Draft Environmental Assessment of Marine Geophysical Surveys by R/V *Sally Ride* at the Cascadia Subduction Zone, northeast Pacific Ocean, September 2025

Prepared for

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ABSTRACT

Researchers from the New Mexico Institute of Mining and Technology (New Mexico Tech or NMT) and Oregon State University (OSU), with funding from the U.S. National Science Foundation (NSF), propose to conduct marine geophysical research at the Cascadia Subduction Zone in the northeast Pacific Ocean, during September 2025. The research would be conducted on the United States (U.S.) Navy-owned R/V *Sally Ride*, operated by Scripps Institution of Oceanography (SIO), using the portable multi-channel seismic (MCS) system operated by marine technicians from SIO. The study would include seismic surveys using two Generator-Injector (GI) airguns with a maximum discharge volume of ~90 in^3, in water depths ranging from 2000 to 3500 m deep. The surveys would take place within the Exclusive Economic Zone (EEZ) of the U.S.

NSF, as the research funding and action agency, has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…". The proposed seismic surveys would collect data in support of a research proposal that has been reviewed under the NSF merit review process and identified as an NSF program priority. The purpose of the proposed seismic surveys is to quantify the thermal effects of fluid circulation in oceanic crust entering the Cascadia Subduction Zone.

This Draft Environmental Assessment (EA) addresses NSF's requirements under the *National Environmental Policy Act* (NEPA) for the proposed NSF federal action within the U.S. EEZ. SIO, on behalf of itself, NSF, NMT, and OSU, have requested an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental (i.e., not intentional) harassment of small numbers of marine mammals should this occur during the seismic surveys. The analysis in this document supports the IHA application process and provides additional information on marine species that are not addressed by the IHA application, including sea turtles, seabirds, fish, and invertebrates that are listed under the U.S. Endangered Species Act (ESA), including candidate species. As analysis on endangered and threatened species was included, this document will also be used to support ESA Section 7 consultations with NMFS. Alternatives addressed in this EA consist of the Proposed Action with issuance of an associated IHA and the No Action alternative, with no IHA and no seismic surveys. This document tiers to the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011) and Record of Decision (June 2012), referred to herein as PEIS.

Numerous species of marine mammals inhabit the proposed project area in the northeast Pacific Ocean. Under the U.S. ESA, several of these species are listed as ***endangered***, including the North Pacific right, humpback (Central America Distinct Population Segment or DPS), sei, fin, blue, and sperm whales. 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. In addition, the ***threatened*** Mexico DPS of the humpback whale and the ***threatened*** Guadalupe fur seal could also occur in the proposed survey area. ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback turtle and ***threatened*** East Pacific DPS of the green turtle. ESA-listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross and Hawaiian petrel. The ***threatened*** marbled murrelet and western snowy plover are unlikely to occur in the offshore survey area. Several ESA-listed fish species occur in the area, including the ***endangered*** Puget Sound/Georgia Basin DPS of bocaccio; the ***threatened*** Pacific eulachon (Southern DPS), green sturgeon (Southern DPS), yelloweye rockfish, and several DPSs of steelhead trout; various ***endangered*** and ***threatened*** evolutionary significant units (ESUs) of chinook, chum, coho, and sockeye salmon; and the ***threatened*** bull trout.

Potential impacts of the proposed seismic surveys on the environment would be primarily a result of the operation of the airgun array. Other acoustic sources, including a multibeam echosounder (MBES), sub-bottom profiler (SBP), and Acoustic Doppler Current Profilers (ADCP) would also be operated during the surveys. Impacts from the Proposed Action would be associated with increased underwater anthropogenic sounds, which could result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned surveys is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed surveys, and to document, as much as possible, the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airguns including high-energy airgun arrays and also are not likely to be caused by other types of sound sources to be used. However, despite the relatively low levels of sound emitted by two GI airguns, a precautionary approach would be taken. The planned monitoring and mitigation measures would reduce the possibility of injurious effects.

Proposed protection measures designed to mitigate the potential environmental impacts to marine mammals, and ESA-listed sea turtles and seabirds include the following: ramp ups; two dedicated observers maintaining a visual watch during all daytime airgun operations; two observers 30 min before and during ramp ups during the day and night; and shut downs when marine mammals are detected in or about to enter designated exclusion zones (EZ). The acoustic source would also be shut down in the event an ESA-listed sea turtle or seabird (diving/foraging) would be observed within the designated EZ. Observers would also watch for impacts the acoustic sources may have on fish. The action proponents (SIO, OSU, NMT, SIO, and NSF) and its contractors are committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other potential environmental impacts. Survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and Incidental Take Statement (ITS) requirements.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals would be anticipated as falling within the *Marine Mammal Protection Act* (MMPA) definition of "Level B Harassment" for those species managed by NMFS. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats. Level A takes would not be anticipated and therefore were not requested.

LIST OF ACRONYMS

~	approximately
AEP	Auditory Evoked Potential
ADCP	Acoustic Doppler Current Profiler
BACI	Before-After/Control-Impact
B.C.	British Columbia
BIA	biologically important area
CCE	California Current Ecosystem
CFR	Code of Federal Regulations
CHIRP	Compressed High-Intensity Radiated Pulse
CIA	Central Intelligence Agency
CITES	Convention on International Trade in Endangered Species
CPA	Closest Point of Approach
CPUE	Catch Per Unit Effort
CSEL	Cumulative Sound Exposure Level
CTD	conductivity, temperature, depth
DAA	Detailed Analysis Area
DASPR	drifting acoustic spar buoys recorders
dB	decibel
DIP	Demographically Independent Population
DON	Department of the U.S. Navy
DPS	Distinct Population Segment
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	(U.S.) Endangered Species Act
EZ	Exclusion Zone
FM	Frequency-Modulated
GI	Generator-Injector
GIS	Geographic Information System
GLD	Geographic Location Description
GVP	Group Vocal Period
h	hour
HF	high frequency
hp	horsepower
Hz	Hertz
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
IODP	International Ocean Drilling Program
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometer
kt	knot
L-DEO	Lamont-Doherty Earth Observatory of Columbia University
LFA	Low Frequency Active (Sonar)
LF	low frequency
LME	large marine ecosystem
m	meter
MBES	multibeam echosounder
MCS	multi-channel seismic
MF	mid frequency
min	minute
MMPA	(U.S.) Marine Mammal Protection Act

MPA	Marine Protected Area
ms	millisecond
n.mi.	nautical mile
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NMFS	(U.S.) National Marine Fisheries Service
NMT	New Mexico Tech (Mexico Institute of Mining and Technology)
NOAA	National Oceanic and Atmospheric Administration
NPC	North Pacific Current
NRC	(U.S.) National Research Council
NSF	National Science Foundation
NWR	National Wildlife Refuges
OAWRS	Ocean Acoustic Waveguide Remote Sensing
OBR	Opercular Beat Rate
OBIS	Ocean Biodiversity Information System
OCNMS	Olympic Coast National Marine Sanctuary
OEIS	Overseas Environmental Impact Statement
ONR	(U.S.) Office of Naval Research
OOI	Ocean Observatories Initiative
OSU	Oregon State University
OW	otariid pinniped underwater
p or pk	peak
PASCAL	Passive Acoustics Survey of Cetacean Abundance Levels
PBR	Potential Biological Removal
PDO	Pacific Decadal Oscillation
PEIS	Programmatic Environmental Impact Statement
PFMC	Pacific Fishery Management Council
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
PW	phocid pinniped underwater
QAA	qualitative analysis area
RL	Received level
rms	root-mean-square
R/V	research vessel
s	second
SEL	Sound Exposure Level
SIO	Scripps Institution of Oceanography
SOSUS	(U.S. Navy) Sound Surveillance System
SPL	Sound Pressure Level
SSRU	Small-scale Research Unit
SST	Sea Surface Temperature
SURTASS	Surveillance Towed Array Sensor System
SWFSC	Southwest Fisheries Science Center
SWOT	State of the World's Sea Turtles
TTS	Temporary Threshold Shift
UNEP	United Nations Environment Programme
U.S.	United States of America
USC	United States Code
USCG	U.S. Coast Guard
USFWS	U.S. Fish and Wildlife Service
µPa	microPascal
VHF	very high frequency
vs.	versus

I. PURPOSE AND NEED

Researchers from the New Mexico Institute of Mining and Technology (New Mexico Tech or NMT) and Oregon State University (OSU), with funding from the U.S. National Science Foundation (NSF), propose to conduct marine geophysical research at the Cascadia Subduction Zone in the northeast Pacific Ocean, during September 2025. The research would be conducted on the United States (U.S.) Navy-owned R/V *Sally Ride*, operated by Scripps Institution of Oceanography (SIO), using the portable multi-channel seismic (MCS) system operated by marine technicians from SIO. This Draft Environmental Assessment (EA) was prepared to address the requirements under the National Environmental Policy Act (NEPA) for the proposed NSF federal action within the U.S. EEZ. The Draft EA tiers to 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 Draft EA also tiers to the Final EA of Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Cascadia Subduction Zone in the northeast Pacific Ocean, 2021 (LGL 2021). The purpose of this Draft EA is to provide the information needed to assess the potential environmental impacts associated with the Proposed Action, including the use of 2 GI airguns during the proposed seismic surveys.

The Draft EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic surveys on marine mammals, sea turtles, seabirds, fish, and marine invertebrates. The Draft EA will also be used in support of other regulatory processes, including an application for an Incidental Harassment Authorization (IHA) and Section 7 consultation under the Endangered Species Act (ESA) with the National Marine Fisheries Service (NMFS). The IHA would allow the non-intentional, non-injurious "take by harassment" of small numbers of marine mammals[1] during the proposed seismic surveys. Because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely and were not requested or anticipated to be issued.

1.1 Mission of NSF

NSF was established by Congress with the *National Science Foundation Act* of 1950 (Public Law 810507, as amended) and is the only federal agency dedicated to the support of fundamental research and education in all scientific and engineering disciplines. Further details on the mission of NSF are described in § 1.2 of the PEIS.

1.2 Purpose of and Need for the Proposed Action

As noted in the PEIS, § 1.3, NSF has a continuing need to support marine geophysical research, including seismic surveys that enable scientists to collect data essential to understanding the complex Earth processes beneath the ocean floor. The Proposed Action would contribute to understanding the thermal structure of oceanic lithosphere, with the immediate objective being to constrain the temperature field of the incoming plate beneath Cascadia.

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[1] To be eligible for an IHA under the MMPA, the proposed "taking" (with mitigation measures in place) must not cause serious physical injury or death of marine mammals, must have negligible impacts on the species and stocks, must "take" no more than small numbers of those species or stocks, and must not have an unmitigable adverse impact on the availability of the species or stocks for legitimate subsistence uses.

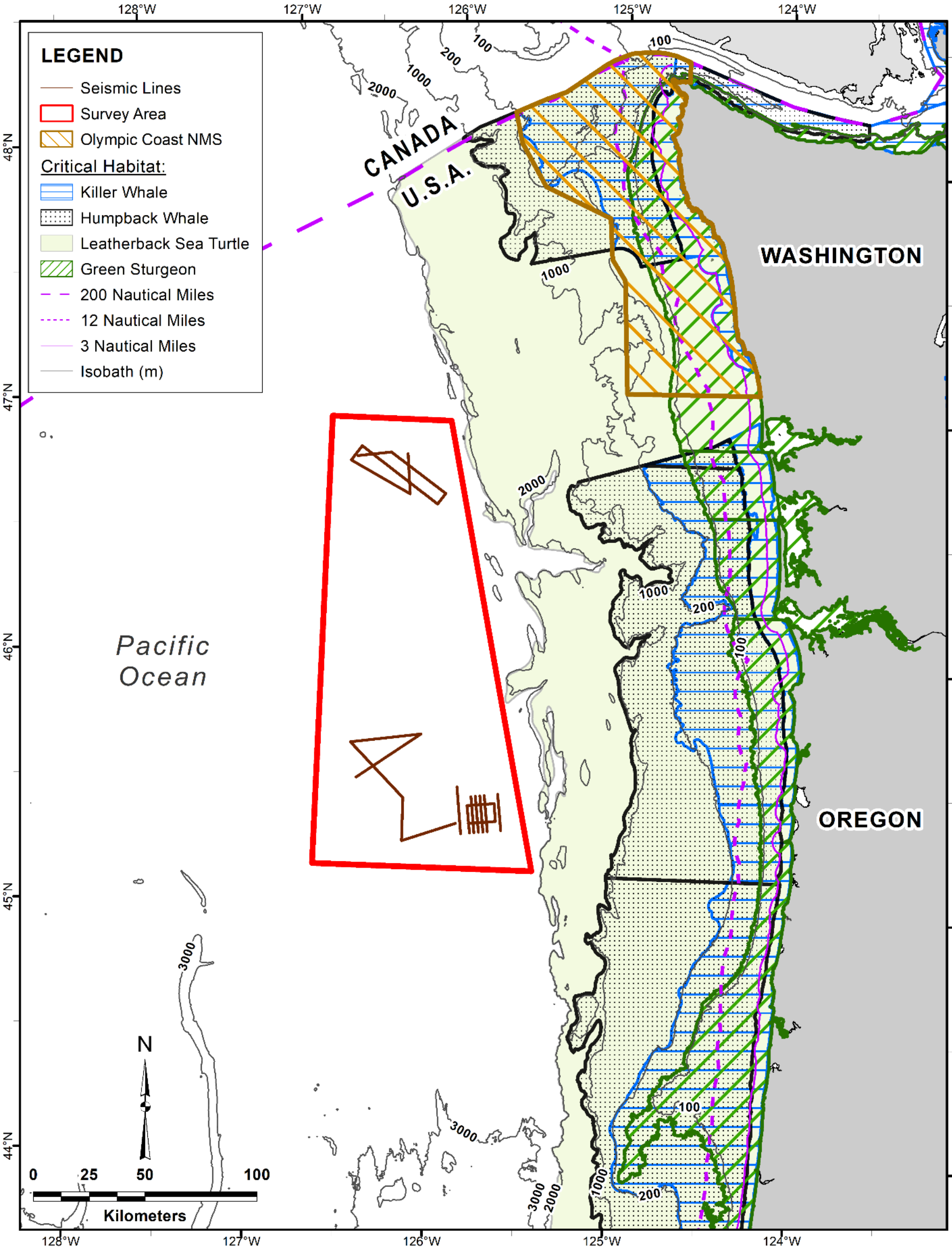

FIGURE 1. Survey area for the proposed seismic surveys at the Cascadia Subduction Zone, showing representative transect lines.

1.3 Background of NSF-funded Marine Seismic Research

The background of NSF-funded marine seismic research is described in § 1.5 of the PEIS.

1.4 Regulatory Setting

The regulatory setting of this EA is described in § 1.8 of the PEIS, including the

- National Environmental Protection Act (NEPA) of 1969 (42 United States Code [USC] §4321 *et seq.*); the Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (Title 40 Code of Federal Regulations [CFR] §§ 1500-1508 *et seq.* ; NSF procedures for implementing NEPA and CEQ regulations (45 CFR 640);
- Marine Mammal Protection Act (MMPA) of 1972 (16 USC 1631 *et seq.*);
- Endangered Species Act (ESA) of 1973 (16 USC ch. 35 §1531 *et seq.*);
- Coastal Zone Management Act (CZMA) of 1972 (16 USC §§1451 *et seq.*); and
- Magnuson-Stevens Fishery Conservation and Management Act - Essential Fish Habitat (EFH) (Public Law 94-265; 16 USC ch. 38 §1801 *et seq.*).

II. ALTERNATIVES INCLUDING PROPOSED ACTION

In this Draft EA, two alternatives are evaluated: (1) Proposed Action: conducting the proposed marine geophysical research, including seismic surveys, and associated issuance of an IHA, and (2) No Action alternative. Two additional alternatives were considered but were eliminated from further analysis. A summary of the Proposed Action, the alternative, and alternatives eliminated from further analysis is provided at the end of this section.

2.1 Proposed Action

The Proposed Action, including project objectives and context, activities, and monitoring/ mitigation measures for the proposed marine geophysical research, is described in the following subsections.

2.1.1 Project Objectives and Context

Principal Investigator (PI) Dr. G. Spinelli (NMT) and co-PIs Drs. R. Harris and A. Tréhu (OSU) propose to conduct seismic surveys to quantify the thermal effects of fluid circulation in oceanic crust entering the Cascadia Subduction Zone. The seismic data would be used to define the basement topography and overlying sedimentary structure. This information is needed to both plan the heat flow survey and interpret the heat flow results, which is the primary goal of the project. This 2025 cruise builds upon research conducted in 2022 which was prematurely halted because of a ship malfunction and research conducted in 2024 which collected heat flow data (no seismic data acquisition). To achieve the program goals, the PIs would use the seismic surveying capabilities of R/V *Sally Ride* to conduct high-resolution MCS profiles at the Cascadia Subduction Zone in the northeast Pacific Ocean.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed surveys would take place at the Cascadia Subduction Zone in the northeast Pacific Ocean, within the U.S. EEZ, within an area bounded by the following approximate coordinates: 45°N/127°W, 47°N/127°W, 47°N/ 126°W, and 45°N/ 125.5°W (Fig. 1). The survey area is located more than 100 km from the coast in water depths ranging from 2000 to 3500 m. Representative seismic survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the seismic surveys could occur anywhere within the survey area and general coordinates noted above.

2.1.2.2 Description of the Activities

The procedures to be used for the seismic surveys would be similar to those used during previous NSF-funded research seismic surveys and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Sally Ride*. Marine technicians would deploy two 45/105 in^3 GI airguns as an energy source, with a maximum discharge volume of ~90 in^3, from R/V *Sally Ride*. The GI airguns would be towed at a depth of 4 m and a speed of 5 kt (9.26 km/h). The receiving system would consist of one 1-km long hydrophone streamer. As the airguns are towed along the survey lines, the solid-state (solid flexible polymer made from extruded polyurethan, not gel or oil filled) hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

The surveys would consist of ~444 km of seismic acquisition (see Fig. 1). All effort would occur in water more than 2000 m deep. There could be additional seismic operations associated with airgun testing and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations (see § 4.1.1.5), 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed.

In addition to the operations of the airgun array, other acoustic sources, including a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and Acoustic Doppler Current Profilers (ADCP), would be operated from R/V *Sally Ride* continuously during the seismic surveys. All planned marine-based geophysical data acquisition activities would be conducted by SIO 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.

2.1.2.3 Schedule

The surveys are proposed to occur during September 2025. R/V *Sally Ride* would likely depart from Newport, OR, on 6 September and return to Newport on 8 September 2025, after the program is completed. The cruise is expected to consist of 3 days at sea, including 2 days of seismic operations and 1 day of transit. The vessel operator strives to schedule its operations in the most efficient manner possible; schedule efficiencies are achieved when regionally occurring research projects are scheduled consecutively and non-operational transits are minimized. Because of the long timeline associated with the ESA Section 7 consultation and IHA processes, not all research project or vessel logistics are identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations.

2.1.2.4 Vessel Specifications

R/V *Sally Ride* is operated by SIO under a charter agreement with the Office of Naval Research. R/V *Sally Ride* has a length of 72.5 m, a beam of ~15 m, and a draft of ~4.6 m. R/V *Sally Ride* is equipped with two Siemens 836 kw motors. The cruising speed is 10.1 kt and the maximum speed is 12.8 kt. The range is 10,545 n.mi. at 12 kt, with an endurance of ~40 days. The vessel speed during seismic operations would be ~5 kt (~9.3 km/h).

Other details of R/V *Sally Ride* include the following:

Owner:	U.S. Navy
Operator:	SIO
Flag:	U.S.
Date Built:	2016
Gross Tonnage:	3043
Accommodation Capacity:	46 including ~26 scientists

R/V *Sally Ride* would also serve as the platform from which vessel-based protected species observers (PSOs) would watch for marine species before and during airgun operations.

2.1.2.5 Airgun Description

R/V *Sally Ride* would tow two GI airguns and one streamer containing hydrophones. The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, would be 45 in^3. The injector chamber (105 in^3) injects air into the previously generated bubble to maintain its shape and does not introduce more sound into the water. The GI airgun(s) would be separated by ~2 m and would be towed 25 m behind R/V *Sally Ride* at a depth of 4 m. Seismic pulses would be emitted at intervals of ~12.5–25 m (5–10 s) from the GI airgun(s).

<u>GI Airgun Specifications</u>

Energy Source:	Two GI airguns of 45 in^3 each
Gun positions used:	Inline airguns spaced ~2 m apart
Towing depth of energy source:	4 m
Source output:	0-peak is 3.6 bar-m (234.3 dB re 1 µPa·m); peak-peak is 7.2 bar-m (239.6 dB re 1 µPa·m)
Air discharge volume:	~90 in^3 (maximum volume to be used)
Dominant frequency components:	0–188 Hz
Gun volumes at each position (in^3):	45
Firing pressure:	2000 psi
Pulse duration:	0.113 s

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 ~5º. 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 rms[2] (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 the literature. A measured received sound pressure level (SPL) of 160 dB re 1 μPa_{rms} in the farfield would typically correspond to ~170 dB re 1 μPa_{p} or 176–178 dB re 1 $\mu Pa_{p\text{-}p}$, as measured for the same pulse received at the same location (Greene 1997; McCauley et al. 1998, 2000). The exact 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 source.

2.1.2.6 Additional Acoustical Data Acquisition Systems

Additional acoustical data acquisition systems would be operated during the Proposed Action at any time to meet scientific objectives. The ocean floor would be mapped with an MBES and SBP, which are further described in § 2.2.3.1 of the PEIS. MBESs include the Kongsberg EM124 (12 kHz) and Kongsberg EM712 (40–100 kHz), with a 0.5 degree x 1 degree transducer array. The Kongsberg SBP29 would be operated at frequencies of 2 to 9 kHz. It has a 3°, 6°, or 12° transmit beam width, with up to 21 beams across per ping, and a source level at 4 kHz of 228 dB for the 3° system. The fisheries echosounder EK80 operates at frequencies of 200 kHz, 70 kHz, 38 kHz, or 18 kHz. The Kongsberg EC150 (dual purpose fisheries echosounder and ADCP) operates at a frequency of 150 kHz. The Teledyne RDI Ocean Surveyor ADCP has three available transducers which operate at frequencies of 38 kHz, 75 kHz, or 150 kHz. The Teledyne RDI 300 kHz Workhorse II Mariner ADCP may also be used. Similar sound sources are described in § 2.2.3.1 of the PEIS.

2.1.3 Monitoring and Mitigation Measures

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.4.1 of the PEIS and would occur in two phases: pre-cruise planning and during operations. The following sections describe the efforts during both stages for the Proposed Action.

2.1.3.1 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 activities. Several factors were considered during the planning phase of the proposed activities, including:

***Energy Source*.—**Part of the considerations for the proposed surveys was to evaluate what source level was necessary to meet the research objectives. Prior experience in the region indicates that 2 GI airguns would be adequate as the energy source to image the basement in this environment.

***Survey Timing*.—**The PIs worked with NSF to consider potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed cruises using R/V *Sally Ride*. Although marine mammals, including baleen whales, are expected

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

to occur regularly in the proposed survey area, late summer (i.e., September) is the most practical season for the proposed surveys based on operational requirements and data quality concerns.

***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 $1\mu Pa_{rms}$) threshold. The proposed surveys would acquire data with the 2-GI airgun array at a tow depth of ~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 background information and methodology for this are provided in Appendix A. Although Level A takes are not requested and would likely not be issued, the predicted distances to the Level A threshold distances are included in Appendix B.

Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound level is expected to be received for the 2-GI airgun array. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. Table 1 also shows the distance at which the 175-dB re $1\mu Pa_{rms}$ sound level is expected to be received for the airgun source; this level is used by NMFS, based on U.S. DoN (2017), to determine behavioral disturbance for sea turtles.

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. Shut downs would be implemented for marine mammals within the designated EZ. A shut down would also be implemented for ESA-listed sea turtles and seabirds (diving/foraging). A 150-m EZ would be used for shut downs of the GI airguns for sea turtles and seabirds. Enforcement of mitigation zones via shut downs would be implemented as described below.

2.1.3.2 Operational Phase

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities would be expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include:

(1) monitoring by PSOs for marine mammals, ESA-listed sea turtles and seabirds (diving/foraging) near the vessel, and observing for potential impacts of acoustic sources on fish;

(2) PSO data and documentation; and

(3) mitigation during operations (speed or course alteration; shut down and ramp up procedures; and special mitigation measures for rare species, and species concentrations).

It would be unlikely that concentrations of large whales would be encountered within the 160-dB isopleth, but if they were, they would be avoided.

TABLE 1. Predicted distances (based on L-DEO modeling) to behavioral disturbance sound levels ≥160-dB re 1 μPa$_{rms}$ and ≥175-dB re 1 μPa$_{rms}$ that could be received during the proposed surveys at the Cascadia Subduction Zone. The 160-dB criterion applies to all hearing groups of marine mammals (Level B harassment) and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distance (in m) to the 160-dB Received Sound Level	Predicted distance (in m) to the 175-dB Received Sound Level
Two 45 in^3 GI guns, 2-m separation distance	4	>1000 m	505	89

During daytime, the PSO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon) 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.

Mitigation measures that would be adopted during the proposed surveys include (1) shut down procedures and (2) ramp up procedures. These measures are being proposed based on past experience and for consistency with the PEIS.

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 airgun(s) 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 airgun(s) 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,
- it has not been seen within the zone for 15 min in the case of small odontocetes, ESA-listed seabirds and sea turtles, or
- it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm and beaked whales.

The airgun array would be ramped up gradually after a shut down for marine mammals but would not be required for ESA-listed sea turtles or seabirds.

Ramp up Procedures.—A ramp up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal has not cleared the EZ as described earlier. As previously noted, for shut downs implemented for sea turtles and ESA-listed seabirds, no ramp up would be required, as long as the animal was no longer observed within the EZ.

Ramp up would begin with one GI airgun, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals or ESA-listed sea turtles are sighted, a shut down would be implemented as though the full array were operational.

The proposed operational mitigation measures are standard for seismic cruises, per the PEIS. Independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours. Monitoring and mitigation measures are further described in the IHA application.

If the EZ has not been monitored by PSOs for at least 30 min prior to the start of operations, ramp up would not commence. A ramp up from a shut down may occur in poor visibility/darkness 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 EZ.

A monitoring report would be provided to NMFS, both the Permits and Conservation Division and the ESA Interagency Cooperation Division, per the IHA and Biological Opinion. With the proposed monitoring and mitigation provisions, potential effects on most, if not all, individual marine mammals and sea turtles would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individuals and on the associated species and stocks. Ultimately, survey operations would be conducted in accordance with all applicable international and U.S. federal regulations, including IHA and ITS requirements.

2.2 Alternative 1: No Action Alternative

An alternative to conducting the proposed activities is the “No Action” alternative, i.e., do not issue an IHA and do not conduct the research operations (Table 2). Under the “No Action” alternative, NSF would not support the conduct of the proposed research operations. From NMFS’ perspective, pursuant to its obligation to grant or deny permit applications under the MMPA, the “No Action” alternative entails NMFS denying the application for an IHA. If NMFS were to deny the application, the action proponents would not be authorized to incidentally take marine mammals. If the research was not conducted, the “No Action” alternative would result in no disturbance to marine mammals attributable to the Proposed Action. Although the “No Action” alternative is not considered a reasonable alternative because it does not meet the purpose and need for the Proposed Action, it is included and carried forward for analysis in § 4.3.

2.3 Alternatives Considered but Eliminated from Further Analysis

2.3.1 Alternative E1: Alternative Location

The survey location is driven by locations of buried seamounts and pseudofaults near the Cascadia Subduction Zone deformation front, based on prior seismic and potential field data. The overall purpose of the proposed survey is to quantify the thermal effects of fluid circulation in oceanic crust entering the Cascadia Subduction Zone. The proposed cruise builds on research cruises conducted in 2022 (which was prematurely halted because of a ship malfunction) and 2024 (which only collected heat flow data; no seismic data acquisition). Thus, there are no other locations outside of this region where this study could be done.

2.3.2 Alternative E2: Use of Alternative Technologies

As described in § 2.6 of the PEIS, alternative technologies to the use of airguns were investigated to conduct marine geophysical research. At this time, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2014a).

TABLE 2. Summary of Proposed Action, Alternative Considered, and Alternatives Eliminated.

Proposed Action	Description/Analysis
Proposed Action: Conduct marine geophysical research and associated activities	Under this action, research activities are proposed to study Earth processes and would involve marine seismic surveys. Active seismic operations would be expected to take ~2 days. The affected environment, environmental consequences, and reasonably foreseeable effects of the proposed activities are described in § III and IV. The standard monitoring and mitigation measures identified in the PEIS would apply, along with any additional requirements identified by international and U.S. regulating agencies. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.
Alternative	Description/Analysis
Alternative 1: No Action	Under this Alternative, no proposed activities would be conducted, and seismic data would not be collected. While this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the Proposed Action. Data of scientific value with the aim to quantify the thermal effects of fluid circulation in oceanic crust entering the Cascadia Subduction Zone would not be collected. In addition, the collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. No permits and authorizations, including an IHA, would be needed from regulatory bodies, as the Proposed Action would not be conducted.
Alternatives Eliminated from Further Analysis	Description/Analysis
Alternative E1: Alternative Location	The survey location is driven by locations of buried seamounts and pseudofaults near the Cascadia Subduction Zone deformation front, based on prior seismic and potential field data. The overall purpose of the proposed survey is to quantify the thermal effects of fluid circulation in oceanic crust entering the Cascadia Subduction Zone. The proposed cruise would complement cruises previously conducted in 2022 (which was prematurely halted because of a ship malfunction) and 2024 (which only collected heat flow data; no seismic data acquisition), completing and building on results from those cruises. Thus, there are no other locations outside of this region where this study could be done.
Alternative E2: Alternative Survey Techniques	Under this alternative, L-DEO would use alternative survey techniques, such as marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the PEIS, § 2.6. At this time, however, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need.

