Wrangell/Zarembo Island (Dahlheim et al. 2019). They noted that the patchy distribution of harbor porpoise in Southeast Alaska did not lend itself to determining a single density estimate for the entire region. The abundance was estimated to be 975 animals for Southeast Alaska based on data collected during 2010–2012.

Based on surveys conducted during 2004 and 2005, Williams and Thomas (2007) estimated that 9120 harbor porpoises are present in inshore coastal waters of B.C. Best et al. (2015) provided an estimate of 8091 based on surveys during 2004–2008. Harbor porpoises are found along the coast year-round, primarily in coastal shallow waters, harbors, bays, and river mouths of B.C. (Osborne et al. 1988), but can also be found in deep water over the continental shelf and over offshore banks that are no deeper than 150 m (Ford 2014; COSEWIC 2016). Many sightings exist for nearshore waters surrounding Haida Gwaii and Vancouver Island (Ford 2014), including within the proposed survey area. Occasionally sightings have also been made in shallow water of Queen Charlotte Sound, Hecate Strait, and Dixon Entrance, as well as off southwestern Vancouver Island on Swiftsure and La Pérouse banks (Ford 2014). Sightings are made year-round (Ford 2014). Harbor porpoises could be encountered in shallower water in the eastern portions of the proposed survey area.

### **Dall's Porpoise (*Phocoenoides dalli*)**

Dall's porpoise is found in temperate to subarctic waters of the North Pacific and adjacent seas (Jefferson et al. 2015). It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979). It is probably the most abundant small cetacean in the North Pacific Ocean, and its abundance changes seasonally, likely in relation to water temperature (Becker 2007). Dall's porpoise is widely distributed over shelf and slope waters, with concentrations near shelf edges, but is also commonly sighted in pelagic offshore waters (e.g., Green et al. 1992; Becker et al. 2014; Carretta et al. 2019).

Dall's porpoise occurs throughout Alaska. It was one of the most frequently sighted species during summer seismic surveys in the central and eastern GOA and Southeast Alaska (MacLean and Koski 2005; Hauser and Holst 2009; Dahlheim et al. 2009), as well as systematic surveys in GOA (e.g., Rone et al. 2014, 2017). Dahlheim et al. (2009) and Jefferson et al. (2019) reported this species to be more common in Southeast Alaska during the spring and summer than in fall; sightings in the summer were made throughout the region, including in eastern Dixon Entrance and around Baranoff and Prince of Wales islands. According to Jefferson et al. (2019), summer densities ranged from 6 to 24.4 porpoises/100 km<sup>2</sup>, and summer abundance in Southeast Alaska was estimated at 2680 animals.

In B.C. waters, Dall's porpoise is common inshore and offshore throughout the year (Jefferson 1990; Ford 2014). It is most common over the continental shelf and slope, but also occurs >2400 km from the coast (Pike and MacAskie 1969 in Jefferson 1990), and sightings have been made throughout the proposed survey area (Ford 2014). There appears to be a distributional shift inshore during the summer and offshore in winter (Ford 2014). Based on surveys conducted in 2004 and 2005, Williams and Thomas (2007) estimated that there are 4910 Dall's porpoises in inshore coastal waters of B.C. High densities occur in Dixon Entrance (Harvey et al. 2017). Best et al. (2015) provided an estimate of 5303 individuals based on surveys during 2004–2008. During an L-DEO cruise from Oregon to Alaska, Dall's porpoises were sighted west of Vancouver Island and Haida Gwaii in early October during the southbound transit; all sightings were made in water deeper than 2000 m (Hauser and Holst 2009). MacLean and Koski (2005) also reported a sighting west of Haida Gwaii during August. Dall's porpoise is likely to be encountered during the proposed seismic survey.

## **Pinnipeds**

### **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. 2019). During the breeding season, most of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering

Sea (NMFS 2007; Lee et al. 2014; Muto et al. 2019). 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. 2019). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2019). 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. 2019).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2019). 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. 2019; Muto et al. 2019). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Immature seals can remain in southern foraging areas year-round until they are old enough to mate (NMFS 2007). In November, females and pups leave the Pribilof Islands and migrate through the GOA to feeding areas primarily off the coasts of B.C., Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al. 2005; Pelland et al. 2014). Pups travel through Aleutian passes and spend the first two years at sea before returning to their islands of origin.

Males usually migrate only as far south as the GOA (Kajimura 1984). Ream et al. (2005) showed that migrating females moved over the continental shelf as they migrated southeasterly. Instead of following depth contours, their travel corresponded with movements of the Alaska Gyre and the North Pacific Current (Ream et al. 2005). Their foraging areas were associated with eddies, the subarctic-subtropical transition region, and coastal mixing (Ream et al. 2005; Alford et al. 2005). Some juveniles and non-pregnant females may remain in the GOA throughout the summer (Calkins 1986). The northern fur seal spends ~90% of its time at sea, typically in areas of upwelling along the continental slopes and over seamounts (Gentry 1981). The remainder of its life is spent on or near rookery islands or haulouts.

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990, including off Vancouver Island and in the western GOA (Buckland et al. 1993). Tagged adult fur seals were tracked from the Pribilof Islands to the waters off Washington/Oregon/California and B.C. with recorded movement through the proposed project area (Pelland et al. 2014). 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; females migrated to the GOA and the California Current, including off the west coasts of Haida Gwaii and Vancouver Island (Sterling et al. 2014). Some individuals reach California by December, after which time numbers increase off the west coast of North America (Ford 2014). The peak density shift over the course of the winter and spring, with peak densities occurring in California in February, April off Oregon and Washington, and May off B.C. and Southeast Alaska (Ford 2014). The use of continental shelf and slope waters of B.C. and the northwestern U.S. by adult females during winter is well documented from pelagic sealing data (Bigg 1990).

Off B.C., females and subadult males are typically found during the winter off the continental shelf (Bigg 1990). They start arriving from Alaska during December and most will leave the B.C. waters by July (Ford 2014). Tagged adult female fur seals were shown to concentrate their habitat utilization within 200 km of the shelf break along the west coast of North America; several traveled through the proposed survey area off Haida Gwaii and western Vancouver Island (Pelland et al. 2014). Ford (2014) also reported the occurrence of northern fur seals throughout B.C. waters, including Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and off the west coasts of Haida Gwaii and Vancouver Island, with concentrations over the shelf and slope, especially on La Pérouse Bank, southwestern Vancouver Island. A few animals are seen in inshore waters in B.C., and individuals occasionally come ashore, usually at sea lion haulouts (e.g.,

Race Rocks, off southern Vancouver Island) during winter and spring (Baird and Hanson 1997). Approximately 125,000 fur seals occur in B.C. over the winter and spring (Ford 2014). Although fur seals sometimes haul out in B.C., there are no breeding rookeries.

Northern fur seals, in particular juveniles, could be observed in the proposed survey area, although adult males are generally ashore at rookeries in the Bering Sea during the reproductive season from May to August, and adult females are generally ashore from June through November.

### **Steller Sea Lion (*Eumetopias jubatus*)**

The Steller sea lion occurs along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). It is 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 (NOAA 2019d). There are two stocks, or DPSs, of Steller sea lions – the Western and Eastern DPSs, which are divided at 144°W longitude (Muto et al. 2019). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (Muto et al. 2019); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013). Although most individuals that could occur in the proposed survey area would be from the Eastern DPS, it is possible that some individuals from the Western DPS could occur in the northern portion of the survey area (e.g., Jemison et al. 2013, 2017; Hastings et al. 2019).

Steller sea lions typically inhabit waters from the coast to the outer continental shelf and slope throughout their range; they are not considered migratory, although foraging animals can travel long distances (Loughlin et al. 2003; Raum-Suryan et al. 2002). Rookeries of Steller sea lions from the Eastern DPS are located in Southeast Alaska, B.C., Oregon, and California; there are no rookeries in Washington (NMFS 2013; Muto et al. 2019). 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). During the summer, they mostly forage within 60 km from the coast; during winter, they can range up to 200 km from shore (Ford 2014).

Steller sea lions are present in Alaska year-round, with centers of abundance in the GOA and Aleutian Islands. There are several rookeries in Southeast Alaska, including Hazy Island, White Sisters Island, Forrester Island near Dixon Entrance, Graves Rock along the outer coast of Glacier Bay National Park & Reserve (GBNPP), and Biali Rock (Calkins et al. 1999; Raum-Suryan and Pitcher 2000; Raum-Suryan 2001; Gelatt et al. 2007; Hastings et al. 2017; Sweeney et al. 2017). The rookeries at Hazy Island, White Sisters Island, and Forrester Island as well as several major haulouts are designated as critical habitat (Fig. 1). Numerous other haulouts occur through Southeast Alaska (Sweeney et al. 2017). During an L-DEO seismic survey off Southeast Alaska, numerous sightings were made north of the survey area during September 2004 (MacLean and Koski 2005). Juvenile sea lions branded as pups on Forrester Island have

been observed at South Marble Island in GBNPP (Mathews 1996), and some juveniles from the Western stock have been observed at South Marble Island and Graves Rocks in GBNPP (Raum-Suryan 2001).

In B.C., there are six main rookeries, which are situated at the Scott Islands off northwestern Vancouver Island, the Kerouard Islands near Cape St. James at the southern end of Haida Gwaii, North Danger Rocks in eastern Hecate Strait, Virgin Rocks in eastern Queen Charlotte Sound, Garcin Rocks off southeastern Moresby Island in Haida Gwaii, and Gosling Rocks on the central mainland coast (Ford 2014). The Scott Islands and Cape St. James rookeries are the two largest breeding sites with 4000 and 850 pups born in 2010, respectively (Ford 2014). Some adults and juveniles are also found on sites known as year-round haulouts during the breeding season. Haul outs are located along the coasts of Haida Gwaii, the central and northern mainland coast, the west coast of Vancouver Island, and the Strait of Georgia; some are year-round sites whereas others are only winter haul outs (Ford 2014). Pitcher et al. (2007) reported 24 major haulout sites (>50 sea lions) in B.C., but there are currently around 30 (Ford 2014). The total pup and non-pup count of Steller sea lions in B.C. in 2002 was 15,438; this represents a minimum population estimate (Pitcher et al. 2007). The highest pup counts in B.C. occur in July (Bigg 1988). Steller sea lions could be encountered in the proposed project areas, especially in the waters closer to shore.

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

The primary range of the California sea lion includes the coastal areas and offshore islands of the eastern North Pacific Ocean from B.C. to central Mexico, including the Gulf of California (Jefferson et al. 2015). However, its distribution is expanding (Jefferson et al. 2015), and its secondary range extends into the GOA (Maniscalco et al. 2004) and southern Mexico (Gallo-Reynoso and Solórzano-Velasco 1991), where it is occasionally recorded.

California sea lion rookeries are on islands located in southern California, western Baja California, and the Gulf of California (Carretta et al. 2019). A single stock is recognized in U.S. waters, but there are five genetically distinct geographic populations (1) Pacific Temperate (includes rookeries in U.S. waters and the Coronados Islands to the south), (2) Pacific Subtropical, (3) Southern Gulf of California, (4) Central Gulf of California, and (5) Northern Gulf of California (Schramm et al. 2009). Animals from the Pacific Temperate population occur in the proposed project area.

In California and Baja California, births occur on land from mid-May to late-June. During August and September, after the mating season, the adult males migrate northward to feeding areas as far north as Washington (Puget Sound) and B.C. (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature California sea lions is less well known but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). However, most immature seals are presumed to remain near the rookeries for most of the year, as are females and pups (Lowry et al. 1992).

California sea lions that are sighted in Alaska are typically seen at Steller sea lion rookeries or haulouts, with most sightings occurring between March and May, although they can be found in the GOA year-round (Maniscalco et al. 2004). California sea lions used to be rare in B.C., but their numbers have increased substantially during the 1970s and 1980s (Ford 2014). Wintering California sea lion numbers have increased off southern Vancouver Island since the 1970s, likely as a result of the increasing California breeding population (Olesiuk and Bigg 1984). Several thousand occur in the waters of B.C. from fall to spring (Ford 2014). Adult and subadult male California sea lions are mainly seen in B.C. during the winter (Olesiuk and Bigg 1984). They are mostly seen off the west coast of Vancouver Island and in the Strait of Georgia, but they are also known to haul out along the coasts of Haida Gwaii, including Dixon Entrance, and the mainland (Ford 2014). California sea lions could be encountered in the proposed project area.



### **Northern Elephant Seal (*Mirounga angustirostris*)**

The northern elephant seal breeds in California and Baja California, primarily on offshore islands, from Cedros off the west coast of Baja California, north to the Farallons in Central California (Stewart et al. 1994). Adult elephant seals engage in two long northward migrations per year, one following the breeding season, and another following the annual molt (Stewart and DeLong 1995). Between the two foraging periods, they return to land to molt, with females returning earlier than males (March–April vs. July–August). After the molt, adults then return to their northern feeding areas until the next winter breeding season. Breeding occurs from December–March (Stewart and Huber 1993). Females arrive in late December or January and give birth within ~1 week of their arrival. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

When not at their breeding rookeries, adults feed at sea far from the rookeries. Adult females and juveniles forage in the California current off California to B.C. (Le Boeuf et al. 1986, 1993, 2000). Males may feed as far north as the eastern Aleutian Islands and the GOA, whereas females feed south of 45°N (Le Boeuf et al. 1993; Stewart and Huber 1993). Adult male elephant seals migrate north via the California current to the GOA during foraging trips, and could potentially be passing through the waters off Washington in May and August (migrating to and from molting periods) and November and February (migrating to and from breeding periods). Northern elephant seals that were satellite-tagged at a California rookery have been recorded traveling as far west as ~175°E (Le Boeuf et al. 2000; Robinson et al. 2012), and were recorded traveling through the proposed survey area off Southeast Alaska and B.C. Post-molting seals traveled longer and farther than post-breeding seals (Robinson et al. 2012).

Race Rocks Ecological Reserve, located off southern Vancouver Island, is one of the few spots in B.C. where elephant seals regularly haul out. Based on their size and general appearance, most animals using Race Rocks are adult females or subadults, although a few adult males also haul out there. Use of Race Rocks by northern elephant seals has increased substantially in recent years, most likely as a result of the species' dramatic recovery from near extinction in the early 20th century and its tendency to be highly migratory. A peak number (22) of adults and subadults were observed in spring 2003 (Demarchi and Bentley 2004); pups have also been born there primarily during December and January (Ford 2014). Haul outs can also be found on the western and northeastern coasts of Haida Gwaii, and along the coasts of Vancouver Island (Ford 2014). Juveniles are sometimes seen molting on beaches along the coast of B.C. from December–May, but sometimes also in summer and autumn (Ford 2014). This species could be encountered during the proposed seismic survey.

### **Harbor Seal (*Phoca vitulina richardsi*)**

Two subspecies of harbor seal occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardsi* in the eastern Pacific Ocean. *P.v. richardsi* occurs in nearshore, coastal, and estuarine areas ranging from Baja California, Mexico, north to the Pribilof Islands in Alaska (Carretta et al. 2019). Twelve stocks of harbor seals are recognized in Alaska: (1) Aleutian Islands, (2) Pribilof Islands, (3) Bristol Bay, (4) North Kodiak, (5) South Kodiak, (6) Prince William Sound, (7) Cook Inlet/Shelikof Strait, (8) Glacier Bay/Icy Strait, (9) Lynn Canal/Stephens Passage, (10) Sitka/Chatham Strait, (11) Dixon/Cape Decision, and (12) Clarence Strait (Muto et al. 2019). Three of these stocks (Sitka/Chatham Strait, Dixon/Cape Decision, Clarence Strait) could occur in nearshore waters of the proposed survey area.

The Sitka/Chatham Strait stock ranges along Baranof Island from Cape Bingham to Cape Ommaney (directly east of a survey transect), as well as inland to Table Bay on the west side of Kuiu Island, north through Chatham Strait to Cube Point off western Admiralty Island, and east to Cape Bendel on

northeastern Kupreanof Island (Muto et al. 2019). The Dixon/Cape Decision stock ranges from Cape Decision on southern Kuiu Island to Point Barrie on Kupreanof Island and south from Port Protection to Cape Chacon along western Prince of Wales Island, northwestern Dixon Entrance to Cape Muzon on Dall Island, and to Forrester Island, and including Coronation Island and all islands off western Prince of Wales Island (Muto et al. 2019). The Clarence Strait stock ranges along the eastern Prince of Wales Island from Cape Chacon north to Clarence Strait and Point Baker, and along the east coast of Mitkof and Kupreanof Islands north to Bay Point, including Ernest Sound, Behm Canal, and Pearse Canal (Muto et al. 2019).

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid-July. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates.

Juvenile harbor seals can travel significant distances (525 km) to forage or disperse, whereas adults were generally found within 190 km of their tagging location in Prince William Sound (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001). Pups tagged in the GOA most commonly undertook multiple return trips of more than 75 km from natal areas, followed by movements of <25 km from the natal area (Small et al. 2005). Pups tagged in Prince William Sound traveled a mean maximum distance of 43.2 km from their tagging location, whereas those tagged in the GOA moved a mean maximum distance of 86.6 km (Small et al. 2005). Ford (2014) noted that harbor seals generally occur within 20 km from shore but can be seen up to 100 km from the coast.

Williams and Thomas (2007) noted an abundance estimate of 19,400 harbor seals for the inshore coastal waters of B.C. based on surveys in 2004 and 2005. Best et al. (2015) provided an abundance estimate of 24,916 seals based on coastal surveys during 2004–2008. The total population in B.C. was estimated at ~105,000 in 2008 (Ford 2014). Harbor seals occur along all coastal areas of B.C., including the western coast of Haida Gwaii and Vancouver Island, with the highest concentration in the Strait of Georgia (13.1 seals per kilometre of coast); average densities elsewhere are 2.6 seals per kilometre (Ford 2014). Almost 1400 haul outs have been reported for B.C., many of them in the Strait of Georgia (Ford 2014). Given their preference for coastal waters, harbor seals could be encountered in the easternmost parts of the proposed project area.

## **Fissipeds**

### **Northern Sea Otter (*Enhydra lutris kenyoni*)**

The northern sea otter can be found along the coast of North America from Alaska to Washington. Sea otters generally occur in shallow (<35 m), nearshore waters in areas with sandy or rocky bottoms, where they feed on a wide variety of sessile and slow-moving benthic invertebrates (Rotterman and Simon-Jackson 1988). Sea otters are generally not migratory and do not disperse over long distances; however, individual sea otters are capable of travelling in excess of 100 km (Garshelis and Garshelis 1984), although movements are likely limited by geographic barriers, high energy requirements of animals, and social behavior. Before commercial exploitation, the worldwide population of sea otters was estimated to be between 150,000 (Kenyon 1969) and 300,000 (Johnson 1982). Commercial exploitation reduced the total sea otter population to as low as 2000 in 13 locations (Kenyon 1969). In 1911, sea otters received protection under the North Pacific Fur Seal Convention, and populations recovered quickly (Kenyon 1969). The world sea otter population is currently estimated at ~150,000 (Davis et al. 2019).

In Alaska, three stocks or DPSs of sea otters are recognized: the Southeast Alaska Stock, Southcentral Alaska Stock, and the Southwest Alaska Stock (USFWS 2014). Only the Southeast Alaska DPS occurs in the proposed survey area. Although southern Southeast Alaska supports a greater number of otters than northern Southeast Alaska, most otters in northern Southeast Alaska occur in Glacier Bay (Tinker et al. 2019). High-density areas occur in water depths <40 m; low-density habitat consists of water <100 m deep or up to 2 km offshore (Tinker et al. 2019). During an L-DEO survey off Southeast Alaska during August–September 2004, MacLean and Koski (2005) reported 13 sightings of sea otters; sightings were made in inland waters of Baranof and Chichagof islands and deep in Yakutat Bay, all to the north of the proposed survey area. During L-DEO’s STEEP seismic survey during late summer/fall 2008, two sightings of four sea otters were made in Yakutat Bay (Hauser and Holst 2009).

Sea otters were translocated from Alaska to B.C. (Bigg and MacAskie 1978). In 2013, the B.C. population was estimated to number at least 6754 individuals (DFO 2015; Nichol et al. 2015). In B.C., sea otters regularly occur off northern and western Vancouver Island, and along the central mainland coast (Ford 2014; DFO 2015; Nichol et al. 2015). Although most individuals occur north of Clayoquot Sound (Nichol et al. 2015), some animals occur in Barkley Sound and in the Strait of Juan de Fuca to Victoria (Ford 2014). Occasionally sightings of lone individuals (mostly males) have been made along the coast of Haida Gwaii (Ford 2014); they likely occurred off Haida Gwaii in large numbers in the past (Nichol et al. 2015). Given that the survey is proposed to occur in water >50 m, sea otters are expected to be rare during the proposed survey. However, some sea otters could occur within the area that is ensonified by airgun sounds.

## 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 Northeast Pacific Ocean in summer 2021. The initial IHA request was submitted on 2 December 2019, but has been revised due to a number of factors including: (1) to address comments from NMFS, (2) a schedule change from summer 2020 to summer 2021 due to COVID-19 impacts, and (3) a change in the mitigation zones which are now based on both modeling for the Level A and Level B thresholds and using empirical measurements from Crone et al. (2014) from the Cascadia Margin, which were then used to revise the take estimates, and (4) a change in location tracklines. Although the location of some tracklines has changed from what was originally proposed, the original trackline locations were used to generate take estimates, because they are still adequately representative of the proposed survey plan. The changes to the tracklines include: a slight decrease in line km from 4260 to 4250 km; 69% of the survey would occur in deep water, instead of 63%; about 1/3 (30%) would occur in intermediate water, instead of 35%; and only 1% would take place in shallow water (instead of 3%). Slightly less effort (548 km vs. 680 km) would occur in Canadian Territorial Waters water.

The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. “Takes” by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of “Level B Harassment” for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, MITIGATION MEASURES), and no lethal takes are expected. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes would be unlikely. However, 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 Northeast 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”.

### Summary of Potential Effects of Airgun Sounds

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

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, but TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

### **Tolerance**

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

### **Masking**

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

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

### **Disturbance Reactions**

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017).

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

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

**Baleen Whales.**—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In

the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995).

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

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in<sup>3</sup> airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in<sup>3</sup>, 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 in<sup>3</sup>) within 3 km and received levels of at least 140 dB re 1  $\mu\text{Pa}^2 \cdot \text{s}$  (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in<sup>3</sup> array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1  $\mu\text{Pa}^2 \cdot \text{s}$  (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000).

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

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

*Bowhead whales* show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999). Subtle but statistically

significant changes in surfacing–respiration–dive cycles were shown by traveling and socializing bowheads exposed to airgun sounds in the Beaufort Sea, including shorter surfacings, shorter dives, and decreased number of blows per surfacing (Robertson et al. 2013). More recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are less responsive to seismic sources (e.g., Miller et al. 2005; Robertson et al. 2013).

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1  $\mu$ Pa; at SPLs <108 dB re 1  $\mu$ 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<sub>10-min</sub> (cumulative SEL over a 10-min period) of ~94 dB re 1  $\mu$ Pa<sup>2</sup> · s, decreased at CSEL<sub>10-min</sub> >127 dB re 1  $\mu$ Pa<sup>2</sup> · s, and whales were nearly silent at CSEL<sub>10-min</sub> >160 dB re 1  $\mu$ Pa<sup>2</sup> · 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 during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1  $\mu$ Pa<sub>rms</sub> (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~170 dB re 1  $\mu$ Pa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away



from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of *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., Pirota 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  $\mu$ Pa, SELs of 145–151 dB  $\mu$ Pa<sup>2</sup> · s). For the same survey, Pirota et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1  $\mu$ Pa<sub>0-peak</sub>. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in<sup>3</sup> airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB  $\mu$ Pa<sup>2</sup> · 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  $\geq 170$  dB disturbance criterion (rather than  $\geq 160$  dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different

approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017; Tyack and Thomas 2019).

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

### **Hearing Impairment and Other Physical Effects**

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

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

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

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  $\mu$ Pa 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  $\sim$ 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; Nachtigall et al. 2018).

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

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012a) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB (Kastelein et al. 2012a). Kastelein et al. (2013b) 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  $\mu$ Pa 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  $\mu$ 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  $\mu$ 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  $\mu$ 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  $\mu$ 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  $\mu$ Pa; no low-frequency TTS was observed. Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018).

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

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

Nowacek et al. (2013a) concluded that current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. Also, many marine mammals and (to a limited degree) sea turtles show some avoidance of

the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves would reduce or (most likely) avoid any possibility of hearing impairment. Aarts et al. (2016) noted that an understanding of animal movement is necessary in order to estimate the impact of anthropogenic sound on cetaceans.

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

Since 1991, there have been 70 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2019e). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (<https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program>), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

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

### **Possible Effects of Other Acoustic Sources**

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

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

Madagascar. During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

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

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

There is nearly no available information on marine mammal behavioral responses to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior of Cuvier’s beaked whales during multibeam mapping in southern California (Varghese et al. 2019). The study found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, but the number of GVP was significantly greater after MBES exposure than before MBES exposure. During an analogous study assessing Naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2019).

In the fall of 2006, an Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiment was carried out in the Gulf of Maine (Gong et al. 2014); the OAWRS emitted three frequency-modulated (FM) pulses centered at frequencies of 415, 734, and 949 Hz (Risch et al. 2012). Risch et al. (2012) found a reduction in humpback whale song in the Stellwagen Bank National Marine Sanctuary during OAWRS activities that were carried out ~200 km away; received levels in the sanctuary were 88–110 dB re 1  $\mu$ 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. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

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

### Other Possible Effects of Seismic Surveys

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

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

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2018). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise

(Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

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

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey area during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and narwhals (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). Pirodda et al. (2015) noted that the physical presence of vessels, not just ship noise, disturbed the foraging activity of bottlenose dolphins. Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015).

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

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

Another concern with vessel traffic is the potential for striking marine mammals. Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but is extremely unlikely, because of the relatively

slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

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

All takes would be anticipated to be Level B “takes by harassment” as described in § I, involving temporary changes in behavior. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating and requesting Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A “takes” would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys; exposures for northern sea otter are not included here, as an IHA is being sought from USFWS. The estimates are based on consideration of the number of marine mammals that could be harassed by sound (Level B takes) produced by the seismic surveys in the Northeast Pacific Ocean outside of Canadian Territorial Waters.

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  $\geq 160$  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 survey 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. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger  $\geq 160$  dB (Level B) radius.

