Draft Environmental Analysis of Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Eastern Tropical Pacific

Prepared for

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ABSTRACT

Researchers from the University of California, San Diego (UCSD), and Woods Hole Oceanographic Institution (WHOI) with funding from the U.S. National Science Foundation (NSF), and in collaboration with the Institut de Physique du Globe de Paris (IPGP), propose to conduct marine geophysical research in Eastern Tropical Pacific or ETP (Proposed Action). The research would include high-energy seismic surveys using an 18-airgun array, with a total discharge volume of approximately (~) 3300 in^3 conducted from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*), which is owned and operated by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University. The project would acquire three-dimensional (3-D) multi-channel seismic (MCS) reflection data in International Waters 2500 to 3200 m deep.

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 geophysical research 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 acquired seismic data would be used to address the evolution of fast-spreading mid-ocean ridge magmatic systems at the East Pacific Rise (EPR) in the ETP.

This Draft Environmental Analysis (EA) addresses NSF's requirements under Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", for the proposed federal action in International Waters. L-DEO, on behalf of itself, NSF, UCSD, and WHOI, 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 marine invertebrates that are listed under the U.S. Endangered Species Act (ESA).

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 could occur in the proposed study area in the ETP. Under the U.S. ESA, several of these species are listed as ***endangered***, including the sei, fin, blue, and sperm whale, and the Central America Distinct Population Segment (DPS) of the humpback whale. The ***threatened*** Mexico DPS of the humpback whale could potentially also occur in the proposed study area. ESA-listed sea turtle species that could occur in the study area include the ***endangered*** leatherback turtle, hawksbill turtle, North Pacific Ocean DPS of loggerhead turtle, and Mexico's Pacific coast breeding population of olive ridley turtle, and the ***threatened*** East Pacific DPS of green turtle. ESA-listed fish that could occur in the area include the ***endangered*** Eastern Pacific DPS of scalloped hammerhead shark and the ***threatened*** oceanic whitetip shark and giant manta ray. ESA-listed seabirds that could be encountered in the area include the ***threatened*** Galápagos petrel.

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) and sub-bottom profiler (SBP) 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 airgun arrays or the other types of sound sources to be used. However, a precautionary approach would be taken, and the planned monitoring and mitigation measures would reduce the possibility of any 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 before and during ramp ups during the day; passive acoustic monitoring (PAM) via towed hydrophones during both day and night to complement visual monitoring during the high-energy surveys; 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. L-DEO 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.

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, seabirds, fish, the populations to which they belong, or their habitats. NSF followed the National Oceanic and Atmospheric Administration's (NOAA) *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2024) to estimate Level A takes for marine mammal species, although Level A takes are very unlikely. No significant impacts would be expected on the populations of those species for which a Level A take is permitted.

LIST OF ACRONYMS

~	approximately
3-D	three-dimensional
4-D	four-dimensional
ADCP	Acoustic Doppler Current Profiler
AEP	Auditory Evoked Potential
AIDCP	Agreement on the International Dolphin Conservation Program
AMVER	Automated Mutual-Assistance Vessel Rescue
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CRD	Costa Rica Dome
dB	decibel
DFO	Canadian Department of Fisheries and Oceans
DoN	Department of the Navy
DPS	Distinct Population Segment
EA	Environmental Analysis
EBSA	Ecologically or Biologically Significant Marine Areas
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EO	Executive Order
EPR	East Pacific Rise
ESA	(U.S.) Endangered Species Act
ETP	Eastern Tropical Pacific
EZ	Exclusion Zone
FAO	Food Agricultural Organization
FM	Frequency Modulated
FONSI	Finding of No Significant Impact
GIS	Geographic Information System
h	hour
HAPC	Habitat Area of Particular Concern
hp	horsepower
Hz	Hertz
IATTC	Inter-American Tropical Tuna Commission
IBA	Important Bird Area
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
IPGP	Institut de Physique du Globe de Paris
ITCZ	Intertropical Convergence Zone
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
LFA	Low-frequency Active (sonar)
m	meter
MBES	Multibeam Echosounder
MCS	Multi-Channel Seismic
MFA	Mid-frequency Active (sonar)
min	minute
MMC	Marine Mammal Commission
MMPA	(U.S.) Marine Mammal Protection Act
MPA	Marine Protected Area

ms	millisecond
M/SI	mortality and serious injuries
NMFS	(U.S.) National Marine Fisheries Service
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NRC	(U.S.) National Research Council
NSF	National Science Foundation
OEIS	Overseas Environmental Impact Statement
p or pk	peak
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PSO	Protected Species Observer
PTS	Permanent Threshold Shift
rms	root-mean-square
ROD	Record of Decision
R/V	research vessel
s	second
SBP	Sub-bottom Profiler
SEA	Supplemental Environment Assessment
SEL	Sound Exposure Level (a measure of acoustic energy)
SOSUS	(U.S. Navy) Sound Surveillance System
SPL	Sound Pressure Level
SWFSC	Southwest Fisheries Science Center
SWOT	State of the World’s Sea Turtles
t	tonnes
TTS	Temporary Threshold Shift
UCSD	University of California, San Diego
U.K.	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
U.S.	United States of America
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
µPa	microPascal
vs.	versus
WCMC	World Conservation Monitoring Centre
WHOI	Woods Hole Oceanographic Institution

I PURPOSE AND NEED

Researchers from the University of California, San Diego (UCSD), and Woods Hole Oceanographic Institution (WHOI) with funding from the U.S. National Science Foundation (NSF), and in collaboration with the Institut de Physique du Globe de Paris (IPGP), propose to conduct marine geophysical research in Eastern Tropical Pacific or ETP (Proposed Action). The research would include high-energy seismic surveys using an 18-airgun array conducted from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*), which is owned and operated by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University. The project would acquire three-dimensional (3-D) multi-channel seismic (MCS) reflection data in the ETP.

This Draft Environmental Analysis (EA) was prepared pursuant to Executive Order 12114, “Environmental Effects Abroad of Major Federal Actions”. 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. It also builds upon the “*Environmental Assessment of two Marine Geophysical Surveys by R/V Marcus G. Langseth in the Eastern Tropical Pacific*“ (LGL Limited 2007) which resulted in a Finding of No Significant Impact (FONSI) for similar seismic surveys conducted in the area during summer 2008. 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 an airgun array 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. Following the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2024), Level A takes will be requested for the remote possibility of low-level physiological effects; however, 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.

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 purpose of the proposed marine geophysical research is to address

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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.

the evolution of fast-spreading mid-ocean ridge magmatic systems at the East Pacific Rise (EPR) in the ETP. The Proposed Action would meet the agency's critical need to foster an understanding of Earth processes.

1.3 Background of NSF-supported 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

- Executive Order 12114 – *Environmental effects abroad of major Federal actions*;
- *Marine Mammal Protection Act* (MMPA) of 1972 (16 USC 1631 *et seq*.); and
- *Endangered Species Act* (ESA) of 1973 (16 USC ch. 35 §1531 *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

The Principal Investigators (PI) from UCSD and WHOI, in collaboration with the IPGP, propose to conduct marine geophysical research in the ETP using the seismic surveying capability of R/V *Langseth* (Fig. 1). The main goal of the high-energy seismic program proposed by PIs Drs. R. Parnell-Turner (UCSD) and J.P. Canales (WHOI), with international collaboration from Dr. M. Marjanović (IPGP and UCSD), is to collect seismic reflection data of volcanic cycles and to examine the active magmatic system at the EPR.

In order to study volcanic cycles on decadal timescales, the proposed project would consist of 3-D MCS surveys at the 9°50'N segment of the EPR, thereby repeating the same experiment conducted in 2008 on board R/V *Langseth*. The two datasets would be processed together using the latest elastic full waveform inversion techniques, in order to obtain high-resolution imagery that would be used to investigate how the magmatic and hydrothermal plumbing systems beneath this submarine volcanic ridge have changed since 2008, thereby allowing for a unique four-dimensional (4-D) time-lapse study. The time-lapse imagery would allow the PIs to test long-debated hypotheses about the eruption cycle for the first time, by distinguishing characteristic changes in the shape and melt content of the magmatic system.

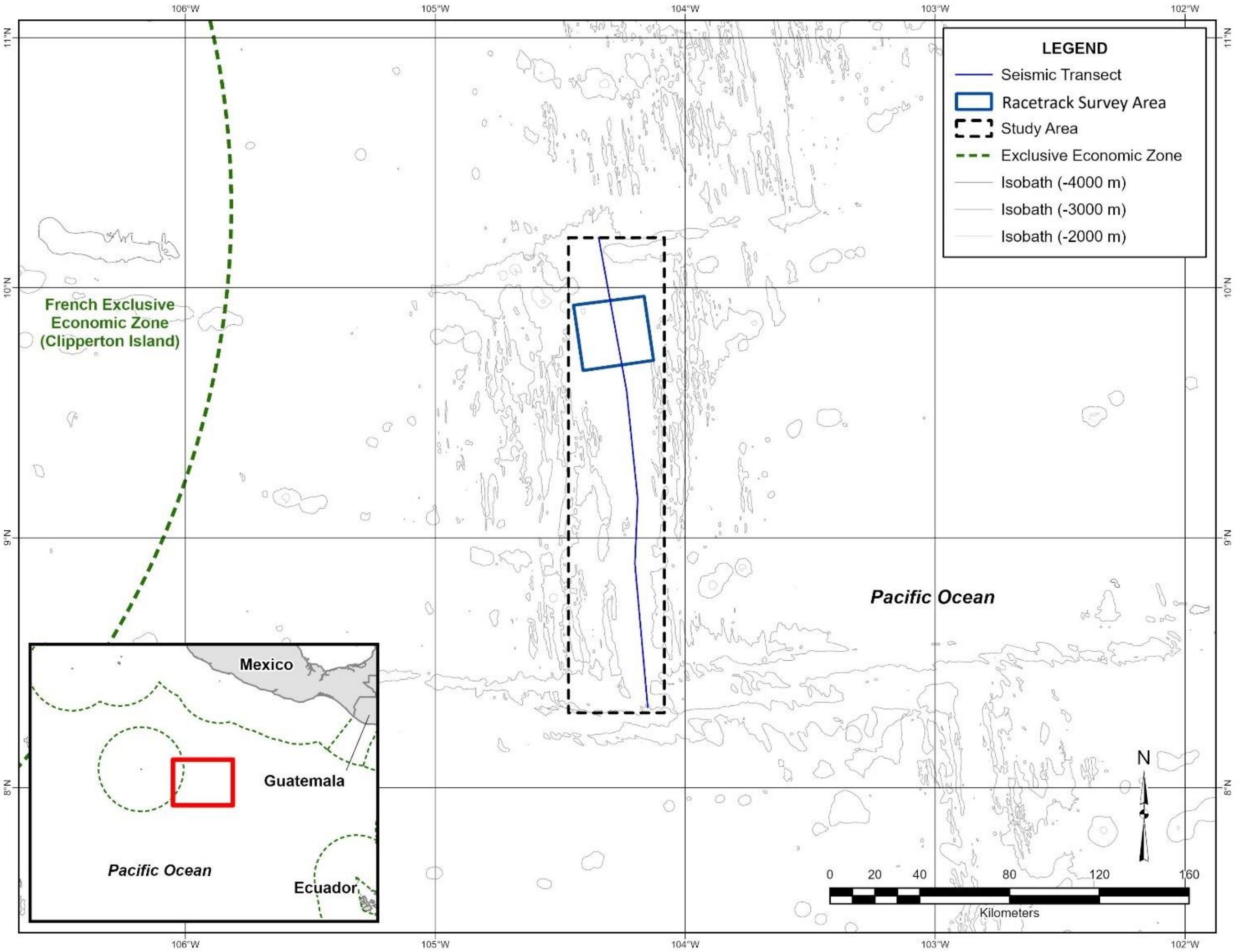

FIGURE 1. Location of the proposed seismic surveys in the ETP.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed marine seismic surveys would occur in International Waters within the study area depicted in Figure 1, bounded by the following coordinates: 10.2°N, 104.5°W; 10.2°N, 104.1°W; 8.3°N, 104.1°W; and 8.3°N, 104.5°W. The water depths in the study area range from 2500 to 3200 m. As described further in this document, some deviation in the tracklines or 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 study area and general coordinates noted above.