III. AFFECTED ENVIRONMENT

As described in the PEIS, Chapter 3, the description of the affected environment focuses only on those resources potentially subject to impacts. Accordingly, the discussion of the affected environment (and associated analyses) focuses mainly on those related to marine biological resources, as the proposed short-term marine activity has the potential to impact marine biological resources within the survey area. These resources are identified in § III, and the potential impacts to these resources are discussed in § IV. Initial review and analysis of the Proposed Action determined that the following resource areas did not require further analysis in this EA:

- *Air Quality/Greenhouse Gases*.—Only one vessel, R/V *Sally Ride*, would be used during the proposed marine seismic surveys. Project vessel emissions would result from the proposed activities; however, these short-term emissions would not result in any exceedance of Federal Clean Air standards. Emissions would be expected to have a negligible impact on the air quality within the survey area;
- *Land Use*.—All activities are proposed to occur in the marine environment; thus, no changes to current land uses or activities within the proposed survey area would result from the project;
- *Safety and Hazardous Materials and Management*.—No hazardous materials would be generated or used during proposed activities. All project-related wastes would be disposed of in accordance with international and U.S. federal requirements;
- *Geological Resources (Topography, Geology and Soil)*.—The proposed project would not involve placement of equipment on the seafloor; therefore, disturbances to geologic resources would not be anticipated. Thus, the proposed activities would not significantly impact geologic resources;
- *Water Resources*.—No discharges to the marine environment that would adversely affect marine water quality are expected in the proposed survey area. Therefore, there would be no impacts to water resources resulting from the proposed project activities;
- *Terrestrial Biological Resources*.—All proposed project activities would occur in the marine environment and would not impact terrestrial biological resources;
- *Visual Resources*—No visual resources would be expected to be negatively impacted as the proposed activities would be short-term and located far offshore. During operations, the vessel would not be within the viewshed of the coast; and
- *Socioeconomics*.—Implementation of the proposed project would not affect, beneficially or adversely, socioeconomic resources, or the protection of children. No changes in the population or additional need for housing or schools would occur. Other human activities in the area around the survey vessel would include fishing and other vessel traffic. Fisheries and potential impacts to fishing are described in further detail in Sections 3.6 and 4.1.2. No other socioeconomic impacts would be anticipated as result of the proposed activities. SCUBA diving and whale watching occur in nearshore waters, not within range of the survey, and are not described in further detail.

3.1 Oceanography

The proposed survey area is located in the northeast Pacific Ocean. The North Pacific Current (NPC) is a warm water current that flows west to east between 40ºN and 50ºN. The NPC forms the northern part of the clockwise-flowing subtropical gyre; to the north of it, the subarctic gyre flows counterclockwise (Escorza-Treviño 2009). The convergence zone of the subarctic and central gyres, known as the Subarctic Boundary, crosses the western and central North Pacific Ocean at 42ºN (Escorza-Treviño 2009). It is in that area that the change in abundance of cold-water vs. warm-water species is the greatest (Escorza-Treviño 2009). In the eastern Pacific, the NPC splits into the northward flowing Alaska Current and the southward flowing California Current (Escorza-Treviño 2009). The California Current system nutrifies offshore waters by mixing with water from the shelf edge (Buchanan et al. 2001).

The proposed survey area off Washington and Oregon is located within the California Current Large Marine Ecosystem (LME). This LME is considered a Class III low productivity ecosystem (<150 gC/m^2/y) although seasonal upwelling of cold nutrient-rich water in this region generate localized areas of high productivity supporting fisheries (Aquarone and Adams 2009). Winds blowing toward the Equator cause upwelling during March–November and are strongest over the main flow of the California Current which is 200–400 km offshore (Longhurst 2007). Persistent eddies in the summer in some locations, like the Strait of Juan de Fuca, can transport upwelling waters up to several hundred kilometers offshore (Longhurst 2007). Even in winter, cold upwelled water "tongues" can extend offshore for hundreds of kilometers, increasing nutrient levels offshore (Longhurst 2007). The highest productivity occurs in May–June (Longhurst 2007). Acoustic backscatter surveys within the California Current LME showed that fish and zooplankton are associated with shallow bathymetry in this region; the highest densities were located in water <4000 m deep (Philbrick et al. 2003).

Numerous publications have examined the role of climate shifts as a forcing agent on species and community structure of the North Pacific Ocean (e.g., Francis and Hare 1994; Klyashtorin 1998; McGowan et al. 1998; Hollowed et al. 1998; Hare and Mantua 2000). Regime shifts that might impact productivity in the region include the Pacific Decadal Oscillation (PDO) and the El Niño Southern Oscillation. The PDO is similar to a long-lived El Niño-like pattern of climate variability; it is mainly evident in the North Pacific/North American area, whereas El Niños are typical in the tropics (Mantua 1999). Changes in the eastern North Pacific Ocean marine ecosystem have been correlated with changes in the PDO. Warm PDOs showed increased coastal productivity in Alaska and decreased productivity off the U.S. West Coast, whereas the opposite north-south pattern of marine ecosystem productivity was seen during cold PDOs (Mantua 1999). PDO "events" persist for 20–30 years, whereas typical El Niño events persist for 6–18 months (Mantua 1999). In the past century, there have been two PDO cycles: "cool" PDO regimes during 1890–1924 and 1947–1976, and "warm" PDO regimes during 1925–1946 and 1977 to the mid-1990s (Mantua et al. 1997; Minobe 1997). This was followed by a "cool" period from 1999–2002, a "warm" period from 2003–2006, and another "cool" period from 2007–2013; in 2014, the PDFO turned to a "warm" phase again (NASA 2025).

A mass of warm water, referred to as "the Blob", formed in the Gulf of Alaska during autumn 2013 and grew and spread across the majority of the North Pacific and Bering Sea during spring and summer 2014, resulting in sea surface temperature anomalies ≥4ºC across the region (Peterson et al. 2016). During autumn 2014, decreased upwelling winds caused a portion of this warm water to travel eastward towards the continental shelf off eastern Alaska and the Pacific Northwest, making the sea surface temperature pattern associated with the Blob resemble a "warm" or "positive" PDO pattern (Peterson et al. 2016). Ongoing effects from "the Blob" were further perturbed by a major El Niño arriving from the south and affecting the region during 2015 and 2016, the combination of which reduced the ecosystem's productivity and altered marine community structure for several years (Brodeur et al. 2018). As of May 2016, sea surface temperature anomalies in the outer shelf waters off Oregon remained 2ºC higher, with indications the trend would likely continue well into 2017 (Peterson et al. 2016).

During late 2018, sustained unseasonably warm conditions likely caused the formation of a new mass of warm water encompassing a large portion of the Pacific Ocean, emulating "the Blob" and dubbed the "Son of the Blob" (Britten 2018). Such warm-water masses are speculated to be linked to climate change and have been correlated with warmer weather on land, deceased whales and extreme mortality events of other higher-trophic level organisms, occurrences of uncommon marine taxa, widespread toxic algal blooms, and poor feeding conditions for many fish species (Britten 2018; Brodeur et al. 2018). A significant shift in prey availability and feeding habits was observed for anchovy, sardine, mackerel, herring, and smelt species in the northern California Current Ecosystem (CCE) off the Washington and Oregon coasts (Brodeur et al. 2018). While the effects of "the Blob" or the "Son of the Blob" are not yet fully understood, the formation of warm water patches are increasingly common in the Pacific Ocean off the western Canadian and American coasts (Britten 2018).

3.2 Protected Areas

3.2.1 Critical Habitat in the U.S.

Several habitats along the U.S. West Coast have been specifically identified as important to U.S. ESA-listed species, including critical habitat for marine mammals, sea turtles, seabirds, and fish; however no critical habitat occurs within the proposed survey area. Critical habitat for the ***endangered*** leatherback turtle is located adjacent to the survey area, and critical habitat for the humpback whale is located ~30 km to the east of the survey area (Fig. 1); critical habitat for these two species is described below. Critical habitat for the ***endangered*** Southern Resident Killer Whale and the ***threatened*** Southern DPS of green sturgeon are located ~70 km and ~100 km, respectively, east of the proposed survey area and are not described further below; however, they are depicted in Figure 1. Critical habitat for the ESA-listed rockfish, Pacific eulachon, and salmonids occurs in shallower nearshore waters (or freshwater rivers and creeks) and is not discussed further. Similarly, critical habitat for the ***threatened*** Pacific Coast population of western snowy plover and the ***threatened*** marbled murrelet is strictly terrestrial and would not be affected by the proposed activities.

Humpback Whale Critical Habitat*.—**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 2021). Critical habitat for the Central America and Mexico DPSs includes waters within the 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 nmi^2 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 2021). No transect lines or ensonified areas would occur within the critical habitat.

Leatherback Sea Turtle Critical Habitat*.—**In January 2012, NMFS designated critical habitat for the ***endangered leatherback sea turtle within the 2000-m isobath along the West Coast of the U.S. (NMFS 2012). The critical habitat includes marine areas of ~64,760 km^2 from Cape Flattery, WA, to Cape Blanco, OR, and ~43,798 km^2 off California (NMFS 2012). The survey area is located just west of the critical habitat (Fig. 1); none of the proposed survey lines or ensonified areas would enter the critical habitat.

3.2.2 Other Conservation Areas in U.S. Waters

There are numerous conservation areas along the coasts of Washington and Oregon: Olympic Coast National Marine Sanctuary (OCNMS), Washington Islands National Wildlife Refuges, Lewis and Clark National Wildlife Refuge, Willapa National Wildlife Refuge, Oregon Islands National Wildlife Refuge, Three Arch Rocks National Wildlife Reserve, Washington State Seashore Conservation Area, Cape Falcon Marine Reserve, Cascade Head Marine Reserve, Otter Rock Marine Reserve, Cape Perpetua Marine Reserve, and Redfish Rock Marine Reserve and Marine Protected Area. Except for the OCNMS, which is described below, the survey activities and ensonified areas would be well outside (>100 km) of any of these areas; thus, they are not discussed further.

***Olympic Coast National Marine Sanctuary*.—**The OCNMS, designated in 1994, includes 8259 km^2 of marine waters off the Washington coast, extending 40–72 km seaward and covering much of the continental shelf and several major submarine canyons (NOAA 2011). The sanctuary protects a productive upwelling zone with high productivity and a diversity of marine life (NOAA 2011). This area also has numerous shipwrecks. The OCNMS management plan provides a framework for the sanctuary to manage potential threats to the sanctuary's marine resources under the *National Marine Sanctuaries Act*. Federal law provides national marine sanctuaries the authority to adopt regulations and issue permits for certain activities, including taking any marine mammal, sea turtle, or seabird in or above the sanctuary, except as authorized by the MMPA, the ESA, and the *Migratory Bird Treaty Act*. The OCNMS is located ~75 km northeast of the proposed survey area (Fig. 1). Coastal Treaty Tribes (Hoh, Makah, Quileute, and Quinault) and the State of Washington also have responsibility for regulation of activities and management of marine resources within the boundaries of the OCNMS; therefore, OCNMS coordinates with them on regulatory jurisdiction over marine resources and activities within the boundaries of the Sanctuary.

3.3 Marine Mammals

Twenty-nine marine mammal species could occur in or near the proposed survey area, including 6 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 project area. It is unlikely that gray whales from the ***endangered*** Western North Pacific DPS (or any other DPS) or ***endangered*** 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 and humpback whales (Central America and Mexico DPS), none of the proposed survey transects enter or would ensonify marine mammal critical habitat to sound levels >160 dB re 1 μPa_{rms}.

Although northern sea otters (*Enhydra lutris kenyoni*), which are managed by the U.S. Fish and Wildlife Service (USFWS), occur in the waters off Oregon and Washington, they are not discussed further, as they typically occur in shallower coastal waters. Similarly, gray whale (*Eschrichtius robustus*), harbor porpoise (*Phocoena phocoena*), harbor seal (*Phoca vitulina*) are not included here, as they typically occur closer to shore. In addition, the rough-toothed dolphin (*Steno bredanensis*) is not included as this species is distributed farther to the south. The aforementioned species are unlikely to be seen in the proposed survey area and are not addressed further.

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

Species	**Occurrence in Area[1]**	**Habitat**	**Abundance[2]**	**U.S. ESA[3]**	**IUCN[4]**	**CITES[5]**
Mysticetes						
North Pacific right whale	Rare	Coastal, shelf, offshore	400-500[6]	EN	CR[7]	I
Humpback whale	Uncommon	Mainly nearshore and banks	4,973[8]	EN/T[9]	LC	I
Common minke whale	Uncommon	Nearshore, offshore	915	NL	LC	I
Sei whale	Rare	Mostly pelagic	864; 27,197[10]	EN	EN	I
Fin whale	Common	Slope, pelagic	11,065; 13,620-18,680[11]	EN	VU	I
Blue whale	Rare	Pelagic and coastal	1,898	EN	EN	I
Odontocetes						
Sperm whale	Common	Pelagic, steep topography	2,606; 26,300[12]	EN	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	4,111	NL	LC	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	LC	II
Cuvier's beaked whale	Common	Pelagic	5,454	NL	VU	II
Baird's beaked whale	Rare	Pelagic	1,363	NL	LC	I
Blainville's beaked whale	Rare	Pelagic	3,044[13]	NL	LC	II
Hubbs' beaked whale	Rare	Slope, offshore	3,044[13]	NL	DD	II
Stejneger's beaked whale	Rare	Slope, offshore	3,044[13]	NL	NT	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	3,477[14]	NL	LC	II
Striped dolphin	Rare	Off continental shelf	29,988	NL	LC	II
Common dolphin	Uncommon	Shelf, pelagic, seamounts	1,056,308[15]	NL	LC	II
Pacific white-sided dolphin	Common	Offshore, slope	34,999	NL	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	29,285	NL	LC	II
Risso's dolphin	Common	Shelf, slope, seamounts	6,336	NL	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	NT	II
Killer whale	Common	Widely distributed	73[16] 349[17] 300[18]	EN[19]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	836	NL	LC	II
Dall's porpoise	Common	Shelf, slope, offshore	16,498	NL	LC	II
Pinnipeds						
Guadalupe fur seal	Rare	Mainly coastal, pelagic	34,187	T	LC	I
Northern fur seal	Uncommon	Pelagic, offshore	14,050[20] 626,618[21]	NL	VU	N.A.
Northern elephant seal	Uncommon	Coastal, pelagic in migration	187,386[22]	NL	LC	N.A.
Steller sea lion	Common	Coastal, offshore	36,308[23]	DL[24]	NT[25]	N.A.
California sea lion	Uncommon	Coastal	257,606[26]	NL	LC	N.A.

NA = not available.

[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. (2024), unless otherwise stated.
[3] U.S. *Endangered Species Act* (ESA): EN = Endangered, T = Threatened, NL = Not listed.
[4] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2024); CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.
[5] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2024): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[6] North Pacific (Jefferson et al. 2015).
[7] The northeast Pacific subpopulation is critically endangered; globally, the North Pacific right whale is endangered.
[8] Estimate for the U.S. West Coast EEZ (Calambokidis and Barlow 2020).
[9] 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).
[10] Central and Eastern North Pacific (Hakamada and Matsuoka 2015).
[11] North Pacific (Ohsumi and Wada 1974).
[12] Eastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
[13] All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2024).
[14] California/Oregon//Washington offshore stock (Carretta et al. 2024).
[15] Estimate for short-beaked common dolphin for CA/OR/WA (Carretta et al. 2024).
[16] Southern Resident stock (Carretta et al. 2024).
[17] West Coast Transient stock; minimum estimate (Young et al. 2024).
[18] Eastern North Pacific Offshore stock (Carretta et al. 2024).
[19] The Southern Resident DPS is listed as endangered; no other stocks are listed.
[20] California stock (Carretta et al. 2024).
[21] Eastern Pacific stock (Young et al. 2024).
[22] California breeding stock (Carretta et al. 2024).
[23] Minimum estimate for Eastern stock (Young et al. 2024).
[24] The Eastern DPS was delisted in 2013 (78 FR 66139, 4 November 2013); the Western DPS is listed as endangered.
[25] Globally considered as near threatened; western population listed as endangered.
[26] U.S. stock (Carretta et al. 2024).

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. (British Columbia) Coast, is located just north of the proposed survey area. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters off the B.C. Coast is discussed in § 3.6.3.2, § 3.7.3.2, § 3.8.3.2, and § 3.9.3.1 of the PEIS, respectively. Southern California was chosen as a detailed analysis area (DAA) in the PEIS. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters 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. Marine mammal occurrence within or near the proposed survey area in the northeast Pacific Ocean is summarized for each species in Appendix C.

3.4 Sea Turtles

Four species of sea turtles have been reported in the waters of Washington and Oregon: the leatherback, green, loggerhead, and olive ridley turtles (Buchanan et al. 2001; McAlpine et al. 2004; Dutton et al. 2009; Halpin et al. 2018). Reports of leatherbacks are numerous, and green turtles have been seen occasionally in the survey area compared to occurrences of loggerhead and olive ridley turtles, which are rare. For Washington, there were eight records of loggerhead turtles from 1980–2017 (Sato 2017a) and few records of olive ridleys (e.g., Richardson 1997; Komo News 2015; Seattle Times 2017). For Oregon, strandings of loggerheads and olive ridley turtles have been reported as recently as December 2024 (Environment Oregon 2025). Boyer (2017) reported that strandings have increased, in particular for olive ridley sea turtles, possibly due to warmer ocean conditions or El Niño. However, the loggerhead and olive ridley turtles are generally warm-water species and are considered extralimital occurrences in these areas (Buchanan et al. 2001) and are not discussed further here. Thus, only leatherback turtles are likely to occur in the survey area, and green turtles could potentially occur there.

Under the ESA, the leatherback turtle and the North Pacific Ocean DPS of the loggerhead turtle are listed as ***endangered***, the olive ridley population on the Pacific coast of Mexico is listed as ***endangered*** whereas other populations are listed as ***threatened***, and the East Pacific DPS of the green turtle is listed as ***threatened***. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles are given in § 3.4.1 of the PEIS. General distribution of sea turtles off B.C. and just south of the survey area off California are discussed in § 3.4.3.2 and 3.4.2.3 of the PEIS, respectively. Sea turtle occurrence within or near the proposed survey area in the northeast Pacific Ocean is summarized below.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the largest and most widely distributed sea turtle, ranging far from its tropical and subtropical breeding grounds to feed (Plotkin 2003). There have been significant declines and some extirpations of nesting populations in the Pacific (Spotila et al. 2000; Dutton et al. 2007). Leatherback turtles in the Pacific are divided into two genetically distinct stocks: the East Pacific stock nests at rookeries along the west coast of the Americas from Mexico to Ecuador; and the West Pacific stock nests at rookeries in Papua, Indonesia; Papua New Guinea; and the Solomon Islands (Dutton 2006; Wallace and Hutchinson 2016). The beaches of Birdshead Peninsula in Papua are the largest remaining nesting sites for leatherbacks in the Pacific Ocean (Dutton et al. 2007; Hitipeuw et al. 2007; Benson et al. 2008). Turtles that hatch during the boreal summer in the western Pacific feed and grow in the northern Pacific, including along the west coast of North America (Dutton 2006; Dutton et al. 2009; Benson 2012; Bailey et al. 2012a; Wallace and Hutchinson 2016). The West Pacific subpopulation has declined by 83% over the past three generations and continues to be threatened by human exploitation of females and eggs, low hatching success, fisheries bycatch, low foraging success, and plastic ingestion (Bailey et al. 2012b; Gregr et al. 2015; Wallace and Hutchinson 2016). Nesting beaches in the western Pacific have been estimated to have 2700–4500 breeding females (NMFS and USFWS 2013).

The leatherback turtle is the most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). During the non-breeding season, it ranges far from its tropical and subtropical nesting grounds, which are located between 38°N and 34°S (Dutton et al. 2009; Eckert et al. 2012). Leatherbacks feed exclusively on gelatinous zooplankton (Fossette et al. 2010, 2012; Dodge et al. 2011; Heaslip et al. 2012) and their presence has been associated with oceanic front systems, such as shelf breaks and the edges of oceanic gyre systems where their prey is concentrated (Morreale et al. 1994; Eckert 1995; Lutcavage 1996; Benson et al. 2011).

Adult leatherbacks appear to migrate along bathymetric contours from 200–3500 m (Morreale et al. 1994). Adults spend the majority of their time in water >1000 m deep and possibly swim more than 10,000 km each year (Eckert 1995). They appear to use the Kuroshio Extension during migrations from Indonesia to the high seas and eastern Pacific (Benson et al. 2008). Hatchling leatherbacks are pelagic, but nothing is known about their distribution for the first four years (Musick and Limpus 1997). Leatherback turtles undertake long migrations from the western, central, or South Pacific toward the California Current LME (Block et al. 2011; Bailey et al. 2012a,b). Frair et al. (1972) and Greer et al. (1973) reported that leatherback turtles have evolved physiological and anatomical adaptations to cold water, allowing them to venture into higher latitudes than other species of turtle.

Leatherbacks forage in pelagic and nearshore waters off the coasts of Washington, Oregon and California during the summer and fall when brown sea nettles (*Chrysaora fuscescens*) and moon jellies (*Aurelia labiata*) aggregate (Sato 2017b). Benson et al. (2011) identified the Columbia River Plume as an important foraging area off southern Washington/northern Oregon. Leatherback turtles satellite-tagged at western Pacific nesting beaches were observed to arrive along the coasts of California to Washington during April–July, and foraging behavior was recorded through late November (Benson et al. 2011). In Washington, 78 occurrences of leatherbacks were documented during 1975–2013 from the mouth of the Columbia River north to Cape Flattery; 70 occurrences occurred during July–October (Sato 2017b). Aerial surveys of California/Oregon/Washington waters suggest that most leatherbacks occur in continental slope waters and fewer occur over the continental shelf. Sightings off Oregon/Washington have been made 8–149 km offshore (Green et al. 1992, 1993; Bowlby et al. 1994; Buchanan et al. 2001). Bowlby et al. (1994) noted that most sightings (13 of 19) during their surveys occurred in waters 200–2000 m deep, with one sighting in waters >2000 m deep. Leatherback turtles could be encountered in the proposed project area.

3.4.2 Green Turtle (*Chelonia mydas*)

The green sea turtle is widely distributed in tropical, subtropical, and to a lesser extent, temperate waters, where it often occurs along continental coasts and around islands (SWOT 2011; Seminoff et al. 2015). Green turtles typically migrate along coastal routes from rookeries to feeding grounds, although some populations conduct trans-oceanic migrations (SWOT 2011). Hatchlings are epipelagic (surface dwelling in the open sea) for ~1–3 years. Subsequently, they live in bays and along protected shorelines and feed during the day on seagrass and algae (Bjorndal 1982). Juvenile and sub-adult green turtles may travel thousands of kilometers before they return to breeding and nesting grounds (Carr et al. 1978). Though primarily known to forage in coastal areas, adult green turtles have also been recorded feeding in oceanic waters (Hatase et al. 2006).

Movement of green turtles across the Pacific appears to be restricted by the East Pacific Barrier; thus only turtles from the East Pacific DPS are expected to occur in the eastern Pacific (Seminoff et al. 2015). The East Pacific DPS is estimated at 20,062 nesting females, ~58% of which nest in Michoacán, Mexico, and the population is likely to increase (Seminoff et al. 2015). Nesting occurs in Michoacán from August–January, with a peak in October–November (Alvarado and Figueroa 1995).

Stinson (1984) reviewed sea turtle sighting records from northern Baja California to Alaska, and reported only three sightings each of green turtles for Oregon, Washington, and B.C., and two sightings for Alaska; most sightings occurred in California (78%). Green turtles are considered rare in Washington, where 28 occurrences, mostly strandings, were documented between 1950 and 2017 (Sato 2017a). There are several occurrences for Oregon (e.g., Oregonian 2012; Apple Valley News Now 2024). It is possible although unlikely that a green turtle would be encountered in the proposed project area.

3.5 Seabirds

Two ESA-listed seabird species could occur in or near the proposed survey area including the ***endangered*** short-tailed albatross and Hawaiian petrel. The ***threatened*** marbled murrelet (*Brachyramphus marmoratus*) and western snowy plover (*Charadrius nivosus nivosus*) are not expected to occur in the proposed offshore survey area and are not discussed further.

3.5.1 Short-tailed Albatross (*Phoebastria albatrus*)

Historically, millions of short-tailed albatrosses bred in the western North Pacific on islands off the coast of Japan (USFWS 2008). This species was the most abundant albatross in the North Pacific. However, the entire global population was nearly wiped out during the last century by feather hunters at Japanese breeding colonies. In addition to hunting pressures, the breeding grounds of the remaining birds were threatened by volcanic eruptions in the 1930s. This species was believed to be extinct by 1949;

however, breeding was detected in 1950 and 1951, aided by pelagic-dwelling maturing birds which escaped the slaughter (USFWS 2008; BirdLife International 2025a). Due to conservation and management actions the population is increasing; the most recent population estimate (end of the 2013-2014 breeding season) was 4200 individuals (Birdlife International 2025a). According to USFWS (2008), threats to this population include volcanic activity on Torishima, commercial fisheries, and pollutants Interactions with vessels in the eastern Pacific have been noted. Incidental take due to commercial fisheries has been documented, with one short-tailed albatross taken as bycatch off Oregon during the sablefish demersal fishery in 2011 (USFWS 2017), and 11 mortalities between 1995 and 2015 in the Alaska hook-and-line groundfish fishery (NMFS 2015; USFWS 2017).

Currently, nearly all short-tailed albatrosses breed on two islands off the coast of Japan: Torishima and Minami-kojima (USFWS 2008; BirdLife International 2025a). Single nests have been found in recent years on other islands, including Kita-Kojima, Senkaku; Yomejima Island; and Midway Island, Hawaii; however, nesting attempts in Hawaii have not been successful (USFWS 2008). During the breeding season (December–May), the highest densities are found around Japan (BirdLife International 2025a), with albatross being seen as far south (23°N) as the Northwestern Hawaiian Islands between November and April (USFWS 2008).

During the non-breeding season, short-tailed albatross roam much of the North Pacific Ocean; females spend more time offshore from Japan and Russia, whereas males and juveniles spend more time around the Aleutian Islands and Bering Sea (Suryan et al. 2007). Post-breeding dispersal occurs from April through August (USFWS 2008). After leaving the breeding areas, short-tailed albatrosses seem to spend the majority of time within the EEZs of Japan, Russia, and the U.S., primarily in the Aleutian Islands and Bering Sea (Suryan et al. 2007). They are considered a continental shelf-edge specialist (Piatt et al. 2006). Most short-tailed albatross sightings off the Pacific coast of North America (south to California) include juveniles and sub-adults (USFWS 2008; O'Connor 2013). Satellite-tracked first- and second-year birds were found off Oregon most often during winter and spring, possibly in response to ice conditions in the Bering Sea (O'Connor 2013). Sightings in the eastern North Pacific are increasing, corresponding with global population increases (COSEWIC 2013). The short-tailed albatross could be encountered in small numbers in the proposed project area.

3.5.2 Hawaiian Petrel (*Pterodroma sandwichensis*)

The Hawaiian petrel has an estimated population size of 7,500–16,600 (Birdlife International 2025b). Large declines in overall numbers and in the number of breeding colonies appear to pre-date European arrival on the Hawaiian Islands, tracing back to animal introductions, habitat modifications, and hunting by Polynesians (Simons and Hodges 1998). The population of Hawaiian petrels continues to decline, mainly because of predation by introduced vertebrates, including mongooses, cats, and goats, and due to collisions and light attraction (USFWS 2005; Raine et al. 2017).

The Hawaiian petrel is endemic to Hawaii, where it nests at high elevation. Known nesting habitats include lava cavities, burrows on cliff faces or steep slopes, and beneath ferns (USFWS 2005). The majority of eggs are laid in May and June, and most young fledge in December (Mitchell et al. 2005). Hawaiian petrels can travel up to 1300 km away from colonies during foraging trips; at-sea densities decrease with distance from the colony (Spear et al. 1995). Spear et al. (1995) showed the distribution of Hawaiian petrels to be concentrated in the southern portion of the Main Hawaiian Islands (below 20°N) during spring and autumn. However, in recent years, the Hawaiian petrel has been recognized to be a regularly occurring offshore species to the eastern Pacific in waters from southern California to B.C. In California, where observer coverage is perhaps highest, there are records from March through September (eBird 2025). There are five accepted records of Hawaiian petrel in Washington for the months of May, August, and September (WBRC 2025), although occurrences are likely more frequent than observations suggest owing to the minimal observer coverage at the distance from shore which these petrels typically frequent. The Hawaiian petrel could be encountered in small numbers in the proposed project area, in particular along the southern transects.

3.6 Fish, Marine Invertebrates, Essential Fish Habitat, and Habitat Areas of Particular Concern

3.6.1 ESA-Listed Fish and Invertebrate Species

The term "species" under the ESA includes species, subspecies, and, for vertebrates only, DPSs or "evolutionarily significant units (ESUs)"; for Pacific salmon, ESUs are essentially equivalent to DPSs for the purpose of the ESA. There are several ESA-listed fish species or populations that occur off the coasts of Washington/Oregon including the ESUs of chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), and sockeye salmon (*O. nerka*), and DPSs of steelhead (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), bocaccio (*Sebastes paucispinis*), yellow-eye rockfish (*S. ruberrimus*), Pacific eulachon (*Thaleichthys pacificus*), and green sturgeon (*Acipenser medirostris*) (Table 4).

Although the ***threatened*** giant manta ray (*Manta birostris*) and oceanic whitetip shark (*Carcharhinus longimanus*), and the ***endangered*** Eastern Pacific DPS of scalloped hammerhead shark (*Sphyrna lewini*) occur in the northeast Pacific Ocean, their most northerly extent is California. In addition, the tope shark (*Galeorhinus galeus*) occurs along the West Coast of the U.S. and is a candidate species for listing under the ESA (NMFS 2022); as this species typically occurs in coastal waters with depths up to 200 m, it is not discussed further.

There are currently no ESA-listed marine invertebrate species that occur in the proposed survey area. However, the sunflower sea star (*Pycnopodia helianthoides*) is proposed for listing as threatened under the ESA (NMFS 2023). It occurs in intertidal and subtidal coastal waters of the eastern Pacific Ocean, from Alaska to Mexico. However, it typically does not occur in waters as deep (>2000 m) as the proposed survey area. Therefore, it is not considered further here.

