

**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* in the
Northeast Pacific Ocean, 2022**

submitted by

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to

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Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeast Pacific Ocean, 2022

SUMMARY

Researchers from New Mexico Institute of Mining and Technology (NMT) and Oregon State University (OSU), with funding from the U.S. National Science Foundation (NSF), propose to conduct seismic surveys from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*), which is owned and operated by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University, at the Cascadia Subduction Zone and Juan de Fuca Plate in the Northeast Pacific Ocean during summer 2022. The proposed two-dimensional (2-D) seismic surveys would occur within Exclusive Economic Zones (EEZ) of the U.S., in water >1600 m deep. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5). In May 2021, NSF was issued an incidental harassment authorization (IHA) for a more extensive high-energy survey off the coast of Oregon, Washington, and British Columbia; information from that IHA application was used in developing this IHA application, with updates to the project information and data as appropriate.

Numerous species of marine mammals occur within the northeastern Pacific Ocean. Under the U.S. ESA, several of these species are listed as *endangered*, including the North Pacific right, gray whale (Western North Pacific Distinct Population Segment or DPS), humpback (Central America DPS), sei, fin, blue, sperm, and Southern Resident DPS of killer whales. However, it is unlikely that Western North Pacific gray whales or Southern Resident killer whales would occur in the proposed offshore project area. In addition, the *threatened* Mexico DPS of the humpback whale and the *threatened* Guadalupe fur seal could occur in the proposed project area. The *threatened* northern sea otter is not expected to occur in the offshore project area.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, “Submission of Requests”, are set forth below. They include descriptions of the specific operations to be conducted, the marine mammals occurring in the survey 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 purpose of the proposed study is to acquire high-resolution 2-D seismic reflection data in conjunction with densely-spaced heat flow measurements off the coasts of Oregon and Washington in the Northeast Pacific Ocean. The proposed surveys would occur within ~42–47°N, ~125–127°W. Four regions where the surveys are proposed to occur are depicted in Figure 1; the tracklines could occur anywhere within the boxes shown in Figure 1. No representative survey tracklines are shown, as actual track lines and order of survey operations are dependent on science objectives and weather. The surveys are proposed to occur within the EEZ of the U.S., in water >1600 m deep. The proposed surveys would be expected to last for 23 days, including ~6 days of seismic operations, 3 days of transit, and 14 days of heat flow measurements. R/V *Langseth* would likely leave out of and return to port in Newport, OR, during summer 2022.

The primary objective of this proposal is to understand the thermal structure of the Juan de Fuca plate as it enters the Cascadia subduction zone. Prior heatflow measurements across the flank of a buried seamount near the subduction zone offshore Washington suggest that the basement surface is isothermal, which implies high permeability and fluid flow within the oceanic crust and an impermeable seal at the seafloor. Prior work on young crust near the Juan de Fuca Ridge indicate that the crustal flow paths are connected over large distances when basement outcrops are present. Recent seismic data indicate that buried seamounts are more widely distributed than previously thought, and some of these seamounts show seismic evidence for fluid flow into the overlying sediments, which is inconsistent with the idea that sediment cover is impermeable. The proposed study would acquire heat flow and seismic data across several distinct structures that have not been previously studied, including a pseudofault, complex buried seamounts, and small outcrops that represent the summit of much larger buried seamounts. Although existing seismic and bathymetric data are adequate for identifying targets for heat flow measurements, they are not adequate for determining basement and sediment structure in order to interpret heat flow observations.

To achieve the project goals, the Principal Investigators (PI) Drs. G. Spinelli (NMT), R. Harris (OSU) and A. Tréhu (OSU) propose to utilize 2-D seismic reflection capabilities of R/V *Langseth*. The 2-D seismic reflection data are required to constrain basement depth and other structural features that affect the heat flow measured near the seafloor and are critical for accurately modeling the heat flow observations. The survey would involve one source vessel, R/V *Langseth*, which would tow two 45/105 in³ GI airguns at a depth of 2–4 m; the shot interval would be 12.5–25 m. The receiving system would consist of an 800–1400 m long hydrophone streamer. Approximately 1135 km of transect lines would be acquired in the Northeast Pacific Ocean. The entire survey would occur in water deeper than 1600 m.

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

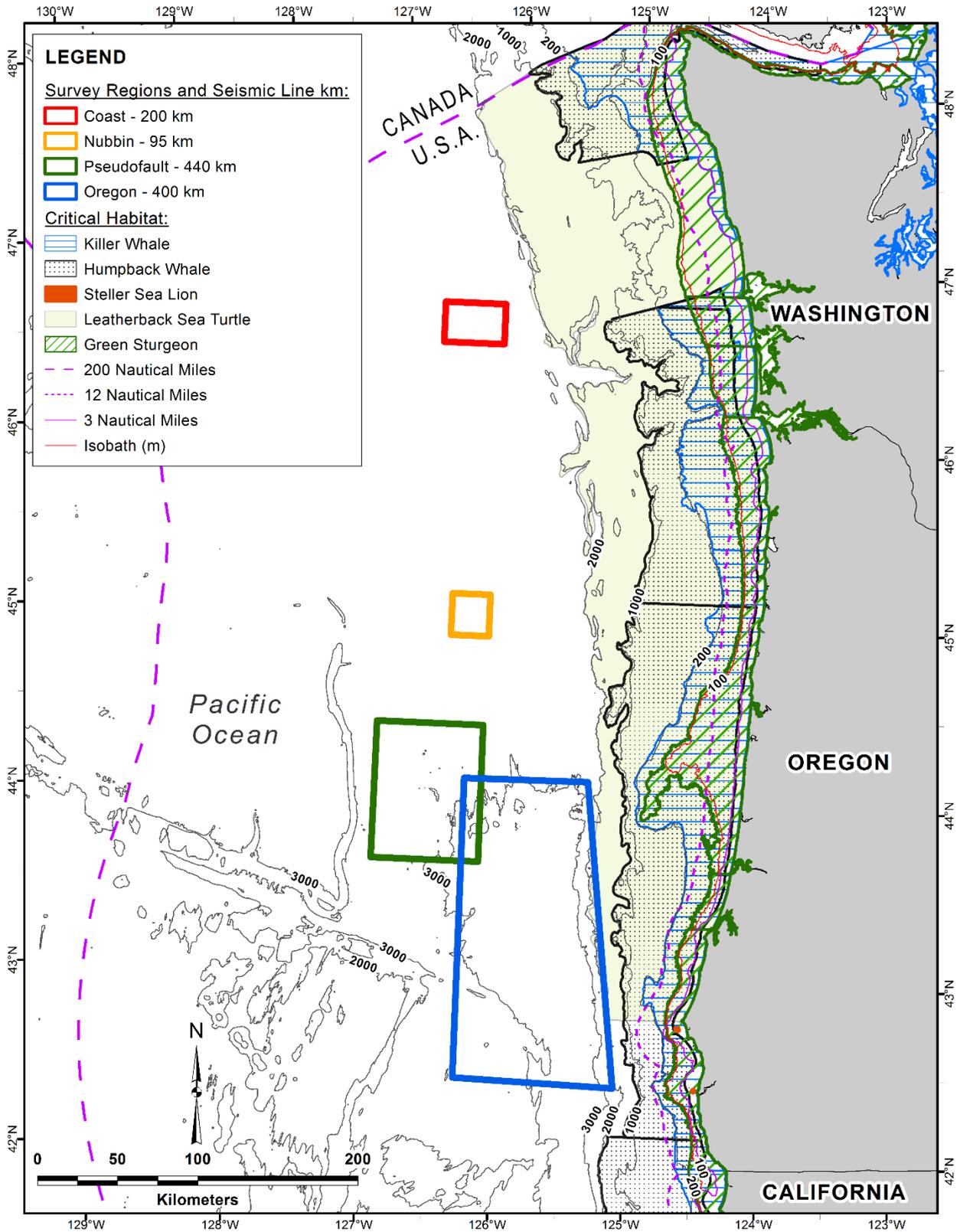


FIGURE 1. Location of the proposed seismic surveys in the Northeast Pacific Ocean and U.S. critical habitat.

Source Vessel Specifications

R/V *Marcus G. Langseth* is described in § 2.2.2.1 of the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. The vessel speed during seismic operations would be ~4.6 kt (~8.5 km/h) during the survey. The maneuverability of the vessel is limited during operations with the streamer.

Airgun Description

During the surveys, R/V *Langseth* would tow a 2 GI-airgun cluster in true GI (45/105) mode as the seismic source, with a total discharge volume of 90 in³. The two inline GI airgun would be spaced 2.46 m apart. The array would be towed at a depth of 2–4 m, and the shot interval would be 12.5–25 m.

GI Airgun Specifications

Energy Source:	Two GI guns of 45 in ³ each
Gun positions used:	Two inline airguns 2.46 m apart
Towing depth of energy source:	2–4 m
Source output (2.46-m gun separation)*:	0-peak is 3.6 bar-m (231.1 dB re 1 μPa·m); peak-peak 7.2 bar-m (237.1 dB re 1 μPa·m)
Air discharge volume:	Approx. 90 in ³
Dominant frequency components:	0–188 Hz
Gun volumes at each position (in ³):	45, 45

*Source output downward based on a conservative tow depth of 4 m.

As the airguns are towed along the survey lines, the towed hydrophone array in the streamer would receive the reflected signals and transfer the data to the on-board processing system. The turning rate of the vessel with gear deployed would be limited; thus, the maneuverability of the vessel would be limited during operations.

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

A further consideration is that the rms¹ (root mean square) received levels that are used as impact criteria for marine mammals are not directly comparable to the peak (p or 0–p) or peak to peak (p–p) values normally used to characterize source levels of airgun arrays. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in biological literature. A measured received sound pressure level (SPL) of 160 dB re 1 μPa_{rms} in the far field would

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

typically correspond to ~170 dB re 1 μPa_p or 176–178 dB re 1 μPa_{p-p} , as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The precise difference between rms and peak or peak-to-peak values depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

Mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ threshold for Level B takes. The background information and methodology for this are provided in Appendix A and briefly summarized here. The proposed surveys would acquire data with the 2-GI airgun array at a tow depth of ~2–4 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 2-GI airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). Table 1 shows the distances at which the 160-dB and 175-dB re 1 $\mu\text{Pa}_{\text{rms}}$ sound levels are expected to be received for the 2-GI airgun array at a 4-m tow depth. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

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 (e.g., Pierson et al. 1998; Weir and Dolman 2007; Nowacek et al. 2013a; Wright 2014; Wright and Cosentino 2015; Acosta et al. 2017; Chou et al. 2021). Although Level A takes would not be anticipated, for other recent low-energy seismic surveys, NMFS required protected species observers (PSOs) to establish and monitor a 100-m exclusion zone (EZ) and a 200-m buffer zone beyond the EZ.

Heat Flow Measurement Description

Heat flow data would be acquired with a new heat flow probe. The probe is lowered into the seafloor sediment, penetrating up to 6 m into the sediment. The heat flow measurements along a transect would be acquired in “pogo” mode, in which the probe is left in the water between sites on a particular transect as the ship slowly moves from site to site along the transect. Heat flow transects would be along new or existing seismic lines with additional seismic data acquired to determine the basement structure perpendicular to the heat flow transects, allowing for incorporation of 3-D effects in the modeling of heat and fluid transport. The heat probe is a passive system that takes the temperature of the sediments like a thermometer.