2.1.2.2 Description of Activities

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys conducted by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Langseth*, which would tow two 18-airgun arrays with a discharge volume of ~3300 in^3 each, at a depth of 7.5 m. The two linear airgun arrays would fire in an alternate “flip-flop” mode every 37.5 m (~16 s). The main receiving system would consist of four 5850-m long solid-state hydrophone streamers, separated by 150 m (solid flexible polymer – not gel nor oil filled). As the airgun arrays are towed along the survey lines, the hydrophone streamers will receive the returning acoustic signals and transfer the data to the on-board processing system.

The majority of the surveys would be acquired in a racetrack formation, a pattern whereby the next acquisition line is several kilometers away from and traversed in the opposite direction of the trackline just completed (see LGL Limited 2007). The acquisition pattern would consist of two racetracks – one with 49 cross-axis transect lines and one with 40 cross-axis transect lines. There would be a total of 89 lines, spaced ~300 m apart. Each line would be 26 km long, for a total of 2314 km line km; however, with infill or repeat acquisition along some transects, the total for the racetrack survey is expected to be ~2900 km. Data would not be acquired during turns; thus, turns are not included in the total. In addition, one single along-axis transect, 210-km long, would be acquired (Fig. 1). Thus, total survey effort would consist of ~3110 km of seismic acquisition. 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 arrays, other acoustic sources, including a multibeam echosounder (MBES), sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP), would be operated from R/V *Langseth* continuously during the seismic surveys. All planned marine-based geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

2.1.2.3 Schedule

The proposed high-energy surveys with the alternating 18-airgun arrays would be expected to take place during February−March 2026 for a period of ~35 days; this includes up to 20 days of seismic operations, 4 days of equipment deployment/recovery, 6 days of contingency, and 5 days of transit. R/V *Langseth* would likely leave out of and return to port in Manzanillo, Mexico (nearly 1000 km north of the proposed study area). Equipment deployment and recovery times would vary and occur anytime during the planned survey, except during transits. L-DEO 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 *Langseth* is described in § 2.2.2.1 of the PEIS; the gross tonnage of R/V *Langseth* is 3834 t. The vessel speed during seismic operations with the 18-airgun arrays would be ~4.5 kt (~8.3 km/h) during MCS reflection data acquisition; during turns between seismic lines when airguns are not firing, the vessel speed would drop to 3.8 kt (7.0 km/h). When R/V *Langseth* tows the airgun arrays and hydrophone streamers, the turning rate of the vessel would be limited to five degrees per minute. Thus, the maneuverability of the vessel would be limited during operations with the streamer. Protected species observers (PSOs) would have a 360-degree view from the vessel's observation tower.

2.1.2.5 Airgun Description

During the seismic surveys, R/V *Langseth* would tow four strings (each ~16 m long) with 36 airguns (plus 4 spares); however, only 18 airguns in two strings would be firing at one time. During the surveys, the two 18-airgun arrays would fire in an alternate "flip-flop" mode every 37.5 m (16 s). The total discharge volume would be 3300 in^3, and the array would be towed at a depth of 7.5 m. The two strings in each 18-airgun array would be separated by 8 m, and the two "flip-flop" arrays would be spaced 75 m apart. The airgun strings would be towed ~265 m behind R/V *Langseth*.

The airgun arrays consists of a mixture of Bolt 1500LL and Bolt 1900LLX airguns. The airgun array and its source level and frequency components are described in § 2.2.3.1 of the PEIS and summarized below, and the airgun configuration is illustrated in Figure 2-11 of the PEIS. During firing, a brief pulse of sound with a duration of ~0.1 s would be emitted. The airguns would be silent during the intervening periods. During operations, airguns would be operated 24/7 for multiple days to meet science objectives unless maintenance or mitigation measures warranted.

18-Airgun Array Specifications

Energy Source	Eighteen Bolt airguns of 40−360 in^3,
Source output (downward)	0-pk is 42 bar-m (252 dB re 1 µPa·m); pk-pk is 87 bar·m (259 dB)
Air discharge volume	~3300 in^3
Dominant frequency components	0−188 Hz
Firing Pressure	~2000 psi

2.1.2.6 Additional Acoustical Data Acquisition Systems

Along with the airgun operations, three additional acoustical data acquisition systems (an MBES, SBP, and ADCP) would be operated from R/V *Langseth* continuously during the proposed surveys, including during transits. The ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. These sources are described in § 2.2.3.1 of the PEIS as well below.

The MBES is a hull-mounted system operating at 10.5−13 kHz (usually 12 kHz). The transmitting beam width would be one or two degrees fore-aft and 150 degrees (maximum) athwartship or perpendicular to the ship's line of travel. The maximum sound source level would be 242 dB re 1 µPa-m. Each ping consists of eight (in water >1000 m) or four (in water <1000 m) successive fan-shaped transmissions, each ensonifying a sector that extends one degree fore-aft. Continuous-wave signals increase from 2−15 milliseconds long in water depths up to 2600 m, and frequency modulated chirp signals up to 100 milliseconds long are used in water >2600 m. The successive transmissions span an overall cross-track angular extent of ~150 degrees, with two millisecond gaps between the pings for successive sectors.

The Knudsen 3260 SBP would be operated to provide information about the near sea floor sedimentary features and the bottom topography that would be mapped simultaneously by the MBES. The beam would be transmitted as a 27-degree cone, which would be directed downward by a 3.5-kHz transducer in the hull of R/V *Langseth*. The nominal power output would be 10 kilowatts, but the actual maximum radiated power would be 3 kilowatts or 222 dB_{rms} re 1 µPa at 1 m. The ping duration would be up to 64 milliseconds, and the ping interval would be one second. A common mode of operation is to broadcast five pulses at one-second intervals followed by a five-second pause. The SBP would be capable of reaching depths of 10,000 m.

A Teledyne RDI 75 kHz Ocean Surveyor ADCP would be used to measure water current velocities. It would have a maximum source level of 224 dB re 1µPa-1 m over a conically-shaped 30° beam and a ping rate of 0.7 Hz.

2.1.3 Monitoring and Mitigation Measures

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.1.1 and 2.4.2 of the PEIS and would occur in two phases: pre-cruise planning and operations. The following sections describe the efforts during both stages for the proposed activities. Numerous papers have been published with recommendations on how to reduce anthropogenic sound in the ocean (e.g., Simmonds et al. 2014; Wright 2014; Dolman and Jasny 2015), some of which have been taken into account here.

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

***Energy Sourc*e.—**Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. However, the scientific objectives for the proposed surveys could not be met using a smaller source. The energy source level must be the same as the airgun array that was used during the 2008 surveys in order to meet time-lapse imagery objectives.

***Survey Location and Timing*.—**The PIs, along with L-DEO and NSF, considered potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using R/V *Langseth*. Winter was determined to be the most practical timing for the proposed surveys based on the occurrence of marine mammals, weather conditions, other operational requirements, and availability of researchers.

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic surveys using the 18-airgun array (at a tow depth of 7.5 m) were not derived from the farfield signature but based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and exposure zones (160 dB re $1\mu Pa_{rms}$) for Level B takes. The background information and methodology for this are provided in Appendix A. L-DEO model results are used to determine the 160-dB_{rms} radius for the airgun source down to a maximum depth of 2000 m (see Appendix A), as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999).

Table 1 shows the distances at which the 160-dB re $1\mu Pa_{rms}$ sound levels are expected to be received for the 18-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 distances at which the 175-dB re $1\mu Pa_{rms}$ sound level is expected to be received for the various airgun sources; this level is used by NMFS, based on DoN (2017a), to determine behavioral disturbance for sea turtles. The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals and sea turtles for impulsive sounds use dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}).

TABLE 1. Predicted distances 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 with the 18-airgun array in the Eastern Tropical Pacific. 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 distances (in m) to the 160-dB Received Sound Level[1]	Predicted distances (in m) to the 175-dB Received Sound Level[1]
2 strings, 18 airguns, 3300 in^3	7.5	>1000 m	3,526	763

[1] Distance is based on L-DEO model results.

Different thresholds are available for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), high-frequency (HF) cetaceans (e.g., most delphinids), very high-frequency (VHF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2024), and sea turtles (DoN 2017a). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (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. Here, SEL$_{cum}$ is used for LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups (Table 2).

TABLE 2. Level A (PTS) threshold distances for different marine mammal hearing groups for the 18-airgun array in the Eastern Tropical Pacific. Consistent with NMFS (2024), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances. PTS threshold distances for sea turtles are also shown.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	High-Frequency Cetaceans	Very High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PTS SEL$_{cum}$	**157.5**	0.1	0.6	7.4	0.3	**250.2**
PTS Peak	23.4	**13.4**	**164.6**	**21.6**	**13.4**	11.9

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017).

For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for shut downs for marine mammals, monitor an additional 500-m buffer zone beyond the EZ for marine mammals prior to ramp up, and implement a 150-m EZ for sea turtles. A 150-m EZ was also monitored for shut downs for and diving/foraging ESA-listed seabirds. Enforcement of EZs 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 study 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) passive acoustic monitoring (PAM); (3) PSO data and documentation; and (4) mitigation during operations (speed or course alteration; shut down and ramp up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats). 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.

During daytime, the PSO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), Big-eye binoculars (25×150), and with the naked eye. 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 proposed by L-DEO based on past experience and for consistency with the PEIS.

***Shut down Procedures*.—**The operating airguns would be shut down if a marine mammal was seen within or approaching the EZ. Shut downs would not be required for small dolphins that are most likely to approach the vessel. The airgun array would be shut down if ESA-listed sea turtles or seabirds (diving/foraging) were observed within a 150-m designated EZ. Following a shut down, airgun activity would not resume until the marine mammal, ESA-listed sea turtle or seabird has cleared the EZ. The animal would be considered to have cleared the EZ if

- it was visually observed to have left the EZ, or
- it was not seen within the zone for 15 min in the case of small odontocetes, ESA-listed seabirds and sea turtles, or
- it was not seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

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

***Ramp up Procedures*.—**A ramp up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that 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 the smallest airgun in the array. Ramp up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals or ESA-listed sea turtles/seabirds (diving/foraging) are sighted, a shut down would be implemented, respectively, as though the full array were operational. Ramp up would only commence at night or during poor visibility if the EZ has been monitored acoustically with PAM for 30 min prior to the start of operations without any marine mammal detections during that period.