3.6.1.1 Salmonids

Pacific salmon and steelhead trout typically spend the majority of their time in the upper water column while at sea (e.g., Daly et al. 2014; PFMC 2014). However, Chinook typically occur at depths >30 m from the sea surface (PFMC 2014). The degree to which Pacific salmon and steelhead migrate offshore varies considerably among seasons, years, life stages and/or populations, with stronger upwelling conditions generally leading to wider dispersal from shore (Pearcy 1992). Tag recoveries from high seas fisheries indicate that chinook occur beyond the shelf break (Myers et al. 1996). Once coho salmon emigrate from freshwater, they spend at least several weeks and up to a summer season in coastal waters before migrating north and offshore (PFMC 2014). Tag recoveries from fisheries indicate that coho are distributed as far west as 175ºE (Myers et al. 1996). However, the oceanic distribution of chum salmon is likely the broadest of any Pacific salmon species; it occurs throughout the North Pacific Ocean north of Oregon/Washington (Neave et al. 1976). Sockeye are thought to follow a similar migration pattern as chum once they enter the ocean, moving north and west along the coast before moving offshore (Quinn 2005; Byron and Burke 2014). Sockeye primarily occur east of 160ºW and north of 48ºN; most fish likely depart offshore waters by early August of their second at-sea year to spawn in their natal rivers (French et al. 1976).

TABLE 4. Fish "species" listed under the ESA that could potentially occur in the proposed survey area in the northeast Pacific Ocean.

Species	ESU or DPS	Status	Critical Habitat
Bocaccio	Puget Sound/Georgia Basin DPS	Endangered	Marine
Yelloweye rockfish	Puget Sound/Georgia Basin DPS	Threatened	Marine
Pacific eulachon/smelt	Southern DPS	Threatened	Freshwater/estuarine
Green sturgeon	Southern DPS	Threatened	Marine/freshwater/estuarir
Chinook salmon	Sacramento River winter-run ESU	Endangered	Freshwater
	Upper Columbia River spring-run ESU	Endangered	Freshwater
	California Coastal ESU	Threatened	Freshwater
	Central Valley spring-run ESU	Threatened	Freshwater
	Lower Columbia River ESU	Threatened	Freshwater
	Puget Sound ESU	Threatened	Freshwater/marine
	Snake River fall-run ESU	Threatened	Freshwater
	Snake River spring/summer-run ESU	Threatened	—
	Upper Willamette River ESU	Threatened	Freshwater
	Central Valley spring-fall run in the San Joaquin River XN	Experimental Pop.	—
	Upper Columbia River spring-run in the Okanogan River subbasin XN	Experimental Pop.	—
	Central Valley spring-run XN Shasta	Experimental Pop.	—
	Sacramento winter-run XN Shasta	Experimental Pop.	—
	Central Valley spring-run XN Yuba	Experimental Pop.	—
	Washington Coast ESU	Candidate	—
	Southern Oregon and Northern California Coastal ESU	Candidate	—
	Oregon Coast ESU	Candidate	—
	Upper Klamath-Trinity Rivers ESU	Candidate	—
Chum salmon	Columbia River ESU	Threatened	Freshwater
	Hood Canal summer-run ESU	Threatened	Freshwater/marine
Coho salmon	Central California Coast ESU	Endangered	—
	Lower Columbia River ESU	Threatened	Freshwater
	Oregon Coast ESU	Threatened	Freshwater
	Southern Oregon and Northern California Coast ESU	Threatened	—
Sockeye salmon	Ozette Lake ESU	Threatened	Freshwater
	Snake River ESU	Endangered	—
Steelhead trout	Middle Columbia River XN	Experimental Pop.	—
	Olympic Peninsula DPS	Candidate	—
	Middle Columbia River DPS	Threatened	Freshwater
	Puget Sound DPS	Threatened	Freshwater
	Snake River Basin DPS	Threatened	Freshwater
	Upper Columbia River DPS	Threatened	Freshwater
	Upper Willamette River DPS	Threatened	Freshwater
Bull trout	Coastal-Puget Sound	Threatened	Freshwater

Pop. = population. — not applicable.

Steelhead appear to rely on offshore waters for feeding than any other Pacific salmonids, making more extensive migrations offshore in their first year (Quinn and Myers 2004). Light et al. (1989) found that steelhead is distributed throughout the North Pacific year-round, occurring in higher abundance closer to the coasts during spring and winter and being distributed more evenly during summer and autumn.

The Coastal-Puget Sound DPS of bull trout is the only known anadromous population in U.S. waters, occurring throughout Puget Sound and the Olympic Peninsula south to the Quinault River Estuary. Bull trout have not been detected to use deep offshore waters or cross deep open-water bodies (e.g., coastal cutthroat trout) and appear to occupy marine waters for a shorter period of time than other anadromous salmonids (Goetz et al. 2013). Juveniles, sub-adults and adults generally occupy marine waters from early spring (March) to summer (late July), but some are known to overwinter in coastal waters. Fish that were radio-tagged in Skagit River in March and April 2006 entered Skagit Bay from March to May and returned upstream from May to late July (Hayes et al. 2011). Saltwater residency of these fish ranged from 36 to 133 days (avg. 75 days), and most were detected less than 14 km (avg. 8.5 km) from the Skagit River.

These bull trout were associated with the shoreline and stayed an average of 0.32 +/- 0.27 km from shore and occupied shallow waters <4 m deep. However, Smith and Huff (2020) detected a tagged bull trout up to 10 km from shore. Goetz (2016) reported that marine residence averaged 62.8 days (SD=37.6 days) but ranged from four days to a maximum of four months.

3.6.1.2 Bocaccio

Bocaccio are distributed in coastal waters over rocky bottoms from the Gulf of Alaska to Baja California, Mexico down to depths of 478 m, but are most common between 50–250 m (NMFS 2008b). Larval and pelagic juvenile bocaccio tend to occur within surficial waters and have been found as far as 480 km offshore the West Coast (NMFS 2014). Bocaccio are most common from Oregon to California, and genetic analysis suggests three population regions including Haida Gwaii, Vancouver Island to Point Conception, and southwards of Point Conception (NMFS 2008b).

3.6.1.3 Yelloweye Rockfish

Yelloweye rockfish are found in coastal waters from the Alaskan Aleutian Islands down to Baja California. They are found in depths ranging from 15–549 m over hard, complex bottoms but are most common in waters 91–180 m (COSEWIC 2008; NMFS 2008b). Yelloweye rockfish are exceptionally long-lived and individuals have been aged at 115 years in B.C. (COSEWIC 2008). Yelloweye rockfish are caught commercially in groundfish trawls and recreationally by hook and line. Yelloweye rockfish was taken commercially and recreationally in Oregon and Washington in 2023 (NOAA 2024a).

3.6.1.4 Eulachon

Eulachon are a small species of smelt that spend 95% of their lives in the marine environment, migrating to freshwater rivers to spawn. Their marine range extends from the Bering Sea to California (COSEWIC 2011). Eulachon spawn after three years, typically in coastal rivers that are associated with glaciers or snowpacks (COSEWIC 2011). Eulachon was fished commercially in Oregon and Washington in 2023 (NOAA 2024b).

3.6.1.5 Green Sturgeon

The green sturgeon is distributed from Alaska to California primarily in marine waters up to 110 m deep, migrating to freshwater during the spawning season. It is found from Grave Harbor, AK, and along the entire coast of B.C. during the spring and winter months. During spawning season in the summer and fall, aggregations of green sturgeon are found in the Columbia River estuary, Willapa Bay, and Grays Harbor, WA, and in the Umpqua River estuary, OR (NMFS 2018a). The Rogue River, Klamath River, Eel River, Sacramento River, and Feather River have been confirmed as spawning rivers for green sturgeon in the U.S. (NMFS 2018a).

3.6.2 Essential Fish Habitat

Under the 1976 *Magnuson Fisheries Conservation and Management Act* (renamed *Magnuson Stevens Fisheries Conservation and Management Act* in 1996), Essential Fish Habitat (EFH) is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity”. “Waters” include aquatic areas and their associated physical, chemical, and biological properties that are used by fish. “Substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities (NOAA 2002). The *Magnuson Stevens Fishery Conservation and Management Act* (16 U.S.C.§1801–1882) established Regional Fishery Management Councils and mandated that Fishery Management Plans (FMPs) be developed to manage exploited fish and invertebrate species responsibly in federal waters of the U.S. When Congress reauthorized the act in 1996 as the *Sustainable Fisheries Act*, several reforms and changes were made. One change was to charge NMFS with designating and conserving EFH for species managed under existing FMPs. In Washington and Oregon, there are four FMPs covering groundfish, coastal pelagic species, highly migratory species, and Pacific salmon. The entire western seaboard from the coast to the limits of the EEZ is EFH for one or more species for which EFH has been designated. The proposed project area encompasses EFH for several fish species. EFH for krill, groundfish and coastal pelagic species are shown in Figure 2; EFH for highly migratory species is shown in Figure 3. EFH for Pacific salmon is shown in Figure 4.

Groundfish EFH.—The Pacific Coast Groundfish FMP manages more than 90 species (160 species/life stage combinations) including roundfish, flatfish, rockfish, sharks, and skates (PFMC 2016a). The FMP provides a description of groundfish EFH for each of the species and their life stages (PFMC 2016a). Collectively, the EFH for Pacific Coast groundfish includes all waters and substrate from the mean higher high water level or the up-river extent of saltwater intrusion along the coasts of Washington, Oregon, and California to within water depths <3500 m and seamounts in depths >3500 m (Fig. 2; PMFC 2016a). In addition to the EFH parameters mentioned above, there are seven distinct EFH Conservation Areas (Fig. 2) that are closed to bottom trawl fishing gear.

Coastal Pelagic Species EFH.—The FMP for Pacific coast Coastal Pelagic Species (CPS) includes four finfish (Pacific sardine, Pacific [chub] mackerel, northern anchovy, and jack mackerel), market squid and all euphausiids (krill) species that occur in the West Coast EEZ (PFMC 2016b). EFH for these species is defined both through geographic boundaries and by sea-surface temperature ranges. Because of similarities in their life histories and similarities in their habitat requirements, the four CPS finfish are treated as a single species complex for the purposes of EFH. Market squid are also treated in this same complex because they are similarly fished above spawning aggregations. The geographic boundary of EFH for CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10°C and 26°C; the southern extent of the EFH is the U.S.-Mexico boundary (Fig. 2). The northern boundary of the range of CPS finfish is the position of the 10°C isotherm which varies both seasonally and annually (PFMC 2016b). EFH for krill (*Thysanoessa spinifera*) extends from the shoreline outwards to a depth of 1000 m, while EFH for *Euphausia pacifica* and other krill species extends from the shoreline to ~2000-m depth (Fig. 2; NOAA 2024c).

Highly Migratory Species EFH.—The FMP for the U.S. West Coast fisheries for highly migratory species includes dorado/dolphinfish and important species of tunas (North Pacific albacore, yellowfin, bigeye, skipjack, and northern bluefin), billfish/swordfish (striped marlin and swordfish), and sharks (common thresher, shortfin mako/bonito and blue) (PFMC 2016d). EFH for each life stage of these species is described in the FMP (PFMC 2016d); collectively the highly migratory species EFH extends outwards from near shore (~10 m water depth) to the limit of the EEZ off of Washington, Oregon, and California (Fig. 3; NOAA 2024c).

Pacific Coast Salmon EFH.—The FMP for Pacific coast salmon includes the coast-wide aggregate of natural and hatchery salmon species that is contacted by salmon fisheries in the EEZ off the coasts of Washington, Oregon, and California (PFMC 2016c). The PFMC manages the fisheries for coho, chinook, and pink (odd-numbered years) salmon and has defined EFH for these three species. Pacific coast salmon EFH includes marine areas within the EEZ, from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the EEZ, along with estuarine and all currently or historically occupied freshwater habitat within the internal waters of Washington, Oregon, Idaho, and California north of Point Conception (Fig. 4; PFMC 2016c).

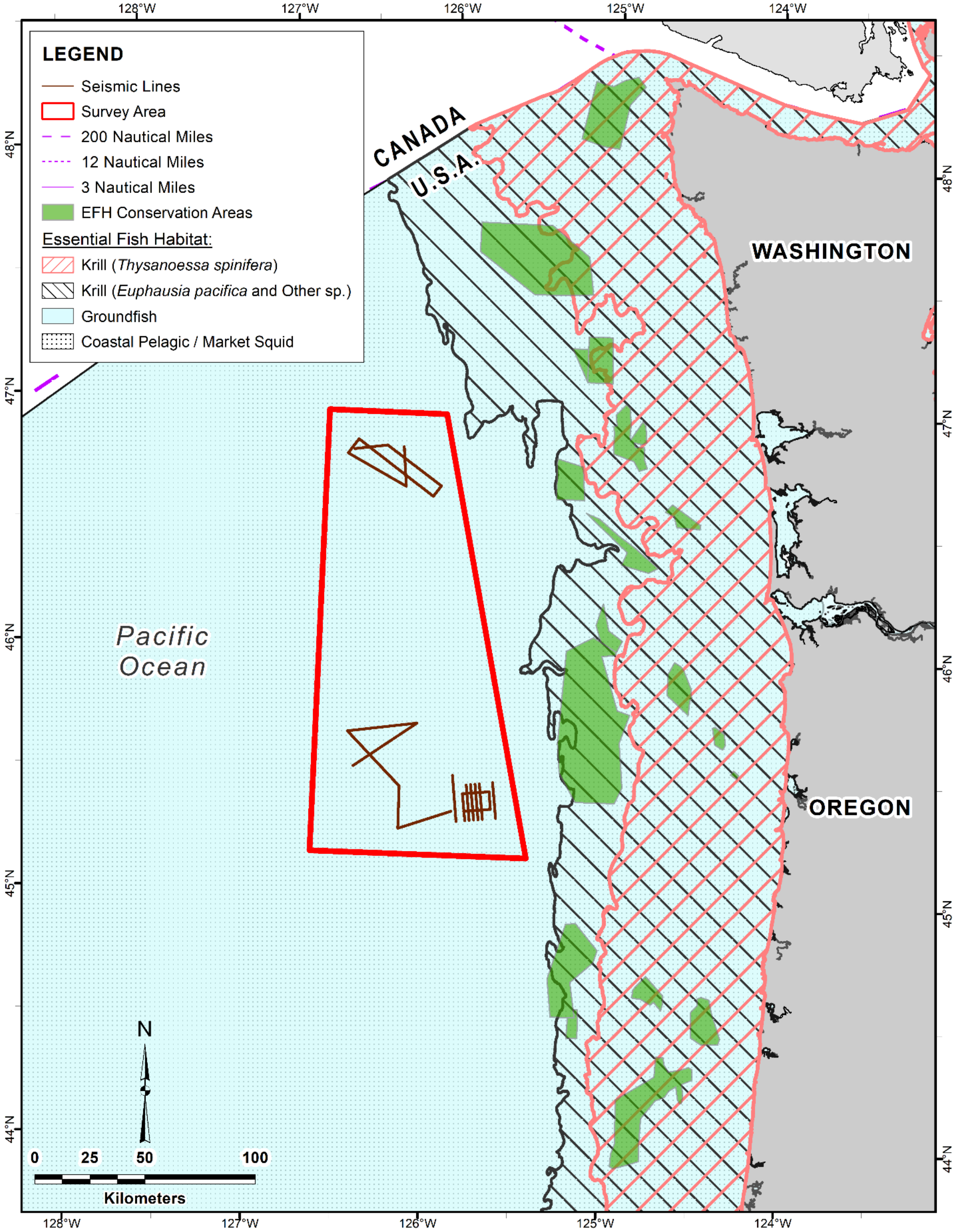

FIGURE 2. EFH for groundfish and coastal pelagic species (including krill and market squid) off Washington and Oregon.

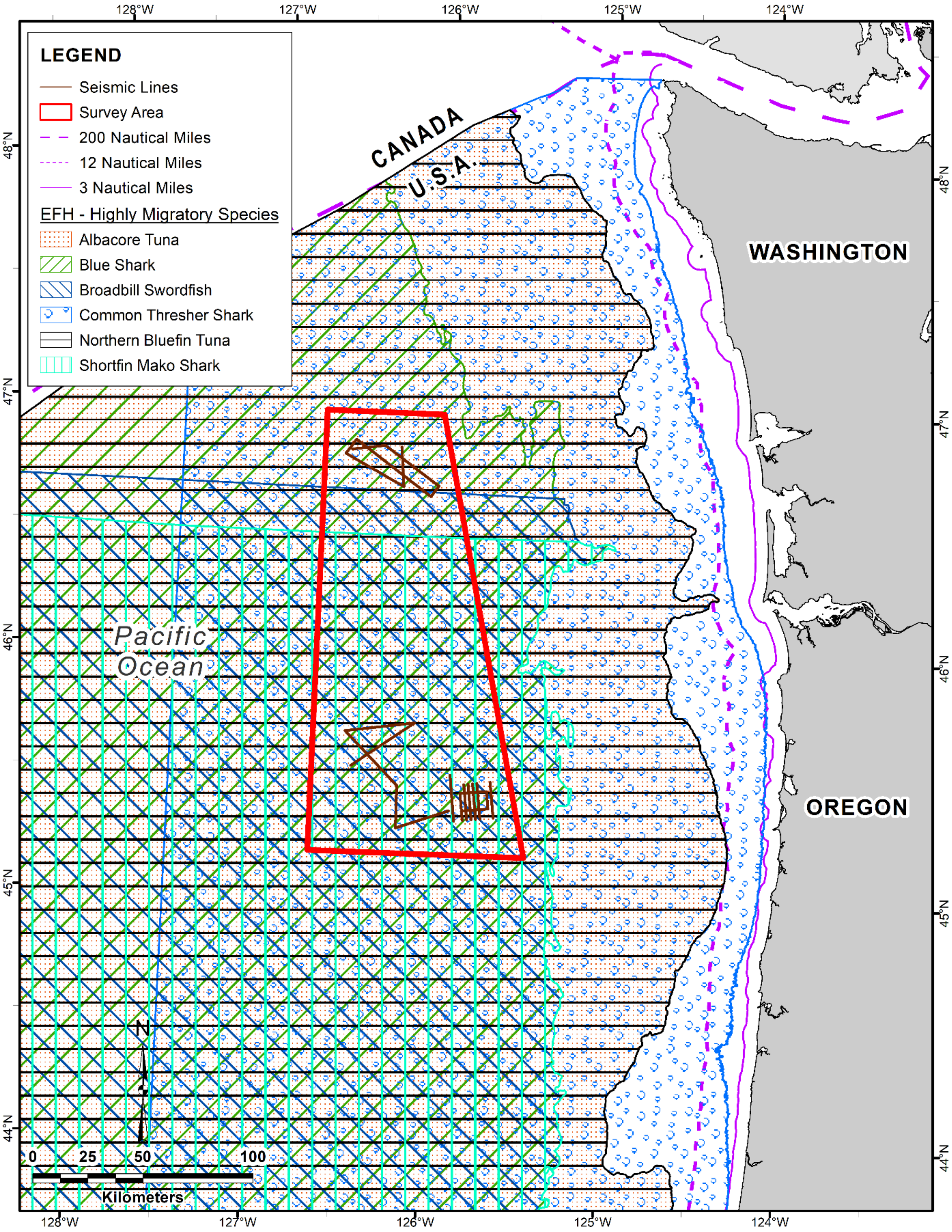

FIGURE 3. EFH for highly migratory species off Washington and Oregon.

Figure 4. EFH for salmonids off Washington and Oregon (PFMC 2016c).

3.6.3 Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPCs) are a subset of EFH that provide important ecological functions, are especially vulnerable to degradation, or include habitat that is rare (NOAA 2021). There are no HAPCs within the proposed survey area, but the rocky reefs HAPCs for groundfish is located adjacent to the survey area (Fig. 5). There are no HAPCs designated at this time for highly migratory species (PFMC 2016d).

***Rocky Reefs HAPC*.**—The rocky reefs HAPC includes waters, substrates, and other biogenic features associated with hard substrate (bedrock, boulders, cobble, gravel, etc.) to mean higher high water level. The HAPC occurs primarily in Oregon waters 200–2000 m deep, adjacent to the proposed survey area (see Fig. 5). The rocky reefs HAPC in Washington are mostly scattered in <200 m depth, including in the northern portion of the OCNMS (PFMC 2016a).

***Daisy Bank/Nelson Island HAPC*.**—Daisy Bank/Nelson Island HAPC is a highly unique geological feature that occurs in Federal waters west of Newport, Oregon (44°38'N) and appears to play a unique and potentially rare ecological role for groundfish and large invertebrate sponge species. The bank supports more than 600,000 juvenile rockfish per km^2. Daisy Bank also supports more and larger lingcod and large sponges than other nearby banks (*in* PFMC 2016a). It is located south of the proposed survey area (Fig. 5).

***Washington State Waters HAPC*.**—The Washington State Waters HAPC encompasses all waters and sea bottom in state waters from the 5.6 km boundary of the territorial sea shoreward to mean higher high-water level (Fig. 5). The HAPC encompasses a variety of habitats important to groundfish, including other HAPCs such as rocky reef habitat supporting juvenile rockfish (primarily north of 47.2°N). Sandy substrates within state waters (primarily south of 47.2°N) are important habitat for juvenile flatfish. This HAPC occurs far to the east of the proposed survey area; a large proportion of the HAPC is located within the OCNMS (PFMC 2016a).

***Thompson and President Jackson Seamounts HAPC*.**—Seamounts have relatively high biodiversity; up to a third of species occurring on these features may be endemic (de Forges et al. 2000 *in* PFMC 2016a). Currents generated by seamounts retain rockfish larvae and zooplankton, a principal food source for rockfish (Genin et al. 1988, Mullineaux and Mills 1997, Haury et al. 2000, and Dower and Perry 2001 *in* PFMC 2016a). Deep-sea corals also occur on seamounts (Monterey Bay National Marine Sanctuary 2005 *in* PFMC 2016a). The Thompson Seamount HAPC has an area of ~430 km^2 and is closed to all bottom contact gear (Oren and DeVogelaere 2014). The HAPC is located more than 100 km west of the survey area.

3.7 Commercial, Recreational, Tribal Fisheries & Aquaculture

Commercial, as well as recreational, and tribal fisheries occur in the waters off Washington and Oregon; these are described in the sections below. Fishing activities, in particular commercial fisheries, could overlap with the proposed survey area. However, the survey activities would not occur near any aquaculture activities, which typically occur close to the coast.

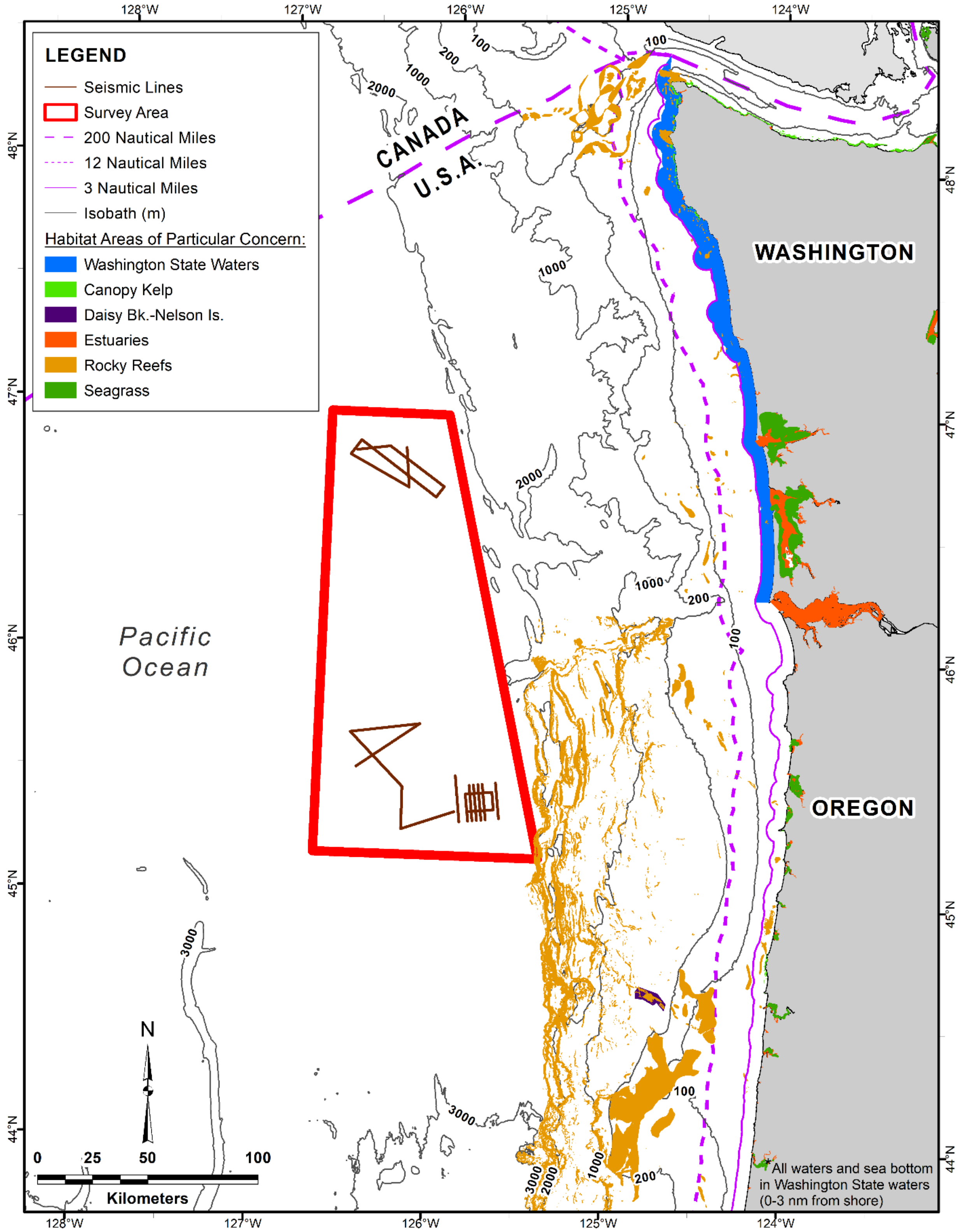

FIGURE 5. Groundfish HAPC in Washington, Oregon, and California.

3.7.1 Commercial Fisheries

The commercial fisheries off Oregon and Washington harvest more than 100 species, including fish such as salmon, rockfish, flatfish, sharks, and tuna; crustaceans; mollusks; and other invertebrates (NOAA 2025a). In order of descending catch weight, the primary fish species landed with more than 1,000 t during 2023 in Oregon were Pacific hake (or whiting, *Mercluccius productus*; 74,392 t), ocean shrimp (*Pandalus jordani*; 20,025 t), Dungeness crab (*Cancer magister*; 16,866 t), widow rockfish (*Sebastes entomelas*; 8,528 t), sablefish (*Anoplopoma fimbria*; 2,986 t), Dover sole (*Microstomus pacificus*; 2,755 t), yellowtail rockfish (*Sebastes flavidus*; 2,000 t), Petrale sole (*Eopsetta jordani*; 1,917 t), and Albacore tuna (*Thunnus alalunga*; 1,112 t). For Washington, landings in 2023 consisted primarily of Dungeness crab (16,385 t), ocean shrimp (6,512 t), Chinook salmon (1,587 t), Pacific oyster (Crassostrea gigas; 1,431 t), Albacore tuna (1,413 t), widow rockfish (1,361 t), sablefish (1,252 t), and pink salmon 1,117 t). The species that brought in the highest catch in dollar value for Oregon and Washington was Dungeness crab (~$100 million for each state). North Pacific hake has been the primary species caught since the mid-1960s, dropping off only between the 1980s and 1990s (Sea Around Us 2025). Pelagic trawls have been the most common gear used off the U.S. West Coast since the 1990s, but in 2018 and 2019, bottom trawls were mainly used in the fishery (Sea Around Us 2025).

3.7.2 Recreational Fisheries

Most marine recreational fisheries on the U.S. West Coast occur within non-federal (shore to 5.6 km off the coast) waters, but some effort also occurs in federal waters (5.6 km to the extent of the EEZ). During 2016, 1.2 million saltwater anglers took 5.2 million saltwater fishing trips, supporting $3 billion in sales on the U.S. West Coast (NOAA 2025b). Species typically taken during recreational fisheries on the West Coast include highly migratory species (albacore and other tunas, striped marlin, common thresher shark, shortfin mako shark), salmon (Chinook, coho), steelhead, groundfish (rockfish, lingcod scorpionfish, greenling, flatfish, sharks), halibut, coastal pelagic species (Pacific sardine, northern anchovy, market squid, Pacific mackerel), various state-managed species (barracuda, bass, bonito, sturgeon, surfperches), and invertebrates (abalone, lobster, crab, clams, oysters) (NOAA 2025b).

Recreational oceanic salmon fisheries off Oregon are open from March–November (location- and species-dependent); during 2023, there were 76,360 angler trips for this fishery (ODFW 2024a). Recreational groundfish taken off Oregon for which catch quotas are set include black rockfish, blue and deacon rockfishes, cabezon, canary rockfish, greenlings, “minor nearshore rockfishes” (China, copper, black-and-yellow, brown, calico, gopher, grass, kelp, olive, treefish, and quillback), and yelloweye rockfish; these species are primarily fished during spring and summer, with peak catches typically during July and August (ODFW 2024b). Pacific halibut are also caught during both nearshore and offshore recreational fisheries off Oregon, with the season running from May–October, with peak catches occurring from May–August (ODFW 2023). Recreational fisheries off Washington include salmon (Chinook, coho, chum, pink, sockeye, jacks), marine fish (bottomfish [e.g., rockfish, lingcod, sole, flounder], forage fish [e.g., herring, smelt], tunas and mackerels, Pacific halibut), and shellfish (e.g., clams, oysters, shrimp, crab) (Kraig and Scalici 2023). The recreational fishing season varies by species and location, but generally runs from May–October with peaks during mid-summer to early-fall (Kraig and Scalici 2023). In 2023, saltwater anglers that fished off Oregon and Washington primarily landed black rockfish (*Sebastes melanops*), Albacore tuna, and lingcod (*Ophiodon elongatus*) (NOAA 2025b).