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 and operated by L-DEO. R/V *Langseth* would deploy a two 45/105 in³ GI airguns as an energy source with a total volume of ~90 in³. The receiving system would consist of one 800–1400 m long hydrophone streamer. As the airguns are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system. Approximately 1135 km of transect lines would be surveyed in four survey regions in the Northeast Pacific Ocean: 200 km, 95, 440 km, and 400 km in the Coast, Nubbin, Pseudofault, and Oregon survey regions, respectively. All survey effort would occur in deep water >1600 m. 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.

TABLE 1. Level B. Predicted distances to the 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ sound level that could be received from two 45/105 in³ GI guns (at a tow depth of 4 m) that would be used during the seismic surveys in the Northeast Pacific Ocean during summer 2022.

Airgun Configuration	Water Depth (m)	Predicted Distances (m) to a Received Sound Level of 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$
Two 45-in ³ GI guns	>1000	553

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 ~42–47°N, ~125–127°W. Four proposed survey regions are indicated in Figure 1 along with the proposed number of line km to be acquired; the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within the EEZ of the U.S. in water >1600 m deep. The proposed surveys would be expected to last for 23 days, including ~6 days of seismic operations, 3 days of transit, and 14 days of heat flow measurements. R/V *Langseth* would likely leave out of and return to port in Newport, OR, during summer 2022. The ensuing analysis (including take estimates) focuses on the time of the survey (summer). For cetaceans, the best available densities available were for summer/fall; for pinnipeds, the highest densities for either spring, summer or fall were 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

Thirty marine mammal species could occur in or near the proposed survey regions, including 7 mysticetes (baleen whales), 18 odontocetes (toothed whales), and 5 pinnipeds (seals and sea lions) (Table 3). Six of the species/populations are listed under the U.S. ESA as *endangered*, including the sperm, humpback (Central America DPS), sei, fin, blue, and North Pacific right whales. The *threatened* Mexico DPS of the humpback whale and the *threatened* Guadalupe fur seal could also occur in the proposed survey area. It is unlikely that gray whales from the *endangered* Western North Pacific DPS or Southern Resident killer whales would occur in the proposed survey area. Although there is critical habitat in the coastal waters for Southern Resident killer whales, humpback whales (Central America and Mexico DPS), and the Steller sea lion, none of the proposed survey transects enter or ensonify marine mammal critical habitat to sound levels >160 dB re 1 $\mu\text{Pa}_{\text{rms}}$.

The long-beaked common dolphin (*D. capensis*) and rough-toothed dolphin (*Steno bredanensis*) are distributed farther to the south. These species are unlikely to be seen in the proposed survey area and are not addressed in the summaries below. Although no sightings of *D. capensis* have been made off Oregon/Washington, Ford (2005) reported seven confirmed *D. capensis* sightings in British Columbia (B.C.) waters from 1993–2003; all records occurred in inshore waters. No other sightings have been made since 2003 (Ford 2014). In addition, harbor porpoise, harbor seal, and sea otters are not included here, as they typically occur closer to shore.

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, § 3.8.1, and § 3.8.1 of the PEIS. One of the qualitative analysis areas (QAAs) defined in the PEIS, the B.C. Coast, is located to the north of the proposed survey area. The general distribution of mysticetes, odontocetes, and pinnipeds 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. Southern California was chosen as a detailed analysis area (DAA) in the PEIS, and is located to the south of the proposed survey area. The general distribution of mysticetes, odontocetes, and pinnipeds in southern California is discussed in § 3.6.2.3, § 3.7.2.3, § 3.8.2.3, and § 3.9.2.2 of the PEIS, respectively. The rest of this section deals specifically with species distribution in the proposed survey area off Washington and Oregon.

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 is likely not much higher than 31 individuals, as this was the abundance estimate for the Bering Sea and Aleutian Islands (Wade et al. 2011a). Critical habitat has been designated in the eastern Bering Sea and in the Gulf of Alaska, south of Kodiak Island (NOAA 2019a). 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).

Whaling records indicate that right whales once ranged across the entire North Pacific north of 35°N and occasionally occurred as far south as 20°N (Kenney 2018). Although right whales were historically reported off Oregon, occasionally in large numbers (Scammon 1874; Rice and Fiscus 1968), extensive shore-based and pelagic commercial whaling operations never took large numbers of the species south of Vancouver Island (Rowlett et al. 1994). Nonetheless, Gilmore (1956) proposed that the main wintering ground for North Pacific right whales was off the Oregon coast and possibly northern California, postulating that the inherent inclement weather in those areas discouraged winter whaling (Rice and Fiscus 1968).

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 acoustically (McDonald and Moore 2002; Munger et al. 2003, 2005, 2008; Berchok et al. 2009). They are known to occur in the 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 Gulf of Alaska 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 Gulf of Alaska during summer (Waite et al. 2003;

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. N.A. means not available.

Species	Occurrence in Area ¹	Habitat	Abundance ²	U.S. ESA ³	IUCN ⁶	CITES ⁷
<i>Mysticetes</i>						
North Pacific right whale	Rare	Coastal, shelf,	400-500 ⁸	EN	CR ⁹	I
Gray whale	Rare	Coastal, shelf	243 ¹⁰ ; 26,960	DL ¹¹	LC ¹³	I
Humpback whale	Uncommon	Mainly nearshore	2,900; 10,103 ¹⁴	EN/T ¹⁵	LC	I
Common minke whale	Uncommon	Nearshore, offshore	636; 20,000 ¹⁶	NL	LC	I
Sei whale	Rare	Mostly pelagic	519; 27,197 ¹⁷	EN	EN	I
Fin whale	Common	Slope, pelagic	9,029; 13,620-18,680 ¹⁸	EN	VU	I
Blue whale	Rare	Pelagic and coastal	1,496	EN	EN	I
<i>Odontocetes</i>						
Sperm whale	Common	Pelagic, steep	1,997; 26,300 ²⁰	EN	VU	I
Pygmy sperm whale	Rare	Deep, off	4,111	NL	LC	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	LC	II
Cuvier's beaked whale	Uncommon	Pelagic	3,274	NL	LC	II
Baird's beaked whale	Uncommon	Pelagic	2,697	NL	LC	I
Blainville's beaked whale	Rare	Pelagic	3,044 ²¹	NL	LC	II
Hubbs' beaked whale	Rare	Slope,	3,044 ²¹	NL	DD	II
Stejneger's beaked whale	Uncommon	Slope,	3,044 ²¹	NL	NT	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1,924 ²²	NL	LC	II
Striped dolphin	Rare	Off continental	29,211	NL	LC	II
Short-beaked common dolphin	Uncommon	Shelf, pelagic,	969,861	NL	LC	II
Pacific white-sided dolphin	Common	Offshore, slope	26,814	NL	LC	II
Northern right whale dolphin	Common	Slope, offshore	26,556	NL	LC	II
Risso's dolphin	Uncommon	Shelf, slope, seamounts	6,336	NL	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	NT	II
Killer whale	Common	Widely distributed	73 ²³ 349 ²⁴ 300 ²⁵	EN ²⁶	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	836	NL	LC	II
Dall's porpoise	Common	Shelf, slope, offshore	25,750	NL	LC	II
<i>Pinnipeds</i>						
Guadalupe fur seal	Rare	Mainly coastal,	34,187	T	LC	I
Northern fur seal	Uncommon	Pelagic, offshore	14,050 ²⁷ 608,143 ²⁸	NL	VU	N.A.
Northern elephant seal	Uncommon	Coastal, pelagic in	179,000 ²⁹	NL	LC	II

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

Species	Occurrence in Area ¹	Habitat	Abundance ²	U.S. ESA ³	IUCN ⁶	CITES ⁷
Steller sea lion	Rare	Coastal, offshore	43,201 ³⁰	DL ³¹	NT ³²	N.A.
California sea lion	Rare	Coastal	257,606 ³³	NL	LC	N.A.

- ¹ Occurrence in area at the time of the survey; based on professional opinion and available data.
- ² Abundance for Eastern North Pacific, U.S., or CA/OR/WA stock from Carretta et al. (2021), unless otherwise stated.
- ³ U.S. *Endangered Species Act* (ESA; NOAA 2021a): EN = Endangered, T = Threatened, NL = Not listed.
- ⁶ Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2021); CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.
- ⁷ Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2021): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
- ⁸ North Pacific (Jefferson et al. 2015).
- ⁹ The Northeast Pacific subpopulation is critically endangered; globally, the North Pacific right whale is endangered.
- ¹⁰ Pacific Coast Feeding Group (Carretta et al. 2021).
- ¹¹ Although the Eastern North Pacific DPS was delisted under the ESA, the Western North Pacific DPS is listed as endangered.
- ¹² Pacific Coast Feeding Aggregation and Western Pacific populations are listed as endangered; the Northern Pacific Migratory population is not at risk.
- ¹³ Globally considered as least concern; western population listed as endangered.
- ¹⁴ Central North Pacific stock (Muto et al. 2021).
- ¹⁵ 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).
- ¹⁶ Northwest Pacific and Okhotsk Sea (IWC 2021).
- ¹⁷ Central and Eastern North Pacific (Hakamada and Matsuoka 2015a).
- ¹⁸ North Pacific (Ohsumi and Wada 1974).
- ²⁰ Eastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
- ²¹ All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2021).
- ²² California/Oregon/Washington offshore stock (Carretta et al. 2021).
- ²³ Eastern North Pacific Southern Resident stock (Carretta et al. 2021).
- ²⁴ West Coast Transient stock; minimum estimate (Muto et al. 2021).
- ²⁵ North Pacific Offshore stock (Carretta et al. 2021).
- ²⁶ The Southern Resident DPS is listed as endangered; no other stocks are listed.
- ²⁷ California stock (Carretta et al. 2021).
- ²⁸ Eastern Pacific stock (Muto et al. 2021).
- ²⁹ California breeding stock (Carretta et al. 2021).
- ³⁰ Eastern U.S. stock (Muto et al. 2021).
- ³¹ The Eastern DPS was delisted in 2013 (78 FR 66139, 4 November 2013); the Western DPS is listed as endangered.
- ³² Globally considered as near threatened; western population listed as endangered, and eastern population is considered least concern.
- ³³ U.S. stock (Carretta et al. 2021).

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, which includes the Gulf of Alaska critical habitat and extends south of 56°N and north of 58°N and beyond the shelf edge (Ferguson et al. 2015).

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 (located in water 1390 m deep) off the Washington coast on 29 June 2013 (Širović et al. 2014).

In B.C., 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). A third sighting was made off Haida Gwaii in June 2018 (CBC 2018). During an L-DEO seismic survey in the Northeast Pacific during summer 2021, a sighting of two individuals was made west of Haida Gwaii on 27 July 2021 (RPS 2021a). 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., Washington, and Oregon in recent decades, and the likelihood that animals would be feeding in the Bering Sea and Gulf of Alaska at the time of the survey, it is possible although very 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, although it is unlikely that a gray whale from the Western North Pacific DPS would be encountered during the time of the survey. 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. In 2009, Punt and Wade (2012) estimated that the eastern North Pacific population was at 85% of its carrying capacity of 25,808 individuals.

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–June (Rice and Wolman 1971), with a peak into the Gulf of Alaska during mid-April (Braham 1984). Instead of migrating to arctic and sub-arctic 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 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), and the U.S. and Canada recognize it as such (COSEWIC 2017; Carretta et al. 2021). However, the status of the PCFG as a separate stock is currently unresolved (Weller et al. 2013). For the purposes of abundance estimates, the PCFG is defined as occurring between 41°N to 52°N from 1 June to 30 November (IWC 2012). The 2015 abundance estimate for the PCFG was 243 whales (Calambokidis et al. 2017).