For the majority of species, we used a combination of habitat-based stratified marine mammal densities developed by the U.S. Navy for assessing potential impacts of training activities in the GOA (DoN 2014) and densities for Behm Canal in Southeast Alaska (DoN 2019). Based on recommendations by NMFS, the GOA densities were used for offshore areas, and the Behm Canal densities were used for coastal waters. Consistent with Rone et al. (2014), four strata were defined by DoN (2014) for the GOA including (1) Inshore: all waters <1000 m deep; (2) Slope: from 1000 m water depth to the Aleutian trench/subduction zone; (3) Offshore: waters offshore of the Aleutian trench/subduction zone; and (4) Seamount: waters

within defined seamount areas. For cetaceans, the preferred densities for coastal waters (shallow and intermediate depths) were from Behm Canal; ‘Offshore’ densities from the GOA were used for offshore waters. If no densities were available for Behm Canal, then ‘Inshore’ densities were used for coastal waters (shallow and intermediate depths); ‘Offshore’ densities were used for offshore waters.

For pinnipeds, we used densities from Behm Canal, when available, for shallow water (<100 m), ‘Inshore’ densities for intermediate-depth water (100–1000 m), and ‘Offshore’ densities for offshore waters. As densities for Behm Canal are for inland waters and are therefore expected to be much greater than densities off the coast, we did not use the Behm Canal densities for intermediate-depth waters. All marine mammal densities corresponding to the various strata in the GOA and single density values for Behm Canal were based on data from several different sources, including Navy funded line-transect surveys in the GOA, as described in Appendix B. Densities for harbor porpoise, northern right whale dolphin, California sea lion, and leatherback turtle were determined using alternate density sources (see Appendix B for details).

All densities used for the analysis are presented in Table 4 and Appendix B. When seasonal densities were available (e.g., as for Behm Canal for humpback, killer, and minke whales; Pacific white-sided dolphin; Steller sea lion; and harbor seal), the calculated exposures were based on summer densities, which were deemed to be most representative of the proposed survey timing. For all other species, summer densities were either not available or the same as for other seasons. There is some uncertainty related to the estimated density data and the assumptions used in their calculations, as with all density data estimates. However, the approach used here is based on the best available data. The calculated exposures that are based on these densities are best estimates for the proposed survey.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Ferrero et al. 2002; Philbrick et al. 2003; Escorza-Treviño 2009). Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1  $\mu\text{Pa}_{\text{rms}}$  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”. Table 5 shows the estimates of the number of marine mammals that potentially could be exposed to  $\geq 160$  dB re 1  $\mu\text{Pa}_{\text{rms}}$  during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix C for more details). With the exception of the right whale, for species for which densities were not available, we have included a *Requested Take Authorization* for at least the mean group size. Right whales are unlikely to occur in the survey area, and no takes have been calculated for that species. 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  $\geq 160$  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 the NSF/USGS PEIS. The 160-dB<sub>rms</sub> 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

TABLE 4. Densities of marine mammals and sea turtles that could be exposed to Level B and Level A thresholds for NMFS defined hearing groups during the proposed survey.

	Shallow Water <100 m	Intermediate Water 100-1000 m	Deep Water >1000 m
<b>LF Cetaceans</b>			
North Pacific right whale	0	0	0
Humpback whale	0.01170	0.01170	0.00100
Blue whale	0.00050	0.00050	0.00050
Fin whale	0.00010	0.00010	0.02100
Sei whale	0.00010	0.00010	0.00010
Minke whale	0.00080	0.00080	0.00060
Gray whale	0.04857	0.04857	0
<b>MF Cetaceans</b>			
Sperm whale	0	0	0.0013
Baird's beaked whale	0.00050	0.00050	0.00050
Cuvier's beaked whale	0.00220	0.00220	0.00220
Stejneger's beaked whale	0	0	0.00142
Pacific white-sided dolphin	0.00750	0.00750	0.02080
Northern right-whale dolphin	0.01100	0.02763	0.03673
Risso's dolphin	0.00001	0.00001	0.00001
Killer whale	0.00570	0.00570	0.00200
<b>HF Cetaceans</b>			
Dall's porpoise	0.12100	0.12100	0.03700
Harbor porpoise	0.03300	0.03300	0
<b>Otariid Seals</b>			
Northern fur seal	0.01500	0.01500	0.01700
California sea lion	0.02880	0.02880	0.00650
Steller sea lion	0.31616	0.00980	0.00980
<b>Phocid Seals</b>			
Northern elephant seal	0.00220	0.00220	0.00220
Harbor seal	0.78110	0.00001	0.00001
<b>Sea Turtle</b>			
Leatherback Turtle	0.000114	0.000114	0.000114

N.A. means not available.

TABLE 5. Estimates of the possible numbers of individual marine mammals and sea turtles that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the Northeast Pacific Ocean during summer 2021. Takes for Canadian Territorial Waters are not included here.

Species	Calculated Take		Regional Population Size	Level B + Level A as % of Pop. <sup>3</sup>	Requested Take Authorization <sup>4</sup>
	Level B <sup>1</sup>	Level A <sup>2</sup>			
LF Cetaceans					
North Pacific right whale	0	0	400	0	0
Humpback whale <sup>5</sup>	404	14	10,103	4.1	417
Blue whale	42	2	1,647	2.7	44
Fin whale	1,146	57	18,680	6.4	1,203
Sei whale	8	0	27,197	0.03	9
Minke whale	57	2	28,000	0.2	59
Gray whale <sup>6</sup>	1,450	45	26,960	5.5	1,495
MF Cetaceans					
Sperm whale	74	0	26,300	0.3	74
Baird's beaked whale	44	0	2,697	1.6	44
Cuvier's beaked whale	193	0	3,274	6.4	193
Stejneger's beaked whale	81	0	3,044	0.3	81
Pacific white-sided dolphin	1,417	3	26,880	5.3	1,420
Northern right-whale dolphin <sup>7</sup>	922	5	26,556	3.5	927
Risso's dolphin <sup>8</sup>	1	0	6,336	0.01	22
Killer whale <sup>9</sup>	289	0	3,738	7.8	290
HF Cetaceans					
Dall's porpoise	5,661	178	83,400	7.0	5,839
Harbor porpoise	990	26	11,146	9.1	1,016
Otariid Seals					
Northern fur seal	1,431	2	620,660	0.2	1,433
California sea lion	1,256	1	257,606	0.5	1,258
Steller sea lion <sup>10</sup>	1,665	2	41,638	4.0	1,666
Phocid Seal					
Northern elephant seal	192	1	179,000	0.1	193
Harbor seal	2,048	4	81,282	2.5	2,052
Sea Turtle					
Leatherback turtle	3	0	N.A.	N.A.	3

N.A. means not applicable or not available.

<sup>1</sup> Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.

<sup>2</sup> Level A takes if there were no mitigation measures.

<sup>3</sup> Requested take authorization (Level A + Level B) expressed as % of population (see Table 3); numbers do not necessarily sum due to rounding.

<sup>4</sup> Requested take authorization is Level A plus Level B calculated takes.

<sup>5</sup> 16 takes from Mexico DPS; remainder from Hawaii DPS.

<sup>6</sup> Two takes from western DPS; remainder from Eastern North Pacific DPS.

<sup>7</sup> All takes expected to occur in Canadian waters (takes in territorial waters not included here).

<sup>8</sup> Requested take increased to mean group size (Barlow 2016).

<sup>9</sup> Takes include individuals from all stocks; no takes expected for Southern Resident DPS.

<sup>10</sup> Seven takes would be from the Western DPS; remainder of takes from Eastern DPS.

response might not occur for some percentage of marine mammals exposed to received levels  $>160$  dB, whereas other individuals or groups might respond in a manner considered as “taken” to sound levels  $<160$  dB (NMFS 2016c). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal’s initial response to the sound (NMFS 2016c).

The number of marine mammals that could be exposed to airgun sounds with received levels  $\geq 160$  dB re  $1 \mu\text{Pa}_{\text{rms}}$  (Level B) for marine mammals on one or more occasions have been estimated using a method recommended by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day, in this case 187 km. A representative line(s) were chosen for the survey effort in the US and Canada. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo 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 for each country were then multiplied by the number of survey days (11 days for survey effort off Canada; 16 days for the US) increased by 25%; this is equivalent to adding an additional 25% to the proposed line kilometers (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 R/V *Langseth* approaches.

Estimates of the numbers of marine mammals and sea turtles that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs observe animals approaching or inside the EZs), are also given in Table 5. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. 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. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area, in particular sea otters, which spend a substantial amount of time each day on the surface of the water.

The estimate of the number of marine mammals that could be exposed to seismic sounds with received levels  $\geq 160$  dB re  $1 \mu\text{Pa}_{\text{rms}}$  in the proposed survey area is 13,111 cetaceans and 6602 pinnipeds (Table 5). That total includes 1348 endangered cetaceans: 1203 fin whales, 16 humpback whales (Mexico DPS), 2 gray whales (Western North Pacific DPS), 44 blue whales, 9 sei whales, and 74 sperm whales, representing 6.4%, 0.3% (16 of 6000 individuals; Bettridge et al. 2016), 0.7% (2 of 290 individuals; Carretta et al. 2019), 2.7%, 0.03%, and 0.3%, respectively. The number of humpback whales (16) assumes that 3.8% of humpbacks that occur in southeast Alaska and northern B.C. are from the Mexico DPS and the rest are from the Hawaii DPS (Wade 2017); no takes are expected for the Central America DPS. For the number of gray whales (2) it is assumed that 0.1% of gray whales could be from the endangered Western North Pacific DPS (NMSF pers. comm. based on Carretta et al. 2019). Based on Hastings et al. (2019), it is expected that 2.2% of Steller sea lions in the central outer coast region of southeast Alaska would be from the endangered Western DPS, and all other individuals would be from the Eastern DPS. Based on 1 survey day that may occur in the central outer coast region, it is estimated that 2 takes would be from the Western DPS and the remainder of the takes would be from the Eastern DPS.

## Conclusions

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

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

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

## VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives. In the GOA, the only marine mammals that are currently hunted are Steller sea lions, harbor seals, and sea otters. These species are an important subsistence resource for Alaska Natives from Southeast Alaska to the Aleutian Islands. There are numerous communities along the shores of the GOA that participate in subsistence hunting, including Juneau, Ketchikan, Sitka, and Yakutat in Southeast Alaska (Wolfe et al. 2013). For 2006–2010, the average subsistence takes of northern sea otters was 447 animals for the Southeast Alaska



Stock (Muto et al. 2019). Raymond et al. (2019) reported 1449 animals were harvested in 2013. Although sea otters are harvested year-round in Southeast Alaska, there is decreased harvest effort during May–August. According to Muto et al. (2019), the annual subsistence take of Steller sea lions from the eastern stock was 11, and 415 northern fur seals are taken annually. In addition, 340 harbor seals are taken annually (Muto et al. 2019). The seal harvest throughout Southeast Alaska is generally highest during spring and fall, but can occur any time of the year (Wolfe et al. 2013). In Canada, various First Nations harvest seals and sea lions.

Any impacts on the subsistence harvest from the proposed activities would mainly be anticipated from use of the airguns from the vessel. The vessel would move continuously throughout the survey area, and any impacts would mainly occur close to the vessel. Given the temporary nature of the proposed activities and the fact that most operations would occur at least several km from shore, 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 area. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in

accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental ‘take’ of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS). In addition, permits for affecting Species at Risk would be requested from the Canadian DFO, and other Canadian guidelines, including the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment, would be followed if these are more stringent than those required by NMFS.

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

## Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. However, the scientific objectives for the proposed surveys could not be met using a smaller source. A large airgun source and long-offset, crustal-scale seismic acquisition is required to penetrate to crustal depths that would address the project goals (crustal structure, basement formation).
2. *Survey Location and Timing*—The PIs worked with NSF to consider potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using R/V *Langseth*, as well as coordination with the Canadian Coast Guard and Geological Survey of Canada. Although marine mammals, including baleen whales, are expected to occur in the proposed survey area during summer, summer is the most practical season for the proposed surveys based on weather conditions and other operational requirements.
3. *Mitigation Zones*—The proposed surveys would acquire data with the 36-airgun array at a tow depth of 12 m. L-DEO model results are used to determine the 160-dB<sub>rms</sub> radius for the 36-airgun array and 40-in<sup>3</sup> (mitigation) airgun in deep water (>1000 m) down to a maximum water depth of 2000 m. Table 1 shows the distances at which the 160-dB re 1μPa<sub>rms</sub> sound levels are expected to be received for the airgun arrays and the 40-in<sup>3</sup> (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.

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

## Mitigation During Operations

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

### Shut-down/Power-down Procedures

The operating airgun(s) would be shut down if a marine mammal is seen within or approaching the EZ or powered down (or if necessary shut down) if a turtle is sighted within the EZ. The operating airgun(s) would also be powered down in the event an ESA-listed seabird were observed diving or foraging within the designated EZ. Special shut downs at any distance would also be implemented for North Pacific right whales, large whales with a calf, and aggregations (6 or more individuals) of large whales. However, shut downs and power downs would not be required for small dolphins that are most likely to approach the vessel.

In a power-down scenario, a shut down would be implemented if (1) a sea turtle or ESA-listed diving seabird enters the EZ of the single airgun after a power down has been initiated, or (2) an animal is initially seen within the EZ of the single airgun when more than one airgun (typically the full array) is operating. A power down involves decreasing the operating airguns in use down to a single 40-in<sup>3</sup> airgun such that the radius of the threshold zone is decreased to the extent that seabirds or turtles are no longer in or about to enter the EZ. In contrast, a shut down occurs when all airgun activity is suspended.

Following a shut down or 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 and turtles, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

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

### Ramp-up Procedures

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

Ramp up would begin with the smallest airgun in the array (40 in<sup>3</sup>). 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 shut down or power down would be implemented, respectively, as though the full array were operational. Ramp up would only commence at night or during poor visibility if the EZ has been monitored acoustically monitored with PAM for 30 min prior to the start of operations without any marine mammal detections during that period.

## **XII. PLAN OF COOPERATION**

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

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

The proposed activity would take place in the Northeast Pacific Ocean, and no activities would take place in traditional Arctic subsistence hunting area. The proposed activities would not preclude or hinder subsistence activities from occurring within the survey area. Therefore, while subsistence activities may occur in the proposed survey area, no impacts would be anticipated on subsistence harvests due to the brief and temporary nature of the proposed activities. NSF plans to conduct outreach to local stakeholders, including subsistence communities, as part of the NEPA process associated with the proposed action. In addition, researchers have proposed conducting outreach in the region to discuss the proposed project in advance of research activities. During operations, radio communications and Notice to Mariners would keep interested parties apprised of vessel activities.

## **XIII. MONITORING AND REPORTING PLAN**

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

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan would be subject to review by NMFS and that refinements may be required. The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. L-DEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

## Vessel-based Visual Monitoring

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

During seismic operations, five PSOs would be based aboard R/V *Langseth*. All PSOs would be appointed by L-DEO with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals 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. PSVO(s) would be on duty in shifts of duration no longer than 4 h, or per the IHA. Other crew would also be instructed to assist in detecting marine mammals and 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.

R/V *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 R/V *Langseth* is underway while the airguns are

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

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

### **PSO Data and Documentation**

PSOs would record data to estimate the numbers of marine mammals, 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 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, USFWS) and Canadian agencies (DFO), and would comply with their requirements.

#### XV. LITERATURE CITED

- Aarts, G., A.M. von Benda-Beckmann, K. Lucke, H.Ö. Sertlek, R. Van Bemmelen, S.C. 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. and R. García-Vernet. 2018. Fin whale *Balaenoptera physalus*. p. 368-371 In: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), *Encyclopedia of Marine Mammals*, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 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.
- Alford, M.H., J.T. Sterling, C.M. Lee, and R.R. Ream. 2005. Using remotely-sensed satellite and autonomous underwater vehicle measurements to characterize northern fur seal migratory habitat. Abstr. 16<sup>th</sup> Bienn. Conf. Biol. Mar. Mamm., 12-16 Dec. 2005, San Diego, CA.
- Allen, G.M. 1942. Extinct and vanishing mammals of the Western Hemisphere with the marine species of all oceans. **Spec. Publ. Am. Comm. Int. Wildl. Protection** No.11. 620 p.
- Andersen Garcia, M., L. Barre, and M. Simpkins. 2016. The ecological role of marine mammal killer whales in the North Pacific Ocean surrounding Alaska. Marine Mammal Commission, Bethesda, MD. 40 p.
- 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. Species Res.** 21(3):231-240.

- Atkinson, S., D. Crocker, D. Houser, and K. Mashburn. 2015. Stress physiology in marine mammals: How well do they fit the terrestrial model? **J. Comp. Physiol. B** 185(5):463-486. doi:10.1007/s00360-015-0901-0.
- 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. Working Pap. SC/58/E35. Int. Whal. Comm., Cambridge, UK. 13 p.
- Baird, R.W. 1994. Foraging behaviour and ecology of transient killer whales. Ph.D. thesis, Simon Fraser University, Burnaby, B.C.
- Baird, R.W. 2001. Status of killer whales, *Orcinus orca*, in Canada. **Can. Field-Nat.** 115(4):676-701.
- Baird, R.W. 2018. Cuvier's beaked whale *Ziphius cavirostris*. p. 234-237 In: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- Baird, R.W. and M.B. Hanson. 1997. Status of the northern fur seal, *Callorhinus ursinus* in Canada. **Can. Field-Nat.** 111(2):263-269.
- Baird, R.W. and P.J. Stacey. 1991. Status of the northern right whale dolphin, *Lissodelphis borealis*, in Canada. **Can. Field-Nat.** 105(2):243-250.
- Baird, R.S., E.L. Walters, and P.J. Stacey. 1993. Status of the bottlenose dolphin, *Tursiops truncatus*, with special reference to Canada. **Can. Field-Nat.** 107(4):466-480.
- Baker, C.S. 1986. Population characteristics of humpback whales in Glacier Bay and adjacent waters, summer 1986. U.S. National Park Service, Glacier Bay National Park and Preserve, Gustavus, AK.
- Baker, C.S. and L.M. Herman. 1989. Behavioral responses of summering humpback whales to vessel traffic: experimental and opportunistic observations. NPS-NR-TRS-89-01. Rep. from Kewalo Basin Mar. Mamm. Lab., Univ. Hawaii, Honolulu, HI, for U.S. Natl. Park Serv., Anchorage, AK. 50 p. NTIS PB90-198409.
- Baker, C.S., L.M. Herman, B.G. Bays, and W.F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. Rep. from Kewalo Basin Mar. Mamm. Lab., Honolulu, HI, for U.S. 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., S.T. Palumbi, R.H. Lambertsen, M.T. Weinrich, J. Calambokidis, and S.J. O'Brien. 1990. Influence of seasonal migration on geographic distribution of mitochondrial DNA haplotypes in humpback whales. **Nature** 344(6263):238-240.
- 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.
- Banfield, A.W.F. 1974. The mammals of Canada. Univ. Toronto Press. 438 p.
- Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: I. Ship surveys. **Fish. Bull.** 86(3):417-432.
- Barlow, J. 2003. Preliminary estimates of the abundance of cetaceans along the U.S. west coast: 1991-2001. Admin. Rep. LJ-03-03. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 31 p.
- Barlow, J. 2010. Cetacean abundance in the California Current estimated from a 2008 ship-based line-transect survey. NOAA Tech. Memo. NMFS NOAA-TM-NMFS-SWFSC-456. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and Southwest Fisheries Science Centre. 19 p.
- Barlow, J. 2016. Cetacean abundance in the California Current estimated from ship-based line-transect surveys in 1991-2014. NOAA Admin. Rep. LJ-16-01. 31 p.



- Barlow, J. and A. Henry. 2005. Cruise report. Accessed on 11 February 2008 at [http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Projects/Research\\_Cruises/Hawaii\\_and\\_Alaska/SPLASHCruiseReport\\_Final.pdf](http://swfsc.noaa.gov/uploadedFiles/Divisions/PRD/Projects/Research_Cruises/Hawaii_and_Alaska/SPLASHCruiseReport_Final.pdf).
- Barlow, J. and R. Gisiner. 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage.** 7(3):239-249.
- 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.
- Barry, S.B., A.C. Cucknell, and N. Clark. 2012. A direct comparison of bottlenose dolphin and common dolphin behaviour during seismic surveys when airguns are and are not being utilised. p. 273-276 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.
- Baumann-Pickering, S., A. Širović, J. Hildebrand, A. Debich, R. Gottlieb, S. Johnson, S. Kerosky, L. Roche, A. Solsona Berga, L. Wakefield, and S. Wiggins. 2012. Passive acoustic monitoring for marine mammals in the Gulf of Alaska Temporary Maritime Activities Area 2011-2012. Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA. MPL Tech. Memo. 538. 42 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/pone.0086072.
- Becker, E.A. 2007. Predicting seasonal patterns of California cetacean density based on remotely sensed environmental data. Ph.D. Thesis, Univ. Calif. Santa Barbara, Santa Barbara, CA. 284 p.
- Becker, E.A., K.A. Forney, D.G. Foley, R.C. Smith, T.J. Moore, and J. Barlow. 2014. Predicting seasonal density patterns of California cetaceans based on habitat models. **Endang. Species Res.** 23: 1-22.
- Berchok, C., J. Keating, J. Crance, H. Klinck, K. Klinck, D. Ljungblad, S.E. Moore, L. Morse, F. Scattorin, and P.J. Clapham. 2009. Right whale gunshot calls detected during the 2008 North Pacific right whale survey. p. 31-32 *In*: Abstr. 18<sup>th</sup> Bienn. Conf. Biol. Mar. Mamm., Québec, Canada, Oct. 2009. 306 p.
- Bernstein, L. 2013. The Washington Post: health, science, and environment. Panel links underwater mapping sonar to whale stranding for first time. Published 6 October 2013. Accessed in December 2015 at [http://www.washingtonpost.com/national/health-science/panel-links-underwater-mapping-sonar-to-whale-stranding-for-first-time/2013/10/06/52510204-2e8e-11e3-bbed-a8a60c601153\\_story.html](http://www.washingtonpost.com/national/health-science/panel-links-underwater-mapping-sonar-to-whale-stranding-for-first-time/2013/10/06/52510204-2e8e-11e3-bbed-a8a60c601153_story.html).
- Best, B.D., C.H. Fox, R. Williams, P.N. Halpin, and P.C. Paquet. 2015. Updated marine mammal distribution and abundance estimates in British Columbia. **J. Cetacean Res. Manage.** 15:9-26.
- 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.
- Bigg, M. A. 1969. The harbour seal in British Columbia. **Fish. Res. Board Can. Bull.** 172. 33 p.
- Bigg, M.A. 1981. Harbor seal, *Phoca vitulina*, Linnaeus, 1758 and *Phoca largha*, Pallas, 1811. p. 1-27 *In*: Ridgeway, S.H. and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 2: Seals. Academic Press, New York, NY. 359 p.
- Bigg, M.A. 1988. Status of the northern sea lion, *Eumetopias jubatus*, in Canada. **Can. Field-Nat.** 102(2):315-336.
- Bigg, M.A. 1990. Migration of northern fur seals (*Callorhinus ursinus*) off western North America. **Can. Tech. Rep. Fish. Aqu. Sci.** 1764.
- Bigg, M.A. and I.B. MacAskie. 1978. Sea otters re-established in British Columbia. **J. Mammal.** 59: 874-876.
- 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.** 114(2):1130-1134.

- 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. Mammal Sci.** 29(4):E342-E365.
- Blackwell, S.B., C.S. Nations, T.L. McDonald, A.M. Thode, D. Mathias, K.H. Kim, C.R. Greene, Jr., and A.M. Macrander. 2015. Effects of airgun sounds on bowhead whale calling rates: evidence for two behavioral thresholds. **PLoS ONE** 10(6):e0125720. 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.
- Braham, H.W. 1983. Northern records of Risso's dolphin, *Grampus griseus*, in the northeast Pacific. **Can. Field-Nat.** 97:89-90.
- Braham, H.W. 1984. Distribution and migration of gray whales in Alaska. p. 249-266 In: Jones, M.L., S.L. Swartz, and S. Leatherwood (eds.), *The gray whale Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.
- 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, and 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. 16<sup>th</sup> 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. 20<sup>th</sup> 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, London, UK. 486 p.
- Brownell, R.L., P.J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. **J. Cetacean Res. Manage.** (Special Issue 2):269-286.
- Brueggeman, J.J., G.A. Green, R.A. Grotefendt, and D.G. Chapman. 1987. Aerial surveys of endangered cetaceans and other marine mammals in the northwestern Gulf of Alaska and southeastern Bering Sea. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 61(1989):1-124. OCS Study MMS 89-0026, NTIS PB89-234645.
- Brueggeman, J.J., G.A. Green, K.C. Balcomb, C.E. Bowlby, R.A. Grotefendt, K.T. Briggs, M.L. Bonnell, R.G. Ford, D.H. Varoujean, D. Heinemann, and D.G. Chapman. 1990. Oregon-Washington marine mammal and seabird survey: information synthesis and hypothesis formulation. OCS Study MMS 89-0030. Rep. from EnviroSphere Co., Bellevue, WA, and Ecological Consulting Inc., Portland, OR, for U.S. Minerals Manage. Serv., Pacific Region, Los Angeles, CA. 374 p.

- Buchanan, J.B., D.H. Johnson, E.L. Greda, G.A. Green, T.R. Wahl, and S.J. Jeffries. 2001. Wildlife of coastal and marine habitats. p. 389-422 *In*: D.H. Johnson and T.A. O'Neil (eds.), Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press.
- 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.
- Burtenshaw, J.C., E.M. Oleson, J.A. Hildebrand, M.A. McDonald, R.K. Andrew, B.M. Howe, and J.A. Mercer. 2004. Acoustic and satellite remote sensing of blue whale seasonality and habitat in the Northeast Pacific. **Deep-Sea Research II** 51:967-986.
- Calambokidis, J. 2007. Summary of collaborative photographic identification of gray whales from California to Alaska for 2004 and 2005. Final Report for Purchase Order AB133F-05-SE-5570. Available at <http://www.cascadiaresearch.org/reports/Rep-ER-04-05c.pdf>.
- Calambokidis, J. and J. Barlow. 2004. Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. **Mar. Mamm. Sci.** 20:63-85.
- Calambokidis, J. and Barlow, J. 2013. Updated abundance estimates of blue and humpback whales off the US west coast incorporating photo-identifications from 2010 and 2011. Final report for contract AB133F-10-RP-0106. Document PSRG-2013-13R. 8 p. Accessed in October 2018 at <http://www.cascadiaresearch.org/files/publications/Rep-Mn-Bm-2011-Rev.pdf>.
- Calambokidis, J. and J. Quan. 1999. Photographic identification research on seasonal resident whales in Washington State. US Dep. Commer., NOAA Tech. Mem. NMFS-AFSC-103:55. Status review of the eastern North Pacific stock of gray whales. 96 p.
- 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., J.D. Darling, V. Deecke, P. Gearin, M. Gosho, W. Megill, C.M. Tombach, D. Goley, C. Toropova, and B. Gisborne. 2002. Abundance, range and movements of a feeding aggregation of gray whales (*Eschrichtius robustus*) from California to southeastern Alaska in 1998. **J. Cetacean Res. Manage.** 4(3):267-276.
- Calambokidis, J., T. Chandler, L. Schlender, G.H. Steiger, and A. Douglas. 2003. Research on humpback and blue whales off California, Oregon, and Washington in 2002. Final Report to Southwest Fisheries Science Center, La Jolla, CA. Cascadia Research, 218½ W Fourth Ave., Olympia, WA, 98501. 47 p.
- Calambokidis, J., G. H. Steiger, D.K. Ellifrit, B.L. Troutman, and C.E. Bowlby. 2004. Distribution and abundance of humpback whales (*Megaptera novaeangliae*) and other marine mammals off the northern Washington coast. **Fish. Bull.** 102:563-580.
- 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.
- Calambokidis, J., J. Barlow, J.K.B. Ford, T.E. Chandler, and A.B. Douglas. 2009. Insights into the population structure of blue whales in the Eastern North Pacific from recent sightings and photographic identification. **Mar. Mammal Sci.** 25(4):816-832.