3.7.3 Tribal Fisheries

The coast and nearshore areas are of cultural and economic importance to indigenous people of the Pacific Northwest. Since time immemorial, exercising fishing, hunting, and gathering for commercial, ceremonial, and subsistence purposes throughout the Pacific Northwest has been essential to Indigenous people in the region. Tribes in Washington State have treaties with the federal government that include fishing rights within "Usual and Accustomed Fishing and Hunting Areas" (U&A). These treaty rights have been confirmed and interpreted under the Boldt Decision[3] and other subsequent court cases[4] to include the right of Treaty Tribes to harvest up to 50% of all fisheries resources that reside in and/or pass through their U&A. These decisions also establish Treaty Tribes in Washington as legal co-managers of fisheries resources,[5] with similar regulations at the Federal level[6]. Treaty Tribes in the region have sophisticated fisheries management and research capacity. Treaty Tribes' commercial and ceremonial/subsistence fisheries in this region are extensive and include but are not limited to: salmon, halibut, groundfish, flatfish, whiting, and Dungeness crab. Tribes also harvest shellfish such as clams, crab, oysters, and shrimp, and many other species as part of treaty fisheries (NWIFC 2019). Treaty fisheries play an integral role in the economy, nutritional security, and culture of the Treaty Tribes. The proposed surveys off the Washington and Oregon coasts would avoid the U&A areas of the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Nation.

IV. ENVIRONMENTAL CONSEQUENCES

4.1 Proposed Action

4.1.1 Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a summary of the expected potential effects (or lack thereof) of airgun sounds on marine mammals and sea turtles given in the PEIS, and reference to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS. Relevant background information on the hearing abilities of marine mammals and sea turtles can also be found in the PEIS. This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys. A description of the rationale for NSF's estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 μPa_{rms} is also provided.

4.1.1.1 Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 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

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[3] *United States v. Washington*, 384 F. Supp. 312 (W.D. Wash. 1974), aff'd, 520 F.2d 676, 684-687 (9th Cir. 1975).

[4] *E.g., Washington v. Washington State* Commercial *Passenger Fishing Vessel Association*, 443 U.S. 658, 685-687 (1979) (salmon); *U.S. v. Washington*, 459 F. Supp. 1020, 1065 (W.D. Wash. 1978) (herring); *U.S. v. Washington*, No. C85-1606R, Subproceeding No. 92-1 (W.D. Wash. Dec. 29, 1993) (halibut); *U.S. v. Washington*, 873 F. Supp. 1422, 1445, n.30 (W.D. Wash. 1994), aff'd in part and rev'd in part, 157 F. 3d 630, 651-652 (9th Cir. 1998) (shellfish); *U.S. v. Washington*, No. 9213, Subproceeding 96-2 (Nov. 4, 1996) (Pacific whiting).

[5] *See generally United States v. Washington*, 384 F. Supp. 312 (W.D. Wash. 1974), aff'd, 520 F.2d 676 (9th Cir. 1975).

[6] *See*, *e.g.*, 50 C.F.R. § 660.50(d)(2).

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, 2019, 2022; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017a; Bröker 2019; Rako-Gospić and Picciulin 2019; Burnham 2023). 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 (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 would be 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 were encountered during an active survey, 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, 2020; Blackwell et al. 2013, 2015; Thode et al. 2020; Fernandez-Betelu et al. 2021; Noad and Dunlop 2023). 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. Kastelein et al. (2023a) reported masking release at various frequencies in harbor seals exposed to noise with fluctuating amplitude. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. We are not aware of any information concerning masking of hearing in sea turtles.

***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) surmised 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.

Southall et al. (2023) proposed data collection and analysis methods to examine the potential effects, including at the population level, of seismic surveys on whales. There have been several 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. 2018; Dunlop et al. 2021; Gallagher et al. 2021; McHuron et al. 2021; Mortensen et al. 2021). Booth et al. (2020) examined monitoring methods for population consequences.

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). Kavanagh et al. (2019) analyzed more than 8000 hr of cetacean survey data in the northeast Atlantic Ocean to determine the effects of the seismic surveys on cetaceans. They found that sighting rates of baleen whales were significantly lower during seismic surveys compared with control surveys.

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

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(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 in^3) within 3 km and received levels of at least 140 dB re 1 μPa$^2 \cdot$ s (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 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 μPa$^2 \cdot$ 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; Stone et al. 2017). 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). During a seismic survey in Cook Inlet, AK, wide-scale displacement was documented for humpback whales; acoustic detections were reduced or absent during the seismic survey period, but detections increased after the survey finished (Castellote et al. 2020).

Matthews and Parks (2021) summarized the known responses of right whales to sounds; however, there are no data on reactions of right whales to seismic surveys. 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 $\mathrm{CSEL}_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, decreased at $\mathrm{CSEL}_{10\text{-min}}$ >127 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, and whales were nearly silent at $\mathrm{CSEL}_{10\text{-min}}$ >160 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$. 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 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b).

In contrast, despite rigorous monitoring and mitigation measures during multiple seismic surveys in 2015 (Aerts et al. 2022; Rutenko et al. 2022), data collected during a program with multiple seismic surveys in 2015 showed short-term and long-term displacement of animals from the feeding area, at least short-term behavioral changes, and responses to lower sound levels than expected (Gailey et al. 2017, 2022a,b; Sychenko et al. 2017). However, stochastic dynamic programming (SDP) model predictions showed similar reproductive success and habitat use by gray whales with or without exposure to airgun sounds during the 2015 program (Schwarz et al. 2022). Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~170 dB re 1 μPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of Balaenoptera (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994–2010 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; Stone et al. 2017). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015; Stone et al. 2017). 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; Stone et al. 2017). 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; Stone et al. 2017). 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 continued to feed off Sakhalin Island every summer, despite seismic surveys in the region. 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; Stone et al. 2017; Barkaszi and Kelly 2024). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994–2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015; Stone et al. 2017). 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; Stone et al. 2017). 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; Stone et al. 2017). 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; Stone et al. 2017).

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.

Similarly, an analysis of protected species observer data from multiple seismic surveys in the northern Gulf of Mexico from 2002–2015 found that delphinids occurred significantly farther from the airgun array when it was active versus silent (Barkaszi and Kelly 2024). Dolphins were sighted significantly farther from the active array during operations at minimum power versus full power. Blackfish were seen significantly farther from the array during ramp up versus full source and minimum source operations, and they were seen significantly closer to the array when it was silent versus during full source, minimum source, and ramp up operations.

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 of travel at distances up to 24 km from a seismic source; however, no long-term effects were reported. Tervo et al. (2021) reported that narwhal buzzing rates decreased in response to concurrent ship noise and airgun pulses (being 50% at 12 km from ship) and that the whales discontinued to forage at 7–8 km from the vessel. Tervo et al. (2023) also noted that narwhals showed increased shallow diving activity and avoided deeper diving, resulting in a reduction in foraging, when exposed to combined ship sounds and airgun pulses. Both studies found that exposure effects could still be detected >40 km from the vessel (Tervo et al. 2021, 2023).

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 1994–2010, 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; Stone et al. 2017). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2018), 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). Barkaszi and Kelly (2024) found that sperm whales occurred at significantly farther CPAs from airgun array during full array activity versus silence based on data from multiple seismic surveys in the northern Gulf of Mexico during 2002–2015; similar results were found for both dwarf and pygmy sperm whales.

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it would be likely that most beaked whales would also show strong avoidance of an approaching seismic vessel. Observations from seismic vessels off the U.K. from 1994–2010 indicated that detection rates of beaked whales were significantly higher ($p<0.05$) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015; Stone et al. 2017). 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). Data from multiple seismic surveys in the northern Gulf of Mexico from 2002–2015 showed no significant difference in beaked whale CPA distances to the airgun array during full power versus silent periods, but the sample size was small, and mean CPA was larger than in other species groups (Barkaszi and Kelly 2024).

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 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015; Stone et al. 2017). 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; Stone et al. 2017). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 µPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). 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). During a seismic survey in Cook Inlet, AK, wide-scale displacement was documented for harbor porpoises; acoustic detections were reduced or absent during the seismic survey, but detections increased after the survey finished (Castellote et al. 2020).

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 µ$\mathrm{Pa}_{\text{0-peak}}$. 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. 2013b). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$. One porpoise moved away from the sound source but returned to natural movement patters 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. According to Scholik-Schlomer (2015), NMFS is developing new guidance for predicting behavioral effects. 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 1994–2010 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; Stone et al. 2017). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015; Stone et al. 2017). There were no significant differences in CPA distances of gray or harbor seals during seismic vs. non-seismic periods (Stone 2015; Stone et al. 2017). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in^3 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.

Sea Turtles

Several papers discuss the morphology of the turtle ear (e.g., Christensen-Dalsgaard et al. 2012; Willis et al. 2013) and the hearing ability of sea turtles (e.g., Martin et al. 2012; Piniak et al. 2012a,b; Lavender et al. 2014). The limited available data indicate that sea turtles will hear airgun sounds and sometimes exhibit localized avoidance (see PEIS, § 3.4.4.3). Additionally, Nelms et al. (2016) suggest that sea turtles could be excluded from critical habitats during seismic surveys. Green and hawksbill turtles were found to respond to low-frequency sounds (i.e., 0.2–1 kHz upsweeps), but did not respond to impulsive sounds (Kastelein et al. 2023b).

DeRuiter and Doukara (2012) observed that immediately following an airgun pulse, small numbers of basking loggerhead turtles (6 of 86 turtles observed) exhibited an apparent startle response (sudden raising of the head and splashing of flippers, occasionally accompanied by blowing bubbles from the beak and nostrils, followed by a short dive). Diving turtles (49 of 86 individuals) were observed at distances from the center of the airgun array ranging from 50–839 m. The estimated sound level at the median distance of 130 m was 191 dB re 1 μPa$_{peak}$. These observations were made during ~150 h of vessel-based monitoring from a seismic vessel operating an airgun array (13 airguns, 2440 in^3) off Algeria; there was no corresponding observation effort during periods when the airgun array was inactive (DeRuiter and Doukara 2012).

Based on available data, it is likely that sea turtles would exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate would likely have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of the year. However, a number of mitigation measures can, on a case-by-case basis, be considered for application in areas important to sea turtles (e.g., Pendoley 1997; van der Wal et al. 2016).

***Hearing Impairment and Other Physical Effects on Marine Mammals*.—**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 evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b, 2023a; 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, 2022a,b; Supin et al. 2016). Additionally, Gransier and Kastelein (2024) found that audiograms are not good predictors of frequency-dependent susceptibility to TTS.

Studies 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 µPa^2 · 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). Bottlenose dolphins exposed to 10-ms impulses at 8 kHz with SELs of 182–183 dB re 1 µPa^2 · s produced a TTS of up to 35 dB (Mulsow et al. 2023).

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; Mulsow et al. 2023). When beluga whales were exposed to fatiguing noise with sound levels of

165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a $\mathrm{SEL_{cum}}$ of 188 and 191 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$, 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; Finneran et al. 2023b,c, 2024).

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 1–88.4 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 1–88.4 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 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). 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). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. 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 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013b). Harbor seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5–40 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 µPa; 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. Kastelein et al. (2024) reported that TTS onset in California sea lions is not as closely associated with their hearing threshold as previously thought.

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, 2018b) accounted 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. Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016b, 2018b), but include all marine mammals (including sirenians), and a re-classification of hearing groups. NMFS (2024) incorporated Southall et al. (2019) recommendations into updated guidance regarding noise exposure criteria. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL ($\mathrm{SEL}_{\mathrm{cum}}$ over 24 hours) and Peak $\mathrm{SPL}_{\mathrm{flat}}$. Onset of PTS is assumed to be 15 dB higher when considering $\mathrm{SEL}_{\mathrm{cum}}$ and 6 dB higher when considering $\mathrm{SPL}_{\mathrm{flat}}$. Different thresholds are provided for the various hearing groups, including Low-frequency (LF) cetaceans (e.g., baleen whales), high-frequency (HF) cetaceans (e.g., most delphinids; previously known as mid-frequency cetaceans), very-high frequency (VHF) cetaceans (e.g., porpoise and *Kogia* spp.; previously known as HF cetaceans), phocid pinnipeds underwater (PW), and otariid pinnipeds underwater (OW).

It should be recognized that there are a number of limitations and uncertainties associated with injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise. Tougaard et al. (2022) indicate that there is empirical evidence to support the thresholds for very-high frequency cetaceans and pinnipeds in water, but caution that above 10 kHz for porpoise and outside of 3–16 kHz for seals, there are differences between the TTS thresholds and empirical data. Tougaard et al. (2023) also noted that TTS-onset thresholds for harbor porpoise are likely impacted by the experimental methods used (e.g., behavioral vs. brain stem recordings, and stationary vs. free-swimming animals), in particular for noise exposure >10 kHz.

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Various authors have reported that sound could be a potential source of stress for marine mammals (e.g., Wright et al. 2011; Atkinson et al. 2015; Houser et al. 2016; Lyamin et al. 2016;

Yang et al. 2021). Gray and Van Waerebeek (2011) 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. Williams et al. (2022) reported an increase in energetic cost of diving by narwhals that were exposed to airgun noise, as they showed marked cardiovascular and respiratory reactions.

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. 2016). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding. Morell et al. (2021) also reported evidence of hearing loss in a harbour porpoise that stranded on the Dutch coast. Morell et al. (2020) described new methodology that visualizes scars in the cochlea to detect hearing loss in stranded marine mammals.

Since 1991, there have been 72 Marine Mammal Unusual Mortality Events (UME) in the U.S., including the currently active UMEs in the North Atlantic for right whales, humpback whales, and minke whales (NOAA 2025c). 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.

***Hearing Impairment and Other Physical Effects on Sea Turtles*.—**There is substantial overlap in the frequencies that sea turtles detect versus the frequencies in airgun pulses. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. In the absence of relevant absolute threshold data, we cannot estimate how far away an airgun array might be audible. Moein et al. (1994) and Lenhardt (2002) reported TTS for loggerhead turtles exposed to many airgun pulses (see § 3.4.4 of the PEIS). Based on TTS from exposure to in-air sound, Mannes et al. (2023) surmised that a freshwater turtle would likely exhibit TTS when exposed to SEL of 160 dB re 1 $\mu Pa^2 \cdot s$ for an underwater sound. Salas et al. (2024) reported TTS in the freshwater Eastern painted turtle (*Chrysemys picta picta*) when exposed to continuous low-frequency white noise at a SEL of 171 dB re 1 $\mu Pa^2 \cdot s$. This suggests that sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs (see Nelms et al. 2016). However, exposure duration during the proposed surveys would be much less than during the aforementioned studies. Also, recent monitoring studies show that some sea turtles do show localized movement away from approaching airguns. At short distances from the source, received sound level diminishes rapidly with increasing distance. In that situation, even a small-scale avoidance response could result in a significant reduction in sound exposure.

The U.S. Navy has proposed the following criteria for the onset of hearing impairment for sea turtles: 232 dB re 1 µPa SPL (peak) and 204 dB re 1 $\mu Pa^2 \cdot s$ SEL_{cum} (weighted) for PTS; and 226 dB peak and 189 dB weighted SEL for TTS (DoN 2017). Although it is possible that exposure to airgun sounds could cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014), especially because sea turtles appear to be resistant to explosives (Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 dB_{peak} for sounds from seismic airguns; however, these criteria were largely based on impacts of pile-driving sound on fish.

The PSOs stationed on R/V *Sally Ride* would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.

4.1.1.2 Possible Effects of Other Acoustic Sources

The Kongsberg EM124 and EM712 MBESs, and the Kongsberg SBP29, would be operated from the source vessel during the proposed surveys. Information about similar 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 ADCPs, and pingers on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

There has been some 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 off Madagascar (Southall et al. 2013). 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 was the first known marine mammal mass stranding closely associated with the operation of an MBES. A leading scientific expert 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. 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). However, Ruppel et al. (2022) found that MBESs, SBPs, sidescan sonars, ADCPs, and pingers are unlikely to result in take of marine mammals as these sources typically operate at frequencies inaudible to marine mammals, have low source and received levels, narrow beams, downward directed transmission, and/or have low exposure (e.g., short pulse lengths, intermittency of pulses).

There is little information available on marine mammal behavioral responses to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior and use of habitat by Cuvier's beaked whales during multibeam mapping with a 12 kHz MBES 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 and habitat use 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. 2020).

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

Frankel and Stein (2020) reported that gray whales responded to a 21–25 kHz active sonar by deflecting 1–2 km away from the sound. Sperm whales exposed to sounds from a low-frequency 1–2 kHz sonar transitioned to non-foraging and non-resting states, but did not respond to 4.7–5.1 kHz or 6–7 kHz sonar signals (Isojunno et al. 2016). 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).

When green and hawksbill sea turtles were exposed to various sounds, they did not respond to impulses or helicopter long range active sonar down-sweeps (Kastelein et al. 2023b). Despite the aforementioned information that has recently become available, this Draft EA remains in agreement with the assessment presented in § 3.4.7, 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs, SBPs, and pingers would not be likely to impact marine mammals and would not be expected to affect sea turtles, (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 or sea turtle given the movement and speed of the vessel. Also, for sea turtles, the associated frequency ranges are above their known hearing range.

4.1.1.3 Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals and/or sea turtles 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 *Sally Ride* could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2018) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014; Veirs et al. 2016; Kyhn et al. 2019; Landrø and Langhammer 2020); low levels of high-frequency sound from vessels have been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have also been shown to affect foraging behavior (Teilmann et al. 2015; Wisniewska et al. 2018; Tervo et al. 2023), habitat use (e.g., Rako et al. 2013; Carome et al. 2022; Gannier et al. 2022), and swim speeds and movement (e.g., Sprogis et al. 2020; Martin et al. 2023a) of cetaceans. Vessel noise has also been shown to affect the dive behavior of pinnipeds (Mikkelsen et al. 2019). Wisniewska et al. (2018) suggests 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, 2018; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2018; Cholewiak et al. 2018; Groenewoud 2023). 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 and Sills 2022). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. Yurk et al. (2023) suggested that killer whales could avoid masking by using adaptive call design or vocalizing at different frequencies depending on noise levels in their environment.

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 vessels, 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; 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; Bittencourt et al. 2017; Fornet et al. 2018; Laute et al. 2022; Brown et al. 2023; Radtke et al. 2023).

In contrast, Sportelli et al. (2024) found that the whistle rates of captive bottlenose dolphins did not differ significantly during the initial sound exposure (e.g., ship noise) compared with before exposure. Similarly, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). However, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017), and spotted seals increased the source levels of their growls in response to increased ambient noise (Yang et al. 2022). 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. For example, Rolland et al. (2012) 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. 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). Martin et al. (2023b) reported no long-range (up to 50 km) responses of bowhead whales to passing vessels; responses <8 km from vessels could not be examined. 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) and killer whales (Williams et al. 2021). 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 (Pirotta et al. 2015) and blue whales (Lesage et al. 2017). Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015).

There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. Tyson et al. (2017) suggested that a juvenile green sea turtle dove during vessel passes and remained still near the seafloor.

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 or sea turtles, 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 or sea turtles (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.4.4.4, § 3.6.4.4, and § 3.8.4.4 of the PEIS. Wiley et al. (2016) concluded that reducing ship speed is one of the most reliable ways to avoid ship strikes. Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but would be 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 during seismic surveys with R/V *Sally Ride* or other vessels of the Academic Research Fleet.

Entanglement of sea turtles in seismic gear is also a concern (Nelms et al. 2016). There have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore from West Africa (Weir 2007); however, these tailbuoys are significantly different than those used on R/V *Sally Ride*. In April 2011, a dead olive ridley turtle was found in a deflector foil of the seismic gear on R/V *Langseth* during equipment recovery at the conclusion of a survey off Costa Rica, where sea turtles were numerous. Such incidents are possible, but that was the only case of sea turtle entanglement in seismic gear for the U.S. Academic Research Fleet. In addition, no entanglements of sea turtles in seismic gear deployed by R/V *Sally Ride* have been recorded. Towing the seismic equipment during the proposed surveys is not expected to significantly interfere with sea turtle movements, including migration.

4.1.1.4 Mitigation Measures

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activities. These measures include the following: ramp ups; two dedicated observers maintaining a visual watch during all daytime airgun operations; two observers maintaining a visual watch for 30 min before and during ramp ups during the day and night; shut downs when marine mammals are detected in or about to enter the designated EZ; and shut downs when ESA-listed sea turtles or seabirds (diving/foraging) are detected in or about to enter EZ. Ramp ups during times of poor visibility would occur where operational planning could not reasonably avoid such circumstances, as long as the EZ has been continually monitored by PSOs for 30 min prior to start up with no marine mammal sightings. These mitigation measures are described in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § 2.1.3. The fact that the GI airguns, as a result of their design, direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure. In addition, mitigation measures to reduce the potential of bird strandings on the vessel include downward-pointing deck lighting and curtains/shades on all cabin windows. Previous and subsequent analysis of the potential impacts takes account of these planned mitigation measures. It would not be meaningful to analyze the effects of the planned activities without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activities and would be implemented under the Proposed Action.

4.1.1.5 Potential Numbers of Level B Takes by Harassment for Marine Mammals and Sea Turtles

The numbers of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 µPa$_{rms}$ (Level B) on one or more occasions have been estimated using a method 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 densities 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 seismic tracklines that could be surveyed on one day (~222 km) that have the same proportion of water depths to be surveyed as during the entire survey (in this case, all effort is in water >1000 m deep). The area expected to be ensonified on a single day was then calculating using the representative line length and multiplying by two times the Level B radii and adding endcaps. The ensonified areas, increased by 25%, were then multiplied by the number of seismic days (2). 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 *Sally Ride* approaches. 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, 2016; Henry et al. 2020). 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, 2014, and 2018 and synthesized by Becker et al. (2020); 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.

Densities from Becker et al. (2020) for summer/fall were used to determine takes for marine mammals for the proposed survey (Table 5). For species for which densities were not available from Becker et al. (2020), we used annual densities from the U.S. Navy Northwest Training and Testing Study area (DON 2019) (Table 5). The U.S. Navy 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 by the Navy (DON 2019). The methods used to determine densities are detailed in Appendix D.

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.

TABLE 5. Densities of marine mammals and sea turtles in the proposed survey area off Washington and Oregon.

Species	Distance Band	Estimated Density (#/km^2)	Source	Density Ccomments
LF Cetaceans				
North Pacific right whale		*0*	-	*Near zero*
Humpback whale		*0.000480*	*Becker et al. (2020)*	*Summer/fall*
Blue whale		*0.000025*	*Becker et al. (2020)*	*Summer/fall*
Fin whale		*0.004482*	*Becker et al. (2020)*	*Summer/fall*
Sei whale		*0.000400*	*USN (2019), MSEL (2021)*	*Annual densities*
Minke whale		0.000869	Becker et al. (2020)	Summer/fall
HF Cetaceans				
Sperm whale		*0.002731*	*Becker, pers. comm., 2025*	*Summer/fall*
Cuvier's beaked whale		0.005120	Barlow et al. (2021)	August-September
Baird's beaked whale		0.000051	Becker et al. (2020)	Summer/fall
Small beaked whale		0.002320	*Becker, pers. comm., 2025*	Summer/fall
Bottlenose dolphin		0.000002	Becker et al. (2020)	Summer/fall
Striped dolphin		0.000057	Becker et al. (2020)	Summer/fall
Short-beaked common dolphin		0.001280	Becker et al. (2020)	Summer/fall
Pacific white-sided dolphin		0.069054	Becker et al. (2020)	Summer/fall
Northern right-whale dolphin		0.116618	Becker et al. (2020)	Summer/fall
Risso's dolphin		0.014357	Becker et al. (2020)	Summer/fall
False killer whale		N.A.		
Killer whale (Offshore waters)		0.000920	USN (2019), MSEL (2021)	Annual densities
Short-finned pilot whale		0.000250	USN (2019), MSEL (2021)	Annual densities
VHF Cetaceans				
Pygmy/dwarf sperm whale		0.001630	USN (2019), MSEL (2021)	Annual densities
Dall's porpoise		0.047357	Becker et al. (2020)	Summer/fall
Otariid Seals				
Northern fur seal*				
	>130 km from shore	0.035031	Based on USN (2019)	Density for February-May
*Guadalupe fur seal**				
	200-m isobath to 300 km	0.033027	Based on USN (2019)	Summer/fall density
California sea lion				
	70-450 km from shore	0.071400	USN (2019), MSEL (2021)	Spring density (highest)
Steller sea lion*				
	200-m isobath to 300 km	0.002771	Based on USN (2019)	Highest density for OR/WA for summer
Phocid Seals				
Northern elephant seal*		0.041794	Based on USN (2019)	Fall density (highest)
Sea Turtle				
Leatherback Turtle		0.000114	USN (2019), MSEL (2021)	Annual density

Note: ESA-listed species in italics. N.A. means not applicable. Dr. Elizabeth Becker, Ocean Associates, Inc., personal communication, January 20, 2025. *Densities adjusted for most recent population size.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 µPa$_{\text{rms}}$ 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 6 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 µPa$_{\text{rms}}$ during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix D for more details). 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 µPa$_{\text{rms}}$ 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$_{\text{rms}}$ 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; Hückstädt et al. 2020; Hastie et al. 2021; Southall et al. 2021; Booth et al. 2022; Miller et al. 2022). Southall et al. (2021) provided a detailed framework for assessing marine mammal behavioral responses to anthropogenic noise and noted that use of a single threshold can lead to large errors in prediction impacts due to variability in responses between and within species.

4.1.1.6 Conclusions for Marine Mammals and Sea Turtles

The proposed seismic surveys would involve towing an airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

Marine Mammals.—In § 3.6.7, § 3.7.7, § 3.8.7, and § 3.9.7 of the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, and pinniped species. Level A takes are considered highly unlikely. The brief duration of exposure of any given animal, the deep waters of the survey area, and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

In this analysis, estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level B harassment are low percentages of the regional population sizes (Table 3). The proposed activities are likely to adversely affect ESA-listed marine mammal species for which takes are being requested (Table 7). However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. In decades of NSF-funded seismic surveys carried out by vessels in the U.S. Academic Research Fleet, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality.

TABLE 6. Estimates of the possible numbers of individual marine mammals and sea turtles that could be exposed to the Level B threshold in the proposed survey area off Washington and Oregon.

Species	**Estimated Level B Takes[1]**	**% of Pop. (Requested Takes)[2]**	**Requested Level B Take Authorization[3]**
LF Cetaceans			
North Pacific right whale	*0*	*0*	*0*
Humpback whale[4]	*0*	*0.04*	***2***
Blue whale	*0*	*0.11*	***2***
Fin whale	*2*	*0.02*	*2*
Sei whale	*0*	*0.23*	***2***
Minke whale	0	0.11	**1**
HF Cetaceans			
Sperm whale	*2*	*0.27*	***7***
Cuvier's beaked whale	3	0.05	3
Baird's beaked whale	0	0.51	**7**
Small beaked whale[5]	1	N.A.	**N.A.**
Blaineville's beaked whale	N.A.	0.07	**2**
Hubbs' beaked whale	N.A.	0.07	**2**
Stejneger's beaked whale	N.A.	0.07	**2**
Bottlenose dolphin	0	0.40	**14**
Striped dolphin	0	0.13	**39**
Short-beaked common dolphin	1	0.01	**156**
Pacific white-sided dolphin	38	0.16	**55**
Northern right-whale dolphin	64	0.22	64
Risso's dolphin	8	0.30	**19**
False killer whale	N.A.	N.A.	**5**
Killer whale	1	2.33	**7**
Short-finned pilot whale	0	3.47	**29**
VHF Cetaceans			
Pygmy/dwarf sperm whale[6]	1	N.A.	**N.A.**
Pgymy sperm whale	N.A.	0.02	**1**
Dwarf sperm whale	N.A.	0.02	**1**
Dall's porpoise	26	0.16	26
Otariid Pinnipeds			
Northern fur seal	18	<0.01	18
Guadalupe fur seal	*18*	*0.05*	*18*
California sea lion	39	0.02	39
Steller sea lion	2	<0.01	2
Phocid Pinniped			
Northern elephant seal	23	0.01	23
Sea Turtle			
Leatherback Turtle[7]	*0*	*N.A.*	***1***

Note: ESA-listed species are in italics. N.A. means not available. [1]Level B takes for marine mammals are based on the 160-dB criterion. [2]Requested take authorization is expressed as % of population (see Table 3). [3]Requested take authorization is based on calculated takes. Takes in bold have been increased to mean group size based on Becker et al. (2020), except for sei, killer, pygmy sperm, dwarf sperm, and short-finned pilot whales for which mean group size is from Barlow (2016), and for false killer whale which is from Mobley et al. (2000). [4]One take each is assumed for the ESA-listed Central America and Mexico DPSs. [5]Minimum group sizes are being requested as takes for each *Mesoplodon* sp. that could occur in the survey area. [6]Assigned mean group size to each species of *Kogia*. [7]Take was rounded up to 1.

TABLE 7. ESA determination for marine mammal species that could be encountered during the proposed surveys off Washington and Oregon.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
North Pacific Right Whale	√		
Humpback Whale (Mexico DPS)			√
Humpback Whale (Central America DPS)			√
Sei Whale			√
Fin Whale			√
Blue Whale			√
Sperm Whale			√
Killer Whale (Southern Resident DPS)	√		
Guadalupe Fur Seal			√

In addition, 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 2014b). 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.

***Sea Turtles*.—**In § 3.4.7, the PEIS concluded that with implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations are likely to sea turtle populations in any of the analysis areas, and that any effects are likely to be limited to short-term behavioral disturbance and short-term localized avoidance of an area of unknown size near the active airguns. In decades of NSF-funded seismic surveys carried out by vessels in the U.S. Academic Research Fleet, PSOs and other crew members have seen no seismic sound-related sea turtle injuries or mortality. The proposed activities are likely to adversely affect ESA-listed sea turtle species that could be encountered in the proposed survey area (Table 8).