The proposed operational mitigation measures are standard for seismic cruises, per the PEIS. Five 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. One PSO would conduct PAM during day- and night-time seismic operations. Monitoring and mitigation measures are further described in the IHA application.

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 Action is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations (Table 3). Under the "No Action" alternative, NSF would not support L-DEO to conduct 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, L-DEO 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

Table 3 provides a summary of the Proposed Action and the alternatives.

2.3.1 Alternative E1: Alternative Location

The proposed study returns to an area of the EPR that was previously surveyed with 3-D MCS. The new data collected during the proposed surveys would create high-resolution imagery to investigate how the magmatic and hydrothermal plumbing systems beneath the submarine volcanic ridge has changed, which will allow for a 4-D timelapse study of how magma bodies evolve over decadal timescales and novel eruption cycle hypothesis testing. The area of the EPR at 9°50'N is an ideal location to conduct this study because it was previously surveyed by 3-D MCS in 2008, and continuous vent temperature monitoring over the past 5 years predicts new eruptions in the region, as shown in the eruption at Tica vent in April 2025. The proposed experiment would also bridge a critical gap between existing seismic datasets and offers a unique opportunity to characterize changes in the shape and melt content of the magmatic system of the EPR over time. The proposed survey location is the only place on Earth where the appropriate data has been previously collected and volcanic eruptions are predicted to occur in the next few years. Thus, an alternative location would not meet the purpose of the proposed surveys.

TABLE 3. Summary of Proposed Action, Alternative Considered, and Alternatives Eliminated.

Proposed Action	**Description**
Proposed Action: Conduct marine geophysical surveys and associated activities in the ETP	Under this action, research activities are proposed to study Earth processes and would involve 3-D marine seismic surveys. The cruise would be 35 days long, with active seismic operations expected to take up to 20 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 regulating agencies in the U.S. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.
Alternatives	**Description**
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. Geological data of scientific value, with the aim to examine a timelapse of crustal mantle body changes within or between volcanic cycles, 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**
Alternative E1: Alternative Location	The proposed timelapse experiment to investigate the eruption cycle requires pre-existing 3-D seismic baseline data which is only available from the 2008 survey collected at 9°50'N at the EPR and during the 2019 seismic survey at the Axial Seamount on the Juan de Fuca Ridge. The goal of the proposed survey is to image changes in the geometry of the magma body. The Axial Seamount dataset has not been fully processed and was collected 4 years after the last documented eruption with indications that the magma has been in a steady state since 2024 with little possibility of another eruption in the near future. In contrast, 9°50'N vent temperatures over the past 5 years predict new eruptions at the EPR within the next year or two. The proposed survey location at 9°50'N is the only feasible place to conduct a 4-D timelapse study of how magma bodies evolve over decadal timescales and novel eruption cycle hypothesis testing. Thus, an alternative location would not meet the purpose of the surveys.
Alternative E2: Alternative Survey Timings	The surveys are proposed for February to March 2026. This timeframe is outside of the hurricane season for the region when weather conditions will be more favorable at this location.
Alternative E3: Use of Alternative Technologies	The goal of the project is to conduct a 4-D study of an eruption cycle. Thus, the technology used for data collection must produce a comparable dataset using similar methodology to the data collected during the baseline surveys in 2008. At this time, alternate technologies are not appropriate to meet the Purpose and Need.

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 high-energy seismic surveys. 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).

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 study 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*—Vessel emissions would result from the proposed activity; 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 proposed study area. To reduce impacts on air quality, R/V *Langseth* uses Ultra-Low Sulfur fuel (<15 ppm Sulfur) and employs a Ship Energy Efficiency Management Plan to reduce and minimize fuel consumption (e.g., speed optimization) resulting in overall lower emissions.
- *Land Use*—All activities are proposed to occur in the marine environment. Thus, no changes to current land uses or activities in the proposed study area would result from the project;
- *Safety and Hazardous Materials and Management*—No hazardous materials would be generated or used during the proposed activities. All project-related wastes would be disposed of in accordance with international, U.S. state and 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 study area. Therefore, there would be no impacts to water resources resulting from the proposed Project activity.
- *Terrestrial Biological Resources*—All proposed 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.

3.1 Physical Environment and Productivity

The center of the ETP is characterized by warm, tropical waters (Reilly and Fiedler 1994). Cooler, high-salinity water is found along the Equator and the eastern boundary current waters of Peru and California; this cool water is brought to the surface by upwelling, causing nutrient enrichment and increased productivity during most periods of the year (Reilly and Fiedler 1994). The two different habitats are generally thought to support different cetacean species (Au and Perryman 1985; Ballance et al. 2006), but both systems are thought to be highly productive (Au and Perryman 1985).

The Peru and California currents feed into the westward-flowing South and North Equatorial currents (Reilly and Fiedler 1994). Between the equatorial currents at 3−10°N is the eastward-flowing North Equatorial Countercurrent (NECC), part of which turns north and becomes the Costa Rica Current when it reaches Central America, and flows along the coast until it turns west off the coast of Mexico and joins the North Equatorial Current. The pattern of cyclonic flow exists only in summer-fall, when it flows around the Costa Rica Dome (CRD), a shoaling of the generally strong and shallow thermocline of the ETP. The NECC does not extend east of 100°W during February−April (Fiedler 2002). The NECC is strong during September−December and weak during February−April (Reilly and Fiedler 1994).

There are several regions of increased biological productivity in the ETP. For example, Kessler (2006) and Pennington et al. (2006) noted that the NECC is associated with a band of higher productivity. Several studies have correlated zones of high productivity with concentrations of cetaceans (Volkov and Moroz 1977; Reilly and Thayer 1990; Wade and Gerrodette 1993). Au et al. (1980, *in* Polacheck 1987) noted an association between cetaceans and the equatorial surface water masses in the ETP, which are thought to be highly productive. The ETP is also characterized by a shallow thermocline and a pronounced oxygen minimum layer (Au and Perryman 1985; Fiedler and Talley 2006). Those features are thought to result in an "oxythermal floor" 20−100 m below the surface, which may cause large groups of cetaceans to concentrate in the warm surface waters (Scott and Cattanach 1998).

The mean productivity is estimated to be 292.335 mgC/m^2/day in the eastern Central Pacific offshore area where the proposed program is anticipated to occur (Sea Around Us 2024). A major factor influencing productivity in waters of the ETP is the Intertropical Convergence Zone (ITCZ). At the ITCZ, the northeast and southeast trade winds flow together, characterized by strong upward motion and heavy rainfall, which affect the transport of species from the Northern to the Southern Hemispheres and vice versa (Millero 1996). In the Pacific, the ITCZ is substantially shifted north of the Equator compared to the Atlantic, because of the considerably larger percentage of land that lies in the Northern Hemisphere in comparison to the Southern Hemisphere (Brown 1995). During July (the Northern Hemisphere summer) and January (the northern winter), the largest effects and fluctuations are seen in the ITCZ. Consequently, areas near the Equator generally experience a drop in productivity during July and January as the productive waters move north with the ITCZ. Interannual variation in the oceanography of the ETP is greater than in any other area of the world because of the quasi-periodic El Niño−Southern Oscillation (ENSO; Fiedler and Talley 2006). Interannual variation usually exceeds any seasonal variation in the equatorial and upwelling zones, but is comparable to seasonal variations in the warm pool (Fiedler and Talley 2006; Pennington et al. 2006).

3.2 Marine Protected Areas

There are no marine protected areas (MPA) near the proposed study area in the ETP; the closest MPA is located within the territorial waters of Clipperton Island ~500 km west of the proposed study area. The Clipperton Atoll ecologically or biologically significant marine area (EBSA) extends out to 200 km from the island. Clipperton Atoll is the only atoll in the ETP and represents a unique ecosystem in the region (CBD 2025). The atoll appears to be a reproductive area for sharks, such as the white tip shark (*Carcharhinus albimarginatus*) (CBD 2025). Clipperton Atoll is also an Important Bird Area (IBA); ~110,000 masked booby (*Sula dactylatra*) occur there, including 20,000 breeding pairs, making it the largest masked booby colony in the world (CBD 2025). The 200-km extent of the EBSA around Clipperton Island is based on the masked booby foraging area (CBD 2025). The Equatorial High-Productivity Zone EBSA is located ~360 km south of the proposed study area. This EBSA is associated with the Equatorial Current System and spans nearly the entire width of the Pacific Basin between 5°N and 5°S (CBD 2025).

The winds in this region bring nutrient-rich water to the surface, thereby increasing primary productivity (CBD 2025). This EBSA is associated with high sperm whale abundance (CBD 2025).

3.3 Marine Mammals

Twenty-eight marine mammal species could occur in or near the proposed study area, including 6 mysticetes (baleen whales) and 22 odontocetes (toothed whales, such as dolphins) (Table 4). Several species that could occur in the proposed study area are listed under the U.S. ESA as ***endangered***, including the sei, fin, blue, sperm, and Central America DPS of humpback whale. The ***threatened*** Mexico DPS of the humpback whale could possibly occur in the proposed study area. The ***threatened*** Guadalupe fur seal is unlikely to occur in the study area.

Another 11 cetacean species that occur in the Northeast Pacific Ocean are unlikely to occur in the proposed study area and are not discussed further, including the North Pacific right whale (*Eubalaena japonica*), gray whale (*Eschrichtius robustus*), Hubbs' beaked whale (*Mesoplodon carlhubbsi*), Stejneger's beaked whale (*M. stejnegeri*), Perrin's beaked whale (*M. perrini*), Baird's beaked whale (*Berardius bairdii*), vaquita (*Phocoena sinus*), harbor porpoise (*Phocoena phocoena*), Dall's porpoise (*Phocoenoides dalli*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), and northern right whale dolphin (*Lissodelphis borealis*).

The most extensive regional distribution and abundance data for cetaceans that encompass the entire study area come primarily from multi-year vessel surveys conducted in the wider ETP by the NMFS Southwest Fisheries Science Center (SWFSC). Ferguson and Barlow (2001) reported on data collected from 1986−1996, and Forney et al. (2012) used SWFSC data collected during 1986−2006 to develop species-habitat models for the ETP. Initial systematic studies of cetaceans in the ETP were prompted by the incidental killing of dolphins in the purse-seine fishery for yellowfin tuna in the area (Smith 1983). Background information on incidental dolphin mortalities during the tuna fishery is discussed in Section 4.1.5, Reasonably Foreseeable Effects. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. In the PEIS, the Southern California detailed analysis area (DAA) is located northeast of the proposed study area, and the Galápagos Ridge DAA is located south of the study area. The general distribution of mysticetes, odontocetes, and pinnipeds in these areas is discussed in § 3.6.2, § 3.7.2, and § 3.8.2 of the PEIS, respectively.

Although there are seven species of pinnipeds known to occur in the ETP including the California sea lion (*Zalophus californianus californianus*), Galápagos sea lion (*Zalophus wollebaeki*), Galápagos fur seal (*Arctocephalus galapagoensis*), Guadalupe fur seal (*Arctocephalus townsendi*), South American fur seal (*A. australis*), South American sea lion (*Otaria flavescens*), and northern elephant seal (*Mirounga angustirostris*), pinnipeds likely would not be encountered during the proposed seismic surveys. Neither Jackson et al. (2004), Smultea and Holst (2003), nor Hauser et al. (2008) encountered any pinnipeds in offshore waters near the proposed study area.