- Calambokidis, J., G.H. Steiger, C. Curtice, J. Harrison, M.C. Ferguson, E. Becker, M. DeAngelis, and S.M. Van Parijs. 2015. 4. Biologically important areas for selected cetaceans within U.S. waters – West Coast Region. **Aquat. Mamm.** 41(1):39-53.
- Calambokidis, J., J. Laake, and A. Perez. 2017. Updated analysis of abundance and population structure of seasonal gray whales in the Pacific Northwest, 1996-2015. Paper SC/A17/GW/05 presented to the International Whaling Commission.
- Calkins, D.G. 1986. Marine mammals. Pages 527-558 *In*: D.W. Hood and S.T. Zimmerman (eds.) The Gulf of Alaska: physical environment and biological resources. Alaska Office, Ocean Assessments Division, NOAA.
- Calkins, D.G., D.C. McAllister, K.W. Pitcher, and G.W. Pendleton. 1999. Steller sea lions status and trend in southeast Alaska: 1979-1997. **Mar. Mamm. Sci.** 15(2):462-477.
- 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., M.S. Lynn, and C.A. LeDuc. 1994. Right whale, *Eubalaena glacialis*, sighting off San Clemente Island, California. **Mar. Mamm. Sci.** 10(1):101-104.
- 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. 2019. U.S. Pacific marine mammal stock assessments: 2018. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-617. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 377 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.
- CBC. 2018. Coast guard crew makes rare sighting of right whale off Haida Gwaii. Accessed in October 2019 at <https://www.cbc.ca/news/canada/british-columbia/coast-guard-crew-makes-rare-sighting-of-right-whale-off-haida-gwaii-1.4714956>.
- CBC. 2019. In the presence of greatness': Rare sighting of blue whale off B.C. coast. Accessed in October 2019 at <https://ca.news.yahoo.com/presence-greatness-rare-sighting-blue-191227045.html>.
- 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.
- 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 22<sup>nd</sup> Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, NS, Canada.
- Cholewiak, D., C.W. Clark, D. Ponirakis, A. Frankel, L.T. Hatch, D. Risch, J.E. Stanistreet, M. Thompson, E. Vu, S.M. Van Parijs. 2018. Communicating amidst the noise: modeling the aggregate influence of ambient and vessel noise on baleen whale communication space in a national marine sanctuary. **Endang. Species Res.** 36:59-75.
- Clapham, P.J. 2018. Humpback whale *Megaptera novaeangliae*. p. 489-492 *In*: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- Clapham P.J. and J.G. Mead. 1999. *Megaptera novaeangliae*. **Mamm. Spec.** 604:1-9.

- 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 19<sup>th</sup> and 20<sup>th</sup> century whaling catch and sighting records. **J. Cetacean 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, UK. 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.
- Consiglieri, L.D., Braham, H.W., and M.L. Jones. 1980. Distribution and abundance of marine mammals in the Gulf of Alaska from the platform of opportunity programs, 1978-1979: Outer Continental Shelf Environmental Assessment Program Quarterly Report RU-68. 11 p.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2006. COSEWIC status report on common minke whale *Balaenoptera acutorostrata*. Committee on the Status of Wildlife in Canada, Ottawa, ON.
- COSEWIC. 2016. COSEWIC assessment and status report on the harbour porpoise *Phocoena phocoena vomerina*, Pacific Ocean population, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.
- COSEWIC. 2017. COSEWIC assessment and status report on the grey whale *Eschrichtius robustus*, Northern Pacific Migratory population, Pacific Coast Feeding Group population and the Western Pacific population, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.
- Costa, D.P. and T.M. Williams. 1999. Marine mammal energetics. p. 176-217 In: J.E. Reynolds III and S.A. Rommel (eds.), Biology of marine mammals. Smithsonian Institution Press, Washington. 578 p.
- 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. Huckstadt, 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.
- Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P.D. Jepson, D. Ketten, C.D. MacLeod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Mead, and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. **J. Cetac. Res. Manage.** 7(3):177-187.
- 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.
- Currie, J.J., S.H. Stack, and G.D. Kaufman. 2017. Modelling whale-vessel encounters: the role of speed in mitigating collisions with humpback whales (*Megaptera novaeangliae*). **J. Cetacean Res. Manage.** 17(1):57-63.
- Dahlheim, M.E. 1988. Killer whale (*Orcinus orca*) depredation on longline catches of sablefish (*Anoplopoma fimbria*) in Alaskan waters. U.S. Dep. Commerce, NWAFC Processed Rep. 88-14. 31 p.
- 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.
- Dahlheim, M.E. and P.A. White. 2010. Ecological aspects of transient killer whales *Orcinus orca* as predators in southeastern Alaska. **Wildl. Biol.** 16:308-322.

- Dahlheim, M.E., A. Schulman-Janiger, N. Black, R. Ternullo, D. Ellifrit, and K.C. Balcomb. 2008. Eastern temperate North Pacific offshore killer whales (*Orcinus orca*): Occurrence, movements, and insights into feeding ecology. **Mar. Mamm. Sci.** 24(3):719-729.
- Dahlheim, M., A. York, R. Towell, J. Waite, and J. Breiwick. 2000. Harbor porpoise (*Phocoena phocoena*) abundance in Alaska: Bristol Bay to Southeast Alaska, 1991–1993. **Mar. Mamm. Sci.** 16(1):28-45.
- Dahlheim, M.E., P.A. White, and J.M. Waite. 2009. Cetaceans of Southeast Alaska: distribution and seasonal occurrence. **J. Biogeogr.** 36(3):410-426.
- Dahlheim, M.E., A.N. Zerbini, J.M. Waite, and A.S. Kennedy. 2015. Temporal changes in abundance of harbor porpoise (*Phocoena phocoena*) inhabiting the inland waters of Southeast Alaska. **Fish. Bull.** 113(3):242-255.
- 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.
- Darling, J.D., K.E. Keogh, and T.E. Steeves. 1998. Gray whale (*Eschrichtius robustus*) habitat utilization and prey species off Vancouver Island, B.C. **Mar. Mammal Sci.** 14(4):692-720.
- Davis, R., J.L. Bodkin, H.A. Coletti, D.H. Monson, S.E. Larson, L.P. Carswell, and L.M. Nichol. 2019. Future directions in sea otter research and management. **Front. Mar. Sci.** 5:510. doi:10.3389/fmars.2018.005010.
- Debich, A.J., S. Baumann-Pickering, A. Širović, J. Hildebrand, J.S. Buccowich, R.S. Gottlieb, A.N. Jackson, S.C. Johnson, L. Roche, J.T. Trickey, B. Thayre, L. Wakefield, and S.M. Wiggins. 2013. Passive acoustic monitoring for marine mammals in the Gulf of Alaska Temporary Maritime Activities Area 2012-2013. Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA. MPL Tech. Memo. 546. 79 p.
- Demarchi, M.W. and M.D. Bentley. 2004. Effects of natural and human-caused disturbances on marine birds and pinnipeds at Race Rocks, British Columbia. LGL Report EA1569. Prepared for Department of National Defence, Canadian Forces Base Esquimalt and Public Works and Government Services Canada. 103 p.
- 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.
- DFO (Department of Fisheries and Oceans Canada). 2011. Recovery strategy for the North Pacific right whale (*Eubalaena japonica*) in Pacific Canadian Waters [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa.
- DFO. 2013. Recovery strategy for the North Pacific humpback whale (*Megaptera novaeangliae*) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa.
- DFO. 2015. Trends in the abundance and distribution of sea otters (*Enhydra lutris*) in British Columbia updated with 2013 survey results. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/043.
- DFO. 2017. Action plan for blue, fin, sei and North Pacific right whales (*Balaenoptera musculus*, *B. physalus*, *B. borealis*, and *Eubalaena japonica*) in Canadian Pacific waters. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa.
- DFO. 2018. Questions and answers: critical habitat for northern and southern resident killer whales in Canada. Accessed September 2019 at <https://www.pac.dfo-mpo.gc.ca/consultation/sara-lep/killerwhales-epaulards/faq-eng.html>.
- Di Iorio, L. and C.W. Clark. 2010. Exposure to seismic survey alters blue whale acoustic communication. **Biol. Lett.** 6(1):51-54.
- Dohl, T.P., R.C. Guess, M.L. Duman, and R.C. Helm. 1983. Cetaceans of central and northern California, 1980–1983: Status, abundance, and distribution. Final Report to the Minerals Management Service, Contract No. 14-12-0001-29090. 284 p.
- Dolman, S.J., and M. Jasny. 2015. Evolution of marine noise pollution management. **Aquat. Mammal.** 41(4):357-374.

- DoN (U.S. Department of the Navy). 2009. Appendix E, Marine Mammal Density Report. Gulf of Alaska Navy Training Activities Draft Environmental Impact Statement/Overseas Environmental Impact Statement. 46 p.
- DoN. 2014. Commander Task Force 3rd and 7th Fleet Navy Marine Species Density Database. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. 486 p.
- DoN. 2019. U.S. Navy Marine Species Density Database Phase III for the Northwest Training and Testing Study Area. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. 262 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.
- Dorsey, E.M., S.J. Stern, A.R. Hoelzel, and J. Jacobsen. 1990. Minke whale (*Balaenoptera acutorostrata*) from the west coast of North America: individual recognition and small-scale site fidelity. **Rep. Int. Whal. Comm. Spec. Iss.** 12:357-368.
- Dunham, J.S. and D.A. Duffus. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia, Canada. **Mar. Ecol. Prog. Ser.** 223:299-310.
- Dunham, J.S. and D.A. Duffus. 2002. Diet of gray whales (*Eschrichtius robustus*) in Clayoquot Sound, British Columbia, Canada. **Mar. Mammal Sci.** 18(2):419-427.
- Dunlop, R.A. 2015. The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. **Animal Behav.** 111:13-21.
- Dunlop, R. 2018. The communication space of humpback whale social sounds in vessel noise. Proceedings of Meetings on Acoustics 35(1):010001. doi:10.1121/2.0000935.
- 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>.
- Dunlop, R.A., M.J. Noad, R.D. McCauley, E. Kniest, R. Slade, D. Paton, and D.H. Cato. 2018. A behavioural dose-response model for migrating humpback whales and seismic air gun noise. **Mar. Poll. Bull.** 133:506-516.
- 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. doi:10.1038/srep11083.
- Edwards, E.F., C. Hall, T.J. Moore, C. Sheredy, and J.V. Redfern. 2015. Global distribution of fin whales *Balaenoptera physalus* in the post-whaling era (1980–2012). **Mamm. Rev.** 45(4):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. Species Res.** 30:95-108.
- Ellison, W.T., B.L. Southall, A.S. Frankel, K. Vigness-Raposa, and C.W. Clark. 2018. An acoustic scene perspective on spatial, temporal, and spectral aspects of marine mammal behavioral responses to noise. **Aquat. Mamm.** 44(3):239-243.
- 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 Paper SC/56/E28. Int. Whal. Comm., Cambridge, UK. 8 p.
- Erbe, C. 2012. The effects of underwater noise on marine mammals. p. 17-22 In: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.
- Erbe, C., C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling. 2016. Communication masking in marine mammals: a review and research strategy. **Mar. Poll. Bull.** 103:15-38.
- Escorza-Treviño, S. 2009. North Pacific marine mammals. p. 781-788 In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals, 2<sup>nd</sup> edit. Academic Press, San Diego, CA. 1316 p.
- Evans, P.G.H. 1987. The natural history of whales and dolphins. Christopher Helm, Bromley, Kent. 343 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 22<sup>nd</sup> Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, NS, Canada.
- Ferguson, M.C., C. Curtice, and J. Harrison. 2015. 6. Biologically important areas for cetaceans within U.S. waters – Gulf of Alaska region. **Aquat. Mamm.** 41(1):65-78.
- Ferrero, R.C., R.C. Hobbs, and G.R. VanBlaricom. 2002. Indications of habitat use patterns among small cetaceans in the central North Pacific based on fisheries observer data. **J. Cetac. Res. Manage.** 4:311-321.
- 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 whales (*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.
- Fisher, H.D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. **Fish. Res. Board Can. Bull.** 93. 58 p.
- Ford, J.K.B. 2014. Marine mammals of British Columbia. Royal BC Museum Handbook, Royal B.C. Museum, Victoria, British Columbia. 460 p.
- Ford, J.K.B. 2018. Killer whale *Orcinus orca*. p. 531-537 In: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- Ford, J.K.B., G.M. Ellis, and K.C. Balcomb. 1994. Killer whales. University of British Columbia Press, Vancouver, British Columbia.
- Ford, J.K.B., R.M. Abernethy, A.V. Phillips, J. Calambokidis, G. M. Ellis, and L.M. Nichol. 2010a. Distribution and relative abundance of cetaceans in Western Canadian Waters from ship surveys, 2002–2008. Canadian Technical Report of Fisheries and Aquatic Sciences 2913. 51 p.
- Ford, J.K.B., B. Koot, S. Vagle, N. Hall-Patch, and G. Kamitakahara. 2010b. Passive acoustic monitoring of large whales in offshore waters of British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences 2898. 30 p.
- Ford, J.K.B., J.W. Durban, G.M. Ellis, J.R. Towers, J.F. Pilkington, L.G. Barrett-Lennard, and R.D. Andrews. 2013. New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. **Mar. Mamm. Sci.** 29(2):325-337.
- Ford, J.K.B., 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. **Mar. Biodiv. Rec.** 9:50. doi:10.1186/s41200-016-0036-3.
- Fornet, M.E.H., L.P. Matthews, C.M. Gabriele, S. Haver, D.K. Mellinger, and H. Klinck. 2018. Humpback whales *Megaptera novaeangliae* alter calling behavior in response to natural sounds and vessel noise. **Mar. Ecol. Prog. Ser.** 607:251-268.
- Forney, K.A. 1994. Recent information on the status of odontocetes in California waters. NOAA Tech. Memo. NMFS-SWFSC-202. Nat. Mar. Fish. Serv., Southwest Fish. Sci. Center, La Jolla, CA. 87 p.
- Forney, K.A., and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991–1992. **Mar. Mamm. Sci.** 14 (3):460-489.
- Forney, K.A., J. Barlow, and J.V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: aerial surveys in winter and spring of 1991 and 1992. **Fish. Bull.** 93:15-26.
- Forney, K.A. and Brownell, R.L., Jr. 1996. Preliminary report of the 1994 Aleutian Island marine mammal survey. Working paper SC/48/O11. Int. Whal. Comm., Cambridge, U.K..
- Forney, K.A., B.L. Southall, E. Sloaten, 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.
- Frasier, T.R., S.M. Koroscil, B.N. White, and J.D. Darling. 2011. Assessment of population substructure in relation to summer feeding ground use in the eastern North Pacific gray whale. **Endang. Species Res.** 14(1):39-48.
- 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 22<sup>nd</sup> Biennial Conference on the Biology of Marine Mammals, 22–27 October, Halifax, NS, Canada.
- Gallo-Reynoso J.P., and J.L. Solórzano-Velasco J.L. 1991. Two new sightings of California sea lions on the southern coast of México. **Mar. Mamm. Sci.** 7:96.
- Gambell, R. 1985a. Sei whale *Balaenoptera borealis* Lesson, 1828. p. 155-170 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, UK. 362 p.
- Gambell, R. 1985b. 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, UK. 362 p.
- Gannier, A. and J. Epinat. 2008. Cuvier's beaked whale distribution in the Mediterranean Sea: results from small boat surveys 1996–2007. **J. Mar. Biol. Assoc. U.K.** 88(6):1245-1251.
- Garrigue, C., A. Aguayo, V.L.U. Amante-Helweg, C.S. Baker, S. Caballero, P. Clapham, R. Constantine, J. Denking, M. Donoghue, L. Flórez-González, J. Greaves, N. Hauser, C. Olavarría, C. Pairoa, H. Peckham, and M. Poole. 2002. Movements of humpback whales in Oceania, South Pacific. **J. Cetac. Res. Manage.** 4(3):255-260.
- 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>.
- Garshelis, D.L. and J.A. Garshelis. 1984. Movements and management of sea otters in Alaska. **J. Wildl. Manage.** 48(3):665-678.
- Gedamke, J. 2011. Ocean basin scale loss of whale communication space: potential impacts of a distant seismic survey. p. 105-106 *In*: Abstr. 19<sup>th</sup> Bienn. Conf. Biol. Mar. Mamm., 27 Nov.–2 Dec. 2011, Tampa, FL. 344 p.
- Gedamke, J., N. Gales, and S. Frydman. 2011. Assessing risk of baleen whale hearing loss from seismic surveys: the effects of uncertainty and individual variation. **J. Acoust. Soc. Am.** 129(1):496-506.
- Gelatt, T.S., A.W. Trites, K. Hastings, L. Jemison, K. Pitcher, and G. O'Corry-Crow. 2007. Population trends, diet, genetics, and observations of Steller sea lions in Glacier Bay National Park. p. 145-149 *In*: Piatt, J.F. and S.M. Gende (eds.), Proceedings of the Fourth Glacier Bay Science Symposium, 26–28 October 2004: U.S. Geological Survey Scientific Investigations Report 2007-5047.
- Gentry, R.L. 1981. Northern fur seal—*Callorhinus ursinus*. p. 119-141 *In*: S.H. Ridgway and R.J. Harrison (eds.), Handbook of marine mammals, Vol. 1: The walrus, sea lions, and sea otter. Academic Press, London, UK. 235 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.
- Gilmore, R.M. 1978. Right whale. *In*: D. Haley (ed.), Marine mammals of eastern North Pacific and arctic waters. Pacific Search Press, Seattle, WA.
- Goddard, P.D. and D.J. Rugh. 1998. A group of right whales seen in the Bering Sea in July 1996. **Mar. Mammal Sci.** 14(2):344-349.
- Gomez, C., J.W. Lawson, A.J. Wright, A.D. 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(12):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 relation to underwater noise and boat traffic. **Mar. Poll. Bull.** 105:193-198.
- Government of Canada. 2019. Species at Risk Public Registry. Accessed in September 2019 at <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html>.
- 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., J.J. Brueggeman, R.A. Grotefendt, C.E. Bowlby, M.L. Bonnell, and K.C. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989–1990. Chapter 1 *In*: J.J. Brueggeman (ed.), Oregon and Washington marine mammal and seabird surveys. Minerals Manage. Serv. Contract Rep. 14-12-0001-30426.
- 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. from Ebasco Environmental, Bellevue, WA, for Nat. Mar.
- 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.
- Gregg, E.J., L. Nichol, J.K.B. Ford, G. Ellis, and A.W. Trites. 2000. Migration and population structure of northeastern Pacific whales off coastal British Columbia: an analysis of commercial whaling records from 1908-1967. **Mar. Mamm. Sci.** 16(4):699-727.
- Gregg, E.J., J. Calambokidis, L. Convey, J.K.B. Ford, R.I. Perry, L. Spaven, and M. Zacharias. 2006. Recovery Strategy for blue, fin, and sei whales (*Balaenoptera musculus*, *B. physalus*, and *B. borealis*) in Pacific Canadian Waters. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver.
- 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. <http://dx.doi.org/doi:10.1121/2.0000312>.
- Guan, S., J.F. Vignola, J.A. Judge, D. Turo, and T.J. Ryan. 2015. Inter-pulse noise field during an arctic shallow-water seismic survey. **J. Acoust. Soc. Am.** 137(4):2212.
- Guerra, M., A.M. Thode, S.B. Blackwell, and M. Macrander. 2011. Quantifying seismic survey reverberation off the Alaskan North Slope. **J. Acoust. Soc. Am.** 130(5):3046-3058.
- Guerra, M., P.J. Dugan, D.W. Ponirakis, M. Popescu, Y. Shiu, and C.W. Clark. 2016. High-resolution analysis of seismic airgun impulses and their reverberant field as contributors to an acoustic environment. p. 371-379 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.
- Hain, J.H.W., W.A.M. Hyman, R.D. Kenney, and H.E. Winn. 1985. The role of cetaceans in the shelf-edge region of the U.S. **Mar. Fish. Rev.** 47(1):13-17.
- Hakamada, T. and K. Matsuoka. 2015. 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.
- 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.

- Hanselman, D.H., C.R. Lunsford, J.T. Fujioka, and C.J. Rodgveller. 2008. Assessment of the sablefish stock in Alaska. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 3:303-420.
- 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.** 55(1):396-404.
- Hartman, K.L. 2018. Risso's dolphin *Grampus griseus*. p. 824-827 *In*: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- Harvey, G.K.A., T.A. Nelson, C.H. Fox, and P.C. Paquet. 2017. Quantifying marine mammal hotspots in British Columbia, Canada. **Ecosphere** 8(7):e01884.
- 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. King, C. Booth, C. Donovan, R.S. Schick, L. Thomas, and L. New. 2016. Understanding the population consequences of acoustic disturbance for marine mammals. **Adv. Exp. Med. Biol.** 875:417-243.
- 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.
- Hastie, G., N.D. Merchant, T. Götz, D.J. Russell, P. Thompson, and V.M. Janik. 2019. Effects of impulsive noise on marine mammals: investigating range-dependent risk. **Ecol. Appl.** 15:e01906.
- Hastings, K.K., L.A. Jemison, G.W. Pendleton, K.L. Raum-Suryan, and K.W. Pitcher. 2017. Natal and breeding philopatry of female Steller sea lions in southeastern Alaska. **PLoS ONE** 12(6):e0176840. doi: 10.1371/journal.pone.0176840.
- Hastings, K.K., M.J. Rehberg, G.M. O'Corry-Crowe, G.W. Pendleton, L.A. Jemison, and T.S. Gelatt. 2019. Demographic consequences and characteristics of recent population mixing and colonization in Steller sea lions, *Eumetopias jubatus*. **J. Mammal.** 101(1):107-120.
- 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.
- Hauser, D.D.W. and M. Holst. 2009. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Gulf of Alaska, September-October 2008. LGL Rep. TA4412-3. Rep. from LGL Ltd., King City, Ont., and St. John's, Nfld, for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 78 p.
- Heide-Jørgensen, M.P., R.G. Hansen, S. Fossette, N.J. Nielsen, M.V. Jensen, and P. Hegelund. 2013a. Monitoring abundance and hunting of narwhals in Melville Bay during seismic surveys. September 2013. Greenland Institute of Natural Resources. 56 p.
- 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.
- Hendrix, A.N., J. Straley, C.M. Gabriele, and S.M. Gende. 2012. Bayesian estimation of humpback whale (*Megaptera novaeangliae*) population abundance and movement patterns in southeastern Alaska. **Can. J. Fish. Aquat. Sci.** 69:1783-1797.
- Herman, L. M., C.S. Baker, P.H. Forestell, and R.C. Antinaja. 1980. Right whale, *Balaena glacialis*, sightings near Hawaii: a clue to the wintering grounds? **Mar. Ecol. Prog. Ser.** 2:271-275.
- 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.

- Hermannsen, L., K. Beedholm, J. Tougaard, 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. 1989. Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. p. 289-308 In: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales. Academic Press, San Diego, CA. 444 p.
- Heyning, J.E. and M.E. Dahlheim. 1988. *Orcinus orca*. **Mammal. Spec.** 304:1-9.
- Hildebrand, J.A. and L. Munger. 2005. Bering Sea right whales: ongoing research and public outreach. North Pacific Research Board Project Final Report R0307. 14 p.
- Hill, P.S., J.L. Laake, and E. Mitchell. 1999. Results of a pilot program to document interactions between sperm whales and longline vessels in Alaska waters. NOAA Tech. Memo. NMFS-AFSC-108. Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, WA. 42 p.
- Hobbs, R. C., and Waite, J.M. 2010. Abundance of harbor porpoise (*Phocoena phocoena*) in three Alaskan regions, corrected for observer errors due to perception bias and species misidentification, and corrected for animals submerged from view. **Fish. Bull. U.S.** 108(3):251-267.
- Hoelzel, A.R., A. Natoli, M. Dahlheim, C. Olavarria, R. Baird and N. Black. 2002. Low worldwide genetic diversity in the killer whale (*Orcinus orca*): implications for demographic history. **Proc. R. Soc. Lond.** 269:1467-1473.
- Hogarth, W.T. 2002. Declaration of William T. Hogarth in opposition to plaintiff's motion for temporary restraining order, 23 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Div.
- Holt, M.M., D.P. Noren, R.C. Dunkin, and T.M. Williams. 2015. Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. **J. Exp. Biol.** 218(11):1647-1654. doi:10.1242/jeb.122424.
- Horwood, J. 1987. The sei whale: population biology, ecology, and management. Croom Helm, Beckenham, Kent, UK. 375 p.
- Horwood, J. 2018. Sei whale *Balaenoptera borealis*. p. 845-848 In: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3<sup>rd</sup> Edition. Academic Press/Elsevier, San Diego, CA. 1157 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). doi:10.1121/1.4976086.
- Houston, J. 1990. Status of Stejneger's beaked whale, *Mesoplodon stejnegeri*, in Canada. **Can. Field-Nat.** 104(1):131-134.
- Huber H.R. 1991. Changes in the distribution of California sea lions north of the breeding rookeries during the 1982–83 El Niño. p. 129-137 In: F. Trillmich and K.A. Ono (eds.), Pinnipeds and El Niño/responses to environmental stress. Springer-Verlag, Berlin. 293 p.
- Huber, H.R., A.C. Rovetta, L.A. Fry, and S. Johnston. 1991. Age-specific natality of northern elephant seals at the Farallon Islands, California. **J. Mamm.** 72(3):525-534.
- IUCN (The World Conservation Union). 2019. The IUCN Red List of Threatened Species. Version 2019-2. Accessed in September 2019 at <http://www.iucnredlist.org/>.