TABLE 8. ESA determination for sea turtle species that could be encountered during the proposed surveys off Washington and Oregon.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Leatherback Turtle			√
Green Turtle (East Pacific DPS)		√	
Loggerhead Turtle (North Pacific Ocean DPS)	√		
Olive Ridley Turtle	√		

4.1.2 Direct Effects on Marine Invertebrates, Fish, Fisheries, and Their Significance

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. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the PEIS are summarized below. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015, 2020, 2021; Carroll et al. 2017; Hawkins and Popper 2017; Popper and Hawkins 2019; Wale et al. 2021; Hawkins 2022a,b; Cones et al. 2023; Popper et al. 2022; Pieniazek et al. 2023; Solé et al. 2023; Vereide and Kühn 2023), including how particle motion rather than sound pressure levels affect invertebrates and fishes that are exposed to sound (Hawkins and Popper 2017; Popper and Hawkins 2018, 2019; McCauley et al. 2021; Azarm-Karnagh et al. 2023).

It is important to note that while all invertebrates and fishes are likely sensitive to particle motion, no invertebrates and not all fishes (e.g., sharks) are sensitive to the sound pressure component. Rogers et al. (2021) found that sounds from a seismic survey measured above ambient conditions up to 10 km away for particle acceleration and up to 31 km for sound pressure. Substrate vibrations caused by sounds may also affect the epibenthos, but sensitivities are largely unknown (Roberts and Elliott 2017). Activities directly contacting the seabed would be expected to have localized impacts on invertebrates and fishes that use the benthic habitat. Substrate vibrations caused by sounds may also affect the epibenthos, but sensitivities are largely unknown (Roberts and Elliott 2017). Nonetheless, several studies have found that substrate-borne vibration and sound elicit behavioral responses in crabs (e.g., Roberts et al. 2016) and mussels (Roberts et al. 2015). Solan et al. (2016) also reported behavioral effects on sediment-dwelling invertebrates during sound exposure. Activities directly contacting the seabed would be expected to have localized impacts on invertebrates and fishes that use the benthic habitat.

A risk assessment of the potential impacts of airgun surveys on marine invertebrates and fish in Western Australia concluded that the greater the intensity of sound and the shallower the water, the greater the risk to these animals (Webster et al. 2018). In water >250 m deep, the impact of seismic surveying on fish and marine invertebrates was assessed as acceptable, while in water <250 m deep, risk ranged from negligible to severe, depending on depth, resource-type, and sound intensity (Webster et al. 2018). Immobile organisms, such as mollusks, were deemed to be the invertebrates most at risk from seismic impacts.

4.1.2.1 Effects of Sound on Marine Invertebrates

Effects of anthropogenic sounds on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses, injuries, mortalities (Wale et al. 2013a,b; Aguilar de Soto 2016; Edmonds et al. 2016; Carroll et al. 2017; Weilgart 2017b, 2023; Elliott et al. 2019; Day et al. 2021; Hawkins 2022a; Solé et al. 2023; Vereide and Kühn 2023; Prosnier 2024), hearing loss (Putland et al. 2023), and stress (Celi et al. 2013; Vazzana et al. 2020). Jézéquel et al. (2021) recently reported that noise (such as from shipping) can mask sounds produced by European lobster (*Homarus gammarus*), and that they may change sound production in response to noise. Cones et al. (2023) reported, based on a review of studies, that impacts tend to be more severe with increased sound levels or closer to the sound source.

Fields et al. (2019) conducted laboratory experiments to study effects of exposure to airgun sound on the mortality, predator escape response, and gene expression of the copepod *Calanus finmarchicus* and concluded that the airgun sound had limited effects on the mortality and escape responses of copepods exposed within 10 m of the airgun source but no measurable impact beyond that distance. McCauley et al. (2017) conducted a 2-day study to examine the potential effects of sound exposure of a 150 in^3 airgun on zooplankton off the coast of Tasmania; they concluded that exposure to airgun sound decreased zooplankton abundance compared to control samples and caused a two- to three-fold increase in adult and larval zooplankton mortality. They observed impacts on the zooplankton as far as 1.2 km from the exposure location—a much greater impact range than previously thought; however, there was no consistent decline in the proportion of dead zooplankton as distance increased and received levels decreased. The conclusions by McCauley et al. (2017) were based on a relatively small number of zooplankton samples, and more replication is required to increase confidence in the study findings.

Richardson et al. (2017) presented results of a modeling exercise intended to investigate the impact of exposure to airgun sound on zooplankton over a much larger temporal and spatial scale than that employed by McCauley et al. (2017). The exercise modeled a hypothetical survey over an area 80 km by 36 km during a 35-day period. Richardson et al. (2017) postulated that the decrease in zooplankton abundance observed by McCauley et al. (2017) could have been due to active avoidance behavior by larger zooplankton. The modeling results did indicate that there would be substantial impact on the zooplankton populations at a local spatial scale but not at a large spatial scale; zooplankton biomass recovery within the exposure area and out to 15 km occurred 3 days after completion of the seismic survey.

Vereide et al. (2023) conducted a field experiment that examined the effects of a seismic survey on the mortality and development of nauplii of the copepod *Acartia tonsa*. The nauplii were held in plastic bags that were suspended at a depth of 6 m; these were exposed at a distance of 50 m for 2.5 hours to discharges from two 40-in^3 airguns towed behind a vessel. Controls of the experiment included periods with vessel noise only (no airguns), as well as silence. After exposure, the nauplii were brought to the laboratory where greater immediate mortality (14%) was observed in the nauplii exposed to airgun sounds compared with those during the vessel only and silent controls. After 4 days, most of the exposed nauplii were dead, whereas most nauplii in the control groups were still alive 6 days after exposure. Exposed nauplii also had lower growth rates than those that were not exposed to airgun sounds. Vereide et al. (2024) found that a rapid pressure drop (~2 bar) associated with seismic exposure caused mortality and negatively affected swimming behavior of two common species of copepods, with *Acartia* sp. being more sensitive to the pressure drop than *Calanus* sp.

Fewtrell and McCauley (2012) exposed captive squid (*Sepioteuthis australis*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 µPa$^2 \cdot$s SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 µPa$^2 \cdot$s; the squid were seen to discharge ink or change their swimming pattern or vertical position in the water column. Solé et al. (2013a,b) exposed four cephalopod species held in tanks to low-frequency (50–400 Hz) sinusoidal wave sweeps (with a 1-s sweep period for 2 h) with received levels of 157 ± 5 dB re 1 µPa and peak levels up to 175 dB re 1 µPa. Besides exhibiting startle responses, all four species examined received damage to the statocyst, which is the organ responsible for equilibrium and movement. The animals also showed stressed behavior, decreased activity, and loss of muscle tone (Solé et al. 2013a). To examine the contribution from near-field particle motion from the tank walls on the study, Solé et al. (2017) exposed common cuttlefish (*Sepia officinalis*) in cages in their natural habitat to 1/3 octave bands with frequencies centered at 315 Hz and 400 Hz and levels ranging from 139–141 dB re 1 µPa^2. The study animals still incurred acoustic trauma and injury to statocysts, despite not being held in confined tanks with walls.

Parsons et al. (2024) conducted a large-scale experiment at a pearl oyster holding lease site to examine the effect of a seismic survey on mortality and productivity of silverlip pearl oysters (*Pinctada maxima*). The oysters were exposed to four days of seismic survey sounds using a 2600 in^3 airgun array with a peak to peak source level of 252 dB re 1 µPa at 1 m and a sound exposure level of 228 dB re 1 µPa^{2}m^{2}s; the experiment also included one vessel-control day. The oysters were monitored for a full two-year production cycle. Only two of 16 groups showed reduced survival and pearl productivity; thus, the study found no conclusive evidence that the commercial important oyster was impacted by the seismic survey sounds.

Hubert et al. (2022a) examined the response of wild-caught blue mussels to exposures of single pulses and pulse trains in an aquarium. They reported that the mussels responded to the sounds by partially closing their valves and that the response waned with repeated exposures. They could not determine whether the decay in response was due to habituation or a sensory adaptation. There was no difference in recovery time between exposures to single pulses or a pulse trains. Hubert et al. (2022b) noted that the sound-induced valve closure varied with pulse train speed – mussels exposed to faster pulse trains returned to baseline conditions faster than those exposed to slower pulse trains; phytoplankton clearance rates were not impacted.

Jézéquel et al. (2023) reported that sound sensitivity in the giant scallop (*Placopecten magelanicus*) depends on the life stage and intensity and frequency of the sound it is exposed to. When New Zealand scallop (*Pecten novaezelandiae*) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited body abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (Aguilar de Soto et al. 2013). Their experiment used larvae enclosed in 60-mL flasks suspended in a 2-m diameter by 1.3-m water depth tank and exposed to a playback of seismic sound at a distance of 5–10 cm.

There have been several *in situ* studies that have examined the effects of seismic surveys on scallops. Although most of these studies showed no short-term mortality in scallops (Parry et al. 2002; Harrington et al. 2010; Przeslawski et al. 2016, 2018), one study (Day et al. 2016a,b, 2017) did show adverse effects including an increase in mortality rates. Przeslawski et al. (2016, 2018) studied the potential impacts of an industrial seismic survey on commercial *Pecten fumatus* and doughboy (*Mimachlamys asperrima*) scallops. *In situ* monitoring of scallops took place in the Gippsland Basin, Australia, using dredging, and autonomous underwater vehicle deployment before the seismic survey, as well as two, and ten months after the survey. The airgun array used in the study was a single 2530 in^3 array made up of 16 airguns operating at 2000 psi with a maximum SEL of 146 dB re 1 µPa$^2 \cdot$ s at 51 m depth. Overall, there was little to no detectable impact of the seismic survey on scallop health as measured by scallop shell size, adductor muscle diameter, gonad size, or gonad stage (Przeslawski et al. 2016). No scallop mortality related to airgun sounds was detected two or ten months after the seismic survey (Przeslawski et al. 2016, 2018).

Day et al. (2016a,b, 2017) exposed scallops (*P. fumatus*) and egg-bearing female spiny lobsters (*Jasus edwardsi*) at a location 10–12 m below the surface to airgun sounds. The airgun source was started ~1–1.5 km from the study subjects and passed over the animals; thus, the scallops and lobsters were exposed to airgun sounds as close as 5–8 m away and up to 1.5 km from the source. Three different airgun configurations were used in the field: 45 in^3, 150 in^3 (low pressure), and 150 in^3 (high pressure), each with maximum peak-to-peak source levels of 191–213 dB re 1 µPa; maximum cumulative SEL source levels were 189–199 dB re 1 µPa$^2 \cdot$ s. Exposure to seismic sound was found to significantly increase mortality in the scallops, especially over a chronic time scale (i.e., months post-exposure), although not beyond naturally occurring rates of mortality (Day et al. 2017). Non-lethal effects were also recorded, including changes in reflex behavior time, other behavioral patterns, haemolymph chemistry, and apparent damage to statocysts (Day et al. 2016b, 2017). However, the scallops were reared in suspended lantern nets rather than their natural environment, which can result in higher mortality rates compared to benthic populations (Yu et al. 2010). The female lobsters were maintained until the eggs hatched; no significant differences were found in the quality or quantity of larvae for control versus exposed subjects, indicating that the embryonic development of spiny lobster was not adversely affected by airgun sounds (Day et al. 2016a,b). No mortalities were reported for either control or exposed lobsters (Day et al. 2016a,b). When Day et al. (2019) exposed rock lobster to the equivalent of a full-scale commercial seismic survey passing within 100–500 m, lobsters exhibited impaired righting and damage to the sensory hairs of the statocyst. Lobsters that were exposed at a more distance range showed recovery, whereas those exposed at closer range had persistent impairment (Day et al. 2019, 2021). Day et al. (2021) noted that there was indication for slowed growth and physiological stress and juvenile lobsters after exposure. Adult lobsters that were collected from areas with high anthropogenic noise were shown to have pre-existing damage to the statocysts which were not damaged further upon exposure to airgun sounds (Day et al. 2020). However, lobsters from noisy environments appeared to be better able to cope with the damage than noise naïve lobsters; they did not show any disruption to the righting reflex (Day et al. 2020).

Fitzgibbon et al. (2017) also examined the impact of airgun exposure on spiny lobster through a companion study to the Day et al. (2016a,b, 2017) studies; the same study site, experimental treatment methodologies, and airgun exposures were used. The objectives of the study were to examine the haemolymph biochemistry and nutritional condition of groups of lobsters over a period of up to 365 days post-airgun exposure. Overall, no mortalities were observed across both the experimental and control groups; however, lobster total haemocyte count decreased by 23–60% for all lobster groups up to 120 days post-airgun exposure in the experimental group when compared to the control group. A lower haemocyte count increases the risk of disease through a lower immunological response. The only other haemolymph parameter that was significantly affected by airgun exposure was the Brix index of haemolymph at 120 and 365 days post-airgun exposure in one of the experiments involving egg-laden females.

Payne et al. (2015) undertook two pilot studies which (i) examined the effects of a seismic airgun recording in the laboratory on lobster (*Homerus americanus*) mortality, gross pathology, histopathology, serum biochemistry, and feeding; and (ii) examined prolonged or delayed effects of seismic air gun pulses in the laboratory on lobster mortality, gross pathology, histopathology, and serum biochemistry. For experiment (i), lobsters were exposed to peak-to-peak and root-mean-squared received sound levels of 180 dB re 1 µPa and 171 dB re 1 μPa_{rms} respectively. Overall, there was no mortality, loss of appendages, or other signs of gross pathology observed in exposed lobster. No differences were observed in haemolymph, feeding, ovary histopathology, or glycogen accumulation in the hepatopancreas. The only observed differences were greater degrees of tubular vacuolation and tubular dilation in the hepatopancreas of the exposed lobsters. For experiment (ii), lobsters were exposed to 20 airgun shots per day for five successive days in a laboratory setting. The peak-to-peak and root-mean-squared received sound levels ranged from ~176–200 dB re 1 µPa and 148–172 dB re 1 μPa_{rms}, respectively. The lobsters were returned to their aquaria and examined after six months. No differences in mortality, gross pathology, loss of appendages, hepatopancreas/ovary histopathology or glycogen accumulation in the hepatopancreas were observed between exposed and control lobsters. The only observed difference was a slight statistically significant difference for calcium-protein concentration in the haemolymph, with lobsters in the exposed group having a lower concentration than the control group.

de Lestang et al. (2024) reported that spaghetti-tagged western rock lobster (*Panulirus cygnus*) changed their behaviors when exposed to sounds from an 80 in^3 sleeve airgun array at a depth of 5 m during a seismic survey. In the short and medium term (within the first few months), exposed lobsters moved and reacted slower than lobsters under control conditions; they were also less likely to be recaught in commercial pots. They found no significant difference in blood protein concentration. No long-term effects were detected on lobster survival or catchability.

Other studies conducted in the field have shown no effects on Dungeness crab (*Cancer magister*) larvae or snow crab (*Chionoecetes opilio*) embryos to seismic sounds (Pearson et al. 1994; DFO 2004; Morris et al. 2018; Cote et al. 2020). However, when Borland (2023) examined the behavior of Dungeness crab during a seismic survey (6600 in^3 discharge volume) off southern Oregon in 2021, she found slight differences in the movement and spatial use of crabs when the airguns were active; however, the results were inconclusive.

Cote et al. (2020) conducted a study using the multi-year Before-After/Control-Impact (BACI) approach in the Carson and Lilly Canyons to evaluate the potential of industry-scale seismic exposure to modify movement behavior of free-ranging adult male snow crab. The crabs were exposed to a commercial seismic array, with a total volume of 4880 in^3, horizontal $SPL_{0\text{-}p}$ of 251 dB re 1 μPa, and SEL of 229 dB re 1 μPa2·s (the same seismic source as used by Morris et al. 2018, noted below). The movements of the snow crabs were tracked using a hyperbolic acoustic positioning array. In total, 201 and 115 snow crabs were tagged in Carson and Lilly canyons, respectively. Before, during, and after exposure periods to a single seismic surveying line of 5 to 8 hours in duration, were matched in time across control and test sites—each site monitored an area 4 km^2. There were no obvious effects of seismic exposure on the movement ecology of adult male snow crab; variation in snow crab movement was primarily attributable to individual variation and factors like handling, water temperature, and time of day. The authors concluded that seismic exposure did not have any important effects on snow crab movement direction, and any variance in the results were shown to be individual-specific. Snow crabs are known to display highly variable movement behavior and individual-specific tendencies can explain experimental variance (Cote et al. 2020). Snow crab have also been considered to be less vulnerable to physiological damages from noise due to their absence of gas filled organs such as swim bladders that are sensitive to seismic exposures (Cote et al. 2020). There was also no evidence of physical damage to internal organs based on histological examinations (Morris et al. 2021).

In total, 201 and 115 snow crab were tagged in Carson and Lilly canyons, respectively. Before, During, and After exposure periods to a single 2D seismic surveying line (5-8 hours duration) were matched in time across Control and Test sites—each site monitored an area 4 km2. There were no obvious effects of seismic exposure on the movement ecology of adult male snow crab; variation in snow crab movement was primarily attributable to individual variation and factors like handling, water temperature and time of day. The authors concluded that the effects of seismic exposure on the behaviour of adult male snow crab, are at most subtle and are "not likely to be a prominent threat to the fishery." There was also no evidence of physical damage to internal organs based on histological examinations (Morris et al. 2021). The study concluded that seismic exposure did not have any important effects on snow crab movement direction, and any variance in the results were shown to be individual-specific. Snow crab have also been considered to be less vulnerable to physiological damages from noise due to their absence of gas filled organs such as swim bladders that are sensitive to seismic exposures (Cote et al. 2020).

Hall et al. (2021) collected tissue samples to investigate the potential impact of seismic surveying on the transcriptome responses of snow crab hepatopancreas. The hepatopancreas is an organ that aids in the absorption and storage of nutrients and produces important digestive enzymes and is therefore assumed to be an indicator suitable for determining the effect of sound exposure effects on crab physiology and health. Snow crabs were subjected to 2-D seismic noise in 2016 for 2 h and sampled before, and 18 h and three weeks after exposure. In 2017, 2-D seismic exposure was repeated, and samples were collected prior to seismic testing, and 1 day, 2 days, and 6 weeks after exposure. Additionally, in 2017 snow crabs were subjected 3-D seismic noises for 2 months and were sampled 6 weeks after exposure. Hall et al. (2021) identified nine transcripts with significantly higher expression after 2-D seismic exposure, and

14 transcripts with significant differential expression between the test and control sites. These included transcripts with functional annotations related to oxidation-reduction, immunity, and metabolism. Significant changes for these transcripts were not observed during the 2017. Thus, although transcript expression changes were detected in snow crab in response to seismic survey sound, the response was variable across years. Hall et al. (2021) concluded that although candidate molecular biomarkers identified in one field season (2016), they were not reliable indicators in the next year (2017), and further study is warranted.

Roberts and Laidre (2019) studied the effect of an impulsive sound source on the chemically mediated shell searching behavior of the hermit crab (*Pagarus acadianus*). Although the sound source was not seismic airgun-related, it was impulsive. An underwater slide hammer was used to create vibration within the seabed, allowing the production of a fully controllable manually operated stimulus. Exposures consisted of repetitive low-frequency pulses, with most energy within the 500–700 Hz range. The average peak particle velocity ranges at 1-m and 5-m were 0.00001–0.0005 m/s and 0.00002–0.00009 m/s, respectively. Results of this study indicated the sound source used can act cross-modally and affect chemically guided search behavior. The broad conclusion was that anthropogenic noise and seabed vibration may have effects on other behaviors mediated by other sensory modalities.

Celi et al. (2013) exposed captive red swamp crayfish (*Procambarus clarkia*) to linear sweeps with a frequency range of 0.1–25 kHz and a peak amplitude of 148 dB re 1 µPa$_{rms}$ at 12 kHz for 30 min. They found that the noise exposure caused changes in the haemato-immunological parameters (indicating stress) and reduced agonistic behaviors. Wale et al. (2013a,b) showed increased oxygen consumption and effects on feeding and righting behavior of shore crabs when exposed to ship sound playbacks.

Leite et al. (2016) reported observing a dead giant squid (*Architeuthis dux*) while undertaking marine mammal observation work aboard a seismic vessel conducting a seismic survey in offshore Brazil. The seismic vessel was operating a 48-airgun array with a total volume of 5085 in^3. As no further information on the squid could be obtained, it is unknown whether the airgun sounds played a factor in the death of the squid.

Heyward et al. (2018) monitored corals *in situ* before and after exposure to a 3-D seismic survey; the maximum SEL and SPL$_{0\text{-pk}}$ were 204 dB re 1 µPa^2·s and 226 dB re 1 µPa. No macroscopic effects on soft tissues or the skeleton were noted days or months after the survey.

Buscaino et al. (2019) exposed caged sea urchins (*Arbacia lixula*) and sea cucumbers (*Holothuria tubulosa*) to sounds from a seismic water gun with a peak pressure level of 122 dB re 1 µPa^2/Hz at 850 Hz and a peak particle speed of 207 dB re (1 nm/s)^2 at 550 Hz. When the coelomic fluid was extracted from each animal (40 individuals of each species), there was evidence of stress as indicated by differences in esterase and peroxidase in sea urchins and total hemocyte count and total protein for the sea cucumbers. Mauro et al. (2024) exposed caged *A. lixula* to peak-peak and root-mean-square pressure levels of 178 dB re 1 µPa and 159 dB re 1 µPa, respectively, and a root-mean-square particle velocity of 227 to 233 dB re 1 (nm/s)^2 from a seismic water gun to examine effects on the physiology of the peristomial membrane. Exposed animals showed stress in the form of decreased total protein and increases in peroxidase, superoxide dismutase, esterase, alkaline phosphatase, and heat shock protein activity.

Spiga (2022) reported behavioral responses of snapping shrimp in the field to playbacks of impulses with frequencies of 50–600 Hz when exposed to sound pressure levels at or above to 130 re 1 µPa and particle motion of 2.06×10^{-06} m/s. Bigger shrimp snapped more for longer durations and moved away from the sound source; peak frequency of snaps decreased during exposure compared with before and after sound exposure.

4.1.2.2 Effects of Sound on Fish

Popper et al. (2019a) and Popper and Hawkins (2021) reviewed the hearing ability of fishes, and potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), Fay and Popper (2012), Weilgart (2017b), Hawkins and Popper (2018), Popper et al. (2019b), Slabbekoorn et al. (2019), and Hawkins (2022a,b), and Lessa (2023); they include pathological, physiological, and behavioral effects. Radford et al. (2014), Putland et al. (2017), de Jong et al. (2020), Pine et al. (2020), and Jones et al. (2023) noted that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Mauro et al. (2020) concluded that noise exposure may have significant effects on fish behavior which may subsequently affect fitness and survival.

Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed include mortality, mortal injury, recoverable injury, TTS, masking, and behavioral effects. Seismic sound level thresholds were discussed in relation to fish without swim bladders, fish with swim bladders, and fish eggs and larvae. Hawkins and Popper (2017) and Hawkins et al. (2020) cautioned that particle motion as well as sound pressure should be considered when assessing the effects of underwater sound on fishes.

Waddell and Širović (2023) examined the effects of seismic survey on larval fish behavior. They exposed presettlement-sized red drum (*Sciaenops ocellatus*), southern flounder (*Paralichthys lethostigma*), spotted seatrout (*Cynoscion nebulosus*), and Florida blenny (*Chasmodes saburrae*) larvae to these sounds and found initial significant avoidance of airgun sounds in three of the four species (except Florida blenny); however, habituation occurred as the experiment carried on. All four species also avoided vessel sounds. The results indicate that these larval fish could habituate relatively quickly (<10 min) to anthropogenic noise.

Borland (2023) examined the behavior of rockfish and lingcod during a seismic survey off southern Oregon in 2021. She found slight differences in the movement and spatial use of these fish when the airguns (total discharge value of 6600 in^3) were active. However, differences diminished after several days. Sample sizes for lingcod were small ($n = 5$). Bruce et al. (2018) studied the potential behavioral impacts of a seismic survey in the Gippsland Basin, Australia, on three shark species: tiger flathead (*Neoplatycephalus richardsoni*), gummy shark (*Mustelus antarcticus*), and swellshark (*Cephaloscylum laticeps*). Sharks were captured and tagged with acoustic tags before the survey and monitored for movement via acoustic telemetry within the seismic area. The energy source used in the study was a 2530 in^3 array consisting of 16 airguns with a maximum SEL of 146 dB re 1 $\mu Pa^2 \cdot s$ at 51 m depth. Flathead and gummy sharks were observed to move in and around the acoustic receivers while the airguns in the survey were active; however, most sharks left the study area within 2 days of being tagged. The authors of the study did not attribute this behavior to avoidance, possibly because the study area was relatively small. Overall, there was little conclusive evidence of the seismic survey impacting shark behavior, though flathead shark did show increases in swim speed that was regarded by the authors as a startle response to the airguns operating within the area.

Peña et al. (2013) used an omnidirectional fisheries sonar to determine the effects of a 3-D seismic survey off Vesterålen, northern Norway, on feeding herring (*Clupea harengus*). They reported that herring schools did not react to the seismic survey; no significant changes were detected in swimming speed, swim direction, or school size when the drifting seismic vessel approached the fish from a distance of 27 km to 2 km over a 6-h period. Peña et al. (2013) attributed the lack of response to strong motivation for feeding, the slow approach of the seismic vessel, and an increased tolerance to airgun sounds.

Miller and Cripps (2013) used underwater visual census to examine the effect of a seismic survey on a shallow-water coral reef fish community in Australia. The census took place at six sites on the reef before and after the survey. When the census data collected during the seismic program were combined with historical data, the analyses showed that the seismic survey had no significant effect on the overall abundance or species richness of reef fish. This was in part attributed to the design of the seismic survey (e.g., ≥400 m buffer zone around reef), which reduced the impacts of seismic sounds on the fish communities by exposing them to relatively low SELs (<187 dB re 1 µPa^2 · s). Meekan et al. (2021) also reported that a commercial seismic source had no short- or long-term effects on the tropical demersal fish community on the Northwest Shelf of Western Australia, as no changes on species composition, abundance, size structure, behavior, or movement were reported. The source level of the airgun array was estimated as 228 dB SEL and 247 dB re 1 µPa m peak-to-peak pressure.

Fewtrell and McCauley (2012) exposed pink snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 µPa^2 · s SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 µPa^2 · s; the fish swam faster and formed more cohesive groups in response to the airgun sounds.

Hastings and Miksis-Olds (2012) measured the hearing sensitivity of caged reef fish following exposure to a seismic survey in Australia. When the AEPs were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at a water depth of 5 m, there was no evidence of TTS in any of the fish examined, even though the cumulative SELs had reached 190 dB re 1 µPa^2 · s.

Davidsen et al. (2019) outfitted Atlantic cod and saithe with acoustic transmitters to monitor their behaviors (i.e., swimming speed, movement in water column) in response to exposure to seismic airgun sound. The study was conducted in Norway using a large sea cage with a 30 m diameter and 25 m depth. Both sound pressure and particle motion were measured within the sea cage. An airgun firing every 10 s was towed toward the sea cage from an initial distance of 6.7 km from the cage to a minimum distance of 100 m from the cage. The SEL_{cum} ranged from 172–175 dB re 1 µPa^2·s. Both the cod and saithe changed swimming depth and horizontal position more frequently during exposure to the sound. The saithe became more dispersed in response to elevated sound levels. Both species exhibited behavioral habituation to the repeated exposures to sound.

van der Knaap et al. (2021) investigated the effects of a seismic survey on the movement behavior of free-swimming Atlantic cod in the southern North Sea. A total of 51 Atlantic cod were caught and tagged with acoustic transmitters and released in the southern North Sea where they were exposed to a towed airgun array 2.5 km from the tagged location over 3.5 days. The airgun array consisted of 36 airguns with a total volume of 2950 in^3, which fired every 10 s during operation in continuous loops, with parallel tracks of 25 km. The cumulative sound exposure level (SEL_{cum} re 1 µPa^{2}s) over the 3.5-day survey period at the receiver position was 186.3 dB in the 40–400 Hz band. During sound exposure, cod became less locally active (moving small distances, showing high body acceleration) and more inactive (moving small distances, showing low body acceleration) at dawn and dusk which interrupted their diurnal activity cycle. The authors concluded that seismic surveying has the potential to affect energy budgets for a commercial fish species, which may have population-level consequences.

Hubert et al. (2020) exposed Atlantic cod in an aquaculture net pen to playback of seismic airgun sounds to determine the effect on swimming patterns and behavioral states. The fish were exposed to sound recordings of a downscaled airgun with a volume of (10 in^3) and a pressure of 800 kPa. During the experimental trials, the fish were exposed to mean zero-to-peak sound pressure levels ($\text{SPL}_{\text{0-p}}$) of 174, 169, and 152 dB re 1 µPa (0-pk) (100–600 Hz bandpass filter) with the speaker at 2, 7.8, and 20 m from the net pen, respectively. They found that individual cod within the net pen did not immediately change their swimming patterns after sound exposure; however, several individuals did change the amount of time they spent in three different behavioral states (transit, locally active, inactive) during the 1 h exposure.

When McQueen et al. (2022, 2023) exposed Atlantic cod on their spawning grounds to airgun sounds with received exposure levels of 115 to 145 dB re 1 µPa^{2}s, the fish showed weak responses by swimming slightly deeper during sound exposure; however, they did not change their swimming acceleration nor were they displaced from the exposed area. According to McQueen et al. (2023), the results suggest that distant seismic surveys 5 to >40 km away would not significantly change cod behaviour (McQueen et al. 2023).

Radford et al. (2016) conducted experiments examining how repeated exposures of different sounds to European seabass (*Dicentrarchus labrax*) can reduce the fishes' response to that sound. They exposed post-larval seabass to playback recordings of seismic survey sound (single strike SEL 144 dB re 1 µPa^2 · s) in large indoor tanks containing underwater speakers. Their findings indicated that short-term exposure of seismic sound increased the ventilation rate (i.e., opercular beat rate [OBR]) of seabass that were not previously exposed to seismic relative to seabass in controlled, ambient sound conditions. Fish that were reared in tanks that were repeatedly exposed to seismic sound over a 12-week period exhibited a reduced OBR response to that sound type, but fish exposed over the same time period to pile-driving noise displayed a reduced response to both seismic and pile-driving noise. An increased ventilation rate is indicative of greater stress in seabass; however, there was no evidence of mortality or effects on growth of the seabass throughout the 12-week study period.