The distributional ranges of the Guadalupe fur seal, California sea lion, and northern elephant seal lie to the north of the proposed study area. Guadalupe fur seals typically occur only off California and Baja California, northern elephant seals occur from Baja California to Alaska, and California sea lions are distributed from southern Mexico north to southwestern Canada. However, the California sea lion has been documented off Costa Rica on several occasions (e.g., Acevedo-Gutierrez 1994, 1996; Cubero-Pardo and Rodríguez 2000; Rodríguez-Herrera et al. 2002; May-Collado 2009), and Guadalupe fur seals have also been reported there (May-Collado 2009).

TABLE 4. The habitat, occurrence, population sizes, and conservation status of marine mammals that could occur in or near the proposed study area in the Eastern Tropical Pacific.

Species	**Occurrence In Study Area During Surveys[1]**	**Habitat**	**Abundance**		**Conservation Status**		
			North Pacific	**ETP[2]**	**U.S. ESA[3]**	**IUCN[4]**	**CITES[5]**
Mysticetes							
Humpback whale	Rare	Mainly nearshore, banks	1496[6] 3477[7] 21,063[8]	2566	EN/T[22]	LC	I
Common minke whale	Rare	Coastal, pelagic	20,000[9]	115	NL	LC	I
Bryde’s whale	Uncommon	Coastal, pelagic	-	10,411	NL	LC	I
Sei whale	Rare	Mostly pelagic	29,600[10]	0	EN	EN	I
Fin whale	Rare	Slope, pelagic	13,620–18,680[11]	574	EN	VU	I
Blue whale	Rare	Coastal, pelagic	2500[12]	1415	EN	EN	I
Odontocetes							
Sperm whale	Uncommon	Pelagic, steep topography	-	4145	EN	VU	I
Pygmy sperm whale	Rare	Deeper waters off shelf	4111[13]	-	NL	LC	II
Dwarf sperm whale	Rare	Deeper waters off shelf	-	11,200[14]	NL	LC	II
Cuvier’s beaked whale	Uncommon	Pelagic	90,725[15]	20,000[16]	NL	LC	II
Longman’s beaked whale	Rare	Pelagic	291[15]	1007	NL	LC	II
Blaineville’s beaked whale	Rare	Pelagic	32,678[17]	25,300[18]	NL	LC	II
Ginkgo-toothed beaked whale	Rare	Pelagic	32,678[17]	25,300[18]	NL	DD	II
Deraniyagala’s beaked whale	Rare	Pelagic	32,678[17]	25,300[18]	NL	DD	II
Pygmy beaked whale	Rare	Pelagic	32,678[17]	25,300[18]	NL	LC	II
Risso’s dolphin	Uncommon	Shelf, slope, seamounts	-	110,457	NL	LC	II
Rough-toothed dolphin	Uncommon	Mainly pelagic	-	107,663	NL	LC	II
Common bottlenose dolphin	Common	Coastal, shelf, pelagic	-	335,834	NL	LC	II
Pantropical spotted dolphin	Common	Coastal and pelagic	-	857,884[19]	NL	LC	II
Spinner dolphin	Common	Coastal and pelagic	-	1,797,716[20]	NL	LC	II
Striped dolphin	Common	Off continental shelf	-	964,362	NL	LC	II
Common dolphin	Common	Shelf, pelagic, seamounts	-	3,127,203	NL	LC	II
Fraser’s dolphin	Common	Pelagic	-	289,300[16]	NL	LC	II
Short-finned pilot whale	Uncommon	Pelagic, high-relief	-	589,315[21]	NL	LC	II

Species	Occurrence In Study Area During Surveys[1]	Habitat	Abundance		Conservation Status		
			North Pacific	ETP[2]	U.S. ESA[3]	IUCN[4]	CITES[5]
Killer whale	Rare	Widely distributed	-	8500[16]	EN	DD	II
False killer whale	Uncommon	Pelagic	-	39,800[16]	NL	NT	II
Pygmy killer whale	Uncommon	Pelagic	-	38,900[16]	NL	LC	II
Melon-headed whale	Uncommon	Pelagic	-	45,400[16]	NL	LC	II

- Not available or not applicable.

[1] Occurrence in area at the time of the surveys; based on professional opinion and available data, including densities.

[2] Abundance for the ETP from NMFS (2015) unless otherwise stated.

[3] U.S. Endangered Species Act (ESA): EN = Endangered; T = Threatened; NL = Not listed.

[4] International Union for the Conservation of Nature Red List of Threatened Species, version 2025-1 (IUCN 2025): EN = Endangered; VU = Vulnerable; LC = Least Concern; NT = Near Threatened; DD = Data Deficient.

[5] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2025): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

[6] Central America/Southern Mexico – CA-OR-WA stock (Carretta et al. 2024a).

[7] Mainland Mexico – CA-OR-WA (Carretta et al. 2024a).

[8] North Pacific (Barlow et al. 2011).

[9] Northwest Pacific and Okhotsk Sea for 2003 (IWC 2025).

[10] Central and Eastern North Pacific (IWC 2025).

[11] North Pacific (Ohsumi and Wada 1974).

[12] Eastern North Pacific (IWC 2025).

[13] Abundance for U.S. West Coast (Carretta et al. 2024a).

[14] Estimate for ETP is mostly for *K. sima* but may also include some *K. breviceps* (Wade and Gerrodette 1993).

[15] Eastern North Pacific (Ferguson and Barlow 2001 *in* Barlow et al. 2006).

[16] Wade and Gerrodette (1993).

[17] This estimate for the Eastern North Pacific includes all species of the genus *Mesoplodon* (Ferguson and Barlow 2001 *in* Barlow et al. 2006).

[18] This estimate for the ETP includes all species of the genus *Mesoplodon* (Wade and Gerrodette 1993).

[19] Northeastern offshore stock.

[20] Includes several stocks added together.

[21] Based on surveys in 2000 (Gerrodette and Forcada 2002).

[22] Central America DPS is endangered; Mexico DPS is threatened.

Galápagos sea lions and Galápagos fur seals occur around the Galápagos Islands and generally are not seen more than ~185 km west of the Galápagos Islands (J. Barlow, NMFS, pers. comm. to LGL Limited 2008). However, Galápagos sea lions are seen occasionally along the coasts of Colombia and Ecuador and as far north as Isla del Coco, Costa Rica, an island 500 km southwest of Costa Rica (Acevedo-Gutiérrez 1994; Capella et al. 2002). A few Galápagos fur seals have also been reported along the coast of South America (D. Palacios, Oregon State University, pers. comm. to LGL Limited 2008).

Southern sea lions and South American fur seals are distributed along the coast of South America. The northernmost breeding colony of southern sea lions occurs on the Peruvian coast (Vaz-Ferreira 1981), but vagrant individuals have been seen along the coast of Colombia (Capella et al. 2002) and as far north as Panama (Méndez and Rodriguez 1984). The northernmost sighting of the South American fur seal was recorded off the Colombian coast (Capella et al. 2002).

3.3.1 Mysticetes

3.3.1.1 Humpback Whale (*Megaptera novaeangliae*)

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

North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008; Bettridge et al. 2015). Humpbacks winter in four different breeding areas: (1) the coast of Mexico; (2) the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016a). If humpbacks are encountered during the proposed surveys, they could be from either the Central America or Mexico DPSs (see Steiger et al. 1991; Calambokidis et al. 2008; Martien et al. 2021; Carretta et al. 2023; Martínez-Loustalot et al. 2023).

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. 2023).

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).

In the Mexican Pacific, there are three main locations where humpbacks aggregate including the southern end of Baja California, the central portion of the mainland, and the Revillagigedo Archipelago; they also aggregate in the northern Gulf of California (Urbán and Aguayo 1987; Urbán et al. 2000). Most northeastern Pacific humpbacks spend the northern winter off the Baja California Peninsula and mainland Mexico, and summer off the western coast of North America from California to Alaska (Urbán and Aguayo 1987; Urbán et al. 2000). While on wintering grounds, humpbacks occur predominantly in coastal waters. The Northern Hemisphere humpbacks occur in the Mexican Pacific from as early as September through the winter to mid-May (Urbán and Aguayo 1987). However, they have been reported in the Gulf of California throughout the year (Bean et al. 1999 *in* Heckel et al. 2020), so it is likely that not all whales undergo the migration (Guerrero et al. 2006).

During surveys of the Pacific EEZ of Mexico, Gerrodette and Palacios (1996) reported 10 sightings of humpback whales. However, during 1986−1996 summer/fall surveys of the ETP, the density of humpback whales in the proposed study area was zero (Ferguson and Barlow 2001). Similarly, Jackson et al. (2004) did not encounter any humpbacks in the proposed study area during surveys in July−December 2003. There are no sightings in the OBIS database for the waters in and adjacent to the proposed study area

(OBIS 2025). Although sightings are regularly made in coastal areas of the ETP during winter, encounters in the offshore survey area are unlikely.

3.3.1.2 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).

Gerrodette and Palacios (1996) reported eight sightings of minke whales during surveys of the Pacific EEZ of Mexico. González et al. (2008) also noted the presence of minke whales off the Pacific coast of Mexico, south of 18°N. Rankin and Barlow (2005) reported acoustic recordings of minke whale calls (boings) between 15° and 35°N in the central and eastern North Pacific Ocean; eastern-type 'boings' were recorded off the coast of Mexico. However, no minke whales were seen in the proposed offshore study area from 1986 through 1996 (Ferguson and Barlow 2001; Jackson et al. 2004; Forney et al. 2012). In the OBIS database, there are no sightings for the waters in or adjacent to the proposed study area. However, there are two records for November between 14.8°–17.2°N and 112.5°–115.5°W (OBIS 2025). Minke whales are expected to be rare in the offshore study area.

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

Bryde's whale occurs in all tropical and warm temperate waters in the Pacific, Atlantic, and Indian oceans, between 40°N and 40°S (Kato and Perrin 2018). It is one of the least known large baleen whales, and it remains uncertain how many species are represented in this complex (Kato and Perrin 2018). *B. brydei* is commonly used to refer to the larger form or "true" Bryde's whale and *B. edeni* to the smaller form; however, some authors apply the name *B. edeni* to both forms (Kato and Perrin 2018). Bryde's whale remains in warm (>16°C) water year-round, although seasonal movements have been recorded towards the Equator in winter and offshore in summer (Kato and Perrin 2018). However, Debrot (1998) noted that this species is sedentary in the tropics. Bryde's whales are known to occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2015).

During surveys of the Pacific EEZ of Mexico, 12 sightings of *B. edeni* were made (Gerrodette and Palacios 1996). Based on July–December 1986–1996 surveys, the density of Bryde's whales in the proposed study area ranged up to 0.0003/km^2 (Ferguson and Barlow 2001). Sightings were made near the proposed study area during surveys in 1998–2000 (Forney et al. 2012) and east of the study area during July–December 2003 (Jackson et al. 2004). There are no confirmed sightings in the OBIS database for the proposed study area (OBIS 2025). However, there is one record at 8.2°N, 104.6°W during September 2000, and two sei/Bryde's whale records for August 1989 (9.33°N, 105.5°W) and September 1986 (10.23°N, 103.3°W) (OBIS 2025).