- IWC (International Whaling Commission). 2007. Report of the standing working group on environmental concerns. Annex K to Report of the Scientific Committee. **J. Cetac. Res. Manage.** 9(Suppl.):227-260.
- IWC. 2012. Report of the Scientific Committee. **J. Cetac. Res. Manage.** (Suppl.) 13.
- IWC. 2019. Whale population estimates. Accessed in October 2019 at <https://iwc.int/estimate>.
- 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* 281:20133222. doi:10.1098/rspb.2013.3222.
- Jaquet, N. and D. Gendron. 2002. Distribution and relative abundance of sperm whales in relation to key environmental features, squid landings and the distribution of other cetacean species in the Gulf of California, Mexico. **Mar. Biol.** 141(3):591-601.
- 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. 1990. Status of Dall's porpoise, *Phocoenoides dalli*, in Canada. **Can. Field-Nat.** 104(1):112-116.
- Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2015. Marine mammals of the world: a comprehensive guide to their identification, 2<sup>nd</sup> ed. Academic Press, London, UK. 608 p.
- Jefferson, T.A., M.A. Webber, and R.L. Pitman. 2015. Marine mammals of the world: a comprehensive guide to their identification, 2<sup>nd</sup> edit. Academic Press, London, U.K. 608 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.E. Dahlheim, A.N. Zerbini, J.M. Waite, and A.S. Kennedy. 2019. Abundance and seasonality of Dall's porpoise (*Phocoenoides dalli*) in Southeast Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-385. 45 p.
- Jemison, L.A., G.W. Pendleton, L.W. Fritz, K.K. Hastings, J.M. Maniscalco, A.W. Trites, and T.S. Gelatt. 2013. Inter-population movements of Steller sea lions in Alaska with implications for population separation. **PLoS ONE** 8(8):e70167. doi:10.1371/journal.pone.0070167.
- Jemison, L.A., G.W. Pendleton, K.K. Hastings, J.M. Maniscalco, and L.W. Fritz. 2018. Spatial distribution, movements, and geographic range of Steller sea lions (*Eumetopias jubatus*) in Alaska. **PLoS ONE** 13(12):e0208093. doi:10.1371/journal.pone.0208093.
- 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, A.M. 1982. Status of Alaska sea otter populations and developing conflicts with fisheries. p. 293-299 *In*: Transactions of the 47<sup>th</sup> North American Wildlife and Natural Resources Conference, Washington, D.C.
- 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.
- 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.** doi:10.1111/1365-2664.12911.
- Kajimura, H. 1984. Opportunistic feeding of the northern fur seal, *Callorhinus ursinus*, in the eastern North Pacific Ocean and eastern Bering Sea. NOAA Tech. Rep. NMFS-SSRF-779. 49 p.
- 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, and L. Hoek, and M. Rambags. 2013b. Hearing frequency thresholds of a harbour porpoise (*Phocoena phocoena*) temporarily affected by a continuous 1.5-kHz tone. **J. Acoust. Soc. Am.** 134(3):2286-2292.
- Kastelein, R., R. Gransier, and L. Hoek. 2013c. Comparative temporary threshold shifts in a harbour porpoise and harbour seal, and severe shift in a seal. **J. Acoust. Soc. Am.** 134(1):13-16.
- Kastelein, R.A., L. Hoek, R. Gransier, M. Rambags, and N. Clayes. 2014. Effect of level, duration, and inter-pulse interval of 1–2 kHz sonar signal exposures on harbor porpoise hearing. **J. Acoust. Soc. Am.** 136:412-422.
- Kastelein, R.A., R. Gransier, J. Schop, and L. Hoek. 2015a. Effects of exposure to intermittent and continuous 6-7 kHz sonar sweeps on harbor porpoise (*Phocoena phocoena*) hearing. **J. Acoust. Soc. Am.** 137(4):1623-1633.
- Kastelein, R.A., R. Gransier, M.A.T. Marijt, and L. Hoek. 2015b. Hearing frequency thresholds of harbor porpoises (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds. **J. Acoust. Soc. Am.** 137(2):556-564.
- Kastelein, R.A., 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.
- Kastelein, R.A., L. Helder-Hoek, and J.M. Terhune. 2018. Hearing thresholds, for underwater sounds, of harbor seals (*Phoca vitulina*) at the water surface. **J. Acoust. Soc. Am.** 143:2554-2563.
- Kastelein, R.A., L. Helder-Hoek, and R. Gransier. 2019a. Frequency of greatest temporary hearing threshold shift in harbor seals (*Phoca vitulina*) depends on fatiguing sound level. **J. Acoust. Soc. Am.** 145(3):1353-1362.
- Kastelein, R.A., L. Helder-Hoek, R. van Kester, R. Huisman, and R. Gransier. 2019b. Temporary threshold shift in harbor porpoises (*Phocoena phocoena*) due to one-sixth octave noise band at 16 kHz. **Aquatic Mamm.** 45(3):280-292.
- 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. and T. Miyashita, T. 1988. Distribution of sperm whale stocks in the North Pacific. **Sci. Rep. Whales Res. Inst.** 39:31-75.
- 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.
- Kenney, R.D. and H.E. Winn. 1987. Cetacean biomass densities near submarine canyons compared to adjacent shelf/slope areas. **Continental Shelf Res.** 7:107-114.
- Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. North American Fauna 68. U.S. Department of the Interior, Washington, D.C.
- 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.
- Klinck, H., S.L. Nieukirk, D.K. Mellinger, K. Klinck, H. Matsumoto, and R.P. Dziak. 2012. Seasonal presence of cetaceans and ambient noise levels in polar waters of the North Atlantic. **J. Acoust. Soc. Am.** 132(3):EL176-EL181.
- Kok, A.C.M., J.P. Engelberts, R.A. Kastelein, L. Helder-Hoek, S. Van de Voorde, F. Visser, H. Slabbekoom. 2017. Spatial avoidance to experimental increase of intermittent and continuous sound in two captive harbour porpoises. **Env. Poll.** 233:1024-1036.
- Krieger, K.J. and B.L. Wing. 1984. Hydroacoustic surveys and identification of humpback whale forage in Glacier Bay, Stephens Passage, and Frederick Sound, southeastern Alaska, summer 1983. NOAA Tech. Memo. NMFS F/NWC-66. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 60 p. NTIS PB85-183887.
- Krieger, K.J. and B.L. Wing. 1986. Hydroacoustic monitoring of prey to determine humpback whale movements. NOAA Tech. Memo. NMFS F/NWC-98. U.S. Natl. Mar. Fish. Serv., Auke Bay, AK. 63 p. NTIS PB86-204054.
- Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). p. 183-212 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 6: The second book of dolphins and the porpoises. Academic Press, San Diego, CA. 486 p.
- Kujawa, S.G. and M.C. Liberman. 2009. Adding insult to injury: cochlear nerve degeneration after "temporary" noise-induced hearing loss. **J. Neurosci.** 29(45):14077-14085.
- 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. 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.** <http://dx.doi.org/doi:1111/mms.12293>.
- Lang, A.R., J. Calambokidis, J. Scordino, V.L. Pease, A. Klimek, V.N. Burkanov, P. Gearin, D.I. Litovka, K.M. Robertson, B.R. Mate, and J.K. Jacobsen. 2014. Assessment of genetic structure among eastern North Pacific gray whales on their feeding grounds. **Mar. Mamm. Sci.** 30(4):1473-1493.
- Laws, R. 2012. Cetacean hearing-damage zones around a seismic source. p. 473-476 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life. Springer, New York, NY. 695 p.
- Le Boeuf, B., D.P. Costa, A.C. Huntley, G.L. Kooyman, and R.W. Davis. 1986. Pattern and depth of dives in northern elephant seals. **J. Zool. Ser. A** 208:1-7.
- Le Boeuf, B.J., D. Crocker, S. Blackwell, and P. Morris. 1993. Sex differences in diving and foraging behavior of northern elephant seals. *In*: I. Boyd (ed.), Marine mammals: advances in behavioral and population biology. Oxford Univ. Press, London, UK.



- Le Beouf, 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.
- 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.
- Leatherwood, S., A.E. Bowles, and R.R. Reeves. 1983. Aerial surveys of marine mammals in the southeastern Bering Sea. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 42(1986):147-490. OCS Study MMS 86-0056; NTIS PB87-192084.
- LeDuc, R., W.L. Perryman, J.W. Gilpatrick, Jr., C. Stinchcomb, J.V. Carretta, and R.L. Brownell, Jr. 2001. A note on recent surveys for right whales in the southeastern Bering Sea. **J. Cetacean Res. Manage. Spec. Iss.** 2:287-289.
- 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.
- 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.
- 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
- Lowry, M.S., P. Boveng, R.J. DeLong, C.W. Oliver, B.S. Stewart, H.DeAnda, and J. Barlow. 1992. Status of the California sea lion (*Zalophus californianus californianus*) population in 1992. Admin. Rep. LJ-92-32. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA 92038. 34 p.
- Lowry, L.F., K.J. Frost, J.M. Ver Hoef, and R.A. DeLong. 2001. Movements of satellite-tagged subadult and adult harbor seals in Prince William Sound, Alaska. **Mar. Mammal Sci.** 17(4):835-861.
- 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.
- 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.
- MacLean, S.A. and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Gulf of Alaska, August–September 2004. LGL Rep. TA2822-28. Rep. by LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 102 p.
- Malakoff, D. 2002. Suit ties whale deaths to research cruise. **Science** 298(5594):722-723.

- 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. Engelhardt, and R.J. Paterson (eds.), Proc. Worksh. Effects Explos. Mar. Envir., Jan. 1985, Halifax, N.S. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, ON. 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 U.S. Minerals Manage. Serv., 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.
- Maniscalco J.M., K. Wynne, K.W. Pitcher, M.B. Hanson, S.R. Melin, and S. Atkinson. 2004. The occurrence of California sea lions in Alaska. **Aquatic Mamm.** 30:427-433.
- Martins, D.T.L., M.R. Rossi-Santos, and F.J. De Lima 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.** 2016:1-8. 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.
- Mathews, E.A. 1996. Distribution and ecological role of marine mammals (in southeast Alaska). Supplemental Environ. Impact Statem, U.S. EPA, Region 10. 110 p.
- Matos, F. 2015. Distribution of cetaceans in Vestfjorden, Norway, and possible impacts of seismic surveys. M.Sc. Thesis, University of Nordland, Norway. 45 p.
- Matthews, L. 2017. Harbor seal (*Phoca vitulina*) reproductive advertisement behavior and the effects of vessel noise. Ph.D. Thesis, Syracuse University. 139 p.
- McCarthy, E., D. Moretti, L. Thomas, N. DiMarzio, R. Morrissey, S. Jarvis, J. Ward, A. Izzi, and A. Dilley. 2011. Changes in spatial and temporal distribution and vocal behavior of Blainville's beaked whales (*Mesoplodon densirostris*) during multiship exercises with mid-frequency sonar. **Mar. Mamm. Sci.** 27(3):E206-E226.
- 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, Western Australia, for Australian Petrol. Produc. & Explor. Assoc., Sydney, NSW. 188 p.
- McDonald, M.A. and S.E. Moore. 2002. Calls recorded from North Pacific right whales (*Eubalaena japonica*) in the eastern Bering Sea. **J. Cetacean Res. Manage.** 4(3):261-266.
- McDonald, M.A., J.A. Hildebrand, and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the northeast Pacific. **J. Acoust. Soc. Am.** 98(2, Pt.1):712-721.
- McDonald, T.L., W.J. Richardson, K.H. Kim, and S.B. Blackwell. 2010. Distribution of calling bowhead whales exposed to underwater sounds from Northstar and distant seismic surveys, 2009. p. 6-1 to 6-38 *In*: W.J. Richardson (ed.), Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil

- development, Alaskan Beaufort Sea: Comprehensive report for 2005–2009. LGL Rep. P1133-6. Rep. by LGL Alaska Res. Assoc. Inc., Anchorage, AK, Greeneridge Sciences Inc., Santa Barbara, CA, WEST Inc., Cheyenne, WY, and Applied Sociocult. Res., Anchorage, AK, for BP Explor. (Alaska) Inc., Anchorage, AK. 265 p.
- McDonald, T.L., W.J. Richardson, K.H. Kim, S.B. Blackwell, and B. Streever. 2011. Distribution of calling bowhead whales exposed to multiple anthropogenic sound sources and comments on analytical methods. p. 199 *In*: Abstr. 19<sup>th</sup> Bienn. Conf. Biol. Mar. Mamm., 27 Nov.–2 Dec. 2011, Tampa, FL. 344 p.
- McGeady, R., B.J. McMahon, and S. Berrow. 2016. The effects of surveying and environmental variables on deep diving odontocete stranding rates along Ireland's coast. *Proceedings of Meetings on Acoustics* 4ENAL 27(1):040006. 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.
- Mead, J.G. 1989. 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.
- Meier, S.K., S.B. Yazvenko, S.A. Blokhin, P. Wainwright, M.K. Maminov, Y.M. Yakovlev, and M.W. Newcomer. 2007. Distribution and abundance of western gray whales off northeastern Sakhalin Island, Russia, 2001-2003. **Environ. Monit. Assess.** 134(1-3):107-136.
- Melcón, M.L., A.J. Cummins, S.M. Kerosky, L.K. Roche, S.M. Wiggins, and J.A. Hildebrand. 2012. Blue whales respond to anthropogenic noise. **PLoS ONE** 7(2):e32681. doi:10.1371/journal.pone.0032681.
- Mellinger, D.K., K.M. Stafford, and S.E. Moore, L. Munger, and C.G. Fox. 2004a. Detection of North Pacific right whale (*Eubalaena Japonica*) calls in the Gulf of Alaska. **Mar. Mammal Sci.** 20(4):872-879.
- Mellinger, D.K., K.M. Stafford, and C.G. Fox. 2004b. Seasonal occurrence of sperm whale (*Physeter macrocephalus*) sounds in the Gulf of Alaska, 1999–2001. **Mar. Mammal Sci.** 20(1):48-62.
- 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. 631 p.
- Miller, P.J.O., M.P. Johnson, P.T. Madsen, N. Biassoni, M. Quero, and P.L. Tyack. 2009. Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. **Deep-Sea Res.** I 56(7):1168-1181.
- Miyashita, T. 1993. Distribution and abundance of some dolphins taken in the North Pacific driftnet fisheries. **Internat. North Pacific Fish. Comm. Bull.** 53(3):435-449.
- 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. Sptiz, 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. Admin. Report LJ-00-14C. Southwest Fish. Sci. Centre, La Jolla, CA. 26 p.
- Monaco, C., J.M. Ibáñez, F. Carrión, and L.M. Tringali. 2016. Cetacean behavioural responses to noise exposure generated by seismic surveys: how to mitigate better? **Ann. Geophys.** 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. 2001. Aleutian Passes cruise: killer whale component introduction. AFSC Quart. Rep. Available at [http://www.afsc.noaa.gov/Quarterly/amj2001/rptNMML\\_amj01.htm#nmml2](http://www.afsc.noaa.gov/Quarterly/amj2001/rptNMML_amj01.htm#nmml2).
- Moore, J.E. and J.P. Barlow. 2013. Declining abundance of beaked whales (family Ziphiidae) in the California Current large marine ecosystem. **PLoS One** 8(1):e52770.
- Moore, J. and J. Barlow. 2017. Population abundance and trend estimates for beaked whales and sperm whales in the California Current from ship-based visual line-transect survey data, 1991-2014. U.S. Dept. of Commerce, NOAA-National Marine Fisheries Service, La Jolla, CA. NOAA-TM-NMFS-SWFSC-585. 16 p.
- Moore, S. E., J.M. Waite, L.L. Mazzuca, and R.C. Hobbs. 2000. Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. **J. Cetacean Res. Manage.** 2(3):227-234.
- Moore, S.E., J.M. Waite, N.A. Friday, and T. Honkalehto. 2002a. Distribution and comparative estimates of cetacean abundance on the central and south-eastern Bering Sea shelf with observations on bathymetric and prey associations. **Prog. Oceanogr.** 55(1-2):249-262.
- Moore, S.E., W.A. Watkins, M.A. Daher, J.R. Davies, and M.E. Dahlheim. 2002b. 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, 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., 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.
- Moore, S.E., K.M. Wynne, J.C. Kinney, and J.M. Grebmeier. 2007. Gray whale occurrence and forage southeast of Kodiak, Island, Alaska. **Mar. Mammal Sci.** 23(2):419-428.
- Moran, J.R., R.A. Heintz, J.M. Straley, and J.J. Vollenweider. 2018. Regional variation in the intensity of humpback whale predation on Pacific herring in the Gulf of Alaska. **Deep-Sea Research II** 147:187-195.
- 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 <https://doi.org/10.1038/srep41848>.
- Morin, P.A., C.S. Baker, R.S. Brewer, A.M. Burdin, M.L. Dalebout, J.P. Dines, I.D. Fedutin, O.A. Filatova, E. Hoyt, J.-L. Jung, M. Lauf, C.W. Potter, G. Richard, M. Ridgway, K.M. Robertson, and P.R. Wade. 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. No. 182. St. John's, Nfld. 28 p.
- 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.** 29:161-178.
- 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(2):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.
- Munger, L., S. Moore, J. Hildebrand, S. Wiggins, and M. McDonald. 2003. Calls of North Pacific right whales recorded in the southeast Bering Sea. Abstract in the Proceedings of the 2003 Annual Symposium Marine

- Science for the Northeast Pacific: Science for Resource Dependent Communities, Anchorage, AK, January 2002.
- Munger L.M., D.K. Mellinger, S.M. Wiggins, S.E. Moore, and J.A. Hildebrand. 2005. Performance of spectrogram cross-correlation in detecting right whale calls in long-term recordings from the Bering Sea. **Can. Acoust.** 33(2):25-34.
- Munger L.M., S.M. Wiggins, S.E. Moore, and J.A. Hildebrand. 2008. North Pacific right whale (*Eubalaena japonica*) seasonal and diel calling patterns from long-term acoustic recordings in the southeastern Bering Sea, 2000-2006. **Mar. Mammal Sci.** 24(4):795-814.
- Muto, M.M, V. T. Helker, R.P. Angliss, 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. Sheldon, K.L. Sweeney, R.G. Towell, P.R. Wade, J.M. Waite, and A.N. Zerbini. 2019. Alaska marine mammal stock assessments, 2018. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-AFSC-393. 390 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 predict 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. 2018. Four odontocete species change hearing levels when warned of impending loud sound. **Integr. Zool.** 13(2):160-165.
- 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.
- Nerini, M. 1984. A review of gray whale feeding ecology. p. 423-450 In: Jones, M.L., S.I. Swartz, and S. Leatherwood (eds.), The gray whale, *Eschrichtius robustus*. Academic Press, Inc. Orlando, FL. 600 p.
- Neves, B.M., C.D. Preez, and E. Edinger. 2014. Mapping coral and sponge habitats on a shelf-depth environment using multibeam sonar and ROV video observations: Learmonth Bank, northern British Columbia. **Deep-Sea Res. II** 90:169-183.
- 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. **Funct. Ecol.** 27(2):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.
- Nichol, L.M. and J.K.B. Ford. 2012. Information relevant to the assessment of critical habitat for Blue, Fin, Sei and North Pacific Right Whales in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/137. vi + 31 p.
- Nichol, L.M., J.C. Watson, R., Abernethy, E. Rechsteiner, and J. Towers. 2015. Trends in the abundance and distribution of sea otters (*Enhydra lutris*) in British Columbia updated with 2013 survey results. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/039. vii + 31 p.
- Nieukirk, S.L., D.K. Mellinger, S.E. Moore, K. Klinck, R.P. Dziak, and J. Goslin. 2012. Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009. **J. Acoust. Soc. Am.** 131(2):1102-1112.
- NMFS (National Marine Fisheries Service). 1993. Designated critical habitat; Steller sea lion. Final Rule. **Fed. Reg.** 58(165, 27 Aug.):45269-45285.
- NMFS. 1998. Recovery plan for the blue whale (*Balaenoptera musculus*). Prepared by R.R. Reeves, P.J. Clapham, R.L. Brownell, Jr., and G.K. Silber for the Nat. Mar. Fish. Serv., Silver Spring, MD. 42 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. Conservation plan for the Eastern Pacific stock of northern fur seal (*Callorhinus ursinus*). National Marine Fisheries Service, Juneau, AK. 137 p.
- NMFS. 2008. Recovery plan for the Steller Sea Lion (*Eumetopias jubatus*). Revision. Nat. Mar. Fish. Serv., Silver Spring, MD. 325 p.
- NMFS. 2013. Status review of the eastern distinct population segment of Steller sea lion (*Eumetopias jubatus*). Protected Resources Division, Alaska Region, National Marine Fisheries Service, 709 West 9th St, Juneau, Alaska 99802. 144 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. Depart. Commerce, National Oceanic and Atmospheric Administration. 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. Reg.** 81(174, 8 Sept.):62260-62320.
- NMFS. 2016c. Effects of oil and gas activities in the Arctic Ocean: supplemental draft environmental impact statement. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources. Available at <http://www.nmfs.noaa.gov/pr/eis/arctic.htm>.
- NMFS. 2018. 2018 revision to: technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 2.0). Underwater thresholds for onset of permanent and temporary threshold shifts. Office of Protected Resources Nat. Mar. Fish. Serv., Silver Spring, MD. 167 p.
- NMFS. 2019a. Endangered and threatened wildlife and plants: proposed rule to designate critical habitat for the Central America, Mexico, and Western North Pacific Distinct Population Segments of Humpback Whales. **Fed. Reg.** 84(196, 9 Oct.):54354-54391.
- NMFS. 2019b. Takes of marine mammals incidental to specified activities; taking marine mammals incidental to a marine geophysical survey in the Gulf of Alaska. **Fed. Reg.** 84(113, 12 June):27246-27270.
- NMFS. 2019c. Takes of marine mammals incidental to specified activities; taking marine mammals incidental to a marine geophysical survey in the Northeast Pacific Ocean. **Fed. Reg.** 84(140, 2 July):35073-35099.
- NOAA (National Oceanographic and Atmospheric Administration). NOAA. 2004. NOAA scientists sight blue whales in Alaska: critically endangered blue whales rarely seen in Alaska waters. 27 July 2004 News Release. NOAA 2004-R160.
- NOAA. 2019a. Species Directory. Accessed in October 2019 at <https://www.fisheries.noaa.gov/species-directory>.
- NOAA. 2019b. North Pacific Right Whale Critical Habitat. Accessed in September 2019 at <https://www.fisheries.noaa.gov/resource/map/north-pacific-right-whale-critical-habitat-map>.
- NOAA. 2019c. 2019 gray whale unusual mortality event along the west coast. Accessed in September 2019 at <https://www.fisheries.noaa.gov/national/marine-life-distress/2019-gray-whale-unusual-mortality-event-along-west-coast>.
- NOAA. 2019d. Steller sea lion. Accessed October 2019 at <https://www.fisheries.noaa.gov/species/steller-sea-lion>.
- NOAA. 2019e. Active and closed unusual mortality events. Accessed September 2019 at <https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events>
- 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. 41 p.
- NSF and USGS (NSF and U.S. Geological Survey). 2011. Final programmatic environmental impact statement/Overseas environmental impact statement for marine seismic research funded by the National Science Foundation or conducted by the U.S. Geological Survey.
- 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.
- O'Brien, J.M., S. Beck, S.D. Berrow, M. André, M. van der Schaar, I. O'Connor, and E.P. McKeown. 2016. The use of deep water berths and the effect of noise on bottlenose dolphins in the Shannon Estuary cSAC. p. 775-783 *In: The effects of noise on aquatic life II*, Springer, New York, NY. 1292 p.
- O'Connor, A.J. 2013. Distributions and fishery associations of immature short-tailed albatrosses (*Phoebastria albatrus*) in the North Pacific. M.Sc. Thesis, Oregon State University, Corvallis, OR, USA.
- Ohsumi, S. and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. **Rep. Int. Whal. Comm.** 25:114-126.
- Olesiuk, P.F. and M.A. Bigg. 1984. Marine mammals in British Columbia. Accessed October 2019 at <http://www.racerocks.ca/marine-mammals-in-british-columbia/>
- Omura, H. 1986. History of right whale catches in the waters around Japan. **Rep. Int. Whal. Comm. Spec. Iss.** 10:35-41.
- Osborne, R., J. Calambokidis, and E.M. Dorsey. 1988. A Guide to marine mammals of greater Puget Sound. Island Publishers, Anacortes, WA. 191 p.
- 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.
- Pardo, M.A., T. Gerrodette, E. Beier, D. Gendron, K.A. Forney, S.J. Chivers, J. Barlow, and D.M. Palacios. 2015. Inferring cetacean population densities from the absolute dynamic topography of the ocean in a hierarchical Bayesian framework. **PLoS One** 10(3):e0120727. doi:10.1371/journal.pone.0120727.
- 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. 4<sup>th</sup> Int. Conf. Effects of Noise on Aquatic Life, July 2016, Dublin, Ireland.
- Parks Canada. 2016. Multi-species action plan for Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site. Species at Risk Action Plan Series. Parks Canada Agency, Ottawa. 25 p.
- Parsons, K.M., M. Everett, M. Dahlheim, and L. Park. 2018. Water, water everywhere: environmental DNA can unlock population structure in elusive marine species. **R. Soc. Open Sci.** 5:180537. doi:10.1098/rsos.180537.
- 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.
- PNCIMAI (Pacific North Coast Integrated Management Area Initiative). 2011. Atlas of the Pacific North Coast Integrated Management Area. Available at [www.pncima.org](http://www.pncima.org).
- Pelland, N.A., J.T. Sterling, M.A. Lea, N.A. Bond, R.R. Ream, C.M. Lee, and C.C. Eriksen. 2014. Female northern fur seals (*Callorhinus ursinus*) off the Washington (USA) coast: upper ocean variability and links to top predator behavior. **PLoS ONE** 9(8):e101268. doi:10.1371/journal.pone.0101268.
- Peng, C., X. Zhao, and G. Liu. 2015. Noise in the sea and its impacts on marine organisms. **Int. J. Environ. Res. Public Health** (12):12304-12323. doi:10.3390/ijerph121012304.
- Perrin, W.F. 2018. Common dolphin *Delphinus delphis*. p. 205-209 *In*: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), *Encyclopedia of Marine Mammals*, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- Perrin, W.F., S.D. Mallette, and R.L. Brownell Jr. 2018. Minke whales *Balaenoptera acutorostrata* and *B. bonaerensis*. p. 608-613 *In*: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), *Encyclopedia of Marine Mammals*, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- Perry, S.L., D.P. DeMaster, and G.K. Silber. 1999a. The great whales: history and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. **Mar. Fish. Rev.** 61(1):7-23.
- Philbrick, V.A., P.C. Fiedler, L.T. Balance, and D.A. Demer. 2003. Report of ecosystem studies conducted during the 2001 Oregon, California, and Washington (ORCAWALE) marine mammal survey on the research vessel *David Starr Jordan* and *McArthur*. NOAA Tech. Memo. NMFS-SWFSC-349. 50 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, UK., 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. Hüeckstädt, 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. 1979. Biology of the harbor seal (*Phoca vitulina richardsi*) in the Gulf of Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 19(1983):231-310.
- 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. and D.C. McAllister. 1981. Movements and haul out behavior of radio-tagged harbor seals, *Phoca vitulina*. **Can. Field-Nat.** 95:292-297.
- 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.
- Pitcher, K.W., P.F. Olesiuk, R.F. Brown, M.S. Lowry, S.J. Jeffries, J.L. Sease, W.L. Perryman, C.E. Stinchcomb, and L.F. Lowry. 2007. Status and trends in abundance and distribution of the eastern Steller sea lion (*Eumetopias jubatus*) population. **Fish. Bull.** 105(1):102-115.
- 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.
- Punt, A.E. and P.R. Wade. 2009. Population status of the eastern North Pacific stock of gray whales in 2009. **J. Cetacean Res. Manage.** 12(1):15-28.
- Putland, R.L., N.D. Merchant, A. Farcas, and C.A. Radford. 2017. Vessel noise cuts down communication space for vocalizing fish and marine mammals. **Glob. Change Biol.** doi:10.1111/gcb.13996.
- 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.
- Raum-Suryan, K. 2001. Trip report: brand resights of Steller sea lions in southeast Alaska and northern British Columbia from 13 June to 3 July, 2001. Unpub. rep., Alaska Department of Fish and Game, Anchorage, AK.
- Raum-Suryan, K. and K. Pitcher. 2000. Trip report: brand resights of Steller sea lions within southeast Alaska and northern British Columbia from 19 June to 10 July 2000. Unpubl. Rep., Alaska Department of Fish and Game, Anchorage, AK.
- Raum-Suryan, K.L., L.A. Jemison, and K.W. Pitcher. 2009. Lose the loop: entanglements of Steller sea lions (*Eumetopias jubatus*) in marine debris. p. 208-209 *In*: Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Oct. 2009. 306 p.
- 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. Mammal Sci.** 18(3):746-764.
- Ream, R.R., J.T. Sterling, and T.R. Loughlin. 2005. Oceanographic features related to northern fur seal migratory movements. **Deep-Sea Res. II**: 823-843.
- 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. and E. Mitchell. 1993. Status of Baird's beaked whale, *Berardius bairdii*. **Can. Field-Nat.** 107(4):509-523.
- 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., B.S. Stewart, P.J. Clapham, and J.A. Powell. 2002. Guide to marine mammals of the world. Chanticleer Press, New York, NY. 525 p.
- Reichmuth, C., A. Ghoul, A. Rouse, J. Sills, and B. Southall. 2016. Low-frequency temporary threshold shift not measured in spotted or ringed seals exposed to single airgun impulses. **J. Acoust. Soc. Am.** 140(4):2646-2658.
- Reyes, J.C. 1991. The conservation of small cetaceans: a review. Report prepared for the Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP.
- 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. NTIS PB 280 794, U.S. Dept. of Comm.
- 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*: S.H. Ridgway 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, 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.
- Rice, A.C., S. Baumann-Pickering, A. Širović, J.A. Hildebrand, A.M. Brewer, A.J. Debich, S.T. Herbert, B.J. Thayre, J.S. Trickey, and S.M. Wiggins. 2015. Passive acoustic monitoring for marine mammals in the Gulf of Alaska Temporary Maritime Activities Area 2014-2015. Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA. MPL Tech. Memo. 600. 58 p.
- 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 (Abstr.).
- 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.
- Rone, B.K., A.B. Douglas, A.N. Zerbini, L. Morse, A. Martinez, P.J. Clapham, and J. Calambokidis. 2010. Results of the April 2009 Gulf of Alaska Line-Transect Survey (GOALS) in the Navy Training Exercise Area. NOAA Tech. Memo. NMFS-AFSC-209. 39 p.
- Rone, B.K., A.B. Douglas, T.M. Yack, A.N. Zerbini, T.N. Norris, E. Ferguson, and J. Calambokidis. 2014. Report for the Gulf of Alaska Line-transect Survey (GOALS) II: marine mammal occurrence in the Temporary Maritime Activities Area (TMAA). Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Honolulu, Hawaii under Contract No. N62470-10-D-3011, Task Order 0022, issued to HDR Inc., San Diego, Calif. Prepared by Cascadia Research Collective, Olympia, Wash.; Alaska Fish. Sci. Cent., Seattle, Wash.; and Bio-Waves, Inc., Encinitas, Calif.. April 2014. 82 p.
- Rone, B.K., A.N. Zerbini, A.B. Douglas, D.W. Weller, and P.J. Clapham. 2017. Abundance and distribution of cetaceans in the Gulf of Alaska. **Mar. Biol.** 164:23. doi:10.1007/s00227-016-3052-2.
- 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.
- Rosel, P.E., A.E. Dizon, and M.G. Haygood. 1995. Variability of the mitochondrial control region in populations of the harbour porpoise, *Phocoena phocoena*, on inter-oceanic and regional scales. **Can. J. Fish. Aqu. Sci.** 52(6):1210-1219.
- Rotterman, L.M. and T. Simon-Jackson. 1988. Sea otter (*Enhydra lutris*). In J.W. Lentfer (ed.), Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, D.C.
- RPS. 2011. Protected species mitigation and monitoring report, Shillington, Aleutian Islands, 27 June 2011 - 05 August 2011, R/V *Marcus G. Langseth*. Prepared for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY and Nat. Mar. Fish. Serv., Office of Protected Resources, Silver Spring, MD. 76 p.
- RPS. 2014a. Final environmental assessment for seismic reflection scientific research surveys during 2014 and 2015 in support of mapping the U.S. Atlantic seaboard extended continental margin and investigating tsunami hazards. Rep. from RPS for United States Geological Survey, August 2014. Available at <http://www.nsf.gov/geo/oce/envcomp/usgssurveyfinalea2014.pdf>.
- RPS. 2014b. Draft protected species mitigation and monitoring report: U.S. Geological Survey 2-D seismic reflection scientific research survey program: mapping the U.S. Atlantic seaboard extended continental margin and investigating tsunami hazards, in the northwest Atlantic Ocean, Phase 1, 20 August 2014–13 September 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.
- 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.
- Salden, D.R. 1993. Effects of research boat approaches on humpback whale behavior off Maui, Hawaii, 1989–1993. p. 94 In: Abstr. 10<sup>th</sup> Bienn. Conf. Biol. Mar. Mamm., Galveston, TX, Nov. 1993. 130 p.
- Savage, K. 2017. Alaska and British Columbia Large Whale Unusual Mortality Event Summary Report. NOAA Fisheries, Juneau, AK. 42 p.