Neo et al. (2014, 2015, 2016, 2018) reported changes in fish (primarily European seabass) behavior (e.g., dive depth, group cohesion, swim speed) upon exposure to impulsive sounds and noted that temporal structure of sound plays a large role in the potential response of fish to noise exposure. Neo et al. (2014) also postulated that intermittent sounds, such as from airguns, may elicit a stronger response by fish than continuous sounds, regardless of the cumulative sound exposure level.

Waddell and Širović (2023) examined larval fish behaviour in a linear acoustic chamber when exposed to airgun sounds. They found that larvae of drum (*Sciaenops ocellatus*), southern flounder (*Paralichthys lethostigma*), and spotted seatrout (*Cynoscion nebulosus*) actively avoided airguns sounds, as well as vessel passage sounds, but habituated to the noise within 10 min.

Sivle et al. (2017) examined the behavioural responses of wild captured mackerel in a net pen to sounds from a 90 in^3 airgun towed behind a vessel; SELs ranged from 146 to 171 re 1 µPa$_{0\text{-p}}$. No overt responses (e.g., changes in swimming dynamics, swim speed, etc.) were recorded during sound exposure. When fish were exposed to airgun sounds at close range (90 m) at received SPLs of 184 dB re 1 µPa$_{0\text{-p}}$, they swam rapidly. This suggests that the threshold between subtle reactions and avoidance responses occurs between 178 and 184 dB re 1 µPa$_{0\text{-p}}$, and that ramp up of sound may be effective at minimizing initial responses to sound.

Popper et al. (2016) conducted a study that examined the effects of exposure to seismic airgun sound on caged pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*); the maximum received peak SPL in this study was 231 dB re 1 µPa. Results of the study indicated no mortality, either during or seven days after exposure, and no statistical differences in effects on body tissues between exposed and control fish.

Andrews et al. (2014) conducted functional genomic studies on the inner ear of Atlantic salmon (*Salmo salar*) that had been exposed to seismic airgun sound. The airguns had a maximum SPL of ~145 dB re 1 µPa^2/Hz and the fish were exposed to 50 discharges per trial. The results provided evidence that fish exposed to seismic sound either increased or decreased their expressions of different genes, demonstrating that seismic sound can affect fish on a genetic level.

Sierra-Flores et al. (2015) examined broadcast sound as a short-term stressor in Atlantic cod (*Gadus morhua*) using cortisol as a biomarker. An underwater loudspeaker emitted SPLs ranging from 104–110 dB re 1 µPa$_{\text{rms}}$. Plasma cortisol levels of fish increased rapidly with sound exposure, returning to baseline levels 20–40 min post-exposure. A second experiment examined the effects of long-term sound exposure on Atlantic cod spawning performance. Tanks were stocked with male and female cod and exposed daily to six noise events, each lasting one hour. The noise exposure had a total SPL of 133 dB re 1 µPa. Cod eggs were collected daily and measured for egg quality parameters as well as egg cortisol content. Total egg volume, floating fraction, egg diameter and egg weight did not appear to be negatively affected by sound exposure. However, fertilization rate and viable egg productivity were reduced by 40% and 50%, respectively, compared with the control group. Mean egg cortisol content was found to be 34% greater in the exposed group as compared to the control group. Elevated cortisol levels inhibit reproductive physiology for males and can result in a greater frequency of larval deformities for spawning females.

Handegard et al. (2013) examined different exposure metrics to explain the disturbance of seismic surveys on fish. They applied metrics to two experiments in Norwegian waters, during which fish distribution were affected by airguns. Even though the disturbance for one experiment was greater, the other appeared to have the stronger SEL, based on a relatively complex propagation model. Handegard et al. (2013) recommended that simple sound propagation models should be avoided and that the use of sound energy metrics like SEL to interpret disturbance effects should be done with caution. In this case, the simplest model (exposures per area) best explained the disturbance effect.

Hovem et al. (2012) used a model to predict the effects of airgun sounds on fish populations. Modeled SELs were compared with empirical data and were then compared with startle response levels for cod. This work suggested that in the future, particular acoustic-biological models could be useful in designing and planning seismic surveys to minimize disturbance to fishing. Their preliminary analyses indicated that seismic surveys should occur at a distance of 5–10 km from fishing areas, in order to minimize potential effects on fishing.

Kok et al. (2021) examined the behavior of pelagic fish to seismic surveys using echosounders; the received SPLs at the echosounder ranged from 123 to 195 dB re 1 µPa$_{\text{0-p}}$. They found that there were fewer schools of fish during the seismic surveys, but the schools were more cohesive than before the sound exposure.

Paxton et al. (2017) examined the effects of seismic sounds on the distribution and behavior of fish on a temperate reef during a seismic survey conducted in the Atlantic Ocean on the inner continental shelf of North Carolina. Hydrophones were set up near the seismic vessel path to measure SPLs, and a video camera was set up to observe fish abundances and behaviors. Received SPLs were estimated at ~202–230 dB re 1 µPa. Overall abundance of fish was lower when undergoing seismic activity as opposed to days when no seismic occurred. Only one fish was observed to exhibit a startle response to the airgun shots. The authors claim that although the study was based on limited data and no post-seismic evaluation was possible, it contributes evidence that normal fish use of reef ecosystems is reduced when they are impacted by seismic sounds.

4.1.2.4 Conclusions for Invertebrates and Fish

The newly available information does not affect the outcome of the effects assessment as presented in 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. PSOs would also watch for any impacts the acoustic sources may have on fish during the surveys. Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect (including ESA-listed) marine invertebrates or marine fish (Table 9). In decades of seismic surveys carried out by vessels in the U.S. Academic Research Fleet, PSOs and other crew members have not observed any seismic sound-related fish or invertebrate injuries or mortality.

4.1.3 Direct Effects on Seabirds and Their Significance

The underwater hearing of marine-associated birds (including loons, scaups, gannets, and ducks) has been investigated by Crowell (2016), and the peak hearing sensitivity was found to be between 1500 and 3000 Hz. The best sensitivity of underwater hearing for great cormorants was found to be at 2 kHz, with a hearing threshold of 71 dB re 1 μPa_{rms} (Hansen et al. 2017).

Gentoo penguins, black ducks, and great cormorants have been found to be able to detect underwater sounds (e.g., Hansen et al. 2017, 2020, 2023; Larsen et al. 2020; Sørensen et al. 2020; McGrew et al. 2022; Rasmussen et al. 2022). Great cormorants may have special adaptations for hearing underwater (Johansen et al. 2016; Hansen et al. 2017). Common murres (*Uria aalge*) were found to respond negatively to pulsed sound (Hansen et al. 2020). African penguins (*Spheniscus demersus*) outfitted with GPS loggers showed strong avoidance of preferred foraging areas and had to forage further away and increase their foraging effort when a seismic survey was occurring within 100 km of the breeding colony (Pichegru et al. 2017). However, the birds resumed their normal behaviors when seismic operations concluded.

Potential effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded marine seismic research on seabirds or their populations. The acoustic source would be shut down in the event an ESA-listed seabird was observed diving or foraging within the designated EZ.

However, ESA-listed seabirds that could be present foraging at the ocean surface rather than diving would not be affected by the airgun operations below the water surface. Thus, given the proposed activities, types of ESA species and behaviors, avoidance measures and unlikelihood of encounter, no effects to ESA-listed seabirds would be anticipated from the proposed action (Table 10). In decades of seismic surveys carried out by U.S. Academic Research Fleet, PSOs and other crew members have seen no seismic sound-related seabird injuries or mortality.

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned. No significant indirect impacts on marine mammals, sea turtles, seabirds, or fish would be expected.

4.1.4 Indirect Effects on Marine Mammals, Seabirds, Fish, and Their Significance

The proposed seismic operations would not result in any permanent impact on habitats used by marine mammals, seabirds, or fish, or to the food sources they use. The main impact issue associated with the proposed activities would be temporarily elevated anthropogenic sound levels and the associated direct effects on marine mammals, seabirds, and fish as discussed above.

Table 9. ESA determination for marine fish that could be encountered during the proposed surveys off Washington and Oregon.

	ESA Determination		
Species	**No Effect**	**May Affect - Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Yelloweye Rockfish (Puget Sound/Georgia Basin DPS)		√	
Steelhead Trout (Various DPSs)		√	
Chinook Salmon (Various ESUs)		√	
Chum Salmon (Various ESUs)		√	
Coho Salmon (Various ESUs)		√	
Sockeye Salmon (Various ESUs)		√	
Pacific Eulachon (Southern DPS)		√	
Bocaccio (Puget Sound/Georgia Basin DPS)	√		
Bull trout (Coastal Puget Sound DPS)	√		
Green Sturgeon (Southern DPS)	√		
Giant Manta Ray	√		
Oceanic Whitetip Shark	√		
Scalloped Hammerhead Shark (Eastern Pacific DPS)	√		

TABLE 10. ESA determination for seabird species that could be encountered during the proposed surveys off Washington and Oregon.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Short-tailed albatross	√		
Hawaiian petrel	√		

4.1.5 Reasonably Foreseeable Effects

Reasonably foreseeable effects refer to the impacts on the environment that result from a combination of the proposed action and other projects and human activities that could occur within the survey area. These effects can result from multiple causes, multiple effects, effects of activities in more than one locale, and recurring events. Human activities, when conducted separately or in combination with other activities, could affect marine animals in the proposed survey area. However, understanding these effects is complex because of the animals' extensive habitat ranges, and the difficulty in monitoring populations and determining the level of impacts that may result from certain activities. Here we focus on activities that could impact animals specifically in the proposed survey area. However, the combination of the proposed surveys with the existing operations in the region would be expected to produce only a negligible increase in overall disturbance effects on marine mammals and other biota.

4.1.5.1 Geophysical Research Activities in the Area

Numerous studies of fluid seeps along the margin and high-resolution seismic studies have been conducted in the region. For example, NSF funded the Cascadia Initiative (CI), an ambitious onshore/offshore seismic and geodetic experiment that took advantage of an amphibious array to study questions ranging from megathrust earthquakes to volcanic arc structure, to the formation, deformation, and hydration of the Juan De Fuca and Gorda Plates (Toomey et al. 2014). CI involved a plate-scale seismic experiment that encompassed components of the Cascadia subduction zone as well as the underthrusting Juan de Fuca Plate. The onshore seismic component of the amphibious array consisted of the EarthScope USArray Transportable Array, and the offshore seismic component consisted of OBSs. Over four field seasons from 2011–2014, oceanographic expeditions and OBSs deployments and recoveries were conducted in the region to collect data in support of the research objectives. Seismic surveys using a 36-airgun array were conducted north of the proposed survey area by R/V *Langseth* during summer 2009, and off the coast of Oregon/Washington during summer 2012, 2021, and 2022. The USGS has also been conducting seismic surveys in the region during multi-year hazard assessment studies of the Pacific Northwest.

SIO conducted low-energy seismic surveys for ~4–7 days off the coast of Oregon/Washington during September 2007, July 2009, and September 2017. During May–June 2018, SIO conducted vibracoring and CHIRP profiles off the Oregon coast, and retrieved seafloor receivers collecting magnetotelluric and passive seismic data offshore Oregon utilizing R/V *Roger Revelle*. SIO deployed geodetic transponders from R/V *Roger Revelle* along the Cascadia Subduction Zone off Oregon during June 2018, which were later retrieved. During June–August 2018, SIO conducted a cabled array survey offshore Oregon using the remote operated vehicle (ROV) *Jason* and R/V *Roger Revelle*. As a component of this survey, a shallow profiler was installed and an ROV was deployed from R/V *Thompson* to turn instruments and/or moorings during July/August 2018. R/V *Sally Ride* was used by SIO to conduct biological sampling to assess mesozooplankton food webs off Oregon and northern California during July 2018, and deploy coastal surface moorings off Oregon and Washington during September–October 2018. SIO utilized two vessels to conduct sampling for a primary production study in the waters off the Northwest Pacific during August–September 2018, and collected atmospheric, water column and surficial sediment samples along 152ºW from Alaska to Tahiti using R/V *Roger Revelle* during September–October and October–November 2018.

There are also ongoing studies using the Ocean Observatories Initiative (OOI) regional cable underwater volcanic observatory, including nodes at Axial Seamount, Juan de Fuca Plate, Hydrate Ridge, and on the Oregon shelf. In addition to having an active volcano which erupted in 1998, 2011, and 2015, Axial Seamount has several hydrothermal fields (OOI 2025). Numerous geophysical, chemical, and biological sensors, as well as cameras, are deployed there, which provide real-time information on seismic events via a cabled array (OOI 2025).

Drilling as a component of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) was undertaken during 1971, 1992, and 2002 off Oregon (IODP 2025). Drilling was also conducted off B.C., Washington, and Oregon during several ODP legs from 1991–1996, 2004, and in 2005 and 2010, as a component of the IODP (IODP 2025).

The Northwest Fisheries Science Center conducts the West Coast Groundfish Bottom Trawl Survey from May to October every year, covering the area twice (NOAA 2025d). The survey takes place from Cape Flattery to the U.S./Mexico border (NOAA 2025d). These surveys are conducted to assess 90 commercially fished stocks to ensure sustainable fisheries (NOAA 2025d).

4.1.5.2 Naval Activities

The Rose Festival Fleet Week occurs annually, for which visiting U.S. Navy ships (e.g., destroyers and mine countermeasure ships) and fleet-related elements (e.g., submarines) transit to Portland, OR; in 2005, the Festival will be held in June (Travel Portland 2025). Seafair annually hosts visiting vessels from the U.S. Navy, U.S. Coast Guard, and Royal Canadian Navy during Fleet Week and the Boeing Maritime Celebration during July/August on the Seattle, WA, waterfront (Seafair 2025). Navy vessels may transit within or near the proposed survey area while travelling to west coast Fleet Week ports, depending on the ship's originating location. Other Navy activities may have been or may be conducted in this region in the future as this area is included in the U.S. Navy's Northwest Training and Testing Area, which extends up to 250 nmi offshore. However, we are not aware of any specific activities that are planned to occur in the proposed survey area during September 2025.

4.1.5.3 Vessel Traffic

Several major ports are located on the northwestern coast of the U.S., including Seattle, Tacoma, and Portland, as well as Vancouver, B.C., and major shipping lanes originate there. Vessel traffic in the proposed survey area would consist mainly of commercial fishing and cargo vessels. Based on the data available through the Automate Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard (USCG), most of the shipping lanes that intersect the survey area had 4 or fewer vessels travelling along them on a monthly basis during September 2024 (USCG 2025). Based on MarineTraffic (2025) which was accessed on 29 January 2025, the majority of vessels that are expected to occur in the offshore survey area include tankers and cargo vessels; however, commercial fishing vessels and U.S. Navy ships may also transit the survey area. The total travel distance by R/V *Sally Ride* of ~700 km would be small relative to total transit length for vessels operating in the general region around the proposed survey area during September. Thus, the addition of SIO's vessel traffic to existing shipping and fishing operations is expected to result in only a minor increase in overall ship traffic.

4.1.5.4 Entanglements

The impacts of fishing on marine mammals and sea turtles involve direct removal of prey items, disturbance due to noise, and potential entanglement (Reeves et al. 2003).

***Marine mammals*.—**According to Lewison et al. (2014), the U.S. West Coast has relatively high bycatch rates for marine mammals. Between 1990 and 1996, an average of 456 cetaceans and 160 pinnipeds were killed or seriously injured per year in the California/Oregon driftnet fishery (Moore et al. 2009). As a result of regulatory action to reduce cetacean bycatch in 1997, bycatch was reduced to a yearly average of 105 cetaceans (8 odontocete species and fin, minke, and gray whales) and 77 pinnipeds (California sea lion and northern elephant seal) during the 1997–2006 period (Moore et al. 2009). Between 2020 and 2023, the observed annual bycatch in the California/Oregon large-mesh drift gillnet fishery for thresher sharks and swordfish was up to 15 short-beaked common dolphins, 3 California sea lions, 2 humpback whales, and 1 Guadalupe fur seal, 1 northern right whale dolphin, and 1 Risso's dolphin (Carretta 2024). Before 2000, high bycatch of harbor porpoises, southern sea otters, and pinnipeds (California sea lion, harbor seals, and elephant seals) occurred in the set gillnet fishery for California halibut. The bycatch likely led to the decline of the harbor porpoise. Restrictions applied between 2000 and 2002 effectively closed most of the fishery (Moore et al. 2009). During 2019, bycatch totals for the U.S. West Coast groundfish fishery included 55 California sea lions, 10 Steller sea lions, 2 northern elephant seals, and 2 harbor seals (Jannot et al. 2022). Carretta et al. (2024) reported mean annual takes in all U.S. West Coast fisheries of 197 California sea lions, 8.2 harbor seals (OR/WA stock), 5.3 northern elephant seals, 1.2 Guadalupe fur seals, 0.8 northern fur seals, 8.1 humpback whales, 30.5 short-beaked common dolphins, 6.6 northern right whale dolphins, 4.0 Pacific white-sided dolphins, 4.0 striped dolphins, 3.7 Risso's dolphins, 1.2 short-finned pilot whales, 3.2 harbor porpoise (northern OR/WA stock), and 0.6 Dall's porpoise.

***Sea Turtles*.**—According to Lewison et al. (2014) and Roe et al. (2014), the northwest coast of the U.S. has relatively low bycatch rates for sea turtles. Finkbeiner et al. (2011) reported that between 1990 and 2007, the annual mean bycatch for sea turtles in the California/Oregon driftnet fishery was 30 individuals before regulations came into effect, and <10 after regulations were put in place. Moore et al.

(2009) reported that an average of 14 leatherbacks were killed annually in the California/Oregon drift gillnet fishery before regulations were implemented to reduce bycatch in 1997 and 2001. Since the year 2000, the observed bycatch of leatherback and loggerhead sea turtles has been zero to one individual per year (Carretta 2024).

Entanglement of sea turtles in seismic gear is also a concern; there have been anecdotal reports of turtles being trapped and killed between the gaps in tail-buoys and industry airgun arrays and becoming entangled in an ocean bottom cable gear offshore of West Africa (Nelms et al. 2016). During one survey in the eastern Pacific in 2011, the R/V *Langseth* reported a dead olive ridley sea turtle on the deflector foil during gear recovery. The probability of entanglements would be a function of turtle density in the proposed survey area, which is expected to be low. Towing of hydrophone streamers or other equipment is not expected to significantly interfere with sea turtle movements, including migration, unless they were to become entrapped as indicated above.

Seabirds.—According to Lewison et al. (2014), the U.S. West Coast has relatively low bycatch rates for seabirds. Net fisheries for salmon in Puget Sound have killed thousands of birds annually, mostly murres and auklets (Moore et al. 2009). Annual seabird bycatch in the set net fishery for California halibut during 1990–2001 ranged from 308–3259; most bycatch consisted of common murres, loons, grebes, and cormorants (Moore et al. 2009). Closure of the central California fishery in depths <110 m in 2002 reduced bycatch to an estimated 61 seabirds in 2003 (Moore et al. 2009). The estimated take of seabirds in the non-Pacific hake fisheries during 2002–2005 totaled 575, half of which were common murres; other species caught included Leach’s storm petrel, Brandt’s cormorant, black-footed albatross, western gull, and brown pelican (NMFS 2008c). The estimated take of seabirds in Pacific hake fisheries during 2002–2009 was 50 birds, including seven black-footed albatrosses, five common murres, 23 northern fulmars, two sooty shearwaters, and 13 unidentified seabirds (NMFS 2008c). Jannot et al. (2021) reported takes of 17 seabird species in the west coast groundfish fishery during 2012–2018, including short-tailed albatross; in 2018, black-footed albatross, shearwaters, and Brandt’s cormorant made up most of the bycatch.

4.1.5.5 Summary of Reasonably Foreseeable Effects on Marine Mammals, Seabirds, and Fish

Impacts of the proposed activities are expected to be no more than a minor (and short-term) increment when viewed in light of other human activities within the proposed survey area. Unlike some other ongoing activities in the area (e.g., fishing), the proposed activities are not expected to result in injuries or deaths of marine mammals, sea turtles, or seabirds. Vessel traffic in the proposed survey area would primarily consist of cargo vessels and tankers. Although the airgun sounds from the seismic surveys would have higher source levels than some other anthropogenic sounds in the area that have lower peak pressures but occur continuously over extended periods; the airgun operations during the surveys would last only 2 days. Thus, the combination of the proposed operations with the existing vessel traffic would be expected to produce only a negligible increase in overall disturbance effects on marine mammals.

The PEIS concluded that seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on fisheries would not be significant. Interactions between the proposed surveys and fishing operations in the proposed survey area are expected to be limited. Two possible conflicts in general are streamer entangling with fishing gear and the temporary displacement of other vessels from the proposed survey area. Some fishing activities could occur within the proposed survey area; however, a safe distance would need to be kept from R/V *Sally Ride* and the towed seismic equipment. During the surveys, the towed equipment is relatively short, so this distance would be small. Conflicts would be avoided through communication with other vessels during the surveys.

4.1.6 Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and sea turtles occurring in the proposed survey area would be limited to short-term, localized changes in behavior of individuals. For marine mammals, some of the changes in behavior may be sufficient to fall within the MMPA definition of "Level B Harassment" (behavioral disturbance; no serious injury or mortality). TTS, if it occurs, would be limited to a few individuals, is a temporary phenomenon, and is unlikely to have long term consequences for the few individuals involved. No long-term or significant impacts would be expected on any of these individual marine mammals or sea turtles, or on the populations to which they belong; NMFS, however, requires NSF to estimate Level A takes. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.7 Coordination with Other Agencies and Processes

This Draft EA was prepared by LGL on behalf of NSF, NMT, and OSU. Potential impacts to marine mammals and endangered species have also been assessed in the document; therefore, it will be used to support the ESA Section 7 consultation process with NMFS and other U.S. regulatory processes as appropriate. This document will also be used as supporting documentation for an IHA application submitted by SIO, on behalf of itself, NSF, NMT, and OSU, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for this proposed seismic surveys.

Coastal Zone Management Act (CZMA)

NSF consulted the Federal Consistency Lists for Oregon and Washington and found NSF was not listed. NSF reviewed the state of Oregon's Marine Renewable Energy Geographic Location Description (GLD), an area starting from the seaward limit of Oregon state jurisdiction (3 n.mi. from the shoreline) and extending seaward to a boundary line along the outer continental shelf which approximates the 500 fathom bathymetric contour. The proposed survey does not overlap with the GLD or meet the GLD thresholds.

NSF considered whether the proposed action would affect coastal state uses or resources. The proposed activity would occur outside of, and significantly beyond, state waters. Given the significant distance from the survey site to the state coastal zone, brevity of the proposed action, low energy source, mitigation and monitoring measures, and planned communication strategy with fishing vessels in the area, NSF came to a "No Effects" determination pursuant to the CZMA on 25 February 2025.

4.2 No Action Alternative

An alternative to conducting the proposed activities is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine mammals attributable to the proposed activities; however, valuable data about the marine environment would be lost. Geological data of scientific value with the aim to quantify the thermal effects of fluid circulation in oceanic crust entering the Cascadia Subduction Zone would not be collected, and the collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. The No Action Alternative would not meet the purpose and need for the proposed activity.

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LIST OF APPENDICES

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 1µPa$_{rms}$) 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-in^3 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-in^3 GI airguns at a tow depth of 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).

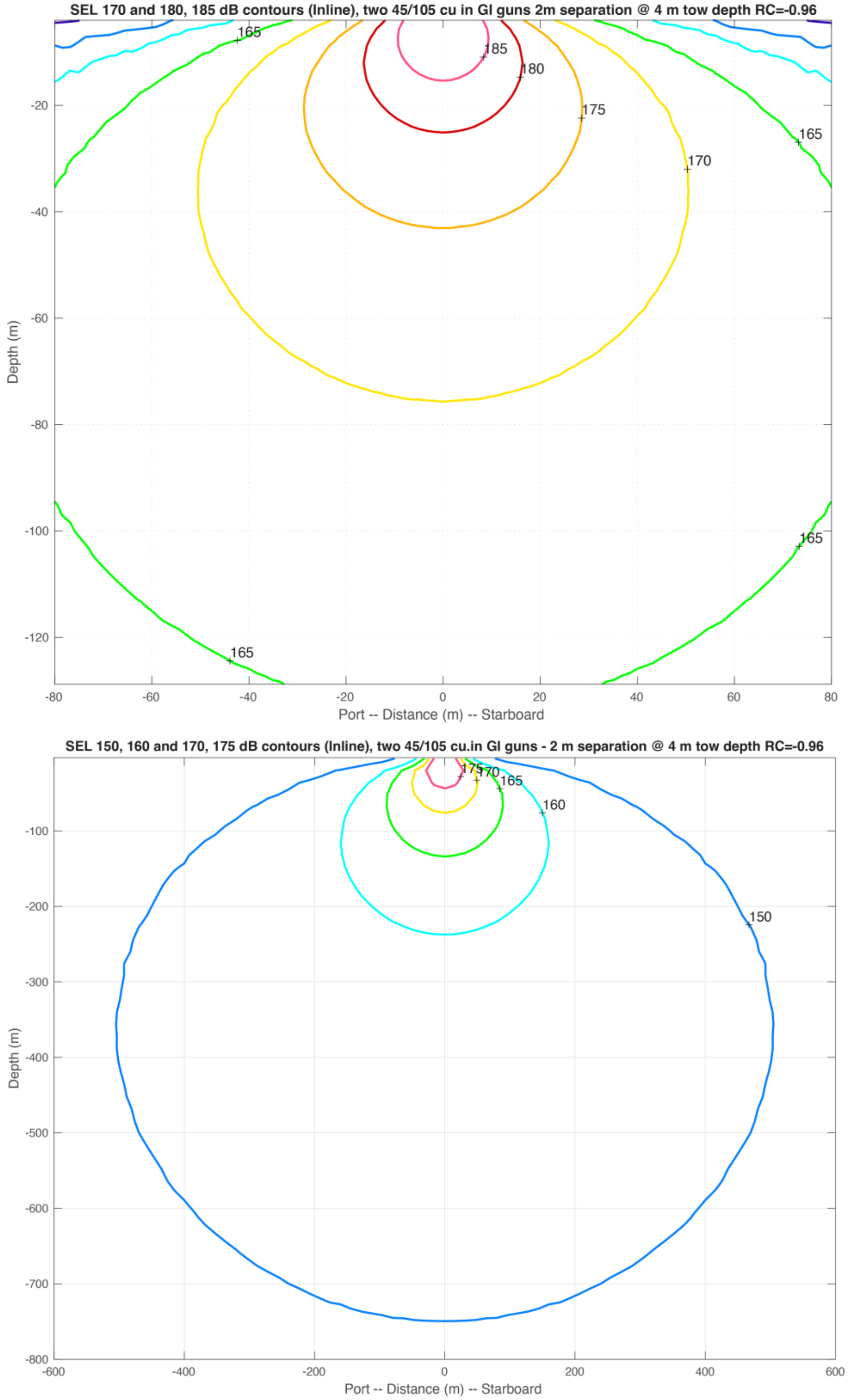

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the two 45-in^3 GI guns, with a 2-m GI airgun separation, at a 4 m two depth, planned for use during the proposed surveys at the Cascadia Subduction Zone. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius 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 1µPa$_{rms}$ sound exposure levels (SEL)[7] 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 (DON 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 level[8] have confirmed that the L-DEO model generated conservative mitigation zones, resulting in significantly larger zones than required by NMFS.

TABLE A-1. Level B. Predicted distances to the 160 and 175-dB re 1 µPa$_{rms}$ sound levels that could be received from two 45/105 in^3 GI guns (at a tow depth of 4 m) that would be used during the seismic surveys at the Cascadia Subduction Zone.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distance (in m) to the 160-dB Received Sound Level	Predicted distance (in m) to the 175-dB Received Sound Level
Two 45-in^3 GI guns, 2-m separation distance	4	>1000 m	505	89

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

[8] 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: DETERMINATION OF LEVEL A RADII

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, at the time, for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The noise exposure criteria for marine mammals accounted for 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). Thresholds differed for various hearing groups including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2018).

Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which were similar to those presented by NMFS (2018), but included all marine mammals (including sirenians) and a re-classification of hearing groups. NMFS (2024) incorporated Southall et al. (2019) recommendations into updated guidance regarding noise exposure criteria. The new guidance incorporates marine mammal auditory weighting functions (Fig. B-1) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds for various hearing groups were provided by NMFS (2024), including for LF cetaceans, HF cetaceans (e.g., most delphinids; previously known as mid-frequency cetaceans), very-high frequency (VHF) cetaceans (e.g., porpoise and *Kogia* spp.; previously known as HF cetaceans), PW, and OW. Thresholds are also available for sea turtles (DoN 2017).

The thresholds for PTS onset for marine mammals and sea turtles for impulsive sounds, such as airgun pulses, use dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Per NMFS (2024), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances for marine mammals. Below we provide the methodology for determining the Level A radii for the two 45-in^3 GI airguns, with 2-m aft-fore, and a two depth of 4 m.