BIAs for feeding gray whales along the coasts of Washington, Oregon, and California have been identified, including northern Puget Sound, Northwestern Washington, and Grays Harbor (WA); Depoe Bay and Cape Blanco & Orford Reef (OR), and Point St. George (CA); most of these areas are of importance from late spring through early fall (Calambokidis et al. 2015); none occur within the proposed survey regions. Resident gray whales have been observed foraging off the coast of Oregon from May–October (Newell and Cowles 2006) and off Washington from June through November (Scordino et al. 2014). A least 28 gray whales were observed near Depoe Bay, OR (~44.8°N), for three successive summers (Newell and Cowles 2006). BIAs have also been identified for migrating gray whales along the entire coasts of Washington, Oregon, and California; although most whales travel within 10 km from shore, the BIAs were extended out to 47 km from the coastline (Calambokidis et al. 2015); the proposed Oregon survey region is located adjacent to this BIA (see Fig. 1). Gray whales from the far north begin to migrate south to breeding grounds on the west coast of Baja California and the southeastern Gulf of California in October and November (Braham 1984; Rugh et al. 2001). Gray whales migrate closest to the Washington/Oregon coastline during spring (April–June), when most strandings are observed (Norman et al. 2004).

Oleson et al. (2009) observed 116 gray whales off the outer Washington coast (~47°N) during 42 small boat surveys from August 2004 through September 2008; mean distances from shore during the southern migration (December–January), northern migration (February–April), and summer feeding (May–October) activities were 29, 9, and 12 km, respectively; mean bottom depths during these activities were 126, 26, and 33 m, respectively. Ortega-Ortiz and Mate (2008) tracked the distribution and movement patterns of gray whales off Yaquina Head on the central Oregon coast (~44.7°N) during the southbound and northbound migration in 2008. The average distance from shore to tracked whales ranged from 200 m to 13.6 km; average bottom depth of whale locations was 12–75 m. The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline. During aerial surveys over the shelf and slope off Oregon and Washington, gray whales were seen during the months of January, June–July, and September; one sighting was made off the Columbia River estuary in water >200 m during June 2011 (Adams et al. 2014). Two sightings of three whales were seen from R/V *Northern Light* during a survey off southern Washington in July 2012 (RPS 2012a). No sightings were made during L-DEO’s Cascadia summer survey off Oregon and Washington (RPS 2021b).

The proposed surveys would occur during the summer feeding season, when most individuals from the eastern North Pacific stock occur farther north. Although individuals, particularly from the PCFG, could be encountered in nearshore waters less than 10 km from shore, few if any gray whales are expected to be encountered in the offshore survey areas.

NOAA (2021b) 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 2019. As of 1 October 2021, a total of 212 dead gray whales have been reported, including 248 in the U.S. (55 in Washington; 12 in Oregon), 225 in Mexico, and 19 in B.C.; some of the whales were emaciated. A UME for gray whales was also declared for 1999–2000 (NOAA 2021c).

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 2016a). 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. 2021). According to Carretta et al. (2021), NMFS is currently reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (e.g., NMFS 2016a).

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). Individuals encountered in the proposed survey area would be from the Hawaii, Mexico, and/or Central America DPSs (Calambokidis et al. 2008; Ford 2014). The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May–November; the highest numbers have been reported off Oregon during May and June and off Washington during July–September (Green et al. 1992; Calambokidis et al. 2000, 2004). Humpbacks occur primarily over the continental shelf and slope during the summer, but a few individuals have been reported in offshore pelagic waters (Green et al. 1992; Calambokidis et al. 2004, 2015; Becker et al. 2012; Barlow 2016; Carretta et al. 2021). BIAs for feeding humpback whales along the coasts of Oregon and Washington, which have been designated from May–November, are all within ~80 km from shore, and include the waters off northern Washington, and Stonewall and Heceta Bank, OR (Calambokidis et al. 2015); none of these occur within the proposed survey regions. Another five BIAs occur off California (Calambokidis et al. 2015). Six humpback whale sightings (8 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey. There were 98 humpback whale sightings (213 animals) made during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a), and 11 sightings (23 animals) during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). Numerous humpback whale sightings were made during L-DEO’s Cascadia summer survey off Oregon and Washington (RPS 2021b).

On 21 April 2021, NMFS designated critical habitat in nearshore waters of the North Pacific Ocean for the *endangered* Central America and Western North Pacific DPSs and the *threatened* Mexico DPS of humpback whale (NMFS 2021a). Critical habitat for the Central America and Mexico DPSs includes waters within the California Current Ecosystem (CCE) off the coasts California, Oregon, and Washington (Fig. 1). Off Washington, critical habitat includes waters from the 50-m to 1200-m isobaths, as well as the Strait of Juan de Fuca eastward to Angeles Point; however, there is an exclusion area of 1461 nmi² around the Navy’s Quinault Range Site. Off Oregon, the critical habitat spans from the 50-m to 1200-m isobath, except for areas south of 42.17°N, where the offshore boundary is at the 2000-m isobath. There is also critical habitat for the Mexico and Western Pacific DPSs in Alaska waters (NMFS 2021a). However, there is no critical habitat within the survey regions, and ensonified areas would not extend into critical habitat.

Humpback whales are expected to be uncommon in the proposed offshore survey areas.

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 Gulf of Alaska 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).

Sightings have been made off Oregon and Washington in shelf and deeper waters (Green et al. 1992; Adams et al. 2014; Barlow 2016; Carretta et al. 2021). An estimated abundance of 211 minke whales was reported for the Oregon/Washington region based on sightings data from 1991–2005

(Barlow and Forney 2007), whereas a 2008 survey did not record any minke whales while on survey effort (Barlow 2010). The abundance for Oregon/Washington for 2014 was estimated at 507 minke whales (Barlow 2016). There were no sightings of minke whales off Oregon/Washington during L-DEO's summer seismic surveys in 2012 or 2021 (RPS 2012b,c, 2021). One minke whale was seen during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a).

Minke whales are expected to be uncommon in the proposed survey areas.

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. 1999). 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 Gulf of Alaska and down to southern California, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N (Rice 1998).

Sei whales are rare in the waters off Washington, Oregon, and California (Brueggeman et al. 1990; Green et al. 1992; Barlow 1994, 1997). Less than 20 confirmed sightings were reported in that region during extensive surveys during 1991–2014 (Green et al. 1992, 1993; Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; Von Sauner and Barlow 1999; Barlow 2003, 2010, 2014; Forney 2007; Carretta et al. 2021). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington was 52 (Barlow 2010); for 2014, the abundance estimate was 468 (Barlow 2016). Two sightings of four individuals were made during the June–July 2012 L-DEO Juan de Fuca plate seismic survey off Washington/Oregon (RPS 2012b). No sei whales were sighted during the summer 2012 or 2021 L-DEO seismic surveys off Oregon and Washington (RPS 2012a,c, 2021).

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 (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). In the central North Pacific, the Gulf of Alaska, and Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009).

Fin whales are routinely sighted during surveys off Oregon and Washington (Barlow and Forney 2007; Barlow 2010, 2016; Adams et al. 2014; Calambokidis et al. 2015; Edwards et al. 2015; Carretta et al. 2021), including in coastal as well as offshore waters. They have also been detected acoustically in those waters during June–August (Edwards et al. 2015). Eight fin whale sightings (19 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; sightings were made in waters 2369–3940 m deep (RPS 2012b). Fourteen fin whale sightings (28 animals) were made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). No fin whales were sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). During L-DEO’s Cascadia survey during June–July 2021, five sightings of seven fin whales were made off Oregon (RPS 2021b). Fin whales were also seen off southern Oregon during July 2012 in water >2000 m deep during surveys by Adams et al. (2014).

Fin whales are likely to be encountered in the proposed survey areas.

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). 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: one in the eastern and one in the western North Pacific (Sears and Perrin 2018). 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). Broad-scale acoustic monitoring indicates that blue whales occurring in the northeast Pacific during summer and fall may winter in the eastern tropical Pacific (Stafford et al. 1999, 2001).

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). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections in the North Pacific. 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). The eastern North Pacific stock feeds in California waters from June–November (Calambokidis et al. 1990; Mate et al. 1999). There are nine BIAs for feeding blue whales off the coast of California (Calambokidis et al. 2015), and core areas have also been identified there (Irvine et al. 2014).

Blue whales are considered rare off Oregon, Washington, and B.C. (Buchanan et al. 2001; Gregor et al. 2006; Ford 2014), although satellite-tracked individuals have been reported off the coast (Bailey et al. 2009). Based on modeling of the dynamic topography of the region, blue whales could occur in relatively high densities off Oregon during summer and fall (Pardo et al. 2015; Hazen et al. 2017). Densities along the U.S. west coast, including Oregon, were predicted to be highest in shelf waters, with lower densities in deeper offshore areas (Becker et al. 2012; Calambokidis et al. 2015). Blue whales have been detected acoustically off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Sauner and Barlow 1999).

Blue whales could be encountered in the proposed survey areas, 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). Off California, they occur year-round (Dohl et al. 1983; Barlow 1995; Forney et al. 1995), with peak abundance from April to mid-June and from August to mid-November (Rice 1974). Off Oregon, sperm whales are seen in every season except winter (Green et al. 1992). Sperm whales were sighted during surveys off Oregon in October 2011 and off Washington in June 2011 (Adams et al. 2014). Sperm whale sightings were also made off Oregon and Washington during the 2014 Southwest Fisheries Science Center (SWFSC) vessel survey (Barlow 2016). Sperm whales were detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC Passive Acoustics Survey of Cetacean Abundance Levels (PASCAL) study using drifting acoustic recorders (Keating et al. 2018). Oleson et al. (2009) noted a significant diel pattern in the occurrence of sperm whale clicks at offshore and inshore monitoring locations off Washington, whereby clicks were more commonly heard during the day at the offshore site and at night at the inshore location, suggesting possible diel movements up and down the slope in search of prey. Sperm whale acoustic detections were also reported at an inshore site from June through January 2009, with an absence of calls during February–May (Širović et al. 2012).

Sperm whales are likely to be encountered in the proposed survey areas.

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

Dwarf and pygmy sperm whales are distributed throughout tropical and temperate waters of the Atlantic, Pacific, and Indian oceans, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted (McAlpine 2018).

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). Stomach content analyses from stranded whales further support this distribution (McAlpine 2018). Recent data indicate that both

Kogia species feed in the water column and on/near the seabed, likely using echolocation to search for prey (McAlpine 2018). Several studies have suggested that pygmy sperm whales live and feed mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf and slope (Rice 1998; Wang et al. 2002; MacLeod et al. 2004; McAlpine 2018). It has also been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993; McAlpine 2018).

Pygmy and dwarf sperm whales are rarely sighted off Oregon and Washington, with only one sighting of an unidentified *Kogia* sp. beyond the U.S. EEZ, during the 1991–2014 NOAA vessel surveys (Carretta et al. 2021). Norman et al. (2004) reported eight confirmed stranding records of pygmy sperm whales for Oregon and Washington, five of which occurred during autumn and winter. Despite the limited number of sightings, it is possible that pygmy or dwarf sperm whales could be encountered within the proposed project areas.

Cuvier’s Beaked Whale (*Ziphius cavirostris*)

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

The population in the California Current LME seems to be declining (Moore and Barlow 2013). Nonetheless, MacLeod et al. (2006) reported numerous sightings and strandings along the Pacific coast of the U.S. Cuvier’s beaked whale is the most common beaked whale off the U.S. west coast (Barlow 2010), and it is the beaked whale species that has stranded most frequently on the coasts of Oregon and Washington. From 1942–2010, there were 23 reported Cuvier’s beaked whale strandings in Oregon and Washington (Moore and Barlow 2013). Most (75%) Cuvier’s beaked whale strandings reported occurred in Oregon (Norman et al. 2004).