3.3.1.4 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). On summer 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). In the North Pacific during summer, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to the Baja California Peninsula, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N (Rice 1998). 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).

Sei whales may have been sighted during surveys in the greater ETP (Wade and Gerrodette 1993; Kinzey et al. 1999, 2000, 2001; Ferguson and Barlow 2001). However, it is difficult to distinguish sei whales from Bryde's whales. Because sei whales generally have a more northerly and temperate distribution (Leatherwood et al. 1988), Wade and Gerrodette (1993) classified any tentative sei whale observations in the ETP as Bryde's whale sightings. Ferguson and Barlow (2001) did not report any sei whales in the ETP south of 30°N during surveys conducted during July–December 1986–1996; however, the density of Bryde's/sei whales in the proposed study area ranged up to 0.0001/km^2 (Ferguson and Barlow 2001). There are no confirmed sightings in the OBIS database for the proposed study area (OBIS 2025). However, there are two unconfirmed sightings (identified as Sei or Bryde's whale) in adjacent waters for August 1989 (9.33°N, 105.5°W) and September 1986 (10.23°N, 103.3°W) (OBIS 2025).

3.3.1.5 Fin Whale (*Balaenoptera physalus physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar 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 1985). 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).

Gerrodette and Palacios (1996) reported an abundance of 145 fin whales for the EEZ of Pacific Mexico, and González et al. (2008) also reported the presence of this species off the west coast of Mexico south of 23°N. Edwards et al. (2015) reported sightings and acoustic detection for the Gulf of California and Baja California, as well as sightings near the proposed study area during December–February and acoustic detections from March–November. However, no sightings were made in the proposed study area during July–December surveys during 1986–1996 and 2003 (Ferguson and Barlow 2001; Jackson et al. 2004). There are no sightings in the OBIS database for the waters in and adjacent to the proposed study area, but there are two records between 15.8°–21.0°N and 116.1°–119.6°W during November and December (OBIS 2025). Fin whales are considered rare in the proposed study area.

3.3.1.6 Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). Blue whales are most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). 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 in the Pacific: the eastern and central (formerly western) stocks (Carretta et al. 2024b). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016). Blue whales from the eastern stock winter in Mexico and Central America (Stafford et al. 1999, 2001) and feed off the U.S. West Coast, as well as the Gulf of Alaska, during summer (Sears and Perrin 2018; Carretta et al. 2024b). However, Busquets-Vass et al. (2021) suggested that most blue whales from the North Pacific feed in the California Current System, whereas some individuals occur in the Gulf of California or CRD for most of the year. The central North Pacific stock feeds off Kamchatka, south of the Aleutians and in the Gulf of Alaska during summer (Stafford 2003; Watkins et al. 2000b) and migrates to the western and central Pacific (including Hawaii) to breed in winter (Stafford et al. 2001; Carretta et al. 2024b).

In the Northeast Pacific Ocean, including the ETP, blue whale calls are detected year-round (Stafford et al. 1999, 2001, 2009; 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 ETP, blue whales have been sighted mainly off the Baja California Peninsula, near Costa Rica particularly the CRD, at and near the Galápagos Islands, and along the coasts of Ecuador and northern Peru (Clarke 1980; Donovan 1984; Reilly and Thayer 1990; Mate et al. 1999; Palacios 1999; Palacios et al. 2005; Branch et al. 2006). Sightings have also been made off the mainland coast of Mexico (Fiedler 2002; Arroyo 2017). In Mexican waters, blue whales generally occur from December–April (Rice 1974; Yochem and Leatherwood 1985; Gendron 2002 *in* Heckel et al. 2020), after which time they migrate northward; a large proportion occurs off California during the summer (Sears and Perrin 2018).

During surveys within the EEZ of Pacific Mexico, 30 sightings of blue whales were reported by Gerrodette and Palacios (1996). The density of blue whales in the proposed study area was zero based on July–December surveys during 1986–1996 (Ferguson and Barlow 2001). However, sightings have been made just east of the proposed study area (Ferguson and Barlow 2001; Jackson et al. 2004; Forney et al. 2012). There are no sightings of blue whales in the OBIS database for the proposed study area (OBIS 2025). However, there are two records for adjacent waters (8.5°N, 102.5° and 9.5°N, 102.5°W) which were made in February 2006 (OBIS 2025). Blue whales are likely to be uncommon to rare in the proposed study area.

3.3.2 Odontocetes

3.3.2.1 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 (Whitehead 2018).

Sperm whales are distributed widely across the North Pacific (Rice 1989). Males migrate north in the summer to feed in the Gulf of Alaska, Bering Sea, and waters around the Aleutian Islands (Kasuya and Miyashita 1988). During summer and fall, sperm whales are widely distributed in the ETP, although they are generally more abundant in deep "nearshore" waters than far offshore (e.g., Polacheck 1987; Wade and Gerrodette 1993). It is not clear whether sperm whales seen in the ETP are part of the Northern or Southern Hemisphere stocks, or whether they should be considered a separate stock (Berzin 1978). More than 180 sightings have been reported for the ETP, with the highest concentrations at 10°N–10°S, 80°–100°W (Guerrero et al. 2006).

During surveys of the EEZ of Pacific Mexico, 46 sightings of sperm whales were made (Gerrodette and Palacios 1996). In the proposed study area, the sperm whale density ranged up to 0.0012/km^2 according to surveys conducted in July–December 1986–1996 (Ferguson and Barlow 2001). No sightings were made in the offshore study area during July–December surveys in 2003 (Jackson et al. 2004). However, sperm whales were seen within and near the proposed study area during surveys in April–August 2008 (Hauser et al. 2008). There are no records of sperm whales within the study area in the OBIS database (OBIS 2025). However, there are eight non-whaling records in the OBIS database for the adjacent waters, all of which occurred in August 1989 (OBIS 2025).

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

The pygmy and dwarf sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). It has been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the ETP (Wade and Gerrodette 1993). Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). However, McAlpine (2018) noted that dwarf sperm whales may be more pelagic than pygmy sperm whales. *Kogia* spp. are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas.

Vocalizations of *Kogia* spp. have been recorded in the North Pacific Ocean (Merkens et al. 2016). During surveys of the Pacific EEZ of Mexico, eight sightings of pygmy sperm whales and 29 sightings of dwarf sperm whales were made (Gerrodette and Palacios 1996). The density of dwarf sperm whales in the proposed study area was 0.021/km^2 during July–December 1986–1996 surveys in the ETP; the density of pygmy sperm whales was zero (Ferguson and Barlow 2001). Dwarf sperm whales were seen near the proposed study area during 1998–2000 (Forney et al. 2012) but not during 2003 (Jackson et al. 2004). One sighting of *Kogia* sp. was seen just west of the proposed study area during surveys in April–August 2008 (Hauser et al. 2008). There are no records of dwarf sperm whales in the OBIS database for the proposed study area, but there are five confirmed records and one unconfirmed sighting (identified as pygmy or dwarf whale) in adjacent waters for August to November (OBIS 2025). There are no confirmed records of pygmy sperm whales within or near the study area (OBIS 2025).

3.3.2.3 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). Ferguson et al. (2006) noted that in the ETP, the mean water depth where Cuvier's beaked whales were sighted was ~3.4 km. 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 whales are widely distributed in the ETP (see Ferguson et al. 2006), and MacLeod and Mitchell (2006) identified this region as a key area for beaked whales. During surveys within the Pacific EEZ of Mexico, 18 sightings of Cuvier's beaked whales were made (Gerrodette and Palacios 1996). Ferguson et al. (2006) reported 90 sightings in the ETP during 1986−1990 and 1993 surveys. During surveys conducted in the ETP during July−December 1986−1996, the density of Cuvier's beaked whales within the proposed study area was 0.003/km^2 (Ferguson and Barlow 2001). In addition, several sightings were made near the proposed study area during surveys in 1998−2000 (Forney et al. 2012) and in 2003 (Jackson et al. 2004). There are no sightings of Cuvier's beaked whales in the OBIS database for the proposed study area; however, there is one confirmed record and seven unconfirmed records in adjacent waters for September through November (OBIS 2025).

3.3.2.4 Longman's Beaked Whale (*Indopacetus pacificus*)

Longman's beaked whale, also known as the Indo-Pacific beaked whale or tropical bottlenose whale, occurs in tropical waters throughout the Indo-Pacific (Pitman 2018a). Longman's beaked whale is most often sighted in waters with temperatures ≥21°C and over or adjacent to continental slopes (Anderson et al. 2006; Jefferson et al. 2015). Longman's beaked whale is rare in the eastern Pacific (Pitman 2018a; Heckel et al. 2020). In the ETP, most tropical bottlenose whale sightings have been made between 3°N and 10°N (Pitman et al. 1999). Kinzey et al. (2001) noted one sighting of *I. pacificus* in the ETP at ~6.9°N, 135.5°W. Pitman et al. (1999) suggested that several sightings of *Hyperoodon* spp. in the ETP were actually misidentifications (e.g., Wade and Gerrodette 1993) and were, in fact, sightings of tropical bottlenose whales.

Both Ferguson and Barlow (2001) and Jackson et al. (2004) reported *I. pacificus* in the ETP. The density of tropical bottlenose whales in the proposed study area was zero based on 10 years of surveys during July−December; however, to the southwest of the study area, the density was reported as 0.004/km^2 (Ferguson and Barlow 2001). There are no sightings in the OBIS database within or near the proposed study area, but there is one record for September 1987 at 14.7°N, 101.6°W and 11 records for November 1989 at 5.3°N, 111.6°W (OBIS 2025).

3.3.2.5 Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans; it has the widest distribution throughout the world of any *Mesoplodon* species (Pitman 2018b). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). Like other beaked whales, Blainville's beaked whale is generally found in waters 200−1400 m deep

(Gannier 2000; Jefferson et al. 2015). In the ETP, Blainville's beaked whales have been sighted in offshore as well as nearshore areas of Central and South America (Pitman et al. 1987; Ferguson and Barlow 2001; Pitman and Lynn 2001). MacLeod et al. (2005) reported stranding and sighting records in the eastern Pacific ranging from 37.3°N to 41.5°S. MacLeod and Mitchell (2006) identified the ETP as a key area for beaked whales. During surveys of the EEZ of Pacific Mexico, one sighting of Blaineville's beaked whale was made (Gerrodette and Palacios 1996). Heckel et al. (2020) reported additional sightings off Mexico. However, no sightings were made within the proposed study area during July−December 1986−1996 surveys (Ferguson and Barlow 2001). There are no sightings in the OBIS database for the waters in and adjacent to the proposed study area, but there are three records for October 1998 at 6.2°N, 105.6°W (OBIS 2025).

3.3.2.6 Ginkgo-toothed Beaked Whale (*Mesoplodon ginkgodens*)

The ginkgo-toothed beaked whale is only known from stranding and capture records (Mead 1989; Jefferson et al. 2015). It is hypothesized to occupy tropical and warm temperate waters of the Indian and Pacific oceans (Pitman 2018b). Its distributional range in the North Pacific extends from Japan to the Galápagos Islands, and there are also records for the South Pacific as far south as Australia and New Zealand (Jefferson et al. 2015). The species is thought to occupy relatively cool areas in the temperate and tropical Pacific, where upwelling is known to occur, such as in the California and Peru currents and the equatorial front (Palacios 1996). Heckel et al. (2020) reported one record off Baja California. The density of unidentified *Mesoplodon* sp. in the proposed study area was 0.0027/km^2 based on July−December 1986−1996 surveys (Ferguson and Barlow 2001); some of these sightings could have potentially been gingko-toothed beaked whales. There are no records for ginkgo-toothed beaked whales in the OBIS database for the proposed study area (OBIS 2025).