- 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.
- Scammon, C.M. 1874. The marine mammals of the north-western coast of North America described and illustrated together with an account of the American whale fishery. John H. Carmany and Co., San Francisco, CA. 319 p. [Reprinted in 1968 by Dover Publications, Inc., New York.]
- 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.** 41:467-487.
- Scheffer, V.B. and J.W. Slipp. 1944. The harbor seal in Washington state. **Amer. Midl. Nat.** 33:373-416.
- Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2016. Temporary shift in masking hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. p. 987-991 *In*: A.N. Popper and A. Hawkins (eds.), The effects of noise on aquatic life II. Springer, New York, NY. 1292 p.
- Scholik-Schlomer, A. 2015. Where the decibels hit the water: perspectives on the application of science to real-world underwater noise and marine protected species issues. **Acoustics Today** 11(3):36-44.
- Schramm, Y., S. L. Mesnick, J. De la Rosa, D.M. Palacios, M.S. Lowry, D. Aurióles-Gamboa, H.M. Snell, and S. Escorza-Treviño. 2009. Phylogeography of California and Galápagos sea lions and population structure within the California sea lion. **Mar. Biol.** 156(7):1375-1387.
- 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. doi:10.1121/2.0000311.
- Sears, R. and J. Calambokidis. 2002. Update COSEWIC status report on the blue whale *Balaenoptera musculus* in Canada. p. 1-32 *In*: COSEWIC Assessment and Update Status Report on the Blue Whale *Balaenoptera musculus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON. 32 p.
- Sergeant, D.E. 1977. Stocks of fin whales *Balaenoptera physalus* L. in the North Atlantic Ocean. **Rep. Int. Whal. Comm.** 27:460-473.
- Sidorovskaia, N., B. Ma, A.S. Ackleh, C. Tiemann, G.E. Ioup, and J.W. Ioup. 2014. Acoustic studies of the effects of environmental stresses on marine mammals in large ocean basins. p. 1155 *In*: AGU Fall Meeting Abstracts, Vol. 1.
- Sigler, M.F., C.R. Lunsford, J.M. Straley, and J.B. Liddle. 2008. Sperm whale depredation of sablefish longline gear in the northeast Pacific Ocean. **Mar. Mammal Sci.** 24(1):16-27.
- 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.
- Širović, A., S.C. Johnson, L.K. Roche, L.M. Varga, S.M. Wiggins, and J.A. Hildebrand. 2014. North Pacific right whales (*Eubalaena japonica*) recorded in the northeastern Pacific Ocean in 2013. **Mar. Mammal Sci.** doi:10.1111/mms.12189.
- Small, R.J., L.F. Lowry, J.M. ver Hoef, K.J. Frost, R.A. Delong, and M.J. Rehberg. 2005. Differential movements by harbor seal pups in contrasting Alaska environments. **Mar. Mamm. Sci.** 21(4):671-694.

- 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. Available at [http://www.agriculturedefensecoalition.org/sites/default/files/file/us\\_navy\\_new/271S\\_8\\_2013\\_Independent\\_Scientific\\_Review\\_Panel\\_Contributing\\_Factors\\_Mass\\_Whale\\_Stranding\\_Madagascar\\_September\\_25\\_2013\\_Final\\_Report.pdf](http://www.agriculturedefensecoalition.org/sites/default/files/file/us_navy_new/271S_8_2013_Independent_Scientific_Review_Panel_Contributing_Factors_Mass_Whale_Stranding_Madagascar_September_25_2013_Final_Report.pdf).
- 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.
- Stacey, P.J. and R.W. Baird. 1991. Status of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, in Canada. **Can. Field-Nat.** 105(2):219-232.
- 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. and S.E. Moore. 2005. Atypical calling by a blue whale in the Gulf of Alaska. **J. Acoust. Soc. Am.** 117(5):2724-2727.
- Stafford, K.M., S.L. Niekirk, 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. Niekirk, 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. Progr. Ser.** 395:37-53.
- 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.
- 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: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, London, UK. 362 p.
- Stewart, B.S., B.J. Le Boeuf, 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. Le Boeuf and R.M. Laws (eds.), Elephant seals. Univ. Calif. Press, Los Angeles, CA.
- 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 UK waters. **J. Cetac. Res. Manage.** 8(3):255-263.
- Straley, J.M. 1990. Fall and winter occurrence of humpback whales (*Megaptera novaeangliae*) in southeastern Alaska. pp. 319-323 In: Hammond, P.S., S.A. Mizroch, and G.P. Donovan (eds.), Individual recognition of cetaceans: use of photo-identification and other techniques to estimate population parameters. **Rep. Int. Whal. Comm. Spec. Iss.** 12. Cambridge, U.K. 440 p.
- Straley, J.M. 1994. Seasonal characteristics of humpback whales (*Megaptera novaeangliae*) in southeastern Alaska. M.Sc. thesis, University of Alaska, Fairbanks, AK.

- Straley, J.M., C.M. Gabriele, and C.S. Baker. 1995. Seasonal characteristics of humpback whales (*Megaptera novaeangliae*) in southeastern Alaska. *In*: Engstrom, D.R. (ed.), Proceedings of the Third Glacier Bay Science Symposium, 1993. National Park Service, Anchorage, AK.
- Straley, J., V. O'Connell, L. Behnken, A. Thode, S. Mesnick, and J. Liddle. 2005. Using longline fishing vessels as research platforms to assess the population structure, acoustic behavior and feeding ecology of sperm whales in the Gulf of Alaska. Abstr. 16<sup>th</sup> Bienn. Conf. Biol. Mar. Mamm., 12–16 Dec. 2005, San Diego, CA.
- Straley, J.M., J.R. Moran, K.M. Boswell, J.J. Vollenweider, R.A. Heintz, T.J. Quinn II, B.H. Witteveen, and S.D. Rice. 2018. Seasonal presence and potential influence of humpback whales on wintering Pacific herring populations in the Gulf of Alaska. **Deep-Sea Research Part II** 147:173-186.
- 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.
- Sweeney, K., L. Fritz, R. Towell, and T. Gelatt. 2017. Results of Steller sea lion surveys in Alaska, June-July 2017. Accessed in November 2019 at <https://www.fisheries.noaa.gov/resource/data/2017-results-steller-sea-lion-surveys-alaska>
- 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 22<sup>nd</sup> Biennial Conference on the Biology of Marine Mammals, 22-27 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 2015, 28-30 January 2015.
- 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. 2013. Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. **Proc. Royal Soc. B** 280: 20132001.
- Tinker, M.T., V.A. Gill, G.G. Esslinger, J. Bodkin, M. Monk, M. Mangel, D.H. Monson, W.W. Raymond, and M.L. Kissling. 2019. Trends and carrying capacity of sea otters in Southeast Alaska. **J. Wildl. Manage.** 83(5):1073-1089.
- 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. doi: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*: H. Brumm (ed.), Animal communication and noise. Springer, Berlin, Heidelberg, Germany. 453 p.

- Tyack, P.L. and L. Thomas. 2019. Using dose-response functions to improve calculations of the impact of anthropogenic noise. **Aquatic Conserv. Mar. Freshw. Ecosyst.** 29(S1):242-253.
- Tynan, C.T., D.P. DeMaster, and W.T. Peterson. 2001. Endangered right whales on the southeastern Bering Sea shelf. **Science** 294(5548):1894.
- UNEP-WCMC (United Nations Environment Programme-World Conservation Monitoring Centre). 2017. Convention on International Trade in Endangered Species of Wild Flora and Fauna. Appendices I, II, and III. Accessed in November 2019 at <https://www.cites.org/eng/app/appendices.php>
- Urbán, R.J., A. Jaramillo L., A. Aguayo L., P. Ladrón de Guevara P., M. Salinas Z., C. Alvarez F., L. Medrano G., J.K. Jacobsen, K.C. Balcomb, D.E. Claridge, J. Calambokidis, G.H. Steiger, J.M. Straley, O. von Ziegesar, J.M. Waite, S. Mizroch, M.E. Dahlheim, J.D. Darling, and C.S. Baker. 2000. Migratory destinations of humpback whales wintering in the Mexican Pacific. **J. Cetac. Res. Manage.** 2(2):101-110.
- USFWS (U.S. Fish and Wildlife Service). 2014. Northern sea otter (*Enhydra lutris kenyoni*): Southeast Alaska Stock. Accessed November 2019 at [https://www.fws.gov/r7/fisheries/mmm/stock/Revised\\_April\\_2014\\_Southeast\\_Alaska\\_Sea\\_Otter\\_SAR.pdf](https://www.fws.gov/r7/fisheries/mmm/stock/Revised_April_2014_Southeast_Alaska_Sea_Otter_SAR.pdf).
- 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.
- Varghese, H.K., J. Miksis-Olds, E. Linder, L. Mayer, D. Moretti, and N. DiMarzio. 2019. Effect of multibeam mapping activity on beaked whale foraging in southern California. Poster presented at the 2019 Effects of Noise on Aquatic Life conference, Den Haag, The Netherlands, July 7-12, 2019.
- 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(1):512-520.
- Waite, J. 2003. Cetacean assessment and ecology program: Cetacean survey. Quarterly report. Accessed in November 2019 at <http://www.afsc.noaa.gov/Quarterly/jas2003/divrptsNMML2.htm>.
- Wade, 2017. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas revision of estimates in SC/66b/IA21. Paper SC/A17/NP10 presented to the International Whaling Commission.
- 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. 2011a. The world's smallest whale population. **Biol. Lett.** 7:83-85.
- Wade, P.R., A. De Robertis, K.R. Hough, R. Booth, A. Kennedy, R.G. LeDuc, L. Munger, J. Napp, K.E.W. Shelden, S. Rankin, O. Vasquez, and C. Wilson. 2011b. Rare detections of North Pacific right whales in the Gulf of Alaska, with observations of their potential prey. **Endang. Spec. Res.** 13(2):99-109.
- Waite, J.M., K. Wynne, and D.K. Mellinger. 2003. Documented sighting of a North Pacific right whale in the Gulf of Alaska and post-sighting acoustic monitoring. **Northw. Nat.** 84:38-43.
- 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. 2013b. Noise negatively affects foraging and antipredator behaviour in shore crabs. **Anim. Behav.** 86:111-118.
- 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, UK. 17 p.
- Weilgart, L. 2017. Din of the deep: noise in the ocean and its impacts on cetaceans. Pages 111-124 *In*: A. Butterworth (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.
- Weise, M. J., D. P. Costa, and R. M. Kudela. 2006. Movement and diving behavior of male California sea lion (*Zalophus californianus*) during anomalous oceanographic conditions of 2005 compared to those of 2004. **Geophys. Res. Lett.** 33, L22S10. doi:10.1029/2006GL027113.
- Weller, D.W., Y.V. Ivashchenko, G.A. Tsidulko, A.M. Burdin, and R.L. Brownell, Jr. 2002. Influence of seismic surveys on western gray whales off Sakhalin Island, Russia in 2001. Paper SC/54/BRG14, IWC, Western Gray Whale Working Group Meet., 22-25 Oct., Ulsan, South Korea. 12 p.
- Weller, D.W., S.H. Rickards, A.L. Bradford, A.M. Burdin, and R.L. Brownell, Jr. 2006a. The influence of 1997 seismic surveys on the behavior of western gray whales off Sakhalin Island, Russia. Paper SC/58/E4 presented to the IWC Scient. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.
- Weller, D.W., G.A. Tsidulko, Y.V. Ivashchenko, A.M. Burdin and R.L. Brownell Jr. 2006b. A re-evaluation of the influence of 2001 seismic surveys on western gray whales off Sakhalin Island, Russia. Paper SC/58/E5 presented to the IWC Scient. Commit., IWC Annu. Meet., 1-13 June, St. Kitts.
- Weller, D.W., A. Klimck, 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., S. Bettridge, R.L. Brownell Jr., J.L. Laake, J.E. Moore, P.E. Rosel, B.L. Taylor, and P.R. Wade. 2013. Report of the national Marine Fisheries Service Gray Whale Stock Identification Workshop. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-507.
- 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. Kvadsheim, P.L. Tyack, and P.J.O. Miller. 2015. How effectively do horizontal and vertical response strategies of long-finned pilot whales reduce sound exposure from naval sonar? **Mar. Environ. Res.** 106:68-81.
- Whitehead, H. 2018. Sperm whale *Physeter macrocephalus*. p. 919-925 *In*: B. Würsig, J.G.M. Thewissen, and K.M. Kovacs (eds.), Encyclopedia of Marine Mammals, 3<sup>rd</sup> ed. Academic Press/Elsevier, San Diego, CA. 1157 p.
- 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. Mammal Sci.** 32(4):1501-1509.
- Williams, R. and L. Thomas. 2007. Distribution and abundance of marine mammals in the coastal waters of British Columbia, Canada. **J. Cet. Res. Manage.** 9(1):15-28.
- 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, 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/j.pone.0054086.
- Willis, P.M. and R.W. Baird. 1998. Sightings and strandings of beaked whales on the west coast of Canada. **Aquatic Mamm.** 24(1):21-25.
- 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, UK. 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.
- Wolfe, R.J., J. Bryant, L. Hutchinson-Scarborough, M. Kookesh, and L.A. Sill. 2013. The subsistence harvest of harbor seals and sea lions in Southeast Alaska in 2012. Tech. Pap. No. 383. Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK.
- 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, ON.
- 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. doi:10.1016/j.marpolbul.2015.08.045.
- Wright, A.J. and L.A. Kyhn. 2014. Practical management of cumulative anthropogenic impacts for working marine examples. **Conserv. Biol.** 29(2):333-340. doi:10.1111/cobi.12425.
- 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.
- 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. doi:10.1007/s10661-007-9809-9.
- 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. doi:10.1007/s10661-007-9810-3.

- Yochem, P.K. and S. Leatherwood. 1985. Blue whale. p. 193-240 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of marine mammals, Vol. 3: The sirenians and baleen whales. Academic Press, New York, NY. 362 p.
- Yoder, J.A. 2002. Declaration of James A. Yoder in opposition to plaintiff's motion for temporary restraining order, 28 October 2002. Civ. No. 02-05065-JL. U.S. District Court, Northern District of California, San Francisco Division.
- Yurk, H., L. Barrett Lennard, J.K.B. Ford, and C.O. Matkin. 2002. Cultural transmission within maternal lineages: vocal clans in resident killer whales in southern Alaska. **Anim. Behav.** 63:1103-1119.
- Zerbini, A.N., P.R. Wade and J.M. Waite. 2004. Summer abundance and distribution of cetaceans in coastal waters of the western Gulf of Alaska and the eastern and central Aleutian Islands. p. 179 *In*: Abstract Book ASLO/TOS 2004 Ocean Research Conference. Honolulu, 15-20 Feb. 2004.
- Zerbini, A.N., J.M. Waite, J.L. Laake, and P.R. Wade. 2006. Abundance, trends and distribution of baleen whales off Western Alaska and the central Aleutian Islands. **Deep Sea Res. I** 53(11):1772-1790.
- Zerbini, A.N., A.S. Kennedy, B.K. Rone, C. Berchok, P.J. Clapham, and S.E. Moore. 2009. Occurrence of the critically endangered North Pacific right whale (*Eubalaena japonica*) in the Bering Sea. p. 285-286 *In*: Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Canada, Oct. 2009. 306 p.
- Zerbini, A.N., A. Andriolo, M.-P. Heide-Jørgensen, S.C. Moreira, J.L. Pizzorno, Y.G. Maia, G.R. VanBlaricom, and D.P. DeMaster. 2011. Migration and summer destinations of humpback whale (*Megaptera novaeangliae*) in the western South Atlantic Ocean. **J. Cetac. Res. Manage. (Spec. Iss.)** 3:113-118.

## **LIST OF APPENDICES**

**APPENDIX A: DETERMINATION OF MITIGATION ZONES**

**APPENDIX B: MARINE MAMMAL DENSITIES**

**APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS**

**APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS**

## APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on both modeling by L-DEO for the Level A and Level B (160 dB re 1 $\mu$ Pa<sub>rms</sub>) thresholds and using empirical measurements from Crone et al. (2014) from the Cascadia Margin. 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-in<sup>3</sup> airgun, which would be used during power downs for sea turtles and ESA-listed diving seabirds; all models used a 12-m tow depth. The L-DEO modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

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

In deep and intermediate-water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) can be scaled for the single airgun at a tow depth of 6 m to derive mitigation radii.

L-DEO collected a multichannel seismic (MCS) data set from R/V *Langseth* on an 8 km streamer in 2012 on the shelf of the Cascadia Margin in water up to 200 m deep that allowed Crone et al. (2014) to analyze the hydrophone streamer (>1100 individual shots). These empirical data were then analyzed to determine in situ sound levels for shallow and upper intermediate water depths to provide mitigation radii.

This analysis is summarized in the Addendum at the end of this Appendix. Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels<sup>1</sup> have confirmed that the L-DEO model generated conservative threshold distances, resulting in significantly larger mitigation zones than required by National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service (NMFS).

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; Table A-1). The radii for the shallow and intermediate water depths are taken from the empirical data from Crone et al. (2014) and corrected for tow depth (i.e., multiplied by 1.15; see Addendum). Similarly, 175 dB<sub>RMS</sub> distances have been determined using the same methodology and are provided in Table A-1.

Measurements have not been reported for the single 40-in<sup>3</sup> airgun. L-DEO model results are used to determine the 160-dB<sub>rms</sub> radius for the 40-in<sup>3</sup> airgun at a 9-m tow depth in deep water (Fig. A-2). For intermediate-water depths, a correction factor of 1.5 was applied to the deep-water model results. For shallow water, a scaling of the GoM field measurements (Fig. A-3) obtained for the 36-airgun array was used. The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS). The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in tow depth between the calibration survey (6 m) and the proposed survey (12 m); whereas the shallow water in the GoM may not exactly replicate the shallow water environment at the proposed survey site, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths determined by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array.

The 150-dB SEL level corresponds to a deep-water radius of 431 m for the 40-in<sup>3</sup> airgun at 12-m tow depth (Fig. A-2) and 7244 for the 36-airgun array at 6-m tow depth (Fig. A-3), yielding a scaling factor of 0.0595. Similarly, the 165-dB SEL level corresponds to a deep-water radius of 77 m for the 40-in<sup>3</sup> airgun at 12-m tow depth (Fig. A-2) and 1284 m for the 36-airgun array at 6-m tow depth (Fig. A-3), yielding a scaling factor of 0.060. The 185-dB SEL level corresponds to a deep-water radius of 7.5 m for the 40-in<sup>3</sup> airgun at 12-m tow depth (Fig. A-2) and 126.3 m for the 36-airgun array at 6-m tow depth (Fig. A-3), yielding a scaling factor of 0.0594. Measured 160- and 175-dB re 1μPa<sub>rms</sub> distances in shallow water for the 36-airgun array towed at 6-m depth were 17.5 km and 2.8 km, respectively, based on a 95<sup>th</sup> percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the difference in array sizes and tow depths yields distances of 1041 m and 170 m, respectively.

---

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

TABLE A-3. Level B. Predicted distances to which sound levels  $\geq 160$ -dB and  $\geq 175$ -dB re 1  $\mu\text{Pa}_{\text{rms}}$  could be received during the proposed surveys in the Northeast Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Single Bolt airgun, 40 in <sup>3</sup>	12	>1000 m	431 <sup>1</sup>	77 <sup>1*</sup>
		100–1000 m	647 <sup>2</sup>	116 <sup>2</sup>
		<100 m	1,041 <sup>3</sup>	170 <sup>3</sup>
4 strings, 36 airguns, 6600 in <sup>3</sup>	12	>1000 m	6,733 <sup>1</sup>	1,864 <sup>1</sup>
		100–1000 m	9,468 <sup>4</sup>	2,542 <sup>4</sup>
		<100 m	12,650 <sup>4</sup>	3,924 <sup>4</sup>

<sup>1</sup> Distance is based on L-DEO model results.

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

<sup>3</sup> Distance is based on empirically derived measurements in the GOM with scaling applied to account for differences in tow depth.

<sup>4</sup> Based on empirical data from Crone et al. (2014).

\* An EZ of 100 m would be used as the shut-down distance for sea turtles in all water depths.

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

The  $\text{SEL}_{\text{cum}}$  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).