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

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

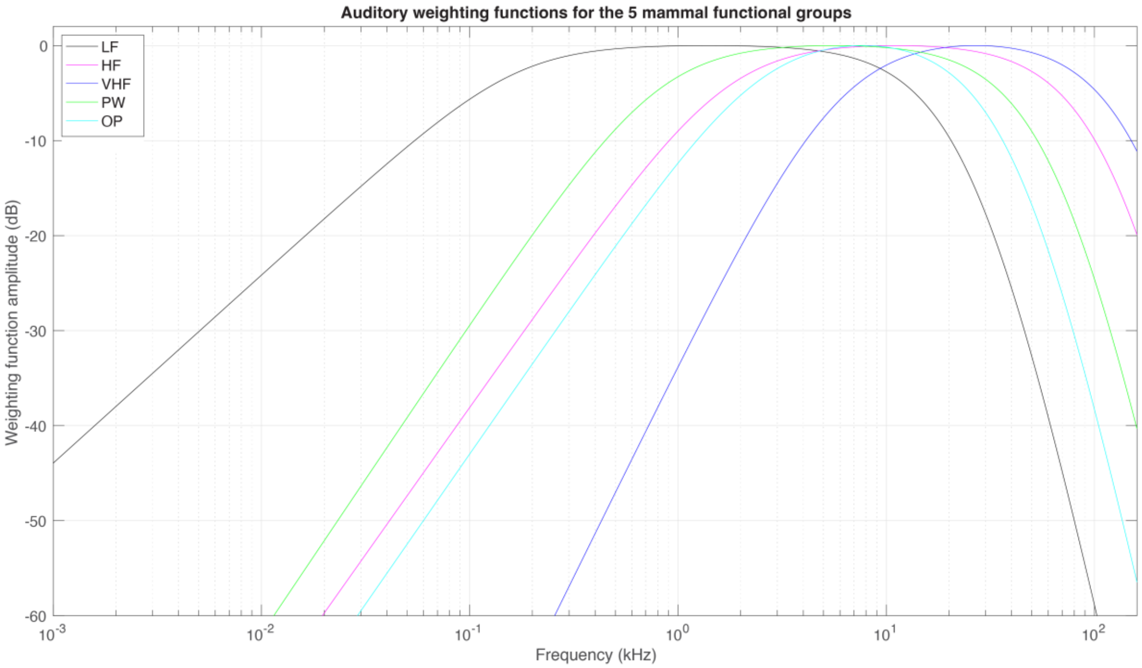

FIGURE B-1. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014).

SEL_{cum} methodology† (spreadsheet – Sivle et al. 2014)

Source Velocity (meters/second)	2.5722 *
1/Repetition rate^ (seconds)	4.862 **

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

^ Time between onset of successive pulses.

* 5 kts

** 12.5 m at 5 knots (this shot spacing is conservative relative to the longer shot spacing of 25 m).

For the low-frequency cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183 dB SEL_{cum} isopleth is located at 14.1 m from the source. We then run the modeling for one single shot with the low-frequency cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL_{cum} isopleth is located at 8.45 m from the source. Difference between 14.1 and 8.45 gives an adjustment factor of 4.45 dB (Table B-1) assuming a propagation of 20log10(R).

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

For the 2-GI airgun array, the results for single shot SEL source level modeling are shown in Table B-1. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the array are shown in Table B-2. Figure B-2 shows the impact of weighting functions by hearing group. Figures B-3–B-5 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure B-6 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

TABLE B-1. One single SEL SL modeling without and with applying weighting function to the 5 hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 log10 (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**193**	**159**	**183**	**185**	**204**
Distance(m) (no weighting function)	14.1095	4.4093	239.0067	14.1095	11.2000	0.9072
Modified Farfield SEL*	205.9902	205.8874	206.5682	205.9902	205.9844	203.1541
Distance (m) (with weighting function)	8.4492	N/A	N/A	N/A	N/A	N/A
Adjustment (dB)	-4.4539	N/A	N/A	N/A	N/A	N/A

* Propagation of 20 log R. N/A = not applicable.

TABLE B-2. Results for single shot SEL source level modeling for the two 45-in^3 GI airguns, at a 5 kt speed and 12.5 m shot interval, with weighting function calculations for SEL$_{cum}$ criteria.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION Please include any assumptions	source : SIO portable system = 2 x 45/105 cu.in GI-gun at a 4m towed depth - 2m separation□ □
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL$_{cum}$

Source Velocity (meters/second)	2.5722	
1/Repetition rate^ (seconds)	4.86	12.5 m shot interval

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

^Time between onset of successive pulses.

Modified farfield SEL	**205.9902**	**205.8874**	**206.5682**	**205.9902**	**205.9844**	**203.1541**
Source Factor	**8.17304E+19**	**7.98185E+19**	**9.33649E+19**	**8.17304E+19**	**8.16213E+19**	**4.25377E+19**

RESULTANT ISOPLETHS*

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

Hearing Group	**Low-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Very High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
SEL$_{cum}$ Threshold	183	193	159	183	185	204
AUD INJ SEL$_{cum}$ Isopleth to threshold (meters)	**17.9**	**0.0**	**0.0**	**0.3**	**0.0**	**0.1**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	**Low-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Very High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
a	0.99	1.55	2.23	1.63	1.58	1.4
b	5	5	5	5	5	2
f_1	0.168	1.73	5.93	0.81	2.53	0.077
f_2	26.6	129	186	68.3	43.8	0.44
C	0.12	0.32	0.91	0.29	1.37	2.35
Adjustment (dB)†	**-4.45**	**-30.56**	**-56.32**	**-22.67**	**-34.52**	-2.54

OVERIDE Using LDEO Modeling

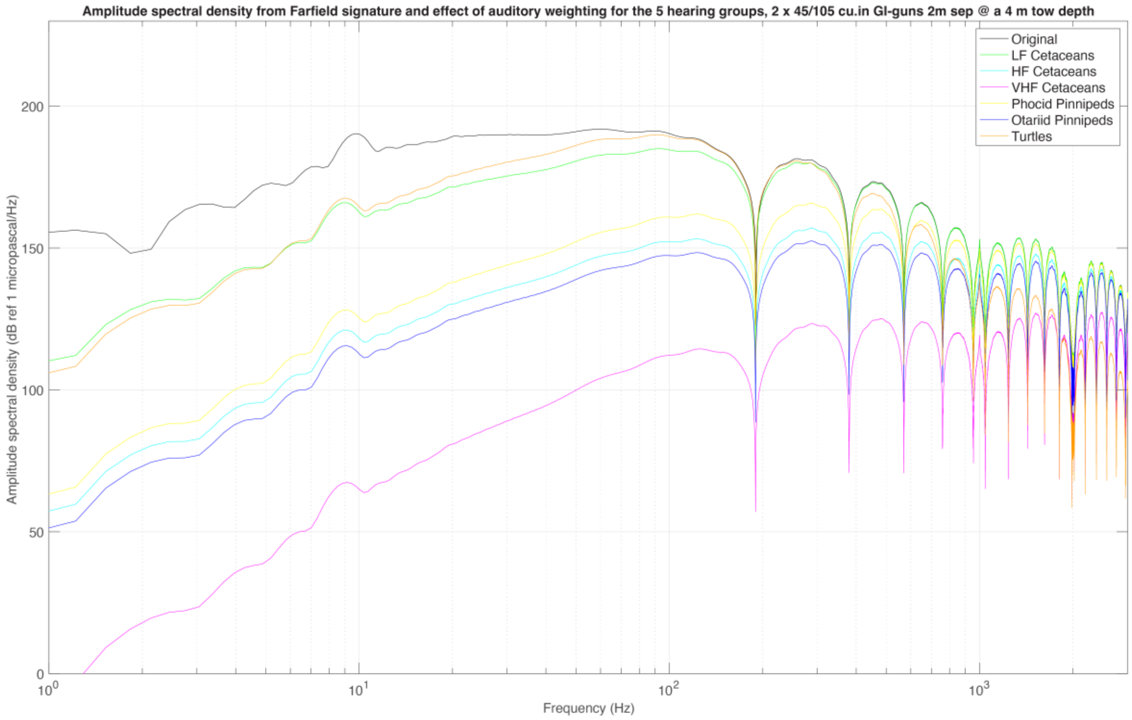

FIGURE B-2. Modeled amplitude spectral density of the two 45-in^3 GI airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting function for the low-frequency (LF) cetaceans, high-frequency (HF) cetaceans, very high-frequency (VHF) cetaceans, phocids, otariids, and sea turtles. Modeled spectral levels in micropascals are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the phocid pinnipeds, otariid pinnipeds, mid-frequency cetaceans, and high-frequency cetaceans as inputs into the NMFS user spreadsheet.

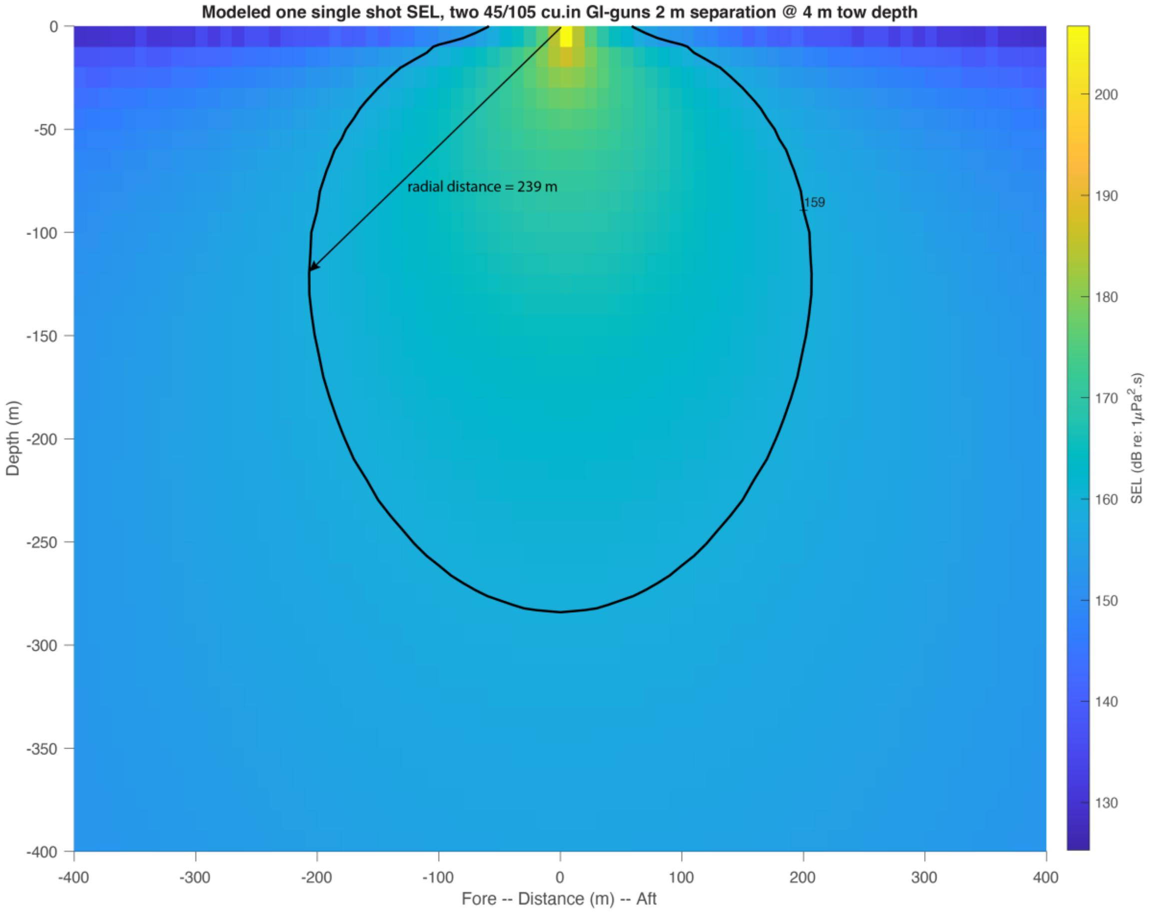

FIGURE B-3. Modeled received sound levels (SELs) in deep water from the two 45 in^3 GI aiguns at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 159-dB SEL isopleth.

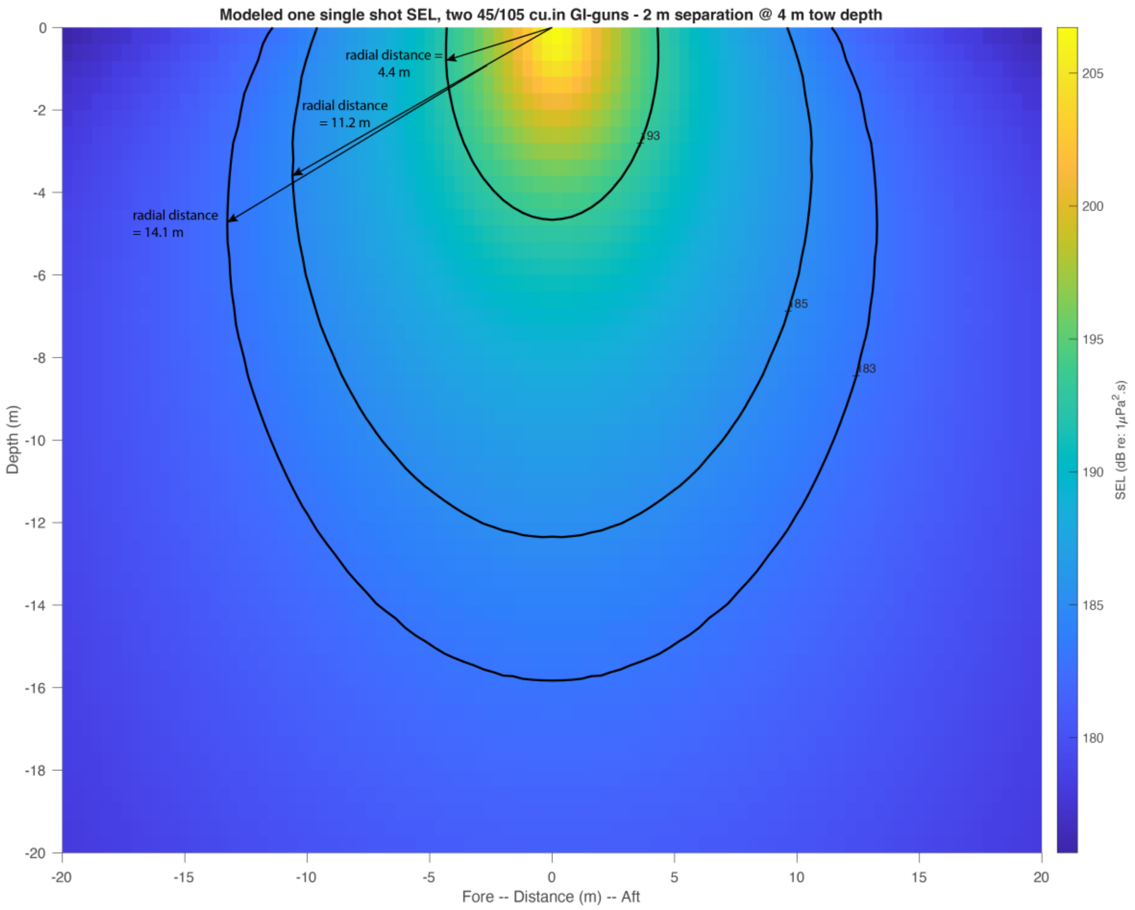

FIGURE B-4. Modeled received sound levels (SELs) in deep water from the two 45 in^3 GI aiguns at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183, 185, and 193 dB isopleths.

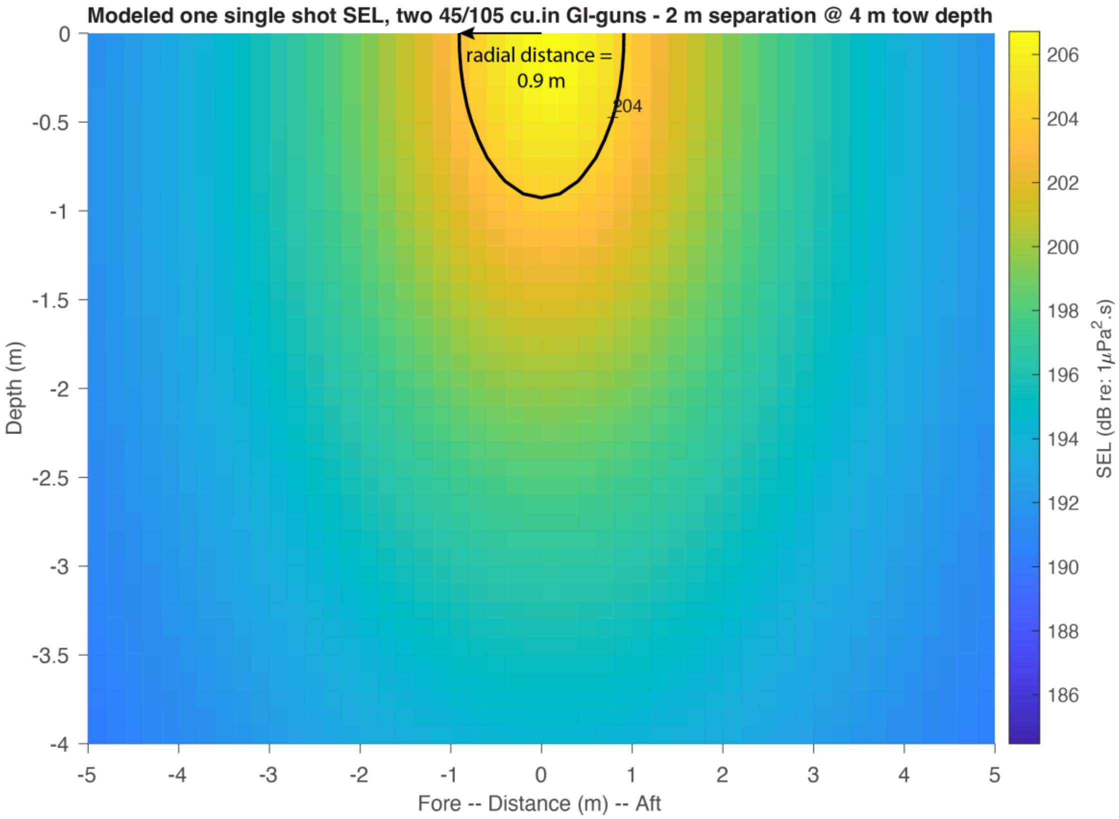

FIGURE B-5 : Modeled received sound levels (SELs) in deep water from the two 45 in^3 GI airguns at a 4-m tow depth. The plot provides the distance from the geometrical center of the source array to the 204 dB SEL isopleth.

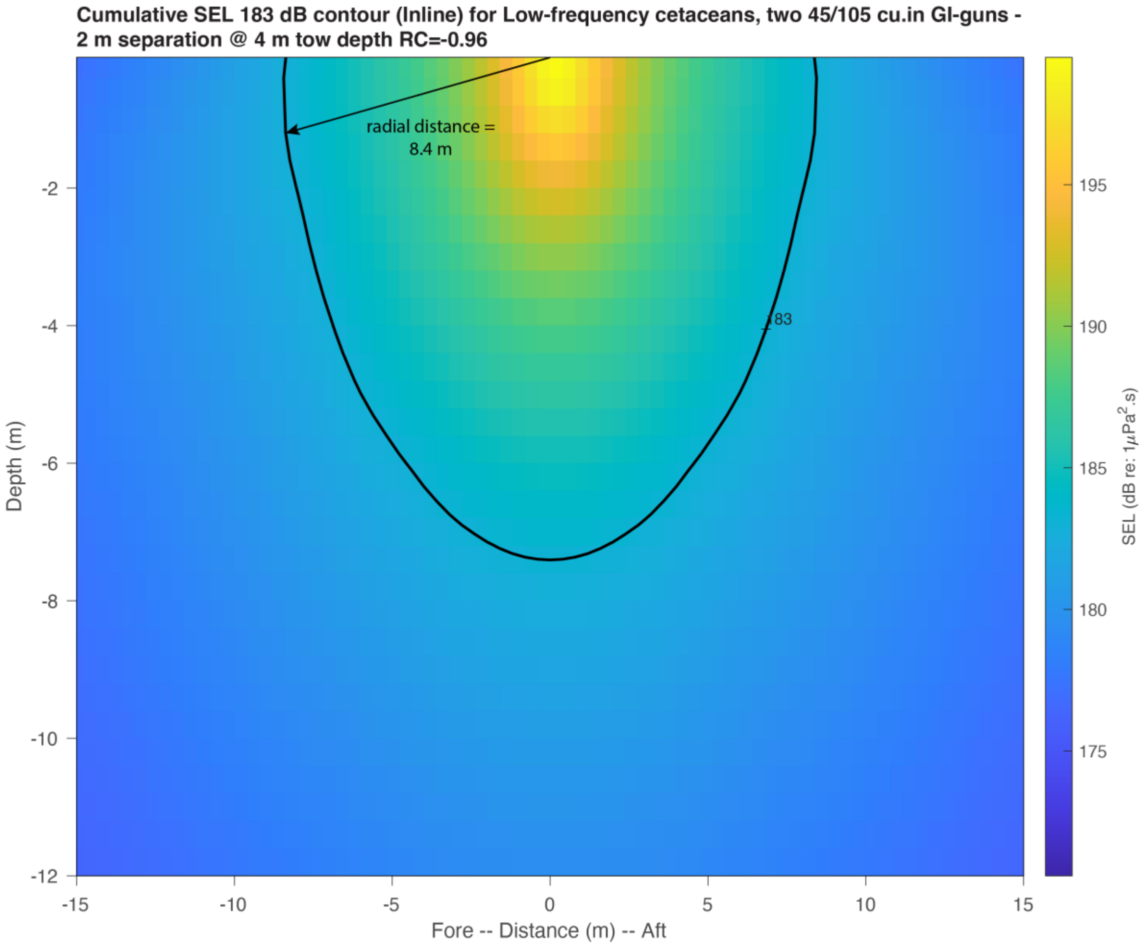

FIGURE B-6: Modeled received sound exposure levels (SELs) from the two 45 in^3 GI-airguns at a 4-m tow depth, after applying the auditory weighting function for the low-frequency cetaceans hearing group following the NMFS technical guidance. The plot provides the radial distance to the 183-dB SEL$_{cum}$ isopleth for one shot. The difference in radial distances between Fig. B-4 (14.1 m) and this figure (8.4 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level

The thresholds for Peak SPL$_{flat}$ for the 2-GI airgun array, as well as the distances to the PTS thresholds, are shown in Table B-3. Figures B-7–B-9 show the modeled received sound levels to the Peak SPL$_{flat}$ thresholds, for a single shot.

TABLE B-3. Level A. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups and sea turtles that could be received from the two 45 in^3 GI airguns (separated by 2 m) at a 4 m tow depth during the proposed seismic surveys.

Hearing Group	Low-Frequency Cetaceans	High-Frequency Cetaceans	Very High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PK Threshold	222	230	202	223	230	232
Radius to threshold (m)	4.0	1.3	37.5	3.5	1.3	0.8

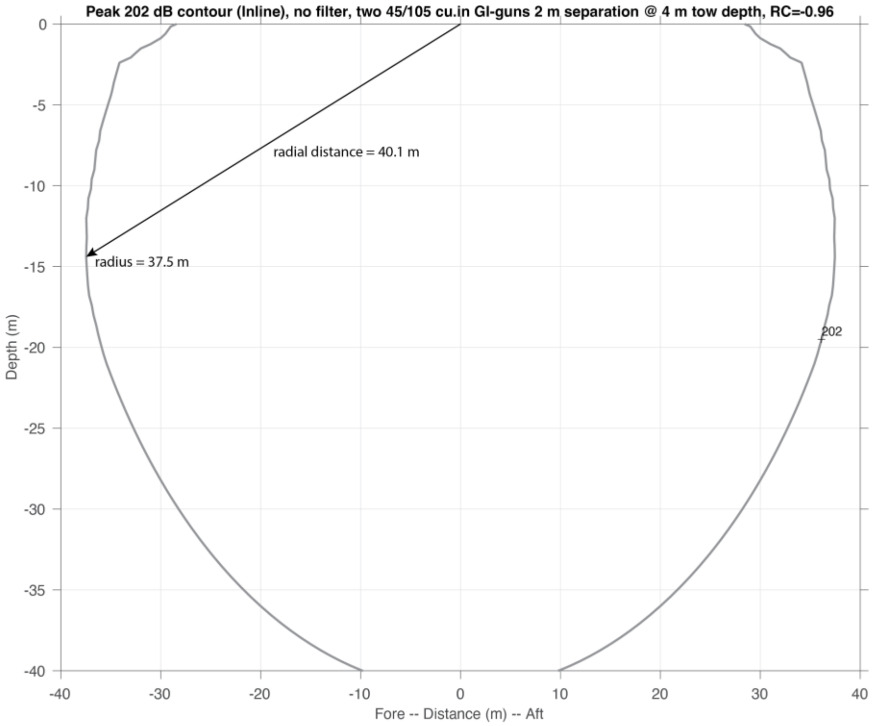

FIGURE B-7: Modeled deep-water received Peak SPL from two 45 in^3 GI airguns at a 4-m tow depth. The plot provides the radius of the 202-dB peak isopleth.

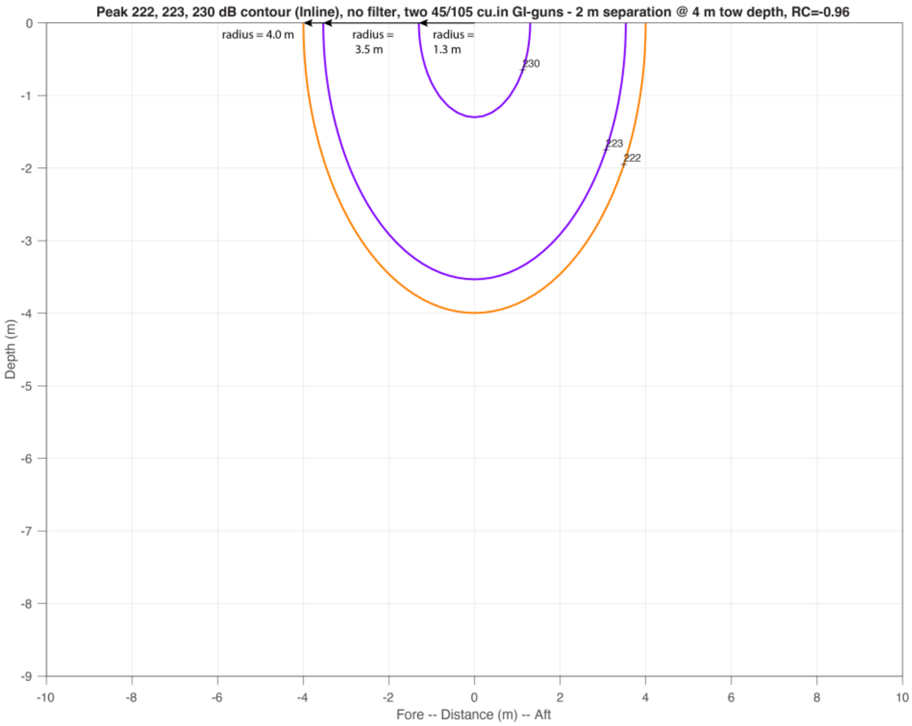

FIGURE B-8: Modeled deep-water received Peak SPL from two 45 in^3 GI airguns at a 4-m tow depth. The plot provides the radii of the 222, 223, and 230 dB peak isopleths.

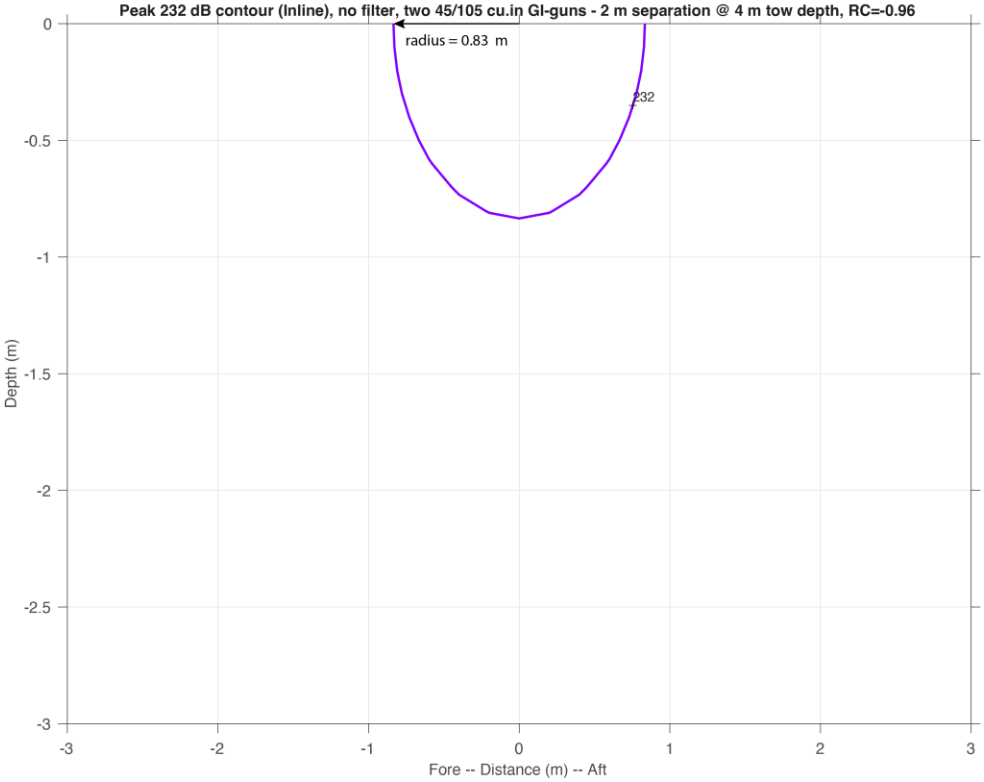

FIGURE B-9: Modeled deep-water received Peak SPL from two 45 in^3 GI airguns at a 4-m tow depth. The plot provides the radius of the 232 dB peak isopleth.

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APPENDIX C: MARINE MAMMAL OCCURRENCE

Mysticetes

North Pacific Right Whale *(Eubalaena japonica)*

North Pacific right whales summer in the northern North Pacific, primarily in the Okhotsk Sea (Brownell et al. 2001) and in the Bering Sea (Shelden et al. 2005; Wade et al. 2006). This species is divided into western and eastern North Pacific stocks. The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011a; Young et al. 2024), and critical habitat has been designated in the eastern Bering Sea and in the Gulf of Alaska, south of Kodiak Island (NOAA 2022). 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 35ºN and occasionally occurred as far south as 20ºN (Kenney 2018). Although right whales were historically reported off the coast of 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 (e.g., Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002a; Wade et al. 2006; Zerbini et al. 2009; Matsuoka et al. 2021); they have also been detected acoustically there (McDonald and Moore 2002; Munger et al. 2003; 2005, 2008; Berchok et al. 2009; Wright et al. 2018, 2019; Matsuoka et al. 2021). 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; Wright et al. 2019).