Four beaked whale sightings were reported in water depths >2000 m off Oregon/Washington during surveys in 2008 (Barlow 2010). None were seen in 1996 or 2001 (Barlow 2003), and several were recorded from 1991–1995 (Barlow 1997). One Cuvier’s beaked whale sighting was made during surveys in 2014 (Barlow 2016). Acoustic monitoring in Washington offshore waters detected Cuvier’s beaked whale calls between January and November 2011 (Širović et al. 2012b in USN 2015). Cuvier’s beaked whales were detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). Cuvier’s beaked whales could be encountered during the proposed surveys.

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).

Along the U.S. west coast, Baird’s beaked whales have been sighted primarily along the continental slope (Green et al. 1992; Becker et al. 2012; Carretta et al. 2021) from late spring to early fall (Green et al. 1992). The whales move out from those areas in winter (Reyes 1991). In the eastern North Pacific Ocean, Baird’s beaked whales apparently spend the winter and spring far offshore, and in June, they move onto the continental slope, where peak numbers occur during September and October. Green et al. (1992) noted that Baird’s beaked whales on the U.S. west coast were most abundant in the summer, and were not sighted in the fall or winter. MacLeod et al. (2006) reported numerous sightings and strandings of *Berardius* spp. off the U.S. west coast.

Green et al. (1992) sighted five groups during 75,050 km of aerial survey effort in 1989–1990 off Washington/Oregon spanning coastal to offshore waters: two in slope waters and three in offshore waters. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, in waters >2000 m deep (Barlow 2010). Acoustic monitoring offshore Washington detected Baird’s beaked whale pulses during January through November 2011, with peaks in February and July (Širović et al. 2012b in USN 2015). Baird’s beaked whales were detected acoustically in the waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018).

Baird’s beaked whales could be encountered in the proposed survey regions.

Blainville’s Beaked Whale (*Mesoplodon densirostris*)

Blainville’s beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2018). It has the widest distribution throughout the world of all *Mesoplodon* species (Pitman 2018). Like other beaked whales, Blainville’s beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). MacLeod et al. (2006) reported stranding and sighting records in the eastern Pacific ranging from 37.3°N to 41.5°S. However, none of the 36 beaked whale stranding records in Oregon and Washington during 1930–2002 included Blainville’s beaked whale (Norman et al. 2004). One Blainville’s beaked whale was found stranded (dead) on the Washington coast in November 2016 (COASST 2016).

There was one acoustic encounter with Blainville’s beaked whales recorded in Quinault Canyon off Washington in waters 1400 m deep during 2011 (Baumann-Pickering et al. 2014). Blainville’s beaked whales were not detected acoustically off Washington or Oregon during the August 2016 SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). Although Blainville’s beaked whales could be encountered during the proposed surveys, an encounter would be unlikely because the proposed survey regions are beyond the northern limits of this tropical species’ usual distribution.

Hubbs’ Beaked Whale (*Mesoplodon carlhubbsi*)

Hubbs’ beaked whale occurs in temperate waters of the North Pacific (Mead 1989). Its distribution appears to be correlated with the deep subarctic current (Mead et al. 1982). Numerous stranding records have been reported for the west coast of the U.S. (MacLeod et al. 2006). Most are from California, but at least seven strandings have been recorded along the B.C. coast as far north as Prince Rupert (Mead 1989; Houston 1990a; Willis and Baird 1998; Ford 2014). Several strandings are known from Washington/Oregon (e.g., Norman et al. 2004; Griffiths et al. 2019). In addition, at least two sightings off Oregon/Washington, but outside the U.S. EEZ, were reported by Carretta et al. (2021), and one bycatch record off Oregon/Washington was reported by Griffiths et al. (2019). During the 2016 SWFSC PASCAL study using drifting acoustic recorders, detections were made of beaked whale sounds presumed to be from Hubbs’

beaked whales off Washington and Oregon during August (Griffiths et al. et al. 2019). This species seems to be less common in the region than some of the other beaked whales, but it could be encountered during the surveys.

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). After Cuvier's beaked whale, Stejneger's beaked whale was the second most commonly stranded beaked whale species in Oregon and Washington (Norman et al. 2004). Stejneger's beaked whale calls were detected during acoustic monitoring offshore Washington between January and June 2011, with an absence of calls from mid-July–November 2011 (Širović et al. 2012b *in* USN 2015). Analysis of these data suggest that this species could be more than twice as prevalent in this area than Baird's beaked whale (Baumann-Pickering et al. 2014). Stejneger's beaked whales were also detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018).

Stejneger's beaked whales could be encountered during the proposed surveys.

Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide in coastal and shelf waters of tropical and temperate oceans (Jefferson et al. 2015). There are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). Coastal common bottlenose dolphins exhibit a range of movement patterns including seasonal migration, year-round residency, and a combination of long-range movements and repeated local residency (Wells and Scott 2009).

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41°N, but few records exist for Oregon and Washington (Carretta et al. 2021). Three sightings and one stranding of bottlenose dolphins have been documented in Puget Sound since 2004 (Cascadia Research 2011 *in* USN 2015). It is possible that offshore bottlenose dolphins may range as far north as the proposed survey area during warm-water periods (Carretta et al. 2021). Adams et al. (2014) made one sighting off Washington during September 2012. It is possible, although unlikely, that bottlenose dolphins could be encountered in the proposed survey regions.

Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994; Jefferson et al. 2015). It occurs primarily in pelagic waters outside of the continental shelf, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). Striped dolphins regularly occur off California (Becker et al. 2012), including as far offshore as ~300 n.mi. during NOAA Fisheries vessel surveys (Carretta et al. 2021). However, few sightings have been made off Oregon, and no sightings have been reported for Washington (Carretta et al. 2021). However, strandings have occurred along the coasts of Oregon and Washington (Carretta et al. 2016). During surveys off the U.S. west coast in 2014, striped dolphins were seen as far north as 44°N; based on those sightings, Barlow (2016) calculated an abundance estimate of 13,171 striped dolphins for Oregon/Washington. The abundance estimates for 2001, 2005, and 2008 were zero (Barlow 2016). It is possible, although unlikely, that striped dolphins could be encountered in the proposed survey area.

Short-beaked Common Dolphin (*Delphinus delphis*)

The short-beaked common dolphin is found in tropical and warm temperate oceans around the world (Jefferson et al. 2015), ranging from ~60°N to ~50°S (Jefferson et al. 2015). It is the most abundant dolphin species in offshore areas of warm-temperate regions in the Atlantic and Pacific (Perrin 2018). It can be found in oceanic and coastal habitats; it is common in coastal waters 200–300 m deep and is also associated with prominent underwater topography, such as seamounts (Evans 1994). Short-beaked common dolphins have been sighted as far as 550 km from shore (Barlow et al. 1997).

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). It is the most abundant cetacean off California; some sightings have been made off Oregon, in offshore waters (Carretta et al. 2021). During surveys off the west coast in 2014 and 2017, sightings were made as far north as 44°N (Barlow 2016; SIO n.d.). Based on the absolute dynamic topography of the region, short-beaked common dolphins could occur in relatively high densities off Oregon during July–December (Pardo et al. 2015). In contrast, habitat modeling predicted moderate densities of common dolphins off the Columbia River estuary during summer, with lower densities off southern Oregon (Becker et al. 2014). A group of six common dolphins was sighted during L-DEO’s Cascadia summer survey just south of the Columbia River off Oregon (RPS 2021b).

Common dolphins could be encountered in the proposed survey regions.

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).

Results of aerial and shipboard surveys strongly suggest seasonal north-south movements of the species between California and Oregon/Washington; the movements apparently are related to oceanographic influences, particularly water temperature (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). During winter, this species is most abundant in California slope and offshore areas; as northern waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). The highest encounter rates off Oregon and Washington have been reported during March–May in slope and offshore waters (Green et al. 1992). Similarly, Becker et al. (2014) predicted relatively high densities off southern Oregon in shelf and slope waters.

Based on year-round aerial surveys off Oregon/Washington, the Pacific white-sided dolphin was the most abundant cetacean species, with nearly all (97%) sightings occurring in May (Green et al. 1992, 1993). Barlow (2003) also found that the Pacific white-sided dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys, and it was the second most abundant species reported during 2008 surveys (Barlow 2010). Adams et al. (2014) reported numerous offshore sightings off Oregon during summer, fall, and winter surveys in 2011 and 2012. Based on surveys conducted during 2014, the abundance was estimated at 20,711 for Oregon/Washington (Barlow 2016).

Fifteen Pacific white-sided dolphin sightings (231 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey (RPS 2012b). There were fifteen Pacific white-sided dolphin sightings (462 animals) made during the July 2012 L-DEO seismic surveys off

southern Washington (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). Numerous Pacific white-sided dolphin sightings were made during L-DEO's Cascadia summer survey off Oregon and Washington (RPS 2021b).

Pacific white-sided dolphins are likely to be common in the proposed survey regions.

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).

Aerial and shipboard surveys suggest seasonal inshore-offshore and north-south movements in the eastern North Pacific Ocean between California and Oregon/Washington; the movements are believed to be related to oceanographic influences, particularly water temperature and presumably prey distribution and availability (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). Green et al. (1992, 1993) found that northern right whale dolphins were most abundant off Oregon/Washington during fall, less abundant during spring and summer, and absent during winter, when this species presumably moves south to warmer California waters (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003).

Becker et al. (2014) predicted relatively high densities off southern Oregon, and moderate densities off northern Oregon and Washington. Based on year-round aerial surveys off Oregon/Washington, the northern right whale dolphin was the third most abundant cetacean species, concentrated in slope waters but also occurring in water out to ~550 km offshore (Green et al. 1992, 1993). Barlow (2003, 2010) also found that the northern right whale dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys. Offshore sightings were made in the waters of Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014). During L-DEO's Cascadia survey during June–July 2021, one sighting of 15 northern right whale dolphins was made off Washington, and another sighting of 12 individuals was made off Oregon (RPS 2021b).

Northern right whale dolphins are likely to be encountered in the proposed survey regions.

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).

Off the U.S. west coast, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007). The distribution and abundance of Risso's dolphins are highly variable from California to Washington, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001). The highest densities were predicted along the coasts of Washington, Oregon, and central and southern California (Becker et al. 2012). Off Oregon and Washington, Risso's dolphins are most abundant over

continental slope and shelf waters during spring and summer, less so during fall, and rare during winter (Green et al. 1992, 1993). Green et al. (1992, 1993) reported most Risso's dolphin groups off Oregon between ~45 and 47°N. Several sightings were made off southern Oregon during surveys in 1991–2014 (Barlow 2016; Carretta et al. 2021). Sightings during ship surveys in summer/fall 2008 were mostly between ~30 and 38°N; none were reported in Oregon/Washington (Barlow 2010). Based on 2014 survey data, the abundance for Oregon/Washington was estimated at 430 (Barlow 2016).

Risso's dolphins could be encountered in the proposed survey regions.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50°N and 50°S (Odell and McClune 1999). It is widely distributed, but not abundant anywhere (Carwardine 1995). The false killer whale generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow (Jefferson et al. 2015; Baird 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). In the eastern North Pacific, it has been reported only rarely north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994); however, the waters off the U.S. west coast all the way north to Alaska are considered part of its secondary range (Jefferson et al. 2015).