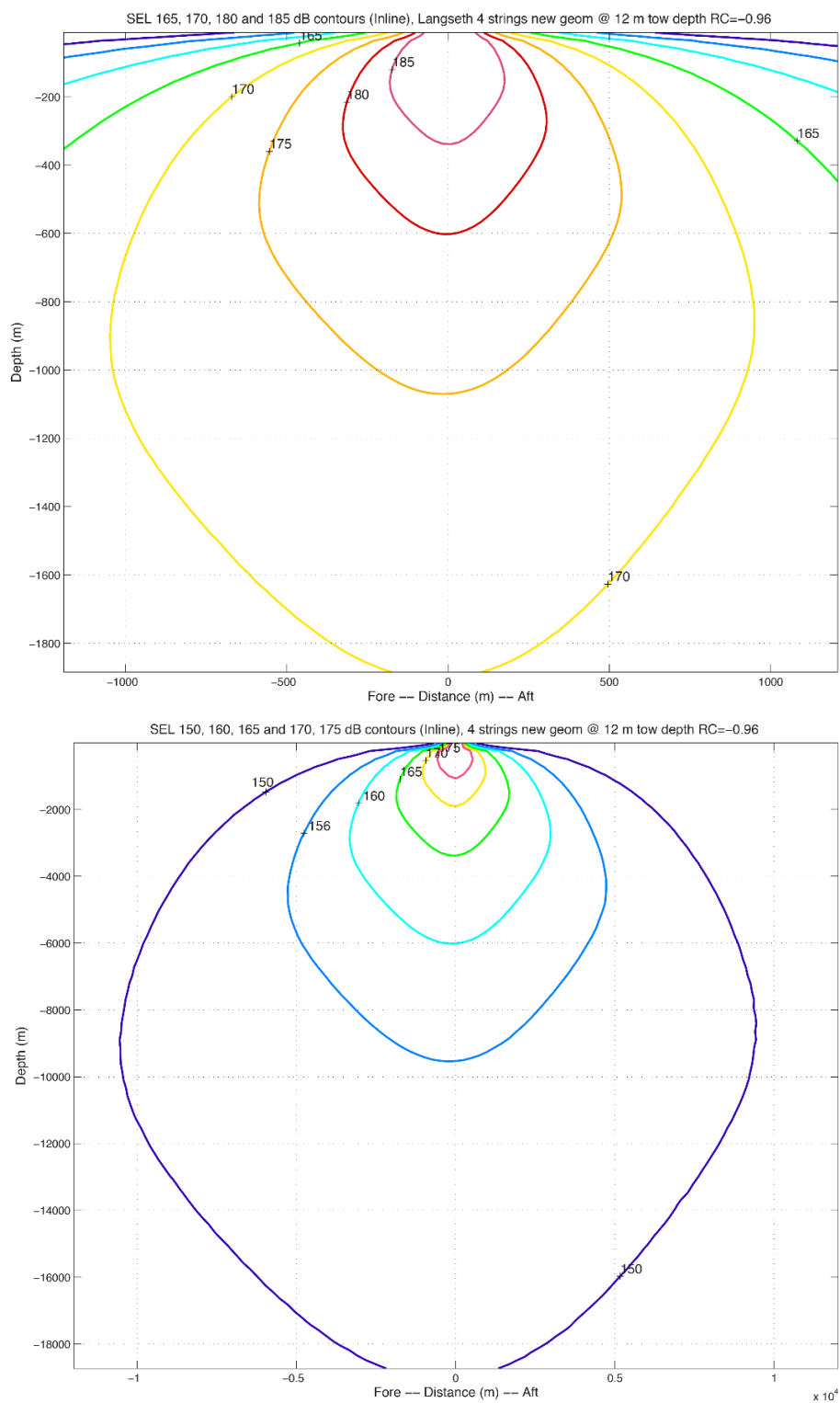


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth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

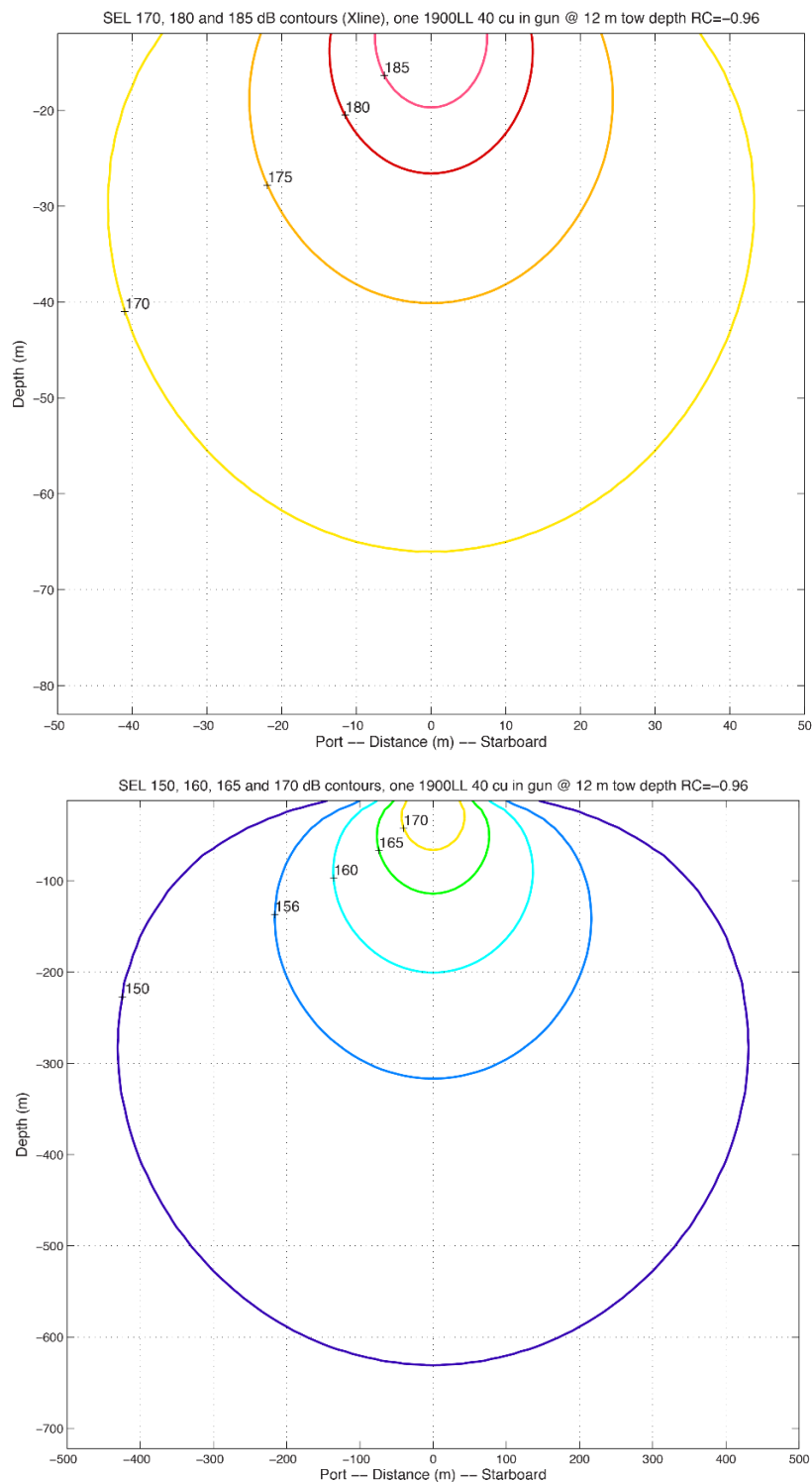


FIGURE A-2. Modeled deep-water received SELs from a single 40-in<sup>3</sup> airgun towed at a 12-m depth, which is planned for use as a mitigation airgun during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to 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.



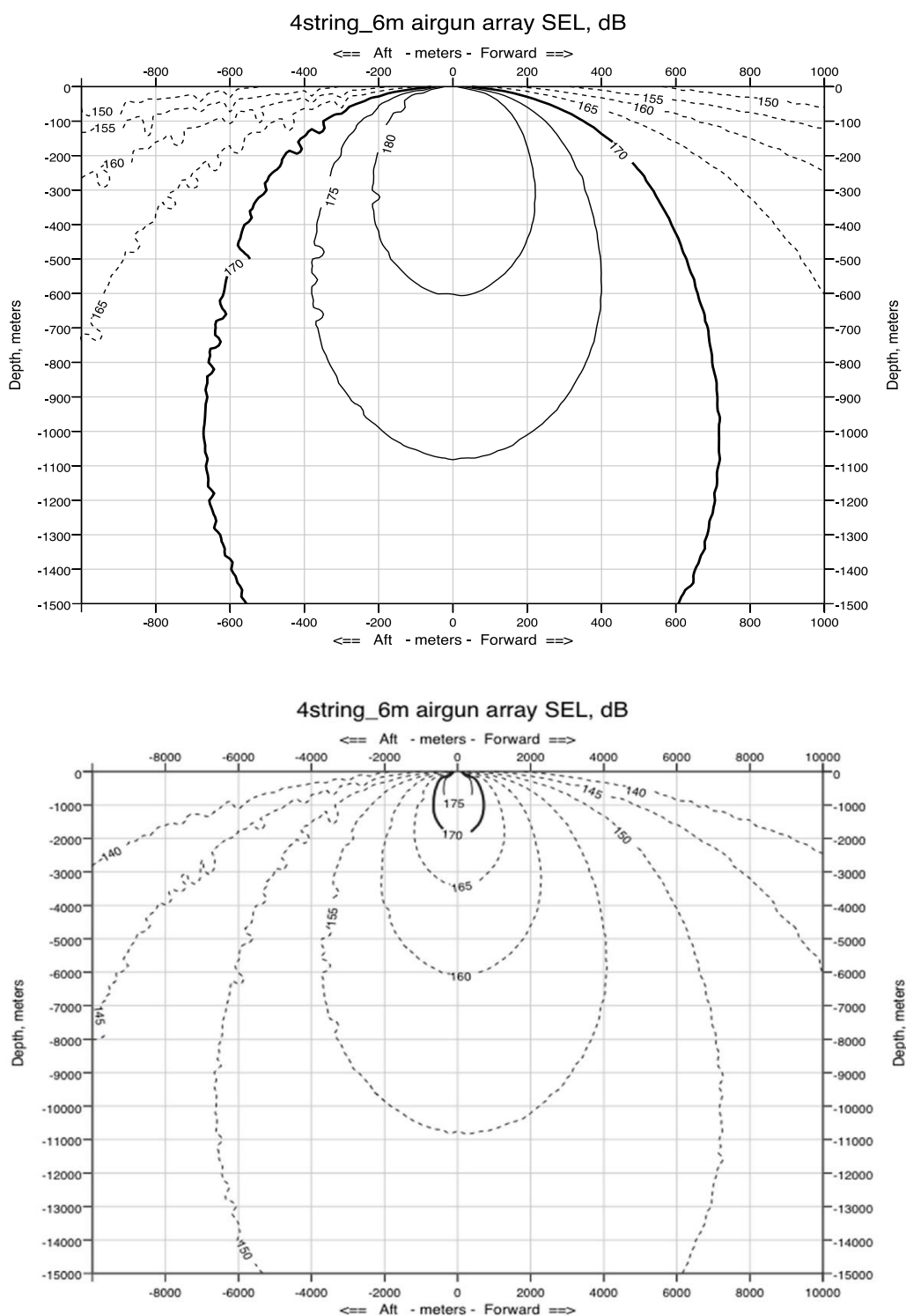


Figure A-3. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

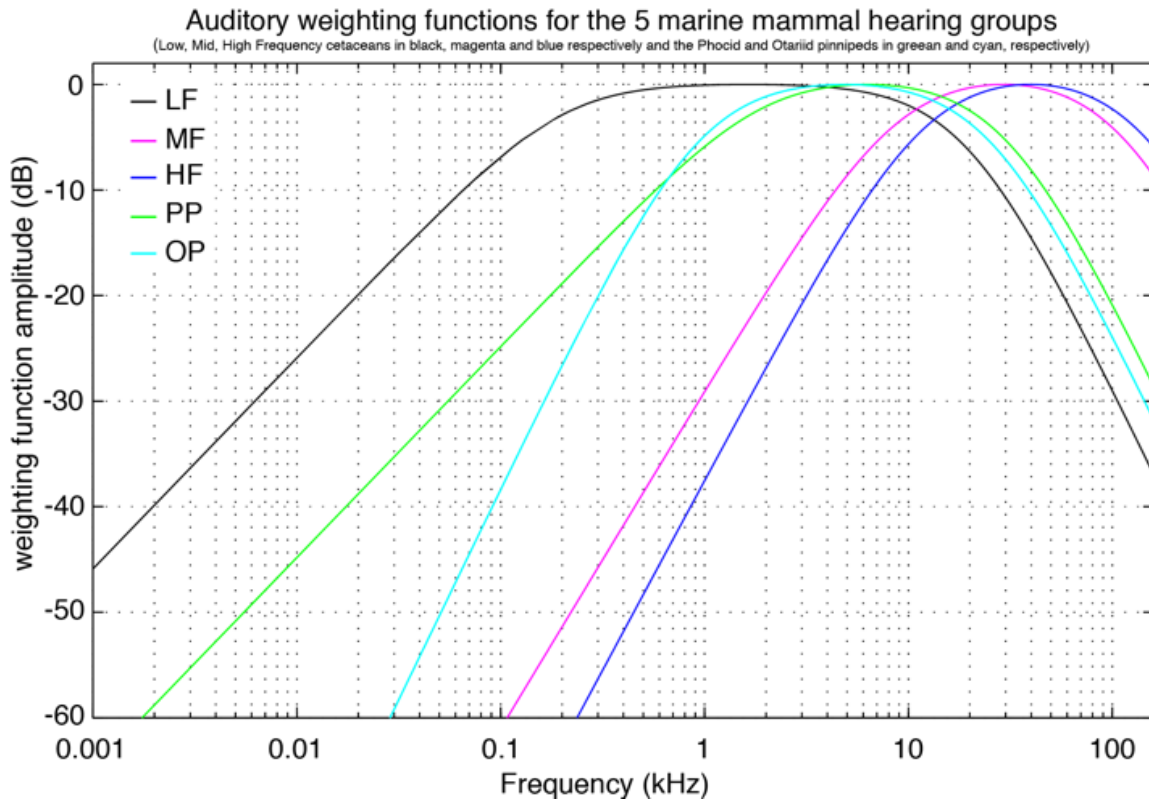


FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance.

Near the source (at short ranges, distances  $<1$  km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of  $SEL_{cum}$  isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics

(source velocity and duty) after Sivle et al. (2014). A source velocity of 2.2 m/s and a 1/Repetition rate of 23.1 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL<sub>cum</sub> PTS thresholds (Level A) for the 36-airgun array and the single 40-in<sup>3</sup> mitigation airgun.

For the LF cetaceans, we estimated an adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL<sub>cum</sub> 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 and assumes a propagation of  $20\log_{10}(\text{Radial distance})$ . The radial distances are used to calculate the modified farfield values, whereas the radius is the vertical projection to the sea surface and distance from the source laterally, which is used for mitigation purposes.

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<sub>cum</sub>, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-5 shows the impact of weighting functions by hearing group. Figures A-6–A-8 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-9 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

TABLE A-2. Results for modified farfield SEL source level modeling for the 36-airgun array with and without applying weighting functions to the five marine mammal hearing groups and sea turtles. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL<sub>cum</sub> threshold is the largest. A propagation of  $20 \log_{10}$  (Radial distance) is used to estimate the modified farfield SEL.

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

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

TABLE A-3. Results for modified farfield SEL source level modeling for the 36-airgun array with weighting function calculations for the SEL<sub>cum</sub> criteria, as well as resulting isopleths to thresholds for hearing groups.

STEP 1: GENERAL PROJECT INFORMATION							
PROJECT TITLE							
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. Source velocity of 4.2 knots					
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) <sup>†</sup>		NA					
<sup>†</sup> Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab		Override WFA: Using LDEO modeling					
		<sup>‡</sup> If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.					
* BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)							
STEP 3: SOURCE-SPECIFIC INFORMATION							
NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both)							
NOTE: LDEO modeling relies on Method F2							
F2: ALTERNATIVE METHOD <sup>†</sup> TO CALCULATE PK and SEL <sub>cum</sub> (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)							
SEL <sub>cum</sub>							
Source Velocity (meters/second)		2.16067					
		4.2 knots					
1/Repetition rate <sup>^</sup> (seconds)		23.14097016					
		50m/2.16067					
<sup>†</sup> Methodology assumes propagation of 20 log R; Activity duration (time) independent							
<sup>^</sup> Time between onset of successive pulses.							
Modified farfield SEL		232.9819	232.8352	233.0978	232.8352	232.079	231.9945
Source Factor		8.58635E+21	8.30115E+21	8.81888E+21	8.30115E+21	6.97459E+21	6.84019E+21
RESULTANT ISOPLETHS*							
* Impulsive sounds have dual metric thresholds (SEL <sub>cum</sub> & PK). Metric producing largest isopleth should be used.							
Hearing Group		Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
SEL <sub>cum</sub> Threshold		183	185	155	185	203	204
PTS SEL <sub>cum</sub> Isopleth to threshold (meters)		320.2	0.0	1.0	10.4	0.0	15.4
WEIGHTING FUNCTION CALCULATIONS							
Weighting Function Parameters		Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
a		1	1.6	1.8	1	2	1.4
b		2	2	2	2	2	2
f <sub>1</sub>		0.2	8.8	12	1.9	0.94	0.077
f <sub>2</sub>		19	110	140	30	25	0.44
c		0.13	1.2	1.36	0.75	0.64	2.35
Adjustment (dB) <sup>†</sup>		-12.91	-56.70	-66.07	-25.65	-32.62	-4.11
							OVERRIDE Using LDEO Modeling

<sup>†</sup>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, pinnipeds, and sea turtles, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-5).

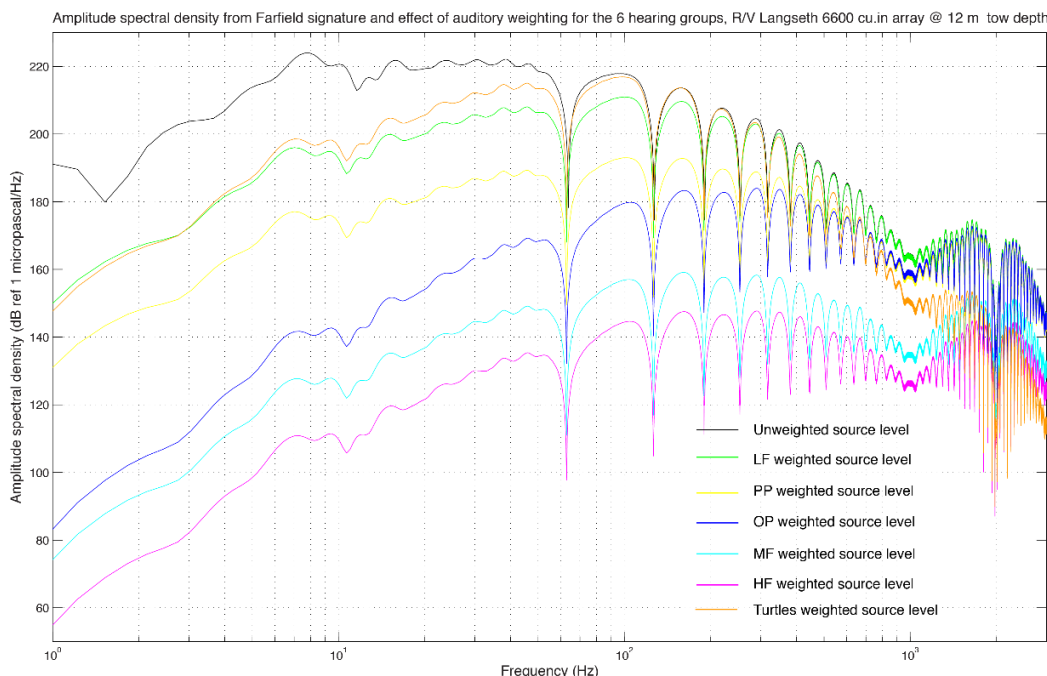


FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), Otariid Pinnipeds (OP), and Sea Turtles. Modeled spectral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

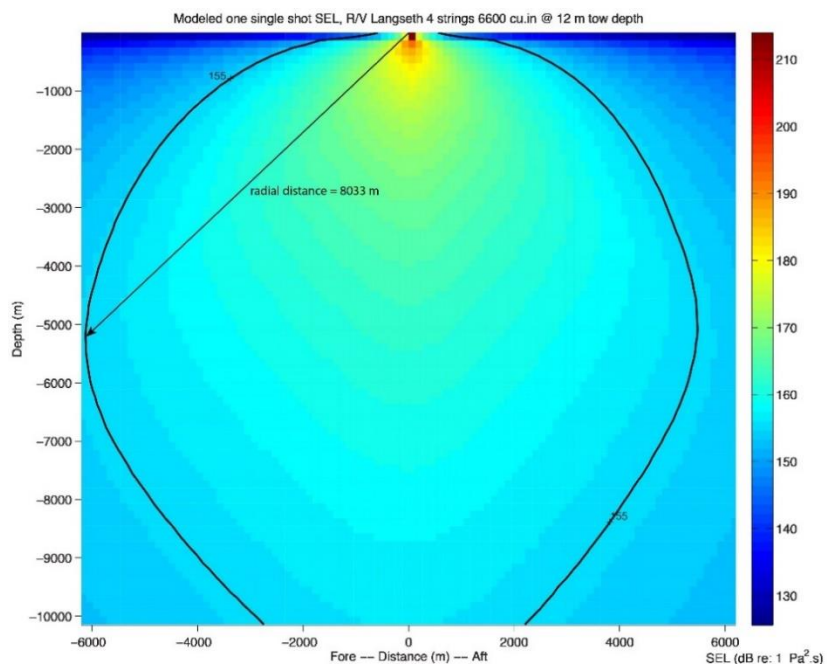


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of 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

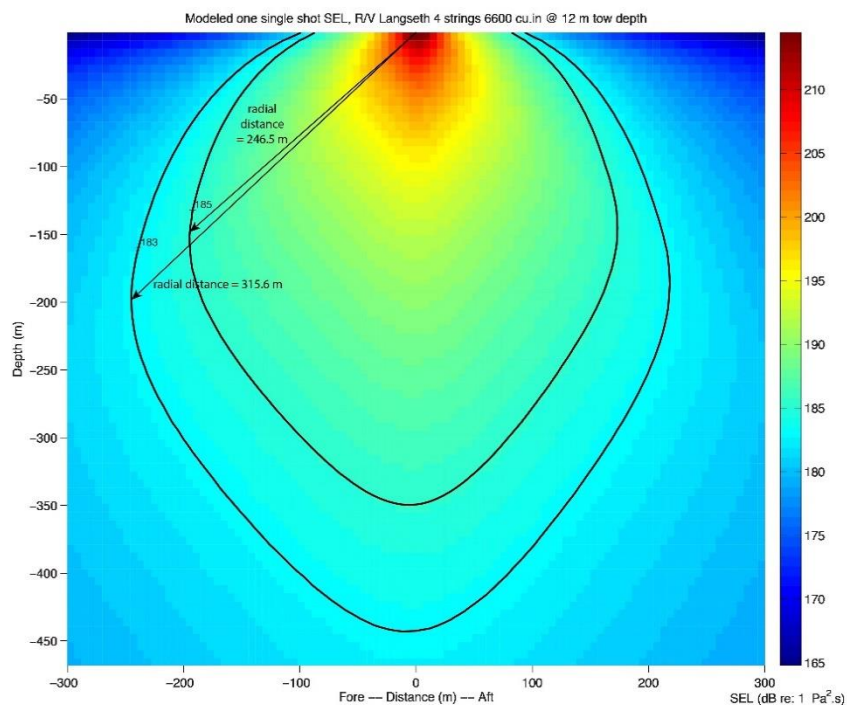


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

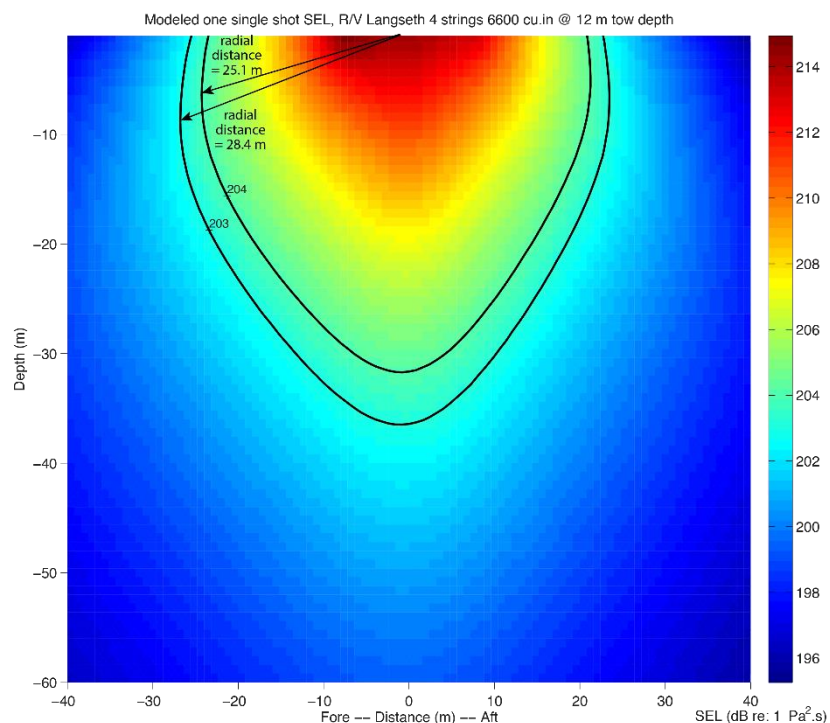


FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB and 204-dB SEL isopleth (28.4 m and 25.1 m, respectively).