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 (e.g., Waite et al. 2003; Mellinger et al. 2004; RPS 2011; Wade et al. 2011a,b; Rone et al. 2014, 2017; Matsuoka et al. 2020; Crance et al. 2022). A biologically important area (BIA) for feeding for North Pacific right whales was delineated east of the Kodiak Archipelago, encompassing the Gulf of Alaska critical habitat and adjacent (Wild et al. 2023).

South of 50ºN 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, only seven documented sightings of right whales were made from 1990–2000 (Waite et al. 2003). Sightings were also made off California and B.C. from 2006 to 2023 (Crance and Kennedy 2024). In addition, 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).

Based on the very low abundance of this species, its rarity off the coasts of 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 unlikely that a North Pacific right whale would be encountered in the proposed survey area during the period of operations.

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 the humpback whale population has made a dramatic recovery since the whaling er, the North Pacific population saw a 20% decline from 2012–2021, suggesting it may have reached its carrying capacity (Cheeseman et al. 2024).

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 2016). Individuals from the Hawaii, Mexico, and Central America DPSs could occur in the proposed survey area (Calambokidis et al. 2008; Martien et al. 2021; Martínez-Loustalot et al. 2021; Carretta et al. 2024).

NMFS recently evaluated the North Pacific DPSs with respect to demographically independent populations (DIPs) and "units" that contain one or more DIPs (Martien et al. 2021; Taylor et al. 2021; Wade et al. 2021; Oleson et al. 2022). Based on these DIPs and units, NMFS has designated five stocks including: the Central America/Southern Mexico – California/Oregon/Washington stock (part of the Central America DPS), the Mainland Mexico – California/Oregon/Washington and Mexico-North Pacific stocks (part of the Mexico DPS), the Hawai'i stock, and the Western North Pacific stock (Carretta et al. 2024). Whales in the Central America/Southern Mexico – CA-OR-WA stock winter off the coasts of Nicaragua, Honduras, El Salvador, Guatemala, Panama, Costa Rica, and southern Mexico including the states of Oaxaca and Guerrero, with some animals ranging even farther north (Taylor et al. 2021); they summer off California, Oregon, and Washington (Calambokidis et al. 2017). Whales from the Mainland Mexico – CA-OR-WA stock mainly winter off the Mexican state of Nayarit and Jalisco, with some animals occurring as far south as Colima and Michoacán; this stock summers off California, Oregon, Washington (Martien et al. 2021), as well as southern B.C., Alaska, and the Bering Sea. The Mexico – North Pacific stock winters off Mexico and the Revillagigedo Archipelago, and most individuals summer in Alaska (Martien et al. 2021).

During summer, most eastern North Pacific humpback whales are on feeding grounds in Alaska, with smaller numbers summering off the U.S. West Coast (Calambokidis et al. 2001, 2008). According to Wade (2017), off southern B.C. and Washington, ~63.5%, 27.9%, and 8.7% are from the Hawaii, Mexico, and Central America DPSs, respectively; off Oregon and California, the majority are from the Central America DPS (67.2%), with 32.7% from the Mexico DPS, and none from the Hawaii DPS. Calambokidis et al. (2024) delineated a large (or parent) feeding BIA (F-BIA) for humpback whales that stretches along most of the U.S. West Coast, from Washington and Oregon to southern California; the inner boundary of the parent BIA was defined by the 30-m isobath. The smaller or core F-BIA was delineated in localized coastal areas off Washington, Oregon, and California, with a shoreward boundary at the 70-m isobath. The BIA primarily is located within the 2000-m isobath and occurs from March to November (Calambokidis et al. 2024).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May–November (Green et al. 1992; Calambokidis et al. 2000, 2004; Henry et al. 2020). According to Green et al. (1992) and Calambokidis et al. (2000, 2004), the highest numbers have been reported off Oregon during May and June and off Washington during July–September. Based on data from 2016–2021, Derville et al. (2020) reported that the peak in humpback occurrence on the shelf of Oregon occurs during August. Humpbacks occur primarily over the continental shelf and slope during the summer, with few reported in offshore pelagic waters (Green et al. 1992; Calambokidis et al. 2004, 2015; Becker et al. 2012; Barlow 2016; Derville et al. 2022). Humpbacks were seen east of the survey area in spring, summer, and fall during 2011–2012 (Foster 2021). 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) 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). Eighty-three sightings totaling 210 humpbacks were made during the June–July 2021 L-DEO Cascadia Subduction Zone seismic survey off the coast of the Pacific Northwest (including Washington, Oregon, and southern B.C.) (RPS 2022a), and 11 sightings of 24 animals were made during the April 2022 L-DEO survey off Oregon (RPS 2022b). There were no sightings during the September–October 2017 SIO cruise off Oregon and Washington (SIO n.d.). During long-term (2004–2013) passive acoustic monitoring at three sites on the shelf, slope, and a canyon off northwestern Washington, the highest number of call detections were recorded at the canyon site and lowest at the slope site (Rice et al. 2021). Most detections occurred during fall and winter, but calls were also detected at all sites during August and September (Rice et al. 2021). Similarly, monitoring at acoustic recorders deployed at different locations off Washington during 2008–2013 showed that call rates were highest during fall and winter (Emmons et al. 2020). Humpback whales could be encountered in the proposed survey area at the time of the survey.

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 2º 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 180ºN, 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 the 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; Henry et al. 2020; Carretta et al. 2024). 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 the June–July 2012 L-DEO Juan de Fuca plate seismic survey or during the July 2012 L-DEO seismic survey off Oregon (RPS 2012b,c). One minke whale was seen during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a). No sightings were made during the June–July 2021 L-DEO Cascadia survey (RPS 2022a), the April 2022 L-DEO survey off Oregon (RPS 2022b), or the September–October 2017 SIO survey off Oregon and Washington (SIO n.d.). During long-term passive acoustic monitoring at a shelf, slope, and canyon site off northwestern Washington during 2004–2013, calls were detected only at the canyon site during November 2012 and April 2013 (Rice et al. 2021). Minke whales are expected to be uncommon in the proposed survey area.

Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2018) but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 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 California, Oregon, and Washington (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 1991–2018 (Green et al. 1992, 1993; Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow 2003, 2010, 2014; Forney 2007; Carretta et al. 2024). 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 July 2012 L-DEO seismic surveys off Oregon and Washington (RPS 2012a,c), the June–July 2021 L-DEO Cascadia survey (RPS 2022a), the April 2022 L-DEO survey off Oregon (RPS 2022b), or the September–October 2017 SIO off Oregon and Washington (SIO n.d.). Nonetheless, 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 (Anguilar 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).

Parent F-BIAs for fin whales have been delineated off the coasts of Oregon and Washington and lie primarily between 200 m and 2000 m in depth; parent F-BIAs have also been delineated off California, including deep, offshore waters (Calambokidis et al. 2024). The core F-BIAs are much reduced in area, and include one small area off Oregon and a larger area off California. The eastern boundaries for the parent and core BIAs extend to the 60-m and 80-m isobaths, respectively (Calambokidis et al. 2024). All BIAs span the June to November period (Calambokidis et al. 2004). 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; Henry et al. 2020; Carretta et al. 2024), including in coastal as well as offshore waters. Based on data from 2016–2021, Derville et al. (2020) reported that peak fin whale density off Oregon occurs in December.

They have also been detected acoustically in those waters during June–November (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), but no fin whales were sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). Fin whales were seen off southern Oregon during July 2012 in water >2000 m deep during surveys by Adams et al. (2014). Seventeen sightings (33 animals) were made during the June–July 2021 L-DEO Cascadia survey (RPS 2022a), one sighting (3 animals) was made during the April 2022 L-DEO survey off Oregon (RPS 2022b), and three fin whale sightings (five animals) were made during the September–October 2017 SIO survey off Oregon and Washington (SIO n.d.). During long-term passive acoustic monitoring at three sites (shelf, slope, canyon) off northwestern Washington during 2004–2013, the highest number of call detections were recorded at the canyon site; most detections were made during fall and winter, but calls were detected throughout the year at all three sites (Rice et al. 2021). Fin whales are likely to be encountered in the proposed survey area.

Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: the Eastern North Pacific and Central North Pacific stocks (Carretta et al. 2024). 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). Thus, Calambokidis et al. (2024) delineated a large parent F-BIA for blue whales that extends from the central Oregon coast to southern California from June–November; off Oregon, the BIA is confined to waters less than 2000 m deep. The core BIA occurs off most of California within the 2000-m isobath (Calambokidis et al. 2024). The eastern extent of the parent and core BIAs were defined by the 50-m and 80-m isobath, respectively (Calambokidis et al. 2024).

Buchanan et al. (2001) considered blue whales to be rare off Oregon and Washington. However, 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). Based on data from 2016–2021, Derville et al. (2020) reported that the peak in blue whale occurrence on the shelf of Oregon occurs during August. 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). Satellite-tracked individuals have been reported off Washington and Oregon (Bailey et al. 2009), and acoustic detections have been made off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999). One sighting (four animals) was made during the June–July 2021 L-DEO Cascadia survey (RPS 2022a), but no sightings were made during the April 2022 L-DEO survey off Oregon (RPS 2022b), or the September–October 2017 SIO survey off Oregon and Washington (SIO n.d.). Long-term passive acoustic monitoring of three shelf, slope, and canyon sites off Washington found the highest number of call detections on the slope and the lowest at the canyon site (Rice et al. 2021). Call rates were highest during fall and winter, but vocalizations were detected at all sites throughout the year (Rice et al. 2021). Blue whales could be encountered in the proposed survey area.

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 <40º where sea surface temperatures are <15ºC; 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). Carretta et al. (2024) also reported numerous sperm whale sightings off Oregon and Washington during shipboard surveys.

Sperm whales were detected acoustically in waters off Oregon and Washington in August 2016 during the Southwest Fisheries Service (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). During long-term passive acoustic monitoring of three sites on the shelf, slope, and at a canyon off Washington during 2004–2013, sperm whale clicks were detected year-round with the highest number of call detections at the slope site (Rice et al. 2021). Similarly, monitoring at acoustic recorders deployed at different locations off Washington during 2008–2013 showed clicks were detected year-round (Emmons et al. 2020). Humpback whales could be encountered in the proposed survey area at the time of the survey. Sperm whales are likely to be encountered in the proposed survey area.

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. 2024). Norman et al. (2004) reported eight confirmed stranding records of pygmy sperm whales for Oregon and Washington between 1930 and 2002. Warlick et al. (2022) reported three strandings of pygmy sperm whales in each of Oregon and Washington from 2000 to 2019. *Kogia* sp. were likely detected at drifting acoustic spar buoys recorders (DASPRs) along the 2000-isobath off southern Oregon and also possibly just south of the proposed survey area, during summer 2016 (Griffiths et al. 2020). Pygmy or dwarf sperm whales could be encountered within the proposed project area.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 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).

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). Warlick et al. (2022) reported another stranding in Washington in 2013. MacLeod et al. (2006) and Carretta et al. (2024) reported numerous sightings and strandings along the Pacific coast of the U.S. Four 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). Sightings were also made off Oregon and Washington in 2018 during a SWFSC California Current Ecosystem Survey (Henry et al. 2020).

Acoustic monitoring in Washington offshore waters detected Cuvier's beaked whale calls between January and November 2011 (Ŝirović et al. 2012b *in* DON 2015). Cuvier's beaked whales were also detected acoustically in the deeper waters off the U.S. West Coast during August–September 2016 using drifting acoustic recorders, with highest densities recorded off California and the lowest off Washington (Keating et al. 2018; Barlow et al. 2021). A drifting acoustic recorder detected this species off Oregon during July–October 2018 during a passive acoustic survey of deep-diving odontocetes in the California Current ecosystem (Simonis et al. 2020). During long-term passive acoustic monitoring of three sites on the shelf, slope, and at a canyon off Washington during 2004–2013, clicks were detected at the canyon site from November through June, but were most common during winter (Rice et al. 2021). Based on the acoustic detections, Barlow et al. (2021) estimated a density of 0.005 animals/km^2 and a population size of 5454 Cuvier's beaked whales within the Pacific U.S. EEZ. Cuvier's beaked whales could be encountered during the proposed survey.

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30°N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). Two forms of Baird's beaked whales have been recognized – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, in the Aleutians, and on the West Coast of North America, whereas the black from 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. 2024) 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. Warlick et al. (2022) reported five strandings of Baird's beaked whale from 2000 to 2019, including two for Oregon and three for Washington.

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 (Ŝirović et al. 2012b *in* DON 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). This species was also detected by a drifting acoustic recorder off Oregon during July–October 2018 during a passive acoustic survey of deep-diving odontocetes in the California Current ecosystem (Simonis et al. 2020). Baird's beaked whales could be encountered in the proposed survey area.

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 whales stranded near Neah Bay, WA, in 2016 (Moore and Barlow 2017; Warlick et al. 2022).

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 survey, an encounter would be unlikely because the proposed survey area is 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 U.S. West Coast (MacLeod et al. 2006). Most are from California in the 1980s and 1990s, but two strandings for Washington/Oregon were reported by Norman et al. (2004), and one stranding occurred in Washington in 2010 (Moore and Barlow 2017; Warlick et al. 2022).

In addition, at least two sightings off Oregon, but outside the U.S. EEZ, were reported by Carretta et al. (2024). During August 2016, detections of beaked whale sounds presumed to be from Hubbs' beaked whales were made off Washington and Oregon (Keating et al. 2018; Griffiths et al. 2019). During long-term passive acoustic monitoring of three sites on the shelf, slope, and at a canyon off Washington during 2004–2013, likely Hubb's beaked whale clicks were detected at the canyon site from December through spring (Rice et al. 2021). A single sighting of two individuals was made west of the proposed survey area, ~350 km off the Columbia River mouth, in September 2021 (Ballance et al. 2024). This species seems to be less common in the proposed survey area than some of the other beaked whales, but it could be encountered during the survey.

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 between 1930 and 2002 (Norman et al. 2004). Warlick et al. (2022) reported three strandings of Stejneger's beaked whale in each of Oregon and Washington from 2000 to 2019.

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 (Ŝirović et al. 2012b *in* DON 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). A drifting acoustic recorder also detected this species off Oregon during July–October 2018 during a passive acoustic survey of deep-diving odontocetes in the California Current ecosystem (Simonis et al. 2020). During long-term passive acoustic monitoring of three sites on the shelf, slope, and at a canyon off Washington during 2004–2013, clicks were detected at the canyon site from October through June, with the highest detection rates during winter; there were no detections from July to September (Rice et al. 2021). Stejneger's beaked whales could be encountered during the proposed survey.

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; although sightings have been made as far north as 41ºN, there are no offshore records for Oregon and Washington (Carretta et al. 2024). Three sightings and one stranding of bottlenose dolphins have been documented in Puget Sound since 2004 (Cascadia Research 2011 *in* DON 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. 2024). 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 area.

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, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). The striped dolphin is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also 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 the NOAA Fisheries vessel surveys (Carretta et al. 2024). However, few sightings have been made off Oregon, and no sightings have been reported for Washington; strandings have also been documented on the West Coast (Carretta et al. 2024). During surveys off the U.S. West Coast in 2014, striped dolphins were seen as far north as 44ºN; 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.

Common Dolphin (*Delphinus delphis*)

The common dolphin is found in oceanic and nearshore waters of tropical and warm temperate oceans around the world, ranging from ~60ºN to ~50ºS (Jefferson et al. 2015). Based on Perrin (2018), here we assume that there are currently three recognized subspecies of common dolphin, including *D. delphis delphis* (the short-beaked form), *D. delphis bairdii* (the long-beaked form, formerly known as *D. capensis*), and *D. delphis tropicalis* (Indian Ocean subspecies). The common dolphin 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).

The distribution of the short-beaked form of 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, but there are no sightings off Washington (Carretta et al. 2024). 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, the short-beaked form 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). Only the short-beaked form of the common dolphin could be encountered in the proposed survey area (see Carretta et al. 2024).

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. Numerous sightings were made offshore of Oregon and Washington in 2018 during a SWFSC California Current Ecosystem Survey (Henry et al. 2020). Based on surveys conducted during 2014, the abundance was estimated at 20,711 for Oregon/Washington (Barlow 2016). During long-term passive acoustic monitoring of three sites on the shelf, slope, and at a canyon off Washington during 2004–2013, the highest number of call detections was made at the slope site and the lowest at the shelf site; clicks were detected from summer to early winter (Rice et al. 2021).

One group of 10 Pacific white-sided dolphins was sighted during the 2009 ETOMO survey west of the proposed survey area (Holst 2017). 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). However, this species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). One sighting (eight animals) was made during the September–October 2017 SIO survey off Oregon and Washington (SIO n.d.), and 19 sightings (224 animals) were made during the June–July 2021 L-DEO Cascadia survey (RPS 2022a). No sightings were made during the 2017 SIO survey off Oregon (SIO n.d.) or the April 2022 L-DEO survey off Oregon (RPS 2022b). Pacific white-sided dolphins are likely to be common in the proposed survey area.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

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

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 off Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014). Sightings were also recorded offshore of Oregon and Washington in 2018 during a SWFSC California Current Ecosystem Survey (Henry et al. 2020). There were three multiple-species sightings involving this species during the June–July 2021 L-DEO Cascadia survey (RPS 2022a), but no sightings during the 2017 SIO survey off Oregon (SIO n.d.), or the April 2022 L-DEO survey off Oregon (RPS 2022b). Northern right whale dolphins are likely to be encountered in the proposed survey area.

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999). although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018). 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 47ºN. Based on 2014 survey data, the abundance for Oregon/Washington was estimated at 430 (Barlow 2016). During long-term passive acoustic monitoring of three sites on the shelf, slope, and at a canyon off Washington during 2004–2013, the highest number of click detections was recorded at the canyon site during summer and early fall (Rice et al. 2021). Risso's dolphins could be encountered in the proposed survey area.

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but 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 (DON 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 survey.

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 (Carretta et al. 2024). Individuals from the ***endangered*** Southern Resident stock are unlikely to be encountered in the proposed survey area, as they mostly occur in coastal waters. However, individuals from the West Coast Transient or Offshore stocks could be encountered in the proposed project area.

Resident killer whales mainly feed on salmon, in particular Chinook, and their movements coincide with those of their prey (Ford 2014). During the spring, summer, and fall, 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; Olson et al. 2018; Carretta et al. 2024). High-use areas along the coast of Washington have also been reported (Hanson et al. 2017, 2018). Southern resident killer whales occur along the outer coasts of B.C. and Washington throughout the year, but individuals have been reported as far south as California and as far north as Alaska (Hanson et al. 2017, 2018; Carretta et al. 2024). Southern resident whales appear to spend the majority of their time on the continental shelf, within 34 km from the coast, in water <100 m deep (Hanson et al. 2017). K/L pods primarily occur on the Washington coast, from Grays Harbor to the Columbia River; high use areas for J pod primarily occur at the western entrance of the Strait of Juan de Fuca and northern Strait of Georgia (Hanson et al. 2017). This small population of 73 individuals (see Carretta et al. 2024) is threatened by reduced prey availability, contaminants, and vessel disturbance including noise (e.g., Lacy et al. 2017; Murray et al. 2019). Calambokidis et al. (2024) delineated a larger year-round small and resident (S)-BIA (parent) for southern resident killer whales that overlaps the critical habitat along the entire U.S. West Coast and also includes the critical habitat in Canadian water; the core S-BIA occurs along the entire western coast of Washington and northern Oregon.

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 (Young et al. 2024). The seasonal movements of transients are largely unpredictable. 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 off Washington and Oregon in the summer, and sightings in the Strait of Juan de Fuca during spring. 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 whale calls were detected at acoustic recorders deployed off Washington during 2008–2013 year-round (Emmons et al. 2020). Humpback whales could be encountered in the proposed survey area at the time of the survey.

Killer whales were sighted off Washington in July and September 2012 (Adams et al. 2014). One satellite-tagged individual was tracked while traversing the survey area and four others were tracked to the east during March 2013 (Schorr et al. 2022). Sightings were also made off Oregon and Washington in 2018 during a SWFSC California Current Ecosystem Survey (Henry et al. 2020). Killer whales were sighted off Oregon off the continental shelf in July 2015, August 2018, and September 2021 (McInnes et al. 2024). One multiple-species sighting involving this species was made during the June–July 2021 L-DEO Cascadia survey (RPS 2022a), but no sightings were made during the April 2022 L-DEO survey off Oregon (RPS 2022b). There was one sighting (10 animals) during the September–October 2017 SIO survey off Oregon and Washington (SIO n.d.). Killer whales could be encountered during the proposed surveys.

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 ~40ºS and as far north as ~50ºN (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. 2024). 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. (2024) 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) and in 2007 (Warlick et al. 2022). Pilot whales are expected to be rare in the proposed survey area.

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found in temperate to subarctic waters of the North Pacific and adjacent seas (Jefferson et al. 2015). It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979). It is probably the most abundant small cetacean in the North Pacific Ocean, and its abundance changes seasonally, likely in relation to water temperature (Becker 2007).

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. 2024). 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 form 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) and in offshore waters off Oregon and Washington in 2018 (Henry et al. 2020).

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). One sighting (four animals) was made during the June–July 2021 L-DEO Cascadia survey (RPS 2022a), but no sightings were made during the 2017 SIO survey off Oregon (SIO n.d.) or the April 2022 L-DEO survey off Oregon (RPS 2022b). Dall's porpoise were likely detected at DASPRs along the 2000-isobath off southern Oregon and also possibly just south of the proposed survey area, during summer 2016 (Griffiths et al. 2020). Dall's porpoise is likely to be encountered during the proposed seismic survey.

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; Aurioles-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. 2024). 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* DON 2019; Carretta et al. 2024). 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* DON 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* DON 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* DON 2019). In 2015–2016, 175 Guadalupe fur seals stranded on the coast of California; NMFS declared this an unusual mortality event (Carretta et al. 2024). Guadalupe fur seals could be encountered during the proposed seismic surveys off the coasts of Washington and Oregon.

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 (Young et al. 2024). 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; Young et al. 2024). 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 (Young et al. 2024). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Young et al. 2024). The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to California during winter (Young et al. 2024).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Young et al. 2024). 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 (Young et al. 2024). 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 Vancouver Island and in the western Gulf of Alaska (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 proposed project area (Pelland et al. 2014). Tracked adult male fur seals that were tagged on St. Paul Island in the Bering Sea in October 2009, wintered in the Bering Sea or northern North Pacific Ocean; females migrated to the Gulf of Alaska and the California Current, including off the west coasts of Haida Gwaii and Vancouver Island (Sterling et al. 2014). Some individuals reach California by December, after which time numbers increase off the west coast of North America (Ford 2014). The peak density shift over the course of the winter and spring, with peak densities occurring in California in February, April off Oregon and Washington, and May off B.C. and Southeast Alaska (Ford 2014). The use of continental shelf and slope waters of B.C. and the northwestern U.S. by adult females during winter is well documented from pelagic sealing data (Bigg 1990).

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). Three northern fur seals were seen during the 2021 L-DEO Cascadia survey (RPS 2022a), and five were seen during the April 2022 L-DEO survey off Oregon (RPS 2022b). Northern fur seals could be observed in the proposed survey area, in particular females and juveniles. However, adult males are generally ashore during the reproductive season from May–August, and 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. Hindell (2009) noted that traveling likely takes place at depths >200 m. 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 45ºN (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 also pass 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). Pupping 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). Thus, this species could be encountered during the proposed seismic survey.

Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion occurs along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). There are two stocks, or DPSs, of Steller sea lions – the Western and Eastern DPSs, which are divided at 144°W longitude (Young et al. 2024). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (Young et al. 2024); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Only individuals from the Eastern DPS could occur in the proposed survey area.

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; Young et al. 2024). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008a).

Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008a). 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 2008a). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008a). 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). Twelve sightings totaling 17 Steller sea lions were made during the 2021 L-DEO Cascadia survey, all in water <2000 m deep (RPS 2022a). This species is unlikely to be encountered in the far offshore survey area.

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. 2024). 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. This species could be encountered in very small numbers in the offshore survey area. Four sightings of nine California sea lions were made during the 2021 L-DEO Cascadia survey; however, all sightings occurred in coastal waters (RPS 2022a).

APPENDIX D: METHODS FOR MARINE MAMMAL DENSITIES AND TAKE CALCULATIONS

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, 2014, and 2018 and synthesized by Becker et al. (2020). These surveys were conducted up to ~556 km from shore typically from July to November, but included the months of June and December in 2018 (Becker et al. 2020). These data were used by SWFSC to develop spatial models of cetacean densities for the California Current Ecosystem (CCE). Although Becker et al. (2020) did not include updated densities for sperm or small beaked whales, these models were provided by Elizabeth Becker via pers. comm. in January 2025. The density models for cetaceans in the CCE were available in the form grid cells in GIS layers; the densities in the grid cells that overlap the proposed survey area were averaged to calculate densities for each species. For species for which densities were not available from Becker et al. (2020), we used annual densities from the U.S. Navy Northwest Training and Testing Study area (DON 2019) to calculate takes for sei whale, offshore killer whale, short-finned pilot whale, *Kogia* spp., California sea lion, and leatherback sea turtle (DON 2019). For pinnipeds other than California sea lions, we used the highest densities for spring, summer, or fall from DON (2019), but corrected the estimates by projecting the most recent population growth/updated population estimates, when available. For Cuvier's beaked whale, we used densities from Barlow et al. (2021). The densities were multiplied by the daily ensonified area (221 km^2) and the number of survey days (2), and increased by 25%, to estimate Level B takes (Table C-1).

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TABLE D-1. Take estimates for the proposed survey area at the Cascadia Subduction Zone.

Species	Density (#/km^2)	Regional Population Size	Hearing Group	Daily Ensonified Area (km^2)	Number of Seismic Days	25% Increase	Estimated Level B Takes[1]	% of Pop. (Requested Takes)[2]	Requested Level B Take Authorization[3]
LF Cetaceans									
North Pacific right whale	0	*400*	*LF*	*221*	*2*	*1.25*	*0*	*0*	*0*
Humpback whale[4]	*0.000480*	*4,973*	*LF*	*221*	*2*	*1.25*	*0*	*0.04*	***2***
Blue whale	*0.000025*	*1,898*	*LF*	*221*	*2*	*1.25*	*0*	*0.11*	***2***
Fin whale	*0.004482*	*11,065*	*LF*	*221*	*2*	*1.25*	*2*	*0.02*	*2*
Sei whale	*0.000400*	*864*	*LF*	*221*	*2*	*1.25*	*0*	*0.23*	***2***
Minke whale	0.000869	915	LF	221	2	1.25	0	0.11	**1**
HF Cetaceans									
Sperm whale	*0.002731*	*2,606*	*HF*	*221*	*2*	*1.25*	*2*	*0.27*	***7***
Cuvier's beaked whale	0.005120	5,454	HF	221	2	1.25	3	0.05	3
Baird's beaked whale	0.000051	1,363	HF	221	2	1.25	0	0.51	**7**
Small beaked whale[5]	0.002320	3,044	HF	221	2	1.25	1	N.A.	**N.A.**
Blaineville's beaked whale	N.A.	3,044	HF	221	2	1.25	N.A.	0.07	**2**
Hubbs' beaked whale	N.A.	3,044	HF	221	2	1.25	N.A.	0.07	**2**
Stejneger's beaked whale	N.A.	3,044	HF	221	2	1.25	N.A.	0.07	**2**
Bottlenose dolphin	0.000002	3,477	HF	221	2	1.25	0	0.40	**14**
Striped dolphin	0.000057	29,988	HF	221	2	1.25	0	0.13	**39**
Short-beaked common dolphin	0.001305	1,056,308	HF	221	2	1.25	1	0.01	**156**
Pacific white-sided dolphin	0.069054	34,999	HF	221	2	1.25	38	0.16	**55**
Northern right-whale dolphin	0.116618	29,285	HF	221	2	1.25	64	0.22	64
Risso's dolphin	0.014357	6,336	HF	221	2	1.25	8	0.30	**19**
False killer whale	N.A.	N.A.	HF	221	2	1.25	N.A.	N.A.	**5**
Killer whale	0.000920	300	HF	221	2	1.25	1	2.33	**7**
Short-finned pilot whale	0.000250	836	HF	221	2	1.25	0	3.47	**29**
VHF Cetaceans									
Pygmy/dwarf sperm whale[6]	0.001630	4,111	VHF	221	2	1.25	1	N.A.	**N.A.**
Pgymy sperm whale	N.A.	4,111	VHF	221	2	1.25	N.A.	0.02	**1**
Dwarf sperm whale	N.A.	4,111	VHF	221	2	1.25	N.A.	0.02	**1**
Dall's porpoise	0.047357	16,498	VHF	221	2	1.25	26	0.16	26
Otariid Pinnipeds									
Northern fur seal	0.033027	626,618	OT	221	2	1.25	18	<0.01	18
Guadalupe fur seal	*0.033027*	*34,187*	OT	*221*	*2*	*1.25*	*18*	*0.05*	*18*
California sea lion	0.071400	257,606	OT	221	2	1.25	39	0.02	39
Steller sea lion	0.002771	36,308	OT	221	2	1.25	2	<0.01	2
Phocid Pinniped									
Northern elephant seal	0.041794	187,386	PW	221	2	1.25	23	0.01	23
Sea Turtle									
Leatherback Turtle[7]	0.000114	*N.A.*	*ST*	*39*	*6*	*1.25*	*0*	*N.A.*	***1***

Note: ESA-listed species are in italics. N.A. means not available. [1]Level B takes for marine mammals are based on the 160-dB criterion. [2]Requested take authorization is expressed as % of population (see Table 3). [3]Requested take authorization is based on calculated takes. Takes in bold have been increased to mean group size based on Becker et al. (2020), except for sei, killer, pygmy sperm, dwarf sperm, and short-finned pilot whales for which mean group size is from Barlow (2016), and for false killer whale which is from Mobley et al. (2000). [4]One take each is assumed for the ESA-listed Central America and Mexico DPSs. [5]Minimum group sizes are being requested as takes for each *Mesoplodon* sp. that could occur in the survey area. [6]Assigned mean group size to each species of *Kogia*. [7]Take was rounded up to 1.