Its occurrence in Washington/Oregon is associated with warm-water incursions (Buchanan et al. 2001). However, no sightings of false killer whales were made along the U.S. west coast during surveys conducted from 1986–2001 (Ferguson and Barlow 2001, 2003; Barlow 2003) or in 2005 and 2008 (Forney 2007; Barlow 2010). One pod of false killer whales occurred in Puget Sound for several months during the 1990s (USN 2015). Two false killer whales were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004).

This species is unlikely to be encountered during the proposed surveys.

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 Aleutians and 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. 2021; Carretta et al. 2021). Individuals from the West Coast Transient and Offshore stocks could be encountered in the proposed project areas. It is unlikely that individuals from the *endangered* Eastern North Pacific Southern Resident stock would be encountered in the offshore survey regions.

During summer, 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. 2021). These areas 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, it occurs along the outer coast and does not spend a lot of time in critical habitat areas (Ford 2014). Critical

habitat for the Southern Resident stock is defined in detail in the Code of Federal Regulations (NMFS 2006). Critical habitat currently includes three specific marine areas of Puget Sound, WA: the Summer Core Area, Puget Sound, and the Strait of Juan de Fuca. The critical habitat includes all waters relative to a contiguous shoreline delimited by the line at a depth of 6.1 m relative to extreme high water. The western boundary of the Strait of Juan de Fuca Area is Cape Flattery, WA (48.38°N; 124.72°W). On 2 August 2021, NMFS (NMFS 2021b) revised the critical habitat for Southern Resident killer whales. The critical habitat now includes the previously designated critical habitat in inland waters of Washington State and expands the habitat between the 6.1 and 200-m isobaths along the coast of U.S. coast from the border with Canada to Point Sur, California. None of the proposed transect lines and associated ensonified areas occur in designated critical habitat; all transect lines are located beyond in water deeper than 1600 m and at least 46 km from shore.

The main diet of transient killer whales consists of marine mammals, in particular porpoises and seals. West coast transient whales (also known as Bigg's killer whales) range from Southeast Alaska to California (Muto et al. 2021). The seasonal movements of transients are largely unpredictable (Baird 1994; Ford 2014). Green et al. (1992) noted that most groups seen during their surveys off Oregon and Washington were likely transients; during those surveys, killer whales were sighted only in shelf waters. Two of 17 killer whales that stranded in Oregon were confirmed as transient (Stevens et al. 1989 in Norman et al. 2004).

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) reported sightings in Southeast Alaska during spring and summer. Eleven sightings of ~536 individuals were reported off Oregon/Washington during the 2008 SWFSC vessel survey (Barlow 2010). Killer whales were sighted offshore Washington during surveys from August 2004 to September 2008 (Oleson et al. 2009). Keating et al. (2015) analyzed cetacean whistles from recordings made during 2000–2012; several killer whale acoustic detections were made offshore Washington. Killer whales were sighted off Washington in July and September 2012 (Adams et al. 2014).

During L-DEO's Cascadia survey during June–July 2021, a sighting of 20 killer whales was made near the shelf edge off northern Oregon (RPS 2021b). Killer whales could be encountered during the proposed surveys, although it is unlikely that southern resident killer whales would occur as far offshore as the survey regions.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical and warm temperate waters (Olson 2018); it is seen as far south as ~40°S and as far north as ~50°N (Jefferson et al. 2015). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2018). Short-finned pilot whales were common off southern California (Dohl et al. 1980) until an El Niño event occurred in 1982–1983 (Carretta et al. 2021). Few sightings were made off California/Oregon/Washington in 1984–1992 (Green et al. 1992; Carretta and Forney 1993; Barlow 1997), and sightings remain rare (Barlow 1997; Buchanan et al. 2001; Barlow 2010). No short-finned pilot whales were seen during surveys off Oregon and Washington in 1989–1990, 1992, 1996, and 2001 (Barlow 2003). Carretta et al. (2021) reported one sighting off Oregon during 1991–2014. Several stranding events in Oregon/southern Washington have been recorded over the past few decades, including in March 1996, June 1998, and August 2002 (Norman et al. 2004).

Pilot whales are expected to be rare in the proposed survey regions.

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).

Off Oregon and Washington, 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 (Morejohn 1979; Green et al. 1992; Becker et al. 2014; Fleming et al. 2018; Carretta et al. 2021). Combined results of various surveys out to ~550 km offshore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North-south movements are believed to occur between Oregon/Washington and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001). Becker et al. (2014) predicted high densities off southern Oregon throughout the year, with moderate densities to the north. According to predictive density distribution maps, the highest densities off southern Washington and Oregon occur along the 500-m isobath (Menza et al. 2016).

Encounter rates reported by Green et al. (1992) during aerial surveys off Oregon/Washington were highest in fall, lowest during winter, and intermediate during spring and summer. Encounter rates during the summer were similarly high in slope and shelf waters, and somewhat lower in offshore waters (Green et al. 1992). Dall's porpoise was the most abundant species sighted off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys up to ~550 km from shore (Barlow 2003, 2010). Oleson et al. (2009) reported 44 sightings of 206 individuals off Washington during surveys from August 2004 to September 2008. Dall's porpoise were seen in the waters off Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014).

Nineteen Dall's porpoise sightings (144 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey (RPS 2012b). There were 16 Dall's porpoise sightings (54 animals) made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). During L-DEO's Cascadia survey during June–July 2021, one sighting of four individuals was made near the shelf edge off the Columbia River (RPS 2021b).

Dall's porpoise is likely to be encountered during the proposed seismic surveys.

Pinnipeds

Guadalupe Fur Seal (*Arctocephalus townsendi*)

Most breeding and births occur at Isla Guadalupe, Mexico; a secondary rookery exists at Isla Benito del Este (Maravilla-Chavez and Lowry 1999; Auriolles-Gamboa et al. 2010). A few Guadalupe fur seals are known to occur at California sea lion rookeries in the Channel Islands, primarily San Nicolas and San Miguel islands, and sightings have also been made at Santa Barbara and San Clemente islands (Stewart et al. 1987; Carretta et al. 2021). Guadalupe fur seals prefer rocky habitat for breeding and hauling out. They generally haul out at the base of towering cliffs on shores characterized by solid rock and large lava blocks (Peterson et al. 1968), although they can also inhabit caves and recesses (Belcher and Lee 2002). While at sea, this species usually is solitary but typically gathers in the hundreds to thousands at breeding sites.

During the summer breeding season, most adults occur at rookeries in Mexico (Norris 2017 *in* USN 2019; Carretta et al. 2021). Following the breeding season, adult males tend to move northward to forage. Females have been observed feeding south of Guadalupe Island, making an average round trip of 2375 km (Ronald and Gots 2003). Several rehabilitated Guadalupe fur seals that were satellite tagged and released in central California traveled as far north as B.C. (Norris et al. 2015; Norris 2017 *in* USN 2019). Fur seals younger than two years old are more likely to travel to more northerly, offshore areas than older fur seals (Norris 2017 *in* USN 2019). Stranding data also indicates that fur seals younger than 2 years are more likely to occur in the proposed survey area, as this age class was most frequently reported (Lambourn et al. 2012 *in* USN 2019). During 2015–2021, 724 Guadalupe fur seals stranded on the West Coast of the U.S., including 182 strandings along the coasts of Oregon and Washington during 2019–2021; NMFS declared this an unusual mortality event (NOAA 2021d).

Guadalupe fur seals could be encountered during the proposed seismic surveys, but most animals are likely to occur at their breeding sites farther south at the time of the surveys.

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. 2021). 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. 2021). 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. 2021). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2021). 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. 2021).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2021). 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. 2021; Muto et al. 2021). 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 Gulf of Alaska 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). Males usually migrate only as far south as the Gulf of Alaska (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 Gulf of Alaska throughout the summer (Calkins 1986). The northern fur seals 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. Pups from the California stock also migrate to Washington, Oregon, and northern California after weaning (Lea et al. 2009).

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990, including off Washington and Oregon (Buckland et al. 1993). Tagged adult fur seals were tracked from the Pribilof Islands to the waters off Washington/Oregon/California, with recorded movement throughout the region (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 Gulf of Alaska and the California Current (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 shifts 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).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon/Washington, with the greatest numbers (87%) occurring in January–May. Northern fur seals were seen as far out from the coast as 185 km, and numbers increased with distance from land; they were 5–6 times more abundant in offshore waters than over the shelf or slope (Bonnell et al. 1992). The highest densities were seen in the Columbia River plume (~46°N) and in deep offshore waters (>2000 m) off central and southern Oregon (Bonnell et al. 1992). The waters off Washington are a known foraging area for adult females, and concentrations of fur seals were also reported to occur near Cape Blanco, Oregon, at ~42.8°N (Pelland et al. 2014). During L-DEO's Cascadia survey during June–July 2021, one northern fur seal was sighted off Washington near the shelf edge (RPS 2021b).

Northern fur seals could be observed in the proposed survey regions, in particular females and juveniles. However, adult males are generally ashore during the reproductive season from May–August; adult females are generally ashore from June through November.

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). Bonnell et al. (1992) reported that northern elephant seals were distributed equally in shelf, slope, and offshore waters during surveys conducted off Oregon and Washington, as far as 150 km from shore, in waters >2000 m deep. Telemetry data indicate that they range much farther offshore than that (Stewart and DeLong 1995). Males may feed as far north as the eastern Aleutian Islands and the Gulf of Alaska, 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 Gulf of Alaska during foraging trips, and could potentially be passing through the area off Washington in May and August (migrating to and from molting periods) and November and February (migrating to and from breeding periods), but likely their presence there is transient and short-lived. Most elephant seal sightings at sea off Washington were made during June, July, and September; off Oregon, sightings were recorded from November through May (Bonnell et al. 1992). Northern elephant seal pups have been sighted at haulouts in the inland waters of Washington State (Jeffries et al. 2000), and at least three were reported to have been born there (Hayward 2003). Popping

has also been observed at Shell Island (~43.3°N) off southern Oregon, suggesting a range expansion (Bonnell et al. 1992; Hodder et al. 1998).

Northern elephant seals could be encountered during the proposed seismic surveys.

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 2021e). 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. 2021). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (Muto et al. 2021); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Only individuals from the Eastern DPS could occur in the proposed survey regions.

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 2013a; Muto et al. 2021). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008). Federally designated critical habitat for Steller sea lions in Oregon and California includes all rookeries (NMFS 1993). Although the Eastern DPS was delisted from the ESA in 2013, the designated critical habitat remains valid (NOAA 2021e). The critical habitat in Oregon is located along the coast at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock). The critical habitat area includes aquatic zones that extend 0.9 km seaward and air zones extending 0.9 km above these terrestrial and aquatic zones (NMFS 1993). The nearest proposed seismic transect would be located 46 km from shore.

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).

During surveys off the coasts of Oregon and Washington, Bonnell et al. (1992) noted that 89% of sea lions occurred over the shelf at a mean distance of 21 km from the coast and near or in waters <200 m deep; the farthest sighting occurred ~40 km from shore, and the deepest sighting location was 1611 m deep. Sightings were made along the 200-m depth contour throughout the year (Bonnell et al. 1992). During aerial surveys over the shelf and slope off Oregon and Washington, one Steller sea lion was seen on the Oregon shelf during January 2011, and two sightings totaling eight individuals were made on September 2012 off southern Oregon (Adams et al. 2014). During a survey off Washington/Oregon June–July 2012,

two Steller sea lions were seen from R/V *Langseth* (RPS 2012b) off southern Oregon. Eight sightings of 11 individuals were made from R/V *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a). No sightings were made during L-DEO's Cascadia summer survey off Oregon and Washington (RPS 2021b). Steller sea lions were also taken as bycatch off southern Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

Steller sea lions could be encountered in the proposed project regions.