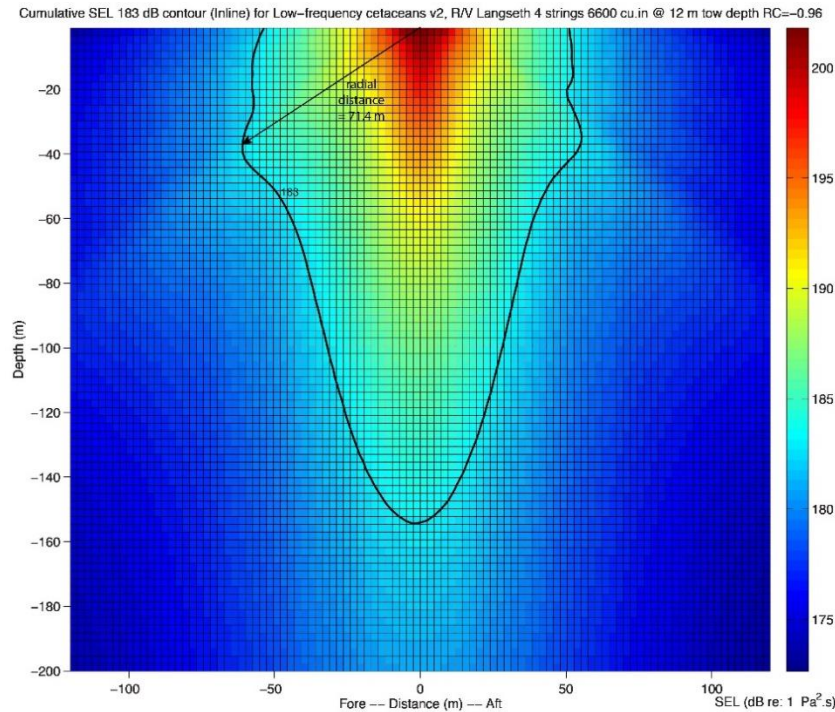


FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL<sub>cum</sub> isopleth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

The thresholds for Peak SPL<sub>flat</sub> for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-10–A-12 show the modeled received sound levels to the Peak SPL<sub>flat</sub> thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

For the single 40 in<sup>3</sup> mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-6. The weighting function calculations, thresholds for SEL<sub>cum</sub>, and the distances to the PTS thresholds for the 40 in<sup>3</sup> airgun are shown in Table A-7. Figure A-13 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-14–A-15 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-16 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL<sub>flat</sub> for the 40 in<sup>3</sup> airgun, as well as the distances to the PTS thresholds, are shown in Table A-8. Figures A-17–A-18 show the modeled received sound levels to the Peak SPL<sub>flat</sub> thresholds, for a single shot.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL<sub>flat</sub>) 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 Northeast 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	13.57	364.67	51.59	10.62
Modified Farfield Peak SPL	252.06	252.65	253.24	252.25	252.52
PTS Peak Isoleth (Radius) to Threshold (m)	38.9	13.6	268.3	43.7	10.6

N.A. means not applicable or not available.

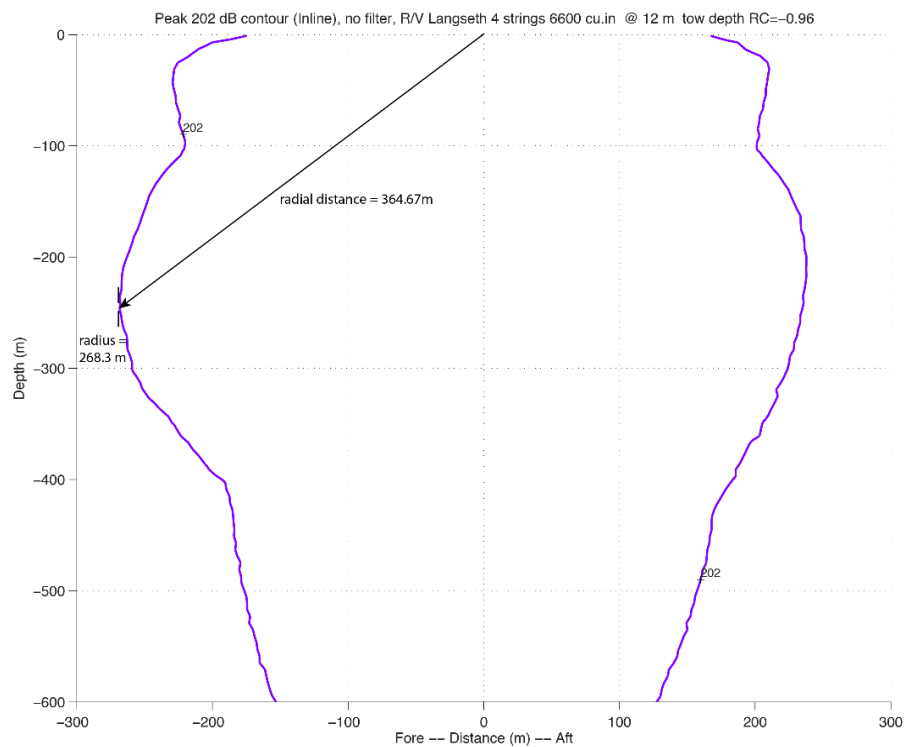


FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.



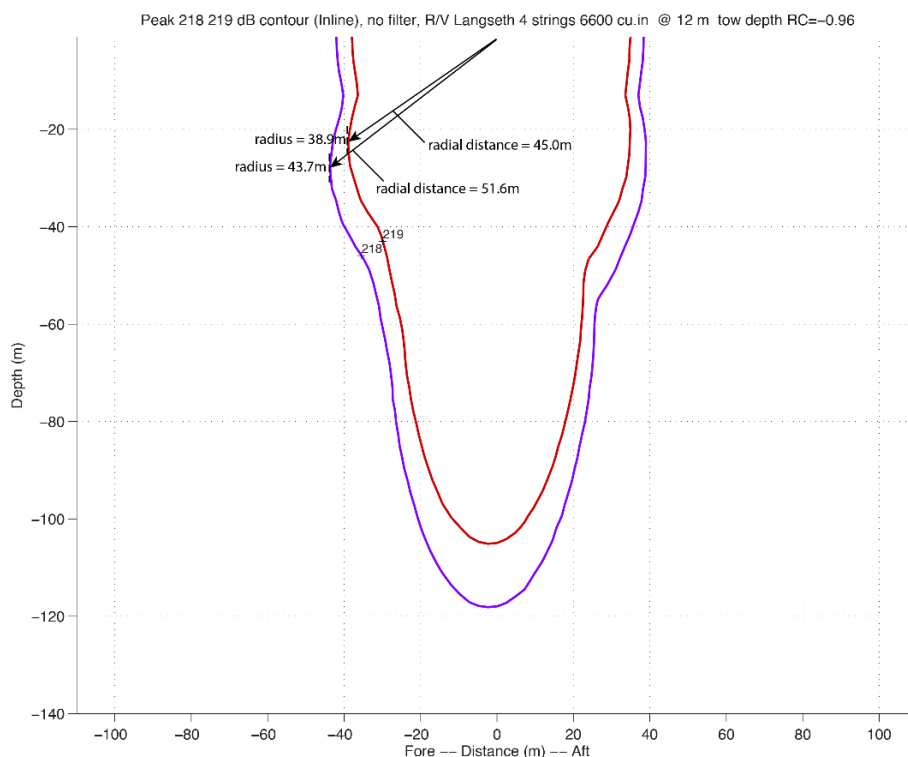


FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

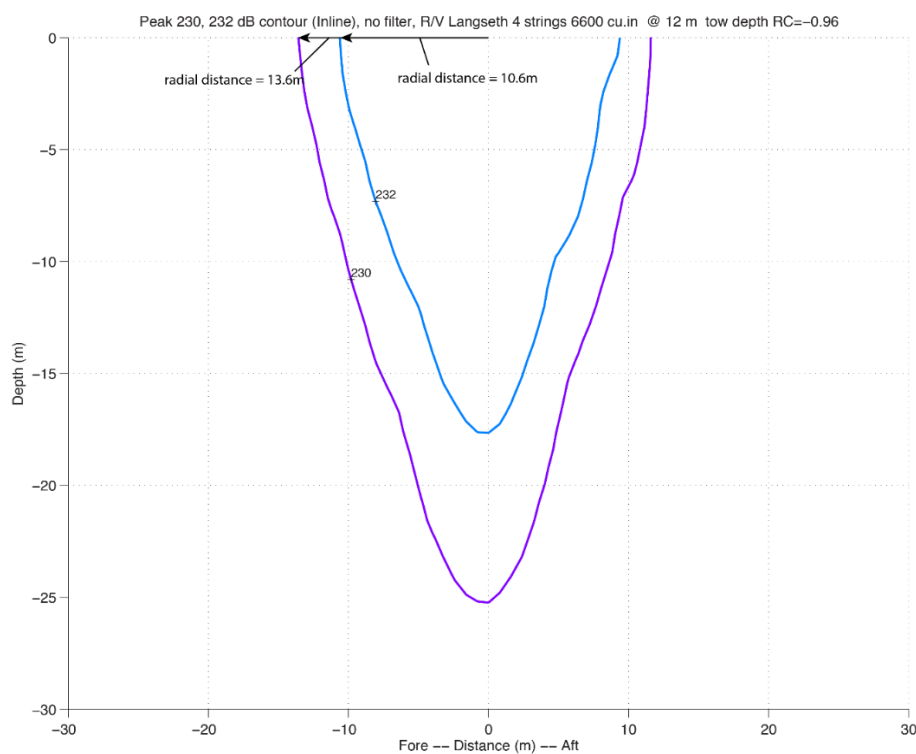


FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

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

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

TABLE A-6. Results for modified farfield SEL source level modeling for the 40 in<sup>3</sup> airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the  $SEL_{cum}$  threshold is the largest. A propagation of  $20 \log_{10}$  (Radial distance) is used to estimate the modified farfield SEL.

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

N.A. means not applicable or not available.

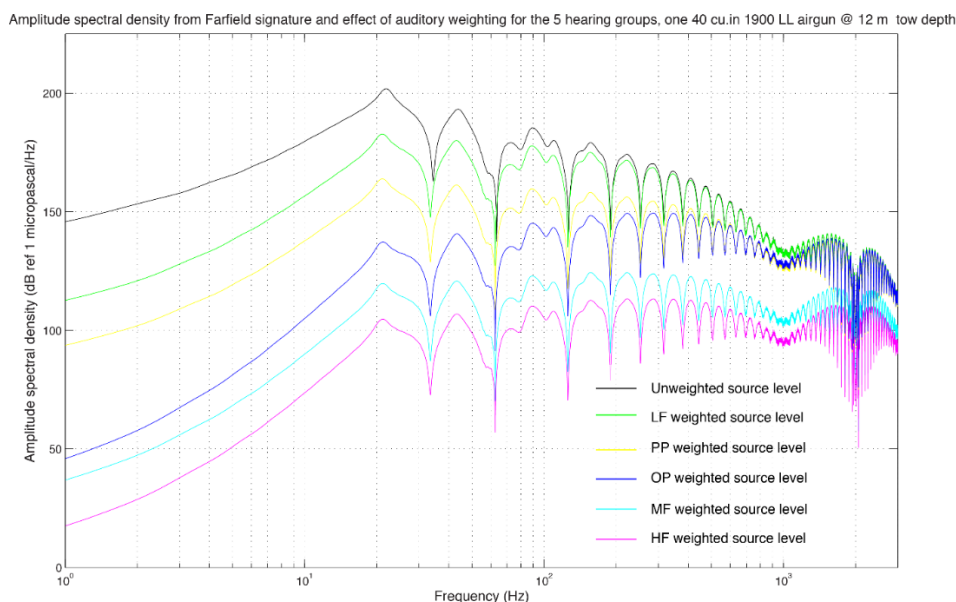


FIGURE A-13. Modeled amplitude spectral density of the 40-in<sup>3</sup> airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral 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 modified farfield SEL source level modeling for the single 40-in<sup>3</sup> mitigation airgun with weighting function calculations for the SEL<sub>cum</sub> criteria, as well as resulting isopleths to thresholds for various marine mammal 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 - speed of 4.2 knots and shot interval of 50 m					
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) <sup>†</sup>	NA					
Override WFA: Using LDEO modeling						
<sup>†</sup> Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab <sup>‡</sup> If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.						
* BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)						
STEP 3: SOURCE-SPECIFIC INFORMATION						
NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both)						
NOTE: LDEO modeling relies on Method F2						
F2: ALTERNATIVE METHOD <sup>‡</sup> TO CALCULATE PK and SEL <sub>cum</sub> (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)						
SEL <sub>cum</sub>						
Source Velocity (meters/second)	2.16067	4.2 knots				
1/Repetition rate <sup>^</sup> (seconds)	23.14097016	50/2.16067				
<sup>†</sup> Methodology assumes propagation of 20 log R; Activity duration (time) independent <sup>^</sup> Time between onset of successive pulses.						
	Modified farfield SEL	202.9907	202.8948	204.368	202.8948	202.3491
	Source Factor	8.60376E+18	8.41586E+18	1.18146E+19	8.41586E+18	7.42213E+18
RESULTANT ISOPLETHS*						
	*Impulsive sounds have dual metric thresholds (SEL <sub>cum</sub> & PK). Metric producing largest isopleth should be used.					
	Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
	SEL <sub>cum</sub> Threshold	183	185	155	185	203
	PTS SEL <sub>cum</sub> Isopleth to threshold (meters)	0.4	0	0	0	0
WEIGHTING FUNCTION CALCULATIONS						
	Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
	a	1	1.6	1.8	1	2
	b	2	2	2	2	2
	f <sub>1</sub>	0.2	8.8	12	1.9	0.94
	f <sub>2</sub>	19	110	140	30	25
	C	0.13	1.2	1.36	0.75	0.64
	Adjustment (dB) <sup>†</sup>	-12.44	-60.85	-70.00	-30.09	-36.69
OVERRIDE Using LDEO Modeling						

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

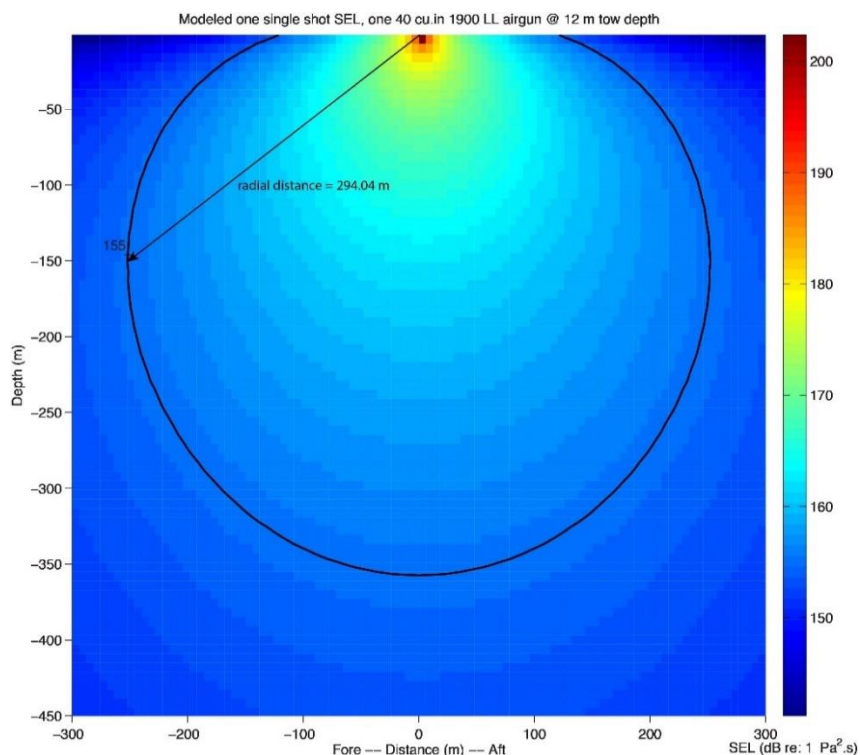


FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in<sup>3</sup> airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

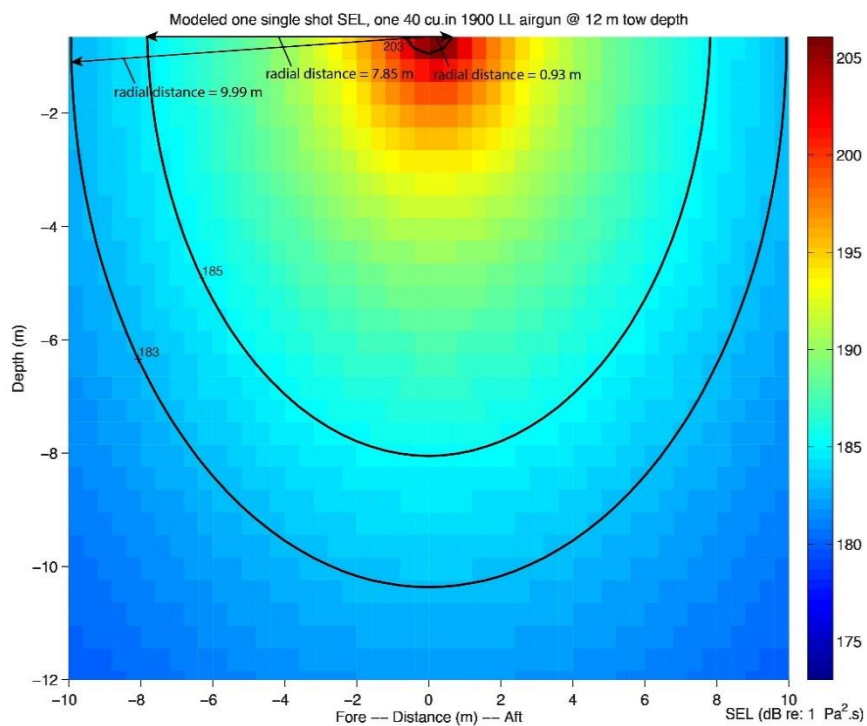


FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in<sup>3</sup> airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

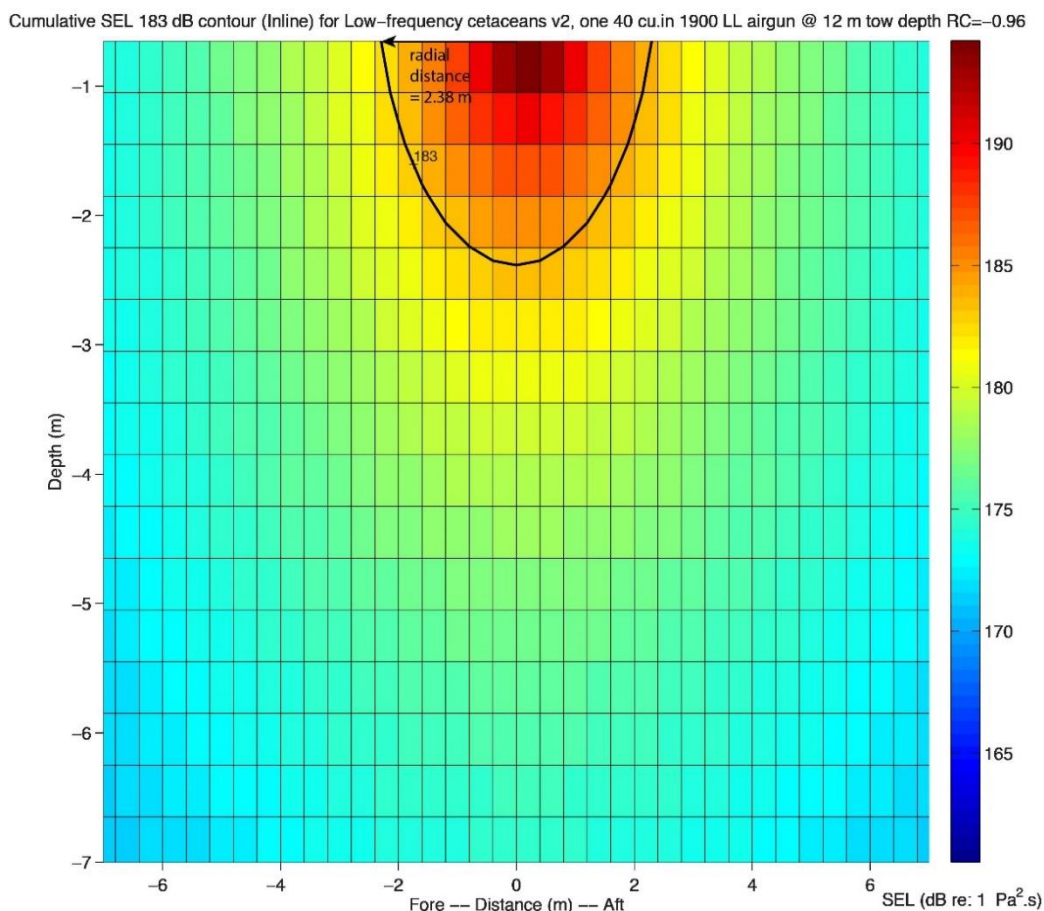


FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in<sup>3</sup> mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL<sub>cum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

TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL<sub>flat</sub>) 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-in<sup>3</sup> airgun during the proposed seismic surveys in the Northeast 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)	1.76	N.A.	12.47	1.98	N.A.
Modified Farfield Peak	223.93	224.09	223.92	223.95	223.95
PTS Peak Isopleth (Radius) to Threshold (m)	1.76	N.A.	12.5	1.98	N.A.

N.A. means not applicable or not available.

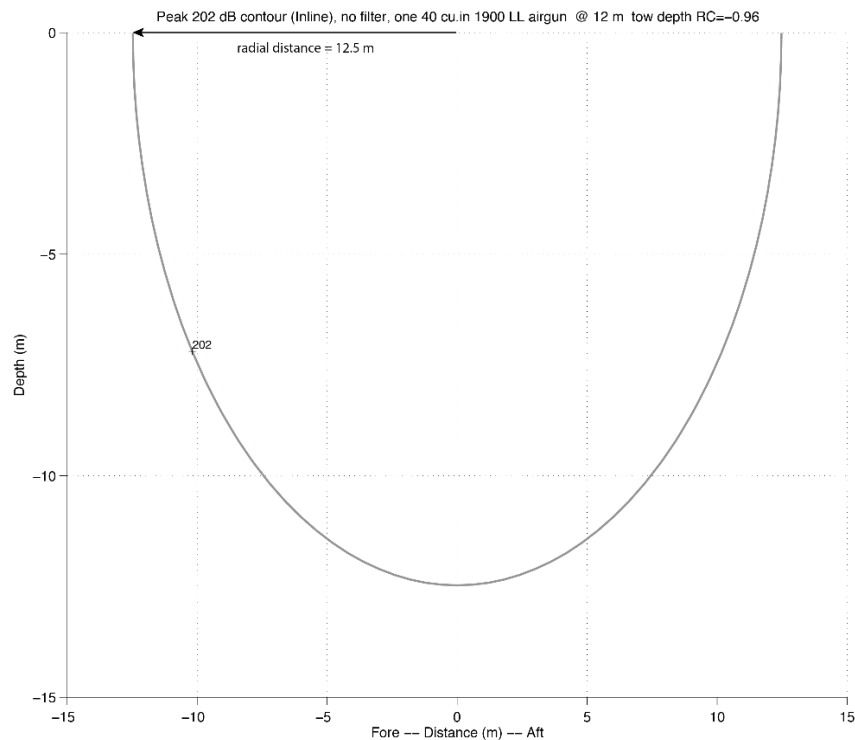


FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in<sup>3</sup> airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

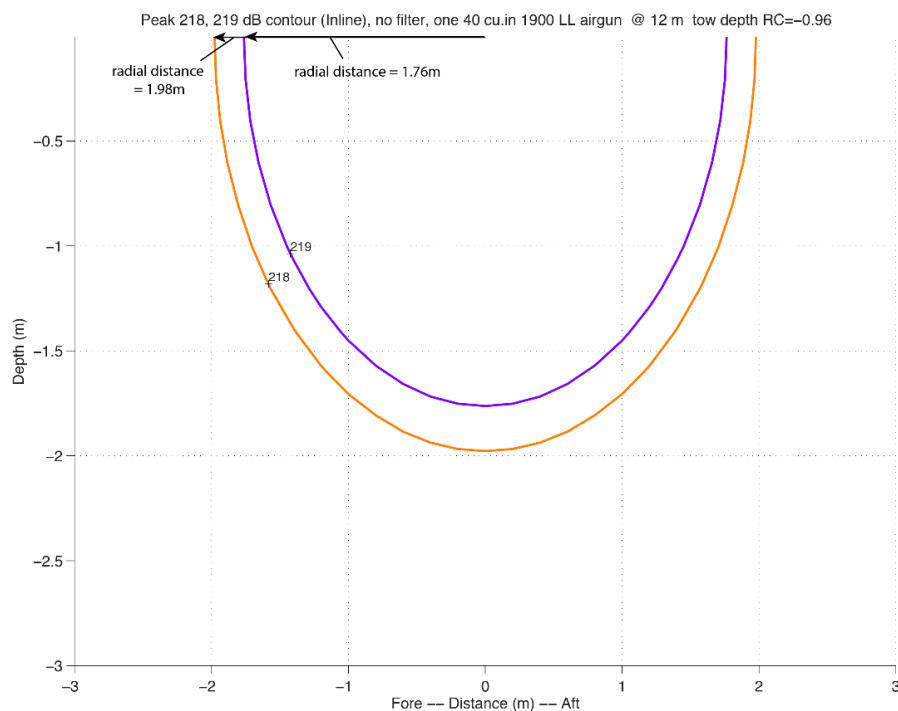


FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in<sup>3</sup> airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

## Literature Cited

- 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.
- Costa, D.P. and T.M. Williams. 1999. Marine mammal energetics. p. 176-217 *In*: J.E. Reynolds III and S.A. Rommel (eds.), *Biology of marine mammals*. Smithsonian Institution Press, Washington. 578 p.
- 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.
- DoN. 2017. Criteria and thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical Report prepared by the U.S. Navy.
- 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>.



## ADDENDUM

### Using Empirical Data for Estimation of Level B Radii

Based on Crone et al. (2014; *Estimating shallow water sound power levels and mitigation radii for the R/V Marcus G. Langseth using an 8 km long MCS streamer*), empirical data collected on the Cascadia Margin in 2012 during the COAST Survey support the use of the multichannel seismic (MCS) streamer data and the use of Sound Exposure Level (SEL) as the appropriate measure to use for the prediction of mitigation radii for the proposed survey. In addition, this peer-reviewed paper showed that the method developed for this purpose is most appropriate for shallow water depths, up to ~200 m deep.

To estimate Level B (behavioral disturbance or harassment) radii in shallow and intermediate water depths, we used the received levels from MCS data collected by R/V *Langseth* during the COAST survey (Crone et al. 2014). Streamer data in shallow water collected in 2012 have the advantage of including the effects of local and complex subsurface geology, seafloor topography, and water column properties and thus allow us to establish mitigation radii more confidently than by using the data from calibration experiments in the Gulf of Mexico (Tolstoy et al. 2004, 2009; Diebold et al. 2010).

As shown by Madsen et al. (2005), Southall et al. (2007), and Crone et al. (2014), the use of the root mean square (RMS) pressure levels to calculate received levels of an impulsive source leads to undesirable variability in levels due to the effects of signal length, potentially without significant changes in exposure level. All these studies recommend the use of SEL to establish impulsive source thresholds used for mitigation. Here we provide both the actual measured 160 dB<sub>RMS</sub> and 160 dB<sub>SEL</sub> to demonstrate that for determining mitigation radii in shallow water and intermediate, both would be significantly less than the modeled data for this region.