3.3.2.7 Deraniyagala's Beaked Whale (*Mesoplodon hotaula*)

Deraniyagala's beaked whale is a newly recognized species of whale that has been described for the tropical Indo-Pacific, where it is thought to occur between ~15°N and ~10°S (Dalebout et al. 2014). Strandings have been reported for the Maldives, Sri Lanka, Seychelles, Kiribati, and Palmyra Atoll (Dalebout et al. 2014), and acoustic detections have been made at Palmyra Atoll and Kingman Reef in the Line Islands (Baumann-Pickering et al. 2014). It is closely related to ginkgo-toothed beaked whale, but DNA and morphological data have shown that the two are separate species (Dalebout et al. 2014). It is possible that this species could occur in the proposed study area. However, there are no records in the OBIS database for the study area (OBIS 2025).

3.3.2.8 Pygmy Beaked Whale (*Mesoplodon peruvianus*)

The pygmy beaked whale is the smallest mesoplodont (Reyes 1991). This eastern-Pacific species is thought to occur between 25°N and 15°S, from the Baja California Peninsula to Peru, foraging in mid-to-deep waters (Urbán-Ramírez and Aurioles-Gamboa 1992). However, Pitman and Lynn (2001) noted a stranding record for the species in Chile, at 29.25°S. Pitman and Lynn (2001) noted that the species may have been known previously as *M.* sp. "A". The pygmy beaked whale is believed to be widespread in the ETP and is the most frequently sighted *Mesoplodon* sp. there (Pitman 2018b); it appears to be concentrated off central Mexico (Pitman and Lynn 2001). Wade and Gerrodette (1993) reported several sightings for *M. peruvianus* as well as *M.* sp. "A" in the ETP.

During surveys of the Pacific EEZ of Mexico, 13 sightings of *Mesoplodon* sp. A were made (Gerrodette and Palacios 1996). Densities of *Mesoplodon* sp. A based on July−December 1986−1996 surveys was 0.0007/km^2 for the proposed study area (Ferguson and Barlow 2001). However, no sightings of pygmy beaked whales were made in the proposed study area during July−December 2003 (Jackson et al.

2004). There are no sightings in the OBIS database for the proposed study area, but there are two record for September 2007 at 12.5°N, 104.4°W (OBIS 2025).

3.3.2.9 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). Polacheck (1987) noted that the highest encounter rates of Risso's dolphin in the ETP were in (relatively) nearshore areas. During surveys of the EEZ of Pacific Mexico, 73 sightings of Risso's dolphins were made (Gerrodette and Palacios 1996). Densities up 0.0172/km^2 were reported for the proposed study area based on July−December 1986−1996 surveys (Ferguson and Barlow 2001). Sightings of Risso's dolphins were made also made near the study area during surveys in 1998−2000 (Forney et al. 2012) and 2003 (Jackson et al. 2004). Jefferson et al. (2014) also reported sightings within the proposed study area. Schwarz et al. (2010) reported sightings between 12°−17°N and 104°−108°W, from late August−November 2007. There are no sightings in the OBIS database for the waters in and adjacent to the proposed study area, but there are 31 sightings between 9.8°N−11.3°N and 101.8°W−102.9°W for September and October 1998−2003 (OBIS 2025).

3.3.2.10 Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994). In the Pacific, it occurs from central Japan and northern Australia to the Baja California Peninsula, Mexico, and southern Peru (Jefferson et al. 2015). It generally occurs in deep, oceanic waters, but can be found in shallower coastal waters in some regions (Jefferson et al. 2015). In the ETP, sightings of rough-toothed dolphins have been reported by Perrin and Walker (1975), Pitman and Ballance (1992), Wade and Gerrodette (1993), Kinzey et al. (1999, 2000, 2001), Ferguson and Barlow (2001), Jackson et al. (2004), and May-Collado et al. (2005).

Gerrodette and Palacios (1996) reported an abundance of 37,511 rough-toothed dolphins for the EEZ of Pacific Mexico. Based on surveys conducted during July−December 1986−1996, densities of rough-toothed dolphins in the proposed study area ranged up to 0.0362/km^2 (Ferguson and Barlow 2001). Sightings of rough-toothed dolphins were made in and near the proposed study area during surveys conducted in 1998−2000 (Forney et al. 2012), but not during 2003 (Jackson et al. 2004). Schwarz et al. (2010) also reported sightings between 12°−17°N and 104°−108°W, from late August−November 2007 (Schwarz et al. 2010). There are no records in the OBIS database for the proposed study area, but there are 97 records in adjacent waters for September through November (OBIS 2025).

3.3.2.11 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 2018). In the ETP, bottlenose dolphins tend to be more abundant close to the coasts and islands (Scott and Chivers 1990); they also seem to occur more inshore than other dolphin species (Wade and Gerrodette 1993).

During surveys of the Pacific EEZ of Mexico, 163 sightings of bottlenose dolphins were made (Gerrodette and Palacios 1996). Densities of up to 0.0118/km^2 were reported for the proposed study area based on surveys conducted during July−December 1986−1996 (Ferguson and Barlow 2001). Sightings of bottlenose dolphins were also made in and near the proposed study area during surveys in 1998−2000 (Forney et al. 2012) and 2003 (Jackson et al. 2004). Schwarz et al. (2010) also reported sightings during surveys between 12°−17°N and 104°−108°W, from late August−November 2007. Acoustic detections were reported near the proposed study area during summer/fall of 1998 and 1999 (Oswald et al. 2003). There are two records in the OBIS database for the proposed study area and 58 records in adjacent waters; records were for August through November (OBIS 2025).

3.3.2.12 Pantropical Spotted Dolphin (*Stenella attenuata*)

The pantropical spotted dolphin is one of the most abundant cetaceans and is distributed worldwide in tropical and some subtropical waters, between ~40°N and 40°S (Jefferson et al. 2015). In the ETP, this species ranges from 25ºN off the Baja California Peninsula to 17ºS, off southern Peru (Perrin and Hohn 1994). Au and Perryman (1985) noted that the pantropical spotted dolphin occurs primarily north of the Equator, off southern Mexico, and westward along 10ºN. There are two forms of pantropical spotted dolphin (Perrin 2018a): coastal (*S. a. graffmani*) and offshore (*S. a. attenuata*). Along the coast of Latin America, the coastal form typically occurs within 20 km from shore (Urbán 2008 *in* Heckel et al. 2020). There are currently three recognized stocks of spotted dolphins in the ETP: the coastal stock and two offshore stocks − the northeast stock (which is most likely to occur in the proposed study area) and the west/south stock (Wade and Gerrodette 1993; Leslie et al. 2019). However, based on more recent data, there are at least nine genetically distinct stocks of this species in coastal areas from the Baja California Peninsula south to Ecuador (Rosales and Escorza-Treviño 2005; Escorza-Treviño et al. 2005).

Much of what is known about the pantropical spotted dolphin in the ETP is related to the tuna purse-seine fishery in that area (Perrin and Hohn 1994). There was an overall stock decline of spotted dolphins from 1960−1980 because of the fishery (Allen 1985). This stock is still considered depleted and may be slow to recover due to continued chase and encirclement by the tuna fishery, which may in turn affect reproductive rates (Cramer et al. 2008; Kellar et al. 2013; Ballance et al. 2021). Gerrodette and Forcada (2005) noted that the population of offshore northeastern spotted dolphins (the stock likely to occur in the proposed study area) had not yet recovered from the earlier population declines; possible reasons for the lack of growth were attributed to unreported bycatch, effects of fishing activity on survival and reproduction, and long-term changes in the ecosystem. In 1979, the population size of spotted dolphins in the ETP was estimated at 2.9−3.3 million (Allen 1985). For 1986−1990, Wade and Gerrodette (1993) reported an estimate of 2.1 million. In 2006, the combined population estimate for the northeastern offshore, western-southern offshore, and coastal stocks in the ETP was ~1.6 million, with ~640,000 northeastern offshore dolphins (Gerrodette et al. 2008).

During surveys of the Pacific EEZ of Mexico, 251 sightings of offshore and eight sightings of coastal spotted dolphins were made (Gerrodette and Palacios 1996). Densities of offshore pantropical spotted dolphins in the proposed study area ranged up to 0.4208/km^2 based on surveys conducted during July−December 1986−1996 (Ferguson and Barlow 2001). Sightings of spotted dolphins were made in and near the proposed study area during surveys in 1998−2000 (Forney et al. 2012) and 2003 (Jackson et al. 2004). Schwarz et al. (201) reported sightings between 12°−17°N and 104°−108°W, from late August−November 2007. There are 250 records in the OBIS database for the proposed study area and ~2000 records for adjacent waters; records were reported from August through November (OBIS 2025).

3.3.2.13 Spinner Dolphin (*Stenella longirostris*)

The spinner dolphin is pantropical in distribution, including oceanic tropical and sub-tropical waters between 40ºN and 40ºS (Jefferson et al. 2015). It is generally considered a pelagic species, but it can also be found in coastal waters (Perrin 2018b). In the Pacific, Au and Perryman (1985) noted that the spinner dolphin occurs primarily north of the Equator, off southern Mexico, and westward along 10ºN; they also noted its occurrence in seasonal tropical waters south of the Galápagos Islands. In the ETP, three types of spinner dolphins have been identified and two of those are recognized as subspecies: the eastern spinner dolphin (*S.l. orientalis*), considered an offshore species, the Central American spinner (*S.l. centroamericana*; also known as the Costa Rican spinner), considered a coastal species occurring from southern Mexico to Costa Rica (Perrin 1990; Dizon et al. 1991), and the 'whitebelly' spinner is thought to be a hybrid of the eastern spinner and Gray's spinner (*S.l. longirostris*). The whitebelly spinner dolphin is common in oceanic waters of the ETP (Heckel et al. 2020).

Although there is a great deal of overlap between the ranges of eastern and whitebelly spinner dolphins, the eastern form generally occurs in the northeastern portion of the ETP, whereas the whitebelly spinner occurs in the southern portion of the ETP, ranging farther offshore (Wade and Gerrodette 1993; Reilly and Fiedler 1994). Reilly and Fiedler (1994) noted that eastern spinners are associated with waters that have high surface temperatures and chlorophyll and shallow thermoclines, whereas whitebelly spinners are associated with cooler surface temperatures, lower chlorophyll levels, and deeper thermoclines. The eastern spinner dolphins are the most likely to occur in the proposed study area (see Ferguson and Barlow 2001), as this subspecies occurs in the ETP, east of 145°W, between 24°N off the Baja California Peninsula and 10°S off Peru (Perrin 1990).