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 Gulf of Alaska (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. 2021). Five genetically distinct geographic populations have been identified: (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 are coastal animals that often haul out on shore throughout the year, but peak numbers off Oregon and Washington occur during the fall (Bonnell et al. 1992). During aerial surveys off the coasts of Oregon and Washington during 1989–1990, California sea lions were sighted at sea during the fall and winter, but no sightings were made during June–August (Bonnell et al. 1992). Numbers off Oregon decrease during winter, as animals travel further north (Mate 1975 *in* Bonnell et al. 1992). King (1983) noted that sea lions are rarely found more than 16 km offshore. During fall and winter surveys off Oregon and Washington, mean distance from shore was ~13 km and most were observed in water <200 m deep; however, sightings were made in water as deep as 356 m (Bonnell et al. 1992). Weise et al. (2006) reported that males normally forage almost exclusively over the continental shelf, but during anomalous climatic conditions they can forage farther out to sea (up to 450 km offshore).

During aerial surveys over the shelf and slope off Oregon and Washington (Adams et al. 2014), California sea lions were seen during all survey months (January–February, June–July, September–October). Although most sightings occurred on the shelf, during February 2012, one sighting was made near the 2000-m depth contour, and during June 2011 and July 2012, sightings were made along the 200-m isobath off southern Oregon (Adams et al. 2014). During October 2011, sightings were made off the Columbia River estuary near the 200-m isopleth and on the southern Oregon shelf; during September 2012, sightings occurred in nearshore waters off Washington and in shelf waters along the coast of Oregon (Adams et al. 2014). Adams et al. (2014) reported sightings more than 60 km off the coast of Oregon. During L-DEO's Cascadia survey during June–July 2021, four sightings of nine California sea lions were

made in nearshore waters off Oregon (RPS 2021b). California sea lions were also taken as bycatch off Washington and Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

California sea lions could be encountered in the proposed project regions.

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 2022. 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 or lethal takes (Level A) is expected, given the nature of the planned operations, the mitigation measures that are planned (see § XI, MITIGATION MEASURES), in addition to the general avoidance by marine mammals of loud sound.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in the 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 (Hastie et al. 2019; Martin et al. 2020), and may become less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016; Houser 2021). Although the possibility cannot be entirely excluded, it is unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

Tolerance

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

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Situations with prolonged strong reverberation are infrequent. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the

Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015; Thode et al. 2020; Fernandez-Betelu et al. 2021). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Disturbance Reactions

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

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

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a

particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

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

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

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 in³ airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in³, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b, 2020). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in³) within 3 km and received levels of at least 140 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in³ array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks 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). Dunlop et al. (2020) found that humpback whales reduce their social interactions at greater distances and lower received levels than regulated by current mitigation practices.

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010

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

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

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

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

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals

within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~ 163 dB re $1 \mu\text{Pa}_{\text{rms}}$ (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~ 170 dB re $1 \mu\text{Pa}$ 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. However, Heide-Jørgensen et al. (2021) did report avoidance reaction at distances >11 km from an active seismic vessel, as well as an increase in travel speed and changes in direction at distances up to 24 km from a seismic source. No long-term effects were reported.

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. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 μ Pa, SELs of 145–151 dB μ Pa² · 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). Similar avoidance behavior and/or decreases in echolocation signals during 3-D seismic operations were reported for harbor porpoise in the North Sea (Sarnocińska et al. 2020). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 $\mu\text{Pa}_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in³ airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB $\mu\text{Pa}^2 \cdot \text{s}$. One porpoise moved away from the sound source but returned to natural movement patterns within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

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

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for gray seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of gray or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in³ airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Hearing Impairment and Other Physical Effects

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

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received

levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, duty cycle, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b, 2020a,b,c,d,e,f, 2021a,b; 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 $1 \mu\text{Pa}$ 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 ~ 17 s) from two airguns with a SEL_{cum} of 188 and 191 $\mu\text{Pa}^2 \cdot \text{s}$, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was < 1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

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

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

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Based on studies that exposed harbor porpoises to one-sixth-octave noise bands ranging from 1 to 88.4 kHz, Kastelein et al. (2019c,d, 2020d,e,f) noted that susceptibility to TTS increases with an increase in sound less than 6.5 kHz but declines with an increase in frequency above 6.5 kHz. At a noise band centered at 0.5 kHz (near the lower range of hearing), the SEL required to elicit a 6 dB TTS is higher than that required at frequencies of 1 to 88.4 kHz (Kastelein et al. 2021a). Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 μ 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. 2013a, 2021). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 μ Pa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 μ Pa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 μ Pa for 1 h induced a 44 dB TTS. A maximum TTS >45 dB was elicited from a harbor seal exposed to 32 kHz at 191 dB SEL (Kastelein et al. 2020c). For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 μ Pa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Harbour seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5 to 40 kHz (Kastelein et al. 2020a,b), but at frequencies of 2 kHz or lower, a higher SEL was required to elicit the same TTS (Kastelein et al. 2020c). Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 μ Pa; no low-frequency TTS was observed. Similarly, no TTS was measured when a bearded seal was exposed to a single airgun pulse with an unweighted SEL of 185 dB and an SPL of 207 dB; however, TTS was elicited at 400 Hz when exposed to four to ten consecutive pulses with a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). Kastelein et al. (2021b) found that susceptibility of TTS

of California sea lions exposed to one-sixth-octave noise bands centered at 2 and 4 kHz is similar to that of harbor seals.

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 noise exposure criteria for marine mammals that were released by NMFS (2016b, 2018) account for the newly available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and peak SPL_{flat} . Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat} . Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens

2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2106). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 71 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2021c). 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). 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. 2021). The study found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, suggesting that the level of foraging likely did not change during multibeam mapping. During an analogous study assessing naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2021).

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

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

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; Popov et al. 2020). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking.

In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals.

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

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

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

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

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

Another concern with vessel traffic is the potential for striking marine mammals. Information on vessel strikes is reviewed in § 3.6.4.4 and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

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

All takes would be anticipated to be Level B “takes by harassment” as described in § I, involving temporary changes in behavior. No injurious takes (Level A) would be expected. In the sections below, we describe methods to estimate the number of potential exposures to Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be harassed or disturbed appreciably by Level B sound levels by the seismic surveys in the Northeast Pacific Ocean. The main sources of distributional and numerical data used in deriving the estimates are summarized below.

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

Basis for Estimating “Takes”

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

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals in offshore waters of Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Barlow and Forney 2007; Forney 2007; Barlow 2010). Ship surveys for cetaceans in slope and offshore waters of Oregon and Washington were conducted by NMFS/SWFSC in 1991, 1993, 1996, 2001, 2005, 2008, and 2014 and synthesized by Barlow (2016); these surveys were conducted up to ~556 km from shore from June or August to November or December. These data were used by SWFSC to develop spatial models of cetacean densities for the CCE. Systematic, offshore, at-sea survey data for pinnipeds are more limited; the most comprehensive studies are reported by Bonnell et al. (1992) based on systematic aerial surveys conducted in 1989–1990.

The U.S. Navy primarily used SWFSC spatial models to develop a marine species density database for the Northwest Training and Testing Study Area (USN 2019), which encompasses the proposed survey areas; if no density spatial modeling was available, other data sources were used (USN 2019). The USN marine species density database is at this time the most comprehensive density data set available for the CCE. However, GIS data layers are currently unavailable for the database; thus, in this analysis the USN data were used only for species for which densities were not available from an alternative spatially-explicit model (e.g., minke, sei, gray, false killer, killer, and short-finned pilot whales, *Kogia* spp., and pinnipeds). Spatially-explicit density data from the NOAA CetSound website (NOAA 2021f) were used for most other species (i.e., humpback, blue, fin, sperm, Baird’s beaked, and other small beaked whales; bottlenose, striped, short-beaked common, Pacific white-sided, Risso’s, and northern right whale dolphins; and Dall’s porpoise).

TABLE 4. Densities and estimates of the possible numbers of individual marine mammals that could be exposed to the Level B thresholds for various hearing groups during the proposed seismic surveys in the Northeast Pacific Ocean during summer 2022. Species in italics are listed under the ESA as *endangered* or *threatened*.

Species	Density (#/km ²)	Level B Calculated Take	Regional Population Size	Requested Take as % of Pop. ¹	Requested Take Authorization ²
LF Cetaceans					
<i>North Pacific right whale</i>	0	0	400	0	0
<i>Humpback whale</i>	0.0005	1	2,900	0.1	2
<i>Blue whale</i>	0.0002	0	1,496	0.1	2
<i>Fin whale</i>	0.0024	4	9,029	<0.1	4
<i>Sei whale</i>	0.0004	1	519	0.4	2
Minke whale	0.0013	2	636	0.3	2
Gray whale	0.0010	1	26,960	<0.1	1
MF Cetaceans					
<i>Sperm whale</i>	0.0029	5	1,997	0.4	7
Baird's beaked whale	0.0004	1	2,697	0.3	9
Small beaked whale ³	0.0024	4	3,044	0.1	4
Bottlenose dolphin	0.0000	0	1,924	1	13
Striped dolphin	0.0021	3	29,211	<0.2	46
Short-beaked common dolphin	0.0048	8	969,861	<0.1	179
Pacific white-sided dolphin	0.0599	99	26,814	0.4	99
Northern right-whale dolphin	0.0495	82	26,556	0.3	82
Risso's dolphin	0.0099	16	6,336	0.3	22
False killer whale	N.A.	N.A.	N.A.	N.A.	5
Killer whale	0.0009	2	649	1.1	7
Short-finned pilot whale	0.0003	0	836	3.5	29
HF Cetaceans					
Pygmy/dwarf sperm whale	0.0016	3	4,111	0.1	3
Dall's porpoise	0.0936	155	25,750	0.6	155
Otariid Seals					
Northern fur seal	0.0361/0.0330*	56	608,143	<0.1	56
<i>Guadalupe fur seal</i>	0.0294	49	34,187	0.1	49
California sea lion	1.2951/0.0714*	794	257,606	0.3	794
Steller sea lion	0.0026	4	43,201	<0.1	4
Phocid Seal					
Northern elephant seal	0.0433	72	179,000	<0.1	72

N.A. means not applicable or not available. * Different densities based on distance from shore (see Appendix B).

¹ Requested take authorization expressed as % of population off California/Oregon/Washington, Eastern North Pacific, or U.S. stock (see Table 3).

² Requested take authorization is Level B calculated takes, used by NMFS as proxy for number of individuals exposed. Numbers in bold are based on mean group size from Mobley et al. (2000) for false killer whale and Barlow (2016) for other species.

³⁵ Requested take includes one each of Blainville's beaked whale, Stejneger's beaked whale, Cuvier's beaked whale, and Hubbs' beaked whale (see Appendix B for more information).

CetMap (<https://cetsound.noaa.gov/cda>) provides output from habitat-based density models for cetaceans in the CCE (Becker et al. 2020) in the form of GIS layers; these were used to calculate takes in the survey regions. The methods used to determine densities are detailed in Appendix B.