The proposed surveys would acquire data with a 4 string 6600 in<sup>3</sup> airgun array at a tow depth of 12 m, while the data collected in 2012 were acquired with a 4 string 6600 in<sup>3</sup> airgun array at a tow depth of 9 m. To account for the differences in tow depth between the COAST survey (6600 in<sup>3</sup> at 9 m tow depth) and the proposed survey (6600 in<sup>3</sup> at 12 m tow depth), we calculated a scaling factor using the deepwater modeling. The 150 dB<sub>SEL</sub> corresponds to deep-water maximum radii of 10,533 m for the 6600 in<sup>3</sup> airguns at 12 m tow depth, and 9,149 m for the 6600 in<sup>3</sup> at a 9 m tow depth yielding a scaling factor of 1.15 to be applied to the shallow-water and intermediate-water 9 m tow depth results.

As the 6600 cu.in source is 18 m wide (across-line direction) and 16m long (along-line direction), this quasi-symmetric source is also able to capture azimuthal variations.

\*\*\*\*\*

*Extracted from Crone et al. 2014 – Section 4.1*

#### 4. Discussion

**4.1. RMS Versus SEL** In his paper, Madsen [2005] makes a compelling argument against the use of RMS (equation (3)) for the determination of safe exposure levels and mitigation radii for marine protected species, partially on the grounds that this measure does not take into account the total acoustic energy that an animal's auditory system would experience. Madsen [2005] recommended the use of SEL as well as measures of peak pressure to establish impulsive source thresholds used for mitigation. Southall et al. [2007] came to similar conclusions.

Our work should provide further motivation for a regulatory move away from RMS power levels for marine protected species mitigation purposes. In shallow waters especially, interactions between direct, reflected, and refracted arrivals of acoustic energy from the array can result in large variations in signal length ( $T_{90}$ ), and commensurate large variations in RMS without necessarily significant changes in exposure level. The use of SEL, which accounts for signal length, should be preferred for mitigation purposes in shallow water.

\*\*\*\*\*



The entire 160 dB<sub>SEL</sub> level data are within the length of the streamer and are well behaved throughout this depth profile. The measured sound level data in this area suggest that the 160 dB<sub>SEL</sub> mitigation radius distance would be well defined at a maximum of 8192 m, but that the 160 dB<sub>RMS</sub> would be close to ~11 km (Fig. 1). For a few shots along this profile, the 160 dB<sub>RMS</sub> is just beyond the end of the streamer (8 km). For these shots, extrapolation was necessary. Crone et al. (2014) could only extrapolate the 160 dB<sub>RMS</sub> levels up to a distance of ~11 km (~133% of the length of the streamer). However, the stable 160 dB<sub>SEL</sub> levels across this interval would support an extrapolated value of not much more than 11 km for the 160 dB<sub>RMS</sub> level given that the 160 dB<sub>RMS</sub> and 160 dB<sub>SEL</sub> levels track consistently along the profile (Fig. 1).

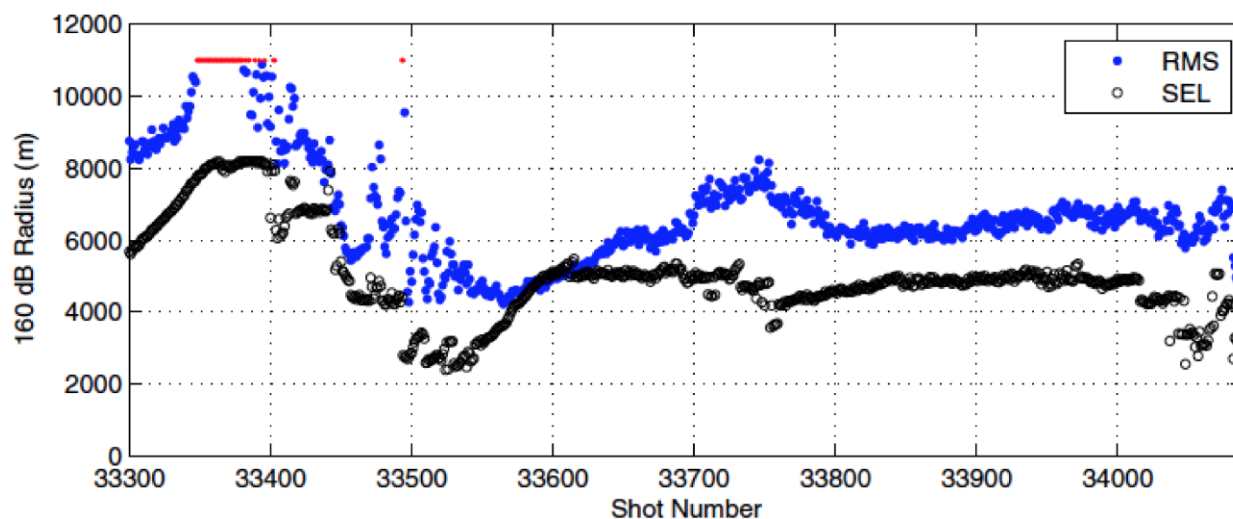


FIGURE 1. Measured radius distances to the 160 dB radii for both SEL and RMS along line A/T collected in 2012 at Cascadia with R/V *Langseth* 6600 in<sup>3</sup> airgun array towed at a depth of 9 m (Fig. 12 from Crone et al. 2014). This line extends across the shelf from ~50m water depth (Shot 33,300), 100m water depth (Shot # 33,675) out ~to the shelf break at 200m water depth (~Shot # 34000).

As noted in Table 2 of Crone et al. (2014), the full range of 160 dB<sub>RMS</sub> measured radii for intermediate waters is 4291m to 8233 m. The maximum 160 dB<sub>RMS</sub> measured radii, 8233 m (represented by a single shot at ~33750 from Figure 1), was selected for the 160 dB<sub>RMS</sub> measured radii in Table 1. Only 2 shots in water depths >100 have radii that exceed 8000 m, and there were over 1100 individual shots analyzed in the data; thus, the use of 8233 m is conservative.

## Summary

The empirical data collected during the COAST Survey on Cascadia Margin and measured 160 dB<sub>RMS</sub> and 160 dB<sub>SEL</sub> values demonstrate that the modeled predictions are quite conservative by a factor of up to ~2 to 2.5 times less than modeled predictions for the 2021 Cascadia project. While we have sought to err on the conservative side for our activities, being overly conservative can dramatically overestimate potential and perceived impacts of a given activity. We understand that the 160 dB<sub>RMS</sub> is the current threshold, and have highlighted that here as the standard metric to be used. However, evidence from multiple publications including Crone et al. (2014) have argued that SEL is a more appropriate metric for mitigation radii calculations. However, it is important to note that use of either measured SEL or RMS metrics yields significantly smaller radii in shallow water than model predictions.

TABLE 1. Comparison of modeled mitigation radii with empirically-derived radii from the Cascadia Margin during the 2012 COAST survey for the 4-string 36 airgun array (6600 in<sup>3</sup>).

Water Depth (m)	Proposed Project Radii using L-DEO Modeling	COAST project Radii using L-DEO Modeling	Predicted Radii for Proposed Project using Empirical Data (Crone et al. 2014). 160 dB rms measured distance proposed for current project shown in red.			
	Distance (m) to 160-dB <sub>rms</sub> at 12 m tow depth	Distance (m) to 160-dB <sub>rms</sub> at 9 m tow depth	Distance (m) to 160-dB <sub>SEL</sub> at 9 m tow depth (Figure 12 in Crone et al. 2014)	Distance (m) to 160-dB <sub>SEL</sub> with conversion factor (1.15) from 9 to 12 m tow depth	Distance (m) to 160 dB <sub>rms</sub> at 9 m tow depth (Figure 12 in Crone et al. 2014)	Distance (m) to 160 dB <sub>rms</sub> with conversion factor (1.15) from 9 to 12 m tow depth
<100	25,494	20,550	8,192	9,421	11,000*	12,650
100-1000	10,100	12,200	5,487	6,300	8,233	9,468

\*This value is extrapolated from end of 8-km streamer. Based on stable SEL values at same shot values. RMS extrapolated value is reasonable approximation.

When evaluating the empirical and modeled distances, all the other considerations and aspects of the airgun array still apply including:

- the airgun array is actually a distributed source and the predicted farfield level is never actually fully achieved
- the downward directionality of the airguns means that the majority of energy is directed downwards and not horizontally
- animals observed at the surface benefit from Lloyds mirror effect
- there is only one source vessel and the entire survey area is not ensonified all at one time, but rather the much smaller area around the vessel.

For these reasons, we believe the more scientifically appropriate approach for the proposed survey is to use Level B threshold distances based on the empirical data for shallow and intermediate water depths.

## Literature Cited

- 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.
- 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.
- Madsen, P.T. 2005. Marine mammals and noise: Problems with root mean square sound pressure levels for transients. **J. Acoust. Soc. Am.** 116(6):3952-3957.
- 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.
- Tolstoy, M., J. Diebold, S.C. Webb, D.R. Bohnenstiehl, E. Chapp, R.C. Holmes, and M. Rawson. 2004. Broadband calibration of R/V *Ewing* seismic sources. **Geochem. Geophys. Geosyst.** 31:L14310.
- Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohnenstiehl, 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.

## **APPENDIX B: MARINE MAMMAL DENSITIES**

## APPENDIX B: MARINE MAMMAL DENSITIES

### Data sources for densities

For the proposed surveys, we consulted with NMFS regarding which marine mammal density sources to use for developing take estimates. In response, NMFS recommended the use of habitat-based stratified marine mammal densities developed by the U.S. Navy for assessing potential impacts of training activities in the GOA (DoN 2014) and densities for Behm Canal in Southeast Alaska (DoN 2019). A combination of these densities were used for the majority of species (see below); based on recommendations by NMFS, the GOA densities were used for offshore areas, and the Behm Canal densities were used for coastal waters, when available.

To develop densities specific to the GOA, the Navy conducted two comprehensive marine mammal surveys in the Temporary Marine Activities Area (TMAA) in the GOA prior to 2014. The first survey was conducted from 10 to 20 April 2009 and the second was from 23 June to 18 July 2013. Both surveys used systematic line-transect survey protocols including visual and acoustic detection methods (Rone et al. 2010, 2014). The data were collected in four strata that were designed to encompass the four distinct habitats within the TMAA and greater GOA. The four strata included (1) Inshore: all waters <1000 m deep; (2) Slope: from 1000 m water depth to the Aleutian trench/subduction zone; (3) Offshore: waters offshore of the Aleutian trench/subduction zone; and (4) Seamount: waters within defined seamount areas.

For the GOA surveys, abundance estimates for unidentified large whales were prorated among blue, fin, and humpback whales within each stratum and proportionately incorporated into each species density estimate. Data from a subsequent survey in 2015 were used to calculate alternative density estimates for several species (Rone et al. 2017); however, the reported densities for blue, fin and humpback whales were not prorated for unidentified large whale sightings so the densities from Rone et al. (2014) were maintained in our calculations. The density estimates for Dall's porpoise in Rone et al. (2017) were somewhat larger than those in Rone et al. (2014), so the larger densities were used as a cautionary approach here.

As harbor seals typically remain close to shore, the DoN assigned minimal estimates for the three deep water zones and a one thousand fold increase of the minimal density was used to represent the entire inshore zone (DoN 2014). Densities for minke whale, Pacific white-sided dolphin, and Cuvier's and Baird's beaked whales were based on Waite (2003 *in* DoN 2009). Although sei whale sightings and Stejneger's beaked whale acoustic detections were recorded during the Navy funded GOA surveys, data were insufficient to calculate densities for these species, so predictions from a global model of marine mammals densities were used (Kaschner et al. 2012 *in* DoN 2014). Steller sea lion and northern elephant seal densities were calculated using shore-based population estimates divided by the area of the GOA Large Marine Ecosystem (DoN 2014). The North Pacific right whale, Risso's dolphin, and California sea lion are only rarely observed in or near the TMAA in the GOA, so the DoN used minimal densities to represent their potential presence.

There were insufficient sightings data from the 2009, 2013 and 2015 line-transect surveys to calculate reliable density estimates for other marine mammal species in the GOA. DoN (2014) derived gray whale densities in two zones, nearshore (0–2.25 n.mi from shore) and offshore (from 2.25–20 n.mi. from shore). In our calculations, the nearshore density was used to represent the shallow and intermediate-depth waters, and the offshore density was used to represent deep water. This approach assumes a higher density of gray whales across a larger area and should yield a conservative estimate of potential exposures.

## Densities as used in take calculations

In our take calculations for cetaceans, the preferred densities for coastal waters (shallow and intermediate depths) were from Behm Canal; ‘Offshore’ densities from the GOA were used for offshore waters. Densities from the slope region in the western GOA were not deemed representative of the shallow and intermediate water depths in the proposed survey area; the slope region is much wider in the western GOA compared to southeast Alaska. If no densities were available for Behm Canal, then ‘Inshore’ densities were used for coastal waters (shallow and intermediate depths); ‘Offshore’ densities were used for offshore waters. For pinnipeds, we used densities from Behm Canal, when available, for shallow water (<100 m), ‘Inshore’ densities for intermediate-depth water (100–1000 m), and ‘Offshore’ densities for offshore waters. As densities for Behm Canal are for inland waters and are therefore expected to be much greater than densities off the coast, we did not use the Behm Canal densities for intermediate-depth waters. All marine mammal densities corresponding to the various strata in the GOA and single density values for Behm Canal were based on data from several different sources, including Navy funded line-transect surveys in the GOA, are shown in Table B-1. Densities for harbor porpoise, northern right whale dolphin, California sea lion, and leatherback turtle were determined using alternate density sources (see below). When seasonal densities were available (e.g., as for Behm Canal for humpback, killer, and minke whales; Pacific white-sided dolphin; Steller sea lion; and harbor seal), the calculated exposures were based on summer densities, which were deemed to be most representative of the proposed survey timing. For all other species, summer densities were either not available or the same as for other seasons. There is some uncertainty related to the estimated density data and the assumptions used in their calculations.

For harbor porpoise, we used densities from Hobbs and Waite (2010) for Southeast Alaska and applied those to shallow and intermediate water depths to be conservative. These densities are more representative of the survey area compared with those from the western GOA. Densities were assumed to be zero in deep water, as reported by the DoN (2014). For northern right whale dolphins, spatially-explicit density data from the NOAA CetSound website (NOAA 2019) were used. These densities were only applied to ensonified areas in Canadian waters, as this species typically does occur as far north as Alaska. CetMap (<https://cetsound.noaa.gov/cda>) provides output from habitat-based density models for cetaceans in the California Current Ecosystem (Becker et al. 2016) in the form of GIS layers; these were averaged in the shallow, intermediate, and deep water across Washington and Oregon to calculate takes in the survey area. For California sea lion, we used density data for August for the Offshore Northwest Training and Testing (NWT) Area from DoN (2019); densities for 0–40 km from shore were applied to shallow and intermediate water depths, and the density for 0–450 km from shore was used for deep water; the density for 40–70 km from shore was the lowest and was therefore not used. For leatherback turtles, annual densities from DoN (2019) were used to calculate takes.

TABLE B-1. Densities of marine mammals and sea turtles expected to occur in the proposed survey area. Species listed as "Endangered" under the ESA are in italics.

	Shallow Water <100 m	Intermediate Water 100-1000 m	Deep Water >1000 m	Comments
<b>LF Cetaceans</b>				
North Pacific right whale	0	0	0	Rare; no takes expected
Humpback whale	0.01170	0.01170	0.00100	Behm Canal (USN 2019); deep water for GOA
Blue whale	0.00050	0.00050	0.00050	All GOA
Fin whale	0.00010	0.00010	0.02100	Behm Canal (USN 2019); deep water for GOA
Sei whale	0.00010	0.00010	0.00010	All GOA
Minke whale	0.00080	0.00080	0.00060	Behm Canal (USN 2019); deep water for GOA
Gray whale	0.04857	0.04857	0	All GOA
<b>MF Cetaceans</b>				
Sperm whale	0	0	0.0013	All GOA
Baird's beaked whale	0.00050	0.00050	0.00050	All GOA
Cuvier's beaked whale	0.00220	0.00220	0.00220	All GOA
Stejneger's beaked whale	0	0	0.00142	All GOA
Pacific white-sided dolphin	0.00750	0.00750	0.02080	Behm Canal (USN 2019); deep water for GOA
Northern right-whale dolphin	0.01100	0.02763	0.03673	Cetcount (Becker et al. 2016); only applied to Canadian deep water (non-territorial) off Haida Gwaii
Risso's dolphin	0.00001	0.00001	0.00001	All GOA
Killer whale	0.00570	0.00570	0.00200	Summer densities for transients for Behm Canal; density larger than for other stocks; deep water GOA
<b>HF Cetaceans</b>				
Dall's porpoise	0.12100	0.12100	0.03700	Behm Canal (USN 2019); deep water for GOA
Harbor porpoise	0.03300	0.03300	0	Hobbs and Waite (2010)
<b>Otariid Seals</b>				
Northern fur seal	0.01500	0.01500	0.01700	All GOA
California sea lion	0.02880	0.02880	0.00650	CC (USN 2019)
Steller sea lion	0.31616	0.00980	0.00980	Behm Canal (USN 2019); Int and deep water for GOA
<b>Phocid Seals</b>				
Northern elephant seal	0.00220	0.00220	0.00220	All GOA
Harbor seal	0.78110	0.00001	0.00001	Behm Canal (USN 2019); Int and deep water for GOA
<b>Sea Turtle</b>				
Leatherback Turtle	0.000114	0.000114	0.000114	USN (2019)

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. NOAA Admin. Rep. LJ-16-01. 31 p. + appendix.
- Becker, E.A., K.A. Forney, P.C. Fiedler, J. Barlow, S.J. Chivers, C.A. Edwards, A.M. Moore, J.V. Redfern. 2016. Moving towards dynamic ocean management: How well do modeled ocean products predict species distributions? **Remote Sens.** 8(149). <https://doi.org/10.3390/rs8020149>.
- DoN (U.S. Department of the Navy). 2009. Appendix E, Marine Mammal Density Report. Gulf of Alaska Navy Training Activities Draft Environmental Impact Statement/Overseas Environmental Impact Statement. 46 p.
- DoN. 2014. Commander Task Force 3rd and 7th Fleet Navy Marine Species Density Database. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. 486 p.
- DoN. 2019. U.S. Navy Marine Species Density Database Phase III for the Northwest Training and Testing Study Area. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. 262 p.
- Hobbs, R. C., and Waite, J.M. 2010. Abundance of harbor porpoise (*Phocoena phocoena*) in three Alaskan regions, corrected for observer errors due to perception bias and species misidentification, and corrected for animals submerged from view. **Fish. Bull. U.S.** 108(3):251-267.
- Kaschner, K., N.J. Quick, R. Jewell, R. Williams, C. M. Harris. 2012. Global coverage of cetacean line-transect surveys: status quo, data gaps and future challenges. **PLoS ONE** 7(9):1-13.
- Mobley, J.R., Jr., S.S. Sptiz, 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. Admin. Report LJ-00-14C. Southwest Fish. Sci. Centre, La Jolla, CA. 26 p.
- NOAA. 2019. Cetacean data availability. Accessed in October 2019 at <https://cetsound.noaa.gov/cda>. Rone, B.K., A.B. Douglas, A.N. Zerbini, L. Morse, A. Martinez, P.J. Clapham, and J. Calambokidis. 2010. Results of the April 2009 Gulf of Alaska Line-Transect Survey (GOALS) in the Navy Training Exercise Area. NOAA Tech. Memo. NMFS-AFSC-209. 39 p.
- Rone, B.K., A.B. Douglas, T.M. Yack, A.N. Zerbini, T.N. Norris, E. Ferguson, and J. Calambokidis. 2014. Report for the Gulf of Alaska Line-transect Survey (GOALS) II: marine mammal occurrence in the Temporary Maritime Activities Area (TMAA). Submitted to Naval Facilities Engineering Command (NAVFAC) Pacific, Honolulu, Hawaii under Contract No. N62470-10-D-3011, Task Order 0022, issued to HDR Inc., San Diego, Calif. Prepared by Cascadia Research Collective, Olympia, Wash.; Alaska Fish. Sci. Cent., Seattle, Wash.; and Bio-Waves, Inc., Encinitas, Calif.. April 2014. 82 p.
- Rone, B.K., A.N. Zerbini, A.B. Douglas, D.W. Weller, and P.J. Clapham. 2017. Abundance and distribution of cetaceans in the Gulf of Alaska. **Mar. Biol.** 164:23. doi:10.1007/s00227-016-3052-2.
- Waite, J.M. 2003. Cetacean Assessment and Ecology Program: Cetacean Survey. *AFSC Quarterly Research Reports* July-Sept 2003.

## **APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS**



## APPENDIX C: MARINE MAMMAL TAKE CALCULATIONS

TABLE C-1. Take estimates (excluding takes in Canadian territorial waters) for the proposed survey area in the Northeast Pacific Ocean.

Species	Estimated Density (#/km <sup>2</sup> )			Regional Population Size	Level B 160 dB Ensonified Area (km <sup>2</sup> )			Level A Ensonified Area (km <sup>2</sup> )			Level B Takes			Level B Takes (All)	Level B minus Level A Takes	Level A Takes	% of Pop. (Total Takes)	Requested Level A+B Take Authorization
	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m		Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m	Shallow <100 m	Intermediate 100-1000 m	Deep >1000 m					
LF Cetaceans																		
North Pacific right whale <sup>1</sup>	0.0000000	0.0000000	0.0000000	400	2,626	28,154	57,150	34	894	2,722	0	0	0	0	0	0	0	0
Humpback whale	0.0117000	0.0117000	0.0010000	10,103	2,626	28,154	57,150	34	894	2,722	31	329	57	417	404	14	4.13	417
Blue whale	0.0005000	0.0005000	0.0005000	1,647	2,626	28,154	57,150	34	894	2,722	1	14	29	44	42	2	2.67	44
Fin whale	0.0001000	0.0001000	0.0210000	18,680	2,626	28,154	57,150	34	894	2,722	0	3	1,200	1,203	1,146	57	6.44	1,203
Sei whale	0.0001000	0.0001000	0.0001000	27,197	2,626	28,154	57,150	34	894	2,722	0	3	6	9	8	0	0.03	9
Minke whale	0.0008000	0.0008000	0.0006000	28,000	2,626	28,154	57,150	34	894	2,722	2	23	34	59	57	2	0.21	59
Gray whale	0.0485700	0.0485700	0.0000000	26,960	2,626	28,154	57,150	34	894	2,722	128	1,367	0	1,495	1,450	45	5.55	1,495
MF Cetaceans																		
Sperm whale	0.0000000	0.0000000	0.0013000	26,300	2,626	28,154	57,150	1	38	115	0	0	74	74	74	0	0.28	74
Baird's beaked whale	0.0005000	0.0005000	0.0005000	2,697	2,626	28,154	57,150	1	38	115	1	14	29	44	44	0	1.63	44
Cuvier's beaked whale	0.0022000	0.0022000	0.0022000	3,274	2,626	28,154	57,150	1	38	115	6	62	126	193	193	0	6.35	193
Stejneger's beaked whale	0.0000100	0.0000100	0.0014200	3,044	2,626	28,154	57,150	1	38	115	0	0	81	81	81	0	0.30	81
Pacific white-sided dolphin	0.0075000	0.0075000	0.0208000	26,880	2,626	28,154	57,150	1	38	115	20	211	1,189	1,420	1,417	3	5.28	1,420
Northern right-whale dolphin	0.0110031	0.0276336	0.0367262	26,556	0	656	24,742	1	38	115	0	18	909	927	922	5	3.49	927
Risso's dolphin	0.0000100	0.0000100	0.0000100	6,336	2,626	28,154	57,150	1	38	115	0	0	1	1	1	0	0.01	22
Killer whale <sup>2</sup>	0.0057000	0.0057000	0.0020000	3,738	2,626	28,154	57,150	1	38	115	15	160	114	290	289	0	7.75	290
HF Cetaceans																		
Dall's porpoise	0.1210000	0.1210000	0.0370000	83,400	2,626	28,154	57,150	28	748	2,280	318	3,407	2,115	5,839	5,661	178	7.00	5,839
Harbor porpoise	0.0330000	0.0330000	0.0000000	11,146	2,626	28,154	57,150	28	748	2,280	87	929	0	1,016	990	26	9.11	1,016
Otariid Seals																		
Northern fur seal	0.0150000	0.0150000	0.0170000	620,660	2,626	28,154	57,150	1	29	90	39	422	972	1,433	1,431	2	0.23	1,433
California sea lion	0.0288000	0.0288000	0.0065000	257,606	2,626	28,154	57,150	1	29	90	76	811	371	1,258	1,256	1	0.49	1,258
Steller sea lion	0.3161600	0.0098000	0.0098000	41,638	2,626	28,154	57,150	1	29	90	830	276	560	1,666	1,665	2	4.00	1,666
Phocid Seal																		
Northern elephant seal	0.0022000	0.0022000	0.0022000	179,000	2,626	28,154	57,150	5	122	371	6	62	126	193	192	1	0.11	193
Harbor seal	0.7811000	0.0000100	0.0000100	81,282	2,626	28,154	57,150	5	122	371	2,051	0	1	2,052	2,048	4	2.52	2,052
Sea Turtle																		
Leatherback Turtle	0.0001140	0.0001140	0.0001140	N.A.	405.2	7,181.6	15,544.1	1.6	42.8	130.7	0	1	2	3	3	0	N.A.	3

N.A. means not available or not applicable.

<sup>1</sup> Rare; no takes expected.

<sup>2</sup> No takes expected for Southern Resident DPS

## **APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS**

## APPENDIX D: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

Survey Zone	Criteria	Daily Ensonified Area (km <sup>2</sup> )	Total Survey Days	25% Increase	Total Ensonified Area (km <sup>2</sup> )	Relevant Isopleth (m)
Shallow <100 m: US	160 dB	131.3	16	1.25	2,625.6	12650
Intermediate 100-1000 m: US	160 dB	1374.9	16	1.25	27,497.7	9468
Deep >1000 m: US	160 dB	1620.4	16	1.25	32,407.1	6733
Intermediate 100-1000 m: Canada non-terr.	160 dB	47.7	11	1.25	656.4	9468
Deep >1000 m: Canada non-territorial	160 dB	1799.4	11	1.25	24,742.4	6733
Intermediate 100-1000 m: US and Canada	160 dB	1422.6	27	1.25	28,154.1	9468
Deep>1000 m: US + Canada	160 dB	3419.8	27	1.25	57,149.5	6733
<b>Overall</b>	<b>160 dB</b>	<b>4973.7</b>	<b>27</b>	<b>1.25</b>	<b>87929.2</b>	
All zones	LF Cetacean	210.8	27	1.25	3,649.0	320.2
All zones	MF Cetacean	8.9	27	1.25	154.7	13.6
All zones	HF Cetacean	176.6	27	1.25	3,056.4	268.3
All zones	Otariid	7.0	27	1.25	120.5	10.6
All zones	Phocid	28.7	27	1.25	497.1	43.7
All zones	Sea Turtle	10.1	27	1.25	175.1	15.4

Note: not all steps of the calculations are shown here for the PTS thresholds (e.g., ensonified areas in US/Canadian waters).