Gerrodette and Forcada (2005) noted that the population of eastern spinner dolphins had not yet recovered from the earlier population declines due to the tuna fishery, but it appears to be slowly increasing (Gerrodette et al. 2008). The population estimate for eastern spinner dolphins in 2003 was 612,662 (Gerrodette et al. 2005), and it was 1,062,879 in 2006 (Gerrodette et al. 2008). The whitebelly spinner dolphin population was estimated at 734,837 in 2006 (Gerrodette et al. 2008). Possible reasons why the eastern spinner dolphin population has been slow to recover include under-reported bycatch, effects of fishing activity on survival and reproduction, and long-term changes in the ecosystem (Gerrodette and Forcada 2005). The continued chase and encirclement by the tuna fishery may be affecting the reproductive rates of the eastern spinner dolphin (Cramer et al. 2008).

During surveys of the Pacific EEZ of Mexico, 163 sightings of eastern spinner dolphin were made (Gerrodette and Palacios 1996). Based on surveys conducted during July−December 1986−1996, densities of eastern spinner dolphin ranged up to was 0.2191/km^2 in the proposed study area; densities for the whitebelly spinner dolphin ranged up to 0.0581/km^2 (Ferguson and Barlow 2001). During 1998−2000 and 2003 surveys, sightings of eastern spinner dolphins were made in the proposed study area; whitebelly spinner dolphins were sighted near the proposed study area (Jackson et al. 2004; Forney et al. 2012). Schwarz et al. (2010) reported sightings of spinner dolphins during surveys between 12°−17°N and 104°−108°W, from late August−November 2007. One individual was seen in the proposed study area during surveys in April−August 2008 (Hauser et al. 2008). There are 91 records in the OBIS database for the proposed study area and ~2000 records in adjacent waters; records were reported from August through November (OBIS 2025).

3.3.2.14 Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994a; Jefferson et al. 2015). It is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). It is common in the ETP up to 25°N (Perrin et al. 1985). In the ETP, striped dolphin distribution is associated with cool, upwelling areas along the Equator (Au and Perryman 1985).

During surveys of the EEZ of Pacific Mexico, 160 sightings of striped dolphins were made (Gerrodette and Palacios 1996). Polacheck (1987) noted that the highest encounter rates in the ETP were off western Mexico. Based on surveys conducted during July−December 1986−1996, Ferguson and Barlow (2001) reported a density of up to 0.1417/km^2 for the proposed study area. Sightings of striped dolphins were also made in and near the proposed study area during surveys in 1998−2000 (Forney et al. 2012) and 2003 (Jackson et al. 2004). Schwarz et al. (2010) reported sightings during surveys between 12°−17°N and 104°−108°W, from late August−November 2007. There are 77 records in the OBIS database for the proposed study area and 863 records in adjacent waters; records were reported for August through November (OBIS 2025).

3.3.2.15 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 (2018c), 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). However, Jefferson et al. (2024) consider the long-beaked form that occurs in the ETP as a separate species (*D. bairdii*). The long-beaked form generally prefers shallower water (Perrin 2018c), typically occurring within 180 km from shore (Jefferson et al. 2015). The common dolphin is very abundant in the ETP (Perrin 2018c) and its distribution there is associated with cool, upwelling areas along the Equator and off the Baja California Peninsula, Central America, and Peru (Au and Perryman 1985; Reilly 1990; Reilly and Fiedler 1994; Ballance et al. 2006). Reilly (1990) noted no seasonal changes in common dolphin distribution, although Reilly and Fiedler (1994) observed interannual changes in distribution that were likely attributable to El Niño events.

Only the short-beaked form is expected to occur within the proposed study area. During surveys of the Pacific EEZ of Mexico, 92 sightings of short-beaked and 74 sightings of long-beaked common dolphins were made. The density of both the short- and long-beaked forms of common dolphin were reported as zero for the proposed study area based on July−December 1986−1996 surveys (Ferguson and Barlow 2001). However, sightings of the short-beaked form of common dolphins were also made in the proposed study area during surveys in 1998−2000 (Forney et al. 2012) and 2003 (Jackson et al. 2004). Schwarz et al. (2010) reported sightings between 12°−17°N and 104°−108°W, from late August−November 2007. Common dolphins were seen south of the proposed study area during surveys in April−August 2008 (Hauser et al. 2008). There are no records of short-beaked common dolphins in the OBIS database for the proposed study area, but there are four sightings in adjacent waters during November; there are no records for the long-beaked form (OBIS 2025).

3.3.2.16 Fraser’s Dolphin (*Lagenodelphis hosei*)

Fraser’s dolphin is a tropical oceanic species distributed between 30°N and 30°S that generally inhabits deep oceanic water (Dolar 2018). It occurs rarely in temperate regions and then only in relation to temporary oceanographic anomalies such as El Niño events (Perrin et al. 1994b). The species occurs throughout the ETP (Perrin et al. 1973, 1994b) and has been sighted there at least 15 km from shore in waters 1500−2500 m deep (Dolar 2018). Wade and Gerrodette (1993) showed a mainly equatorial distribution in the ETP and estimated its abundance in the area at 289,300 individuals. Pitman and Ballance (1992) also noted its occurrence in the ETP. González et al. (2008) reported the presence of Fraser’s dolphin off the west coast of Mexico between 18° and 23°N, as well as the possible presence south of 18°N. The density of Fraser's dolphin in the proposed study area was zero based on 1986−1996 surveys, but the density to the southwest was 0.0379/km^2 (Ferguson and Barlow 2001). There are no sightings for the waters in or near the proposed study area in the OBIS database (OBIS 2025).

3.3.2.17 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, such as California and Hawaii (Olson 2018). Pilot whales occur on the shelf break, over the slope, and in areas with prominent topographic features (Olson 2018). Based on genetic data, Van Cise et al. (2016) suggested that two types of short-finned pilot whales occur in the Pacific − one in the western and central Pacific, and one in the Eastern Pacific; they hypothesized that prey distribution rather than sea surface temperature determine their latitudinal ranges.

Pilot whales have a wide distribution throughout the ETP, but are most abundant in colder waters where upwelling occurs (Wade and Gerrodette 1993). Polacheck (1987) noted that encounter rates for pilot whales in the ETP were highest inshore, and that offshore concentrations may also occur, but at lower densities (Polacheck 1987). During surveys of the EEZ of Pacific Mexico, 15 sightings of short-finned pilot whales were made (Gerrodette and Palacios 1996). Densities in the proposed study area ranged up to 0.01/km^2 based on 1986−1996 surveys (Ferguson and Barlow 2001). Sightings within or near the proposed study area were also made during July−December surveys in 1998−2000 (Forney et al. 2012), during July−December 2003 (Jackson et al. 2004), and April−August 2008 (Hauser et al. 2008). There are no records in the OBIS database for the proposed study area, but there are 256 records for adjacent waters during August through November (OBIS 2025).

3.3.2.18 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 tend to be more common in nearshore areas and at higher latitudes (Jefferson et al. 2015). Nonetheless, they can be found throughout the ETP (Pitman and Ballance 1992; Wade and Gerrodette 1993), but are most densely distributed near the coast from 35ºN to 5ºS (Dahlheim et al. 1982). Dahlheim et al. (1982) noted the occurrence of a cluster of sightings at two offshore locations in the ETP. One location was bounded by 7−14ºN and 127−139ºW, and the other was within a band between the Equator and 5ºN and from the Galápagos Islands to 115ºW.

During surveys of the EEZ of Pacific Mexico, 15 sightings of killer whales were made (Gerrodette and Palacios 1996). Densities of killer whales in the proposed study area based on 1986−1996 surveys ranged up to 0.0007/km^2 (Ferguson and Barlow 2001). One sighting was made west of the proposed study area during July−December surveys in 2003 (Jackson et al. 2004). There are no records in the OBIS database for the proposed study area, but there are 12 records in adjacent waters; records were reported for August through September (OBIS 2025).

3.3.2.19 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 rare to uncommon throughout its range (Baird 2018b). The false killer whale generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow water (Jefferson et al. 2015). In the North Pacific, it occurs from Japan and southern California, southward and across the Pacific, including Hawaii.

Wade and Gerrodette (1993) noted the occurrence of false killer whales especially along the Equator. False killer whales in the ETP are usually seen far offshore (Wade and Gerrodette 1983). During surveys of the EEZ of Pacific Mexico, during July−December 1986−1990, 1992 and 1993, three sightings of false killer whales were made (Gerrodette and Palacios 1996). Douglas et al. (2023) reported 24 sightings totaling 103 false killer whales in the Pacific waters of Mexico from 1991 to 2022. The density of this species in the proposed study area based on 1986−1996 surveys was zero, although adjacent areas had densities up to 0.0043/km^2 (Ferguson and Barlow 2001). There are no sightings in the OBIS database for the waters in and adjacent to the proposed study area (OBIS 2025).

3.3.2.20 Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical waters (Baird 2018c), generally not ranging south of 35°S (Jefferson et al. 2015). In the North Pacific, it occurs from Japan and to the Baja California Peninsula, southward and across the Pacific Ocean, including Hawaii. In warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. Pygmy killer whales are known to occur in the ETP (e.g., Van Waerebeek and Reyes 1988; Pitman and Ballance 1992; Wade and Gerrodette 1993; Gerrodette and Palacios 1996). During surveys of the EEZ of Pacific Mexico, during July−December 1986−1990, 1992 and 1993, 13 sightings of pygmy killer whales were made (Gerrodette and Palacios 1996). Densities of this species in the proposed study area, based on 1986−1996 surveys, ranged up to 0.0154/km^2 (Ferguson and Barlow 2001). Sightings were also made during surveys between 12°−17°N and 104°−108°W, from late August−November 2007 (Schwarz et al. 2010). A group of three pygmy killer whales was seen in the proposed study area during surveys in April−August 2008 (Hauser et al. 2008). There are no records in the OBIS database for the proposed study area, but there are five records in adjacent waters during October 1998 (OBIS 2025).

3.3.2.21 Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is an oceanic species found worldwide in tropical and subtropical waters from ~40°N to 35°S (Jefferson et al. 2015). It is commonly seen in mixed groups with other cetaceans (Jefferson and Barros 1997). It occurs most often in deep offshore waters and occasionally in nearshore areas where deep oceanic waters occur near the coast (Perryman and Danil 2018). In the North Pacific, it is distributed south of central Japan and southern California, as well as across the Pacific, including Hawaii. Au and Perryman (1985) and Perryman et al. (1994) reported that the melon-headed whale occurs primarily in equatorial waters, although Wade and Gerrodette (1993) noted its occurrence in non-equatorial waters. Based on surveys conducted during 1986−1996, the density of this species in the proposed study area ranged up to 0.0007/km^2 (Ferguson and Barlow 2001). There are no sightings in the OBIS database within the proposed study area, but there were 327 records for September 1989 and October 2003 between 11.3°−12.8°N and 102.9°−103.0°W (OBIS 2025).

3.4 Sea Turtles

Five sea turtle species could occur in the proposed study area (Table 5). Under the ESA, the leatherback, hawksbill, and North Pacific Ocean DPS of the loggerhead turtle are listed as ***endangered***, and the olive ridley population on the Pacific coast of Mexico is listed as ***endangered*** whereas other populations are listed as ***threatened***; the East Pacific DPS of the green turtle is also listed as ***threatened***.

TABLE 5. The habitat, occurrence, and conservation status of sea turtles that could occur in or near the proposed study area in the Eastern Tropical Pacific.