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 4 shows the estimates of the number of marine mammals that potentially could be exposed to ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details). When seasonal densities were available, the calculated exposures were based on summer densities (Appendix B), which were deemed to be most representative of the proposed survey timing. It should be noted that the exposure estimates assume that the proposed surveys would be completed in entirety. Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF/USGS PEIS. The 160-dB_{rms} criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of “takes by harassment” of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as “taken” to sound levels <160 dB (NMFS 2013b). The context of an exposure of a marine mammal to sound can affect the animal’s initial response to the sound (e.g., Ellison et al. 2012; NMFS 2013b; Hastie et al. 2020; Hückstädt et al. 2020; Southall et al. 2021). Southall et al. (2021) provide a detailed framework for assessing marine mammal behavioral responses to anthropogenic noise and note that use of a single threshold can lead to large errors in prediction impacts due to variability in responses between and within species.

The numbers of marine mammals that could be exposed to airgun sounds with received levels ≥ 160 dB re 1 $\mu\text{Pa}_{\text{rms}}$ (Level B) on one or more occasions have been estimated using a method recommended by NMFS for calculating the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day (~200 km) that is roughly similar to that of the entire survey. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by “drawing” the applicable Level B (Table 1) buffers around that line. The ensonified areas, increased by 25%, were then multiplied by the number of survey days (6 days). This is equivalent to adding an additional 25% to the proposed line km (Appendix B). The approach assumes that no marine mammals would move away or toward the trackline

in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches.

Conclusions

The proposed seismic surveys would involve towing a small 2-GI airgun cluster, 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, and 3.8.7, the PEIS concluded that outside the Gulf of Alaska, airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some cetaceans and pinnipeds, that Level A effects were unlikely, and that operations were unlikely to adversely affect ESA-listed species. Level A takes are considered highly unlikely. The brief duration of exposure of any given animal, the large proportion of survey effort in deeper water, 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.

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

There is limited whaling and sealing by indigenous groups in the Pacific Northwest. In the U.S., the Makah tribe has historically hunted gray whales; in recent times, a gray whale was successfully hunted on 17 May 1999 (NOAA 2021g). NOAA has recently released a proposed rule to allow a limited hunt for gray whales by the Makah tribe (NOAA 2019b). Given the temporary nature of the proposed activities and the fact that most operations would occur at least 46 km from shore, the proposed activities would not have any impact on the availability of the species or stocks for subsistence users.

IX. ANTICIPATED IMPACT ON HABITAT

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

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

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

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

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

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

XI. MITIGATION MEASURES

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

Numerous marine mammal species are known to occur in the proposed survey regions. To minimize the likelihood that impacts would occur to the species and stocks, airgun operations would be conducted in accordance with the MMPA and the ESA, including obtaining permission for incidental harassment or incidental ‘take’ of marine mammals and other endangered species and following requirements issued in the IHA and associated Incidental Take Statement (ITS).

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

Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed surveys was to evaluate what source level was necessary to meet the research objectives. It was decided that the scientific objectives could be met using a low-energy source consisting of two 45/105 in³ GI guns (total volume of 90 in³) at a tow depth of ~2–4 m.
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), weather conditions, equipment, and optimal timing for other proposed seismic surveys using R/V *Langseth*. Although marine mammals, including baleen whales, are expected to occur regularly in the proposed survey area, summer is the most practical season for the proposed surveys based on operational requirements.
3. *Mitigation Zones*—During the planning phase, mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by L-DEO for the Level B (160 dB re 1 μ Pa_{rms}) threshold. The background information and methodology for this are provided in Appendix A. The proposed surveys would acquire data with the 2-GI airgun array at a tow depth of ~2–4 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the 2-GI airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999).

The NSF and USGS PEIS defined a low-energy source as any towed acoustic source whose received level is ≤ 180 dB re 1 μ Pa_{rms} (the Level A threshold under the former NMFS acoustic guidance) at 100 m, including any single or any two GI airguns and a single pair of clustered airguns with individual volumes of ≤ 250 in³. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applied a 100-EZ for all low-energy acoustic sources in water depths >100 m. Consistent with the PEIS, that approach is used here for the pair of 45/105 in³ GI airguns in all water depths. If marine mammals are detected in or about to enter the appropriate EZ, the airguns would be shut down immediately. Enforcement of mitigation zones via shut downs would be implemented in the Operational Phase, as noted below. A fixed 160-dB “Safety Zone” was not defined for the same suite of low-energy sources in the NSF and USGS PEIS.

Mitigation During Operations

Mitigation measures that would be adopted include (1) vessel speed or course alteration, provided that doing so would not compromise operational safety requirements, (2) GI-airgun shut down within EZs, and (3) ramp-up procedures. Although power-down procedures are often standard operating practice for seismic surveys, they would not be used here because powering down from two airguns to one airgun would make only a small difference in the EZs—probably not enough to allow continued one-airgun operations if a mammal mammals came within the safety radius for two airguns.

Speed or Course Alteration

If a marine mammal is detected outside the EZ, based on its position and the relative motion, is likely to enter the EZ, the vessel’s speed and/or direct course could be changed. This would be done if operationally practicable while minimizing the effect on the planned science objectives. The activities and movements of the marine mammal (relative to the seismic vessel) would then be closely monitored to determine whether the animal is approaching the applicable EZ. If the animal appears likely to enter the EZ, further mitigative actions would be taken, i.e., either further course alterations or a shut down of the

seismic source. Typically, during seismic operations, the source vessel is unable to change speed or course and one or more alternative mitigation measures (see below) would need to be implemented.

Shut-down Procedures

If a marine mammal is detected outside the EZ but is likely to enter the EZ, and if the vessel’s speed and/or course cannot be changed to avoid having the animal enter the EZ, the GI airguns would be shut down before the animal is within the EZ. Likewise, if a marine mammal is already within the EZ when first detected, the GI airguns would be shut down immediately. Following a shut down, seismic activity would not resume until the marine mammal has cleared the EZ, or until the PSO is confident that the animal has left the vicinity of the vessel. The animal would be considered to have cleared the EZ zone if

- it is visually observed to have left the EZ, or
- it has not been seen within the zone for 15 min in the case of small odontocetes, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

Ramp-up Procedures

A ramp-up procedure would be followed when the pair of GI airguns begins operating after a specified period without GI airgun operations. It is proposed that, for the present survey, this period would be 15 min. Ramp up would not occur if a marine mammal has not cleared the EZ as described earlier. Ramp up would begin with one GI airgun 45 in³, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals are sighted, a shut down would be implemented as though the full array were operational.

If the EZ has not been monitored by PSOs for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up would not commence. A ramp up from a shut down may occur at night or in poor visibility as long as the EZ has been continually monitored by PSOs for 30 minutes prior to ramp-up with no marine mammal detections. Ramp up of the GI airguns would not be initiated if a marine mammal is sighted within or near the applicable EZ.

XII. PLAN OF COOPERATION

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

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

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

XIII. MONITORING AND REPORTING PLAN

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

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring and to satisfy the expected monitoring requirements of the IHA. L-DEO is not proposing to conduct passive acoustic monitoring, as the proposed cruise is a low-energy survey, and visual-based monitoring is expected to be sufficient to monitor the relatively small EZ. NMFS has not required passive acoustic monitoring during other low energy surveys.

L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan would be subject to review by NMFS and that refinements may be required. The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. L-DEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

Observations by PSOs would take place during daytime airgun operations and nighttime start ups of the airguns. Airgun operations would be suspended when marine mammals are observed within, or about to enter, designated EZs [see § XI above] where there is concern about potential effects on hearing or other physical effects. PSOs would also watch for marine mammals near the seismic vessel for at least 30 min prior to the planned start of airgun operations. Observations would also be made during daytime periods when R/V *Langseth* is underway without seismic operations, such as during transits.

During seismic operations, three 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". Typically, two observers would be on duty; however, for brief periods (such as during meal times), only one PSVO may be on duty. PSVO(s) would be on duty in shifts of duration no longer than 4 h. Other crew would also be instructed to assist in detecting marine mammals and turtles and implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew would be given additional instruction regarding how to do so.

R/V *Langseth* is a suitable platform for marine mammal observations. When stationed on the observation platform, the eye level would be ~21.5 m above sea level, and the observer would have a good view around the entire vessel. During daytime, the PSVO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.

PSO Data and Documentation

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

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

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

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

All observations and 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 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 near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations and all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities). The report would also include estimates of the number and nature of exposures that could result in “takes” of marine mammals by harassment or in other ways.

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

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

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LIST OF APPENDICES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

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APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for the Level B (160 dB re $1\mu\text{Pa}_{\text{rms}}$) threshold. 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 airguns, for the two 45-in³ GI airguns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the GoM in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth (~2000 m) for marine mammals (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 sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The results are summarized below.

In deep and intermediate-water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) for the 36-airgun array at a tow depth of 6 m can be used to derive mitigation radii.

The proposed surveys would acquire data with two 45-in³ GI guns at a tow depth of 2–4 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).

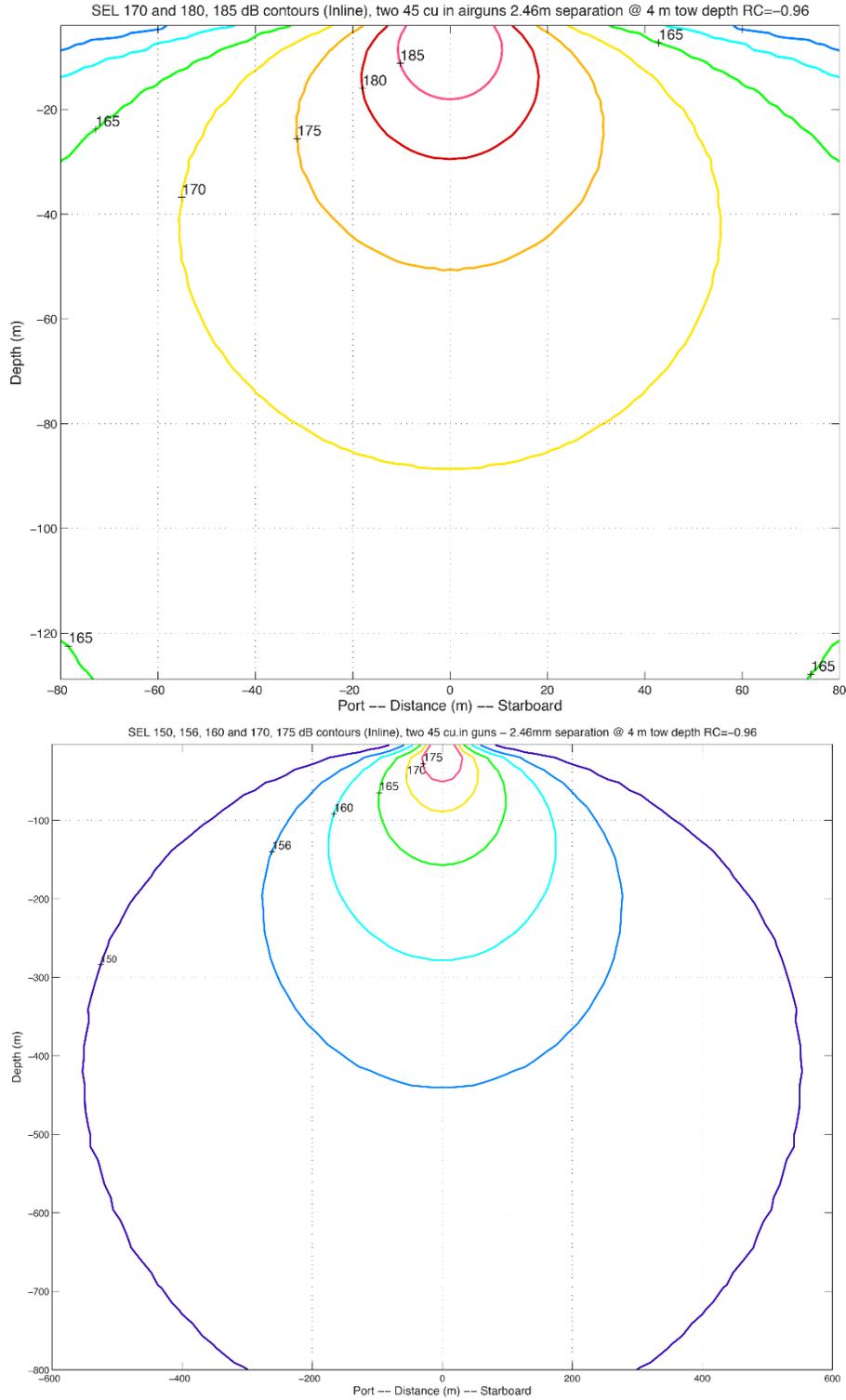


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the two 45-in³ GI guns, with a 2.46 m gun separation, planned for use during the proposed surveys in the Northeast Pacific Ocean at a 4-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

Table A-1 shows the distances at which the 160- and 175-dB re $1\mu\text{Pa}_{\text{rms}}$ sound exposure levels (SEL)² are expected to be received for the 2-GI airgun array at the maximum 4-m tow depth in deep water. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated Level B takes for marine mammals; a 175-dB level is used by NMFS, as well as the U.S. Navy (USN 2017), to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of R/V *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for R/V *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that in situ measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with in situ received level³ have confirmed that the L-DEO model generated conservative mitigation zones, resulting in significantly larger zones than required by NMFS.

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species, but did not establish new thresholds for Level B Harassment. The 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). 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. However, many data gaps remain where exposure criteria are concerned (Southall 2021). This document has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

TABLE A-2. Level B. Predicted distances to the 160 dB re $1\mu\text{Pa}_{\text{rms}}$ sound levels that could be received from two 45/105 in³ GI guns (at a tow depth of 4 m) that would be used during the seismic surveys in the Northeast Pacific Ocean during summer 2022.

Airgun Configuration	Water Depth (m)	Predicted Distances (m) to a Received Sound Level of 160 dB re $1\mu\text{Pa}_{\text{rms}}$
Two 45-in ³ GI guns	>1000	553

² SEL (measured in dB re $1\mu\text{Pa}^2 \cdot \text{s}$) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO's model.

³ 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).

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APPENDIX B: METHODS FOR MARINE MAMMAL DENSITIES AND TAKE CALCULATIONS

The U.S. Navy (USN) primarily used SWFSC spatial models to develop a marine species density database for the Northwest Training and Testing Study Area, which encompasses the proposed survey area; if no density spatial modeling was available, other data sources were used (USN 2019). The USN marine species density database is currently the most comprehensive density data set available for the CCE. However, GIS data layers are currently unavailable for the database; thus, in this analysis the USN data were used only for species for which density data were not available from an alternative spatially-explicit model (i.e., for minke, sei, gray, killer, and short-finned pilot whales, *Kogia* spp., pinnipeds, and leatherback sea turtle). The densities (Table B-1) were then multiplied by the daily ensonified area and the number of survey days (6) to determine Level B takes (Table B-2).

For most pinnipeds, we used the the highest densities for spring, summer, or fall from USN (2019), but corrected the estimates by projecting the most recent population growth/updated population estimates to 2022, when available. This same approach was used by NMFS for a previous L-DEO survey (i.e., CASCADIA) in the region in 2021. For California sea lions, spring densities from USN (2019) were used directly; the density for the '40–70 km from shore' distance band was used for the Oregon survey region, and the density for the '70–450 km from shore' distance band was used for the other survey regions. For the northern fur seal, the density for spring for the 'up to 70 km from shore' distance band was used for the Oregon survey region, and the spring density for the '>130 km from shore' distance band was used for the other survey regions. For the Guadalupe fur seal and Steller sea lion, summer densities for the '200-m isobath to 300 km from shore' were used. For the gray whale, the summer/fall density for the '10–47 km from shore' distance band (USN 2019) was used for the Oregon survey region; a density of zero was used for all other survey regions. For killer whales, the annual density for all stocks occurring offshore was used from USN (2019).

As recommended by NMFS, spatially-explicit density data from summer/fall from the NOAA CetSound website (NOAA 2021) were used for most other species (i.e., humpback, blue, fin, sperm, Baird's beaked, and other small beaked whales; bottlenose, striped, short-beaked common, Pacific white-sided, Risso's, and northern right whale dolphins; and Dall's porpoise). CetMap (<https://cetsound.noaa.gov/cda>) provides output of summer/fall habitat-based density models for cetaceans in the CCE (Becker et al. 2020) in the form of GIS layers; these were used to calculate takes in the survey area. The density estimates were available in the form of a GIS grid with each cell in the grid measuring ~7 km east-west by 10 km north-south. This grid was intersected with a GIS layer of the area expected to be ensonified to >160 dB SPL (i.e., the survey area). North, west, and south boundaries are based on overlap/intersection with geographic extents of all four combined survey regions; eastern grid coverage limit was defined by inclusion of cells that contained >25% overlap with the angled boundary of the survey area polygon. The densities from all grid cells overlapping the ensonified areas were averaged to calculate an average species-specific density for each species (Table B-1). These densities were then multiplied by the daily area expected to be ensonified and by the number of survey days (6) to estimate Level B takes (Table B-2).

The requested take for false killer whales was increased to mean group size provided by Mobley et al. (2000), as no density information was available for Oregon or Washington. Requested takes for some other species (indicated in bold in Table 5) were also increased to mean group size (Barlow 2016).

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TABLE B-1. Marine mammal densities expected to occur in the proposed survey area in the Northeast Pacific Ocean.

Species	Distance Band	Estimated Density (#/km ²)	Source	Comments
LF Cetaceans				
<i>North Pacific right whale</i>		0	-	Near zero
Humpback whale		0.000464	Becker et al. (2020)	Summer/fall
<i>Blue whale</i>		0.000226	Becker et al. (2020)	Summer/fall
<i>Fin whale</i>		0.002410	Becker et al. (2020)	Summer/fall
<i>Sei whale</i>		0.000400	USN (2019)	Summer/fall
Minke whale		0.001300	USN (2019)	Summer/fall
Gray whale	10-47 km from shore	0.001000	USN (2019)	Highest density applied for summer/fall; applied to Oregon survey region
MF Cetaceans				
<i>Sperm whale</i>		0.002859	Becker et al. (2020)	Summer/fall
Baird's beaked whale		0.000407	Becker et al. (2020)	Summer/fall
Small beaked whale		0.002446	Becker et al. (2020)	Summer/fall
Bottlenose dolphin		0.000038	Becker et al. (2020)	Summer/fall
Striped dolphin		0.002095	Becker et al. (2020)	Summer/fall
Short-beaked common dolphin		0.004845	Becker et al. (2020)	Summer/fall
Pacific white-sided dolphin		0.059902	Becker et al. (2020)	Summer/fall
Northern right-whale dolphin		0.049535	Becker et al. (2020)	Summer/fall
Risso's dolphin		0.009917	Becker et al. (2020)	Summer/fall
False killer whale				
Killer whale (Offshore waters)		0.000920	USN (2019)	Annual densities
Short-finned pilot whale		0.000250	USN (2019)	Annual densities
HF Cetaceans				
Pygmy/dwarf sperm whale		0.001630	USN (2019)	Annual densities
Dall's porpoise		0.093613	Becker et al. (2020)	Summer/fall
Otariid Seals				
Northern fur seal*				
	up to 70 km from shore	0.036115	USN (2019)	Density for February-May (higher than June-September, but lower than in January)
	>130 km from shore	0.032983	USN (2019)	Density for February-May (higher than June-September, but lower than in January)
<i>Guadalupe fur seal*</i>				
	200-m isobath to 300 km	0.029450	USN (2019)	Summer/fall density
California sea lion				
	40-70 km from shore	1.295100	USN (2019)	Spring density (highest)
	70-450 km from shore	0.071400	USN (2019)	Spring density (highest)
Steller sea lion*				
	200-m isobath to 300 km	0.002573	USN (2019)	Used highest density for OR/WA for summer
Phocid Seals				
Northern elephant seal*		0.043301	USN (2019)	Fall density (highest)

*densities adjusted for most recent population size

TABLE B-2. Take estimates for the proposed survey area in the Northeast Pacific Ocean.

Species	Density (#/km ²)	Regional Population Size	Daily Ensonified Area (km ²)	Number of Seismic Days	25% Increase	Estimated Level B Takes	% of Pop. (Requested Takes)	Requested Level B Take Authorization ^A
LF Cetaceans								
<i>North Pacific right whale</i>	0	400	221	6	1.25	0	0.00	0
Humpback whale	0.000464	2,900	221	6	1.25	1	0.07	2
<i>Blue whale</i>	0.000226	1,496	221	6	1.25	0	0.13	2
<i>Fin whale</i>	0.002410	9,029	221	6	1.25	4	0.04	4
<i>Sei whale</i>	0.000400	519	221	6	1.25	1	0.39	2
Minke whale	0.001300	636	221	6	1.25	2	0.34	2
Gray whale	0.001000	26,960	221	2	1.25	1	0.00	1
MF Cetaceans								
<i>Sperm whale</i>	0.002859	1,997	221	6	1.25	5	0.35	7
Baird's beaked whale	0.000407	2,697	221	6	1.25	1	0.33	9
Small beaked whale	0.002446	3,044	221	6	1.25	4	0.13	4
Bottlenose dolphin	0.000038	1,924	221	6	1.25	0	0.68	13
Striped dolphin	0.002095	29,211	221	6	1.25	3	0.16	46
Short-beaked common dolphin	0.004845	969,861	221	6	1.25	8	0.02	179
Pacific white-sided dolphin	0.059902	26,814	221	6	1.25	99	0.37	99
Northern right-whale dolphin	0.049535	26,556	221	6	1.25	82	0.31	82
Risso's dolphin	0.009917	6,336	221	6	1.25	16	0.35	22
False killer whale	N.A.	N.A.	221	6	1.25	N.A.	N.A.	5
Killer whale	0.000920	649	221	6	1.25	2	1.08	7
Short-finned pilot whale	0.000250	836	221	6	1.25	0	3.47	29
HF Cetaceans								
Pygmy/dwarf sperm whale	0.001630	4,111	221	6	1.25	3	0.07	3
Dall's porpoise	0.093613	25,750	221	6	1.25	155	0.60	155
Otariid Seals								
Northern fur seal	0.01103/0.01007*	608,143	221	6	1.25	17	0.00	17
<i>Guadalupe fur seal</i>	0.029450	34,187	221	6	1.25	49	0.14	49
California sea lion	0.0037/0.0065*	257,606	221	6	1.25	9	0.00	9
Steller sea lion	0.002573	43,201	221	6	1.25	4	0.01	4
Phocid Seal								
Northern elephant seal	0.037279	179,000	221	6	1.25	62	0.03	62

N.A. = not available. Highlighted cells indicate species for which densities were based on Becker et al. (2020); non-highlighted cells indicate species with densities from USN (2019), except for the right whale, for which densities were assumed to be zero. ^ARequested take for false killer whale is based on mean group size from Mobley et al. (2000); all other requested takes in bold are mean group sizes from Barlow (2106). *Two different densities were used depending on water depth/distance from shore (see Table B-1 for densities).