Species	Habitat	Occurrence in Study Area	ESA[1]	IUCN[2]	CITES[3]
Leatherback sea turtle	Beaches (nesting females); oceanic (juveniles and foraging adults)	Uncommon	EN	VU	I
Loggerhead sea turtle *North Pacific Ocean DPS*	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults); oceanic (migration)	Uncommon	T	VU	I
Green sea turtle *East Pacific DPS*	Beaches (nesting females); oceanic (juveniles and migrating adults); coastal (foraging adults)	Uncommon	T	EN	I
Hawksbill sea turtle	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults)	Uncommon	EN	CR	I
Olive ridley sea turtle	Beaches (nesting females); coastal/oceanic (juveniles); coastal (foraging adults)	Common	EN	VU	I

[1] U.S. Endangered Species Act (ESA): EN = Endangered; T = Threatened.

[2] International Union for the Conservation of Nature Red List of Threatened Species, version 2025-1 (IUCN 2025): CR = Critically Endangered; E = Endangered; VU = Vulnerable.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2025): Appendix I = Threatened with extinction.

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 Southern California and the Galápagos Ridge are discussed in § 3.4.2.3 and 3.4.2.5 of the PEIS, respectively. The rest of this section deals specifically with the distribution of sea turtles within the proposed study area in the ETP.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback turtle is the largest and most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). It ranges far from its tropical and subtropical breeding grounds to feed (Plotkin 2003). During the non-breeding season, leatherback turtles range far from their tropical and subtropical nesting grounds to feed (Plotkin 2003). Nesting beaches are generally 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).

Leatherback turtles in the Pacific are divided into two genetically distinct stocks: the East Pacific stock or DPS nests at rookeries along the west coast of the Americas from Mexico to Ecuador; and the West Pacific stock or DPS nests at rookeries in Papua, Indonesia; Papua New Guinea; and the Solomon Islands (Dutton 2006; Wallace and Hutchinson 2016; NMFS and USFWS 2020). 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); however, individuals from the West Pacific DPS typically do not occur within the proposed study area.

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.

There have been significant declines and some extirpations of nesting populations in the Pacific (Spotila et al. 2000; Dutton et al. 2007). 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). There were also large declines at Mexican beaches (Benson et al. 2015), with 70,000 nesting females in 1982 plummeting to <250 in 1998 (Spotila et al. 2000). Sarti et al. (1994 *in* NMFS and USFWS 2020) noted the declines were due to egg harvesting, killing of adult female, and changes in reproductive biology. Currently, it is estimated that there are 755 nesting females in the East Pacific DPS and 1277 breeding females in the West Pacific DPS (NMFS and USFWS 2020).

In the eastern Pacific, leatherbacks nest primarily along the coast of Mexico, Costa Rica, and Nicaragua, from September−March. Telemetry data has shown that most nesting females moved south (through the proposed study area) from Mexiquillo towards the Southeast Pacific Ocean to forage (Eckert and Sarti 1997). The largest nesting aggregations are found in Mexico, where nesting occurs in 11 states (Sarti 2002 *in* NMFS and USFWS 2020). The majority of turtles (70−75%) nest at Playa Mexiquillo (Michoacán); Playa de Tierra Colorada (Guerrero); and Cahuitán, Chacahua, and Barra de la Cruz in Oaxaca (Gaona Pineda and Barragán Rocha 2016 *in* NMFS and USFWS 2020). The mean clutch frequency is 5.5 nests per season; clutch size averages 62−64 eggs (Sarti Martínez et al. 2007; NMFS and USFWS 2020). The proposed study area is expected to have a low probability of encounter (Lopez et al. 2024) and low use by leatherbacks (Roe et al. 2014). However, some sightings have been made within and near the study area (Pitman 1990; Smultea and Holst 2003; Roe et al. 2014; Lopez et al. 2024). There are no records in the OBIS database for the waters in or adjacent to the proposed study area (OBIS 2025).

3.4.2 Green Turtle (*Chelonia mydas*)

The green 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 (Seminoff et al. 2015). Each female has an average of 3.1 nests/year at Michoacán (Seminoff et al. 2015).

Nesting occurs in Michoacán, Mexico, from August−January, with a peak in October−November (Alvarado and Figueroa 1995). Green sea turtles also nest in Central America (SWOT 2011). Sightings of possible green sea turtles were seen within the proposed study area during surveys in July 2003 (Smultea and Holst 2003) and in April−August 2008 (Hauser et al. 2008). There are no records in the OBIS database for the waters in and adjacent to the proposed study area (OBIS 2025).

3.4.3 Hawksbill Sea Turtle (*Eretmochelys imbricata*)

Hawksbill turtles are the most tropical of all sea turtles. They occur in the waters of at least 82 nations and nest on the beaches of ~60 of those (Spotila 2004). The hawksbill is a solitary nester, and population trends or estimates are difficult to determine. However, a minimum of 20,000−26,000 females are thought to nest annually (Spotila 2004); since females nest once every three years, the total adult female population is estimated at 60,000−78,000 females (Spotila 2004).

Nesting is confined to areas where water temperature is 25º−35ºC and occurs in the spring and summer. Hawksbill turtles nest on low and high-energy beaches, often sharing high-energy locations with green turtles. Hawksbill turtles most commonly perform short-distance movements between nesting beaches and offshore feeding banks, although long-distance movements are also known. Post-hatchlings are believed to be pelagic, taking shelter in weed lines around convergence zones, and they re-enter coastal waters once attaining a length of ~20−25 cm. Hawksbill turtles are observed in shallow waters with seagrass or algal meadows, and are most common where reef formations are present. They live in clear, littoral waters of mainland and island shelves.

No major nesting sites for hawksbill turtles occur on the Pacific coast of Mexico or Central America, although a few hawksbills are known to nest at the La Flor National Wildlife Refuge in Nicaragua (SWOT 2008) and at Punta Banco, Caña Blanca, and Playa Caletas in Costa Rica (Gaos et al. 2006; SWOT 2008). Hawksbill turtles also reportedly nested at Barra de Santiago in El Salvador decades ago, but now only occur there sporadically (Hasbún and Vásquez 1999). Chiriqui Beach in western Panama was once famous for its huge nesting colony of hawksbill turtles (Spotila 2004), but was essentially abandoned by 1990 due to overharvesting. Efforts to restore the beach have progressed and in recent years several hundred nests have been observed (Spotila 2004). The nesting season of the hawksbill turtle is approximately six months in duration; nesting generally occurs from June−December. For the ETP, Pitman (1990) reported three sightings off Mexico and one sighting off Central America. There are no sightings in the OBIS database for the proposed study area, but there are three records in adjacent waters from August to November (OBIS 2025).

3.4.4 Olive Ridley Sea Turtle (*Lepidochelys olivacea*)

Olive ridley turtles are pantropical, occurring in waters with temperatures of at least 20ºC or 68ºF; they have a large range in the Pacific, Indian, and South Atlantic oceans. They travel between breeding and feeding grounds in continental coastal waters and are rare around oceanic islands. The worldwide population of olive ridley turtles is estimated at 2 million nesting females (Spotila 2004).

Most olive ridleys nest synchronously in huge colonies called “arribadas”, with several thousand females nesting at the same time; others nest alone, out of sequence with the arribada (Kalb and Owens 1994). The arribadas usually last from three to seven nights (Aprill 1994). Satellite telemetry of nesting cohorts (small groups of females that arrive at the nesting beach at the same time) indicates that an arribada is not a social event, but rather an aggregation of turtles reacting in a similar way to as-yet-unknown common stimuli (Plotkin et al. 1991). Most females lay two clutches of eggs with an inter-nesting period of 1−2 months (Plotkin et al. 1994a). Radio-tracking studies have shown that females that nested in arribadas remain within 5 km of the beach most of the time during the inter-nesting period (Kalb and Owens 1994).

Reasons for the timing of, and even the occurrence of, arribadas are not clear. Chaves et al. (1994) reported that arribadas follow a lunar cycle, with nesting during the new moon, in the darkest nights, starting during the high tide. At Playa La Flor, Nicaragua, during August 1993−January 1994, six arribadas occurred, arriving every 23−30 days without relation to the moon phase (Ruiz 1994). During the same period, turtles emerged during the day and night in September and October, but only at night in the other months (Cerna et al. 1996). In some cases, an arribada will skip a month. In a study of inter-nesting behavior at Nancite, Costa Rica, in 1990 and 1991, Plotkin et al. (1995) noted that there were arribadas in September and November, but not in October, contrary to expectations. In 1991, there were arribadas in each month from September−December. Hatching success of olive ridley nests in arribada beaches is low. Especially when the arribadas are large, many of the eggs are destroyed by the turtles themselves (Alvarado 1990).

Although most mating is generally assumed to occur near nesting beaches, Pitman (1990) observed olive ridleys mating at sea in the ETP, as far as 1850 km from the nearest mainland, during every month of the year except March and December. However, there was a sharp peak in offshore mating activity during August and September, corresponding with peak breeding activity in mainland populations. Fifty of 324 turtles observed during NMFS/SWFC dolphin surveys during July−December 1998 and 1999 were involved in mating (Kopitsky et al. 2002). Aggregations of turtles[2], sometimes >100 individuals, have been observed as far offshore as 120°W, ~3000 km from shore (Arenas and Hall 1991). Arribadas take place in Oaxaca at Ixtapilla, Santuario Playa de Escobilla (the largest), and Morro Ayuta; the number of clutches at each of these sites falls within the range of 100,000 to 1 million (SWOT 2021).

Outside of the breeding season, the turtles disperse, but little is known of their behavior. Neither males nor females migrate to one specific foraging area, but exhibit a nomadic movement pattern and occupy a series of feeding areas in oceanic waters (Plotkin et al. 1994a,b, 2010). Typically, turtles will feed during the morning and bask on the water's surface in the afternoon. Olive ridleys are primarily carnivorous, feeding on crabs, jellyfish, and fish eggs. They feed on algae if no other food is available. They are generally thought to be surface feeders, but have been caught in trawls at depths of 80−110 m (NMFS and USFWS 1998).

The Pacific population migrates from their nesting grounds in Mexico and Central America to the North Pacific (NMFS 2002). The post-nesting migration routes of olive ridleys tracked via satellite from Costa Rica traversed thousands of kilometers of deep oceanic waters ranging from Mexico to Peru, and more than 3000 km out into the central Pacific (Plotkin et al. 1994b, 2010). The olive ridley is considered the most abundant sea turtle in the open ocean waters of the ETP (Pitman 1990), and the population there is estimated to number 1.39 million (Eguchi et al. 2007). Pitman (1990) compiled sightings of hardshell turtles (the vast majority were olive ridleys) in the ETP for a period of 15 years; in the vicinity of the proposed study area, densities ranged up to 75 turtles per 2° square. Eguchi et al. (2007) estimated at-sea densities of olive ridleys in the ETP from surveys conducted in summer/autumn from 1992−2006; in the northern stratum, which includes the proposed study area, olive ridley densities ranged from ~0.02−0.16 turtles/km^2. Satellite-tracked olive ridleys have been recorded in the proposed study area (Figgener et al. 2022), and Hauser et al. (2008) also reported olive ridley sea turtles within the proposed study area during surveys in April−August 2008. Montero et al. (2016) reported bycatch of olive ridleys in the purse-seine fishery within the proposed study area. There are no records in the OBIS database for

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[2] Of sea turtles observed at sea, 75% were olive ridleys.

the proposed study area, but there are five records in adjacent waters for September to November (OBIS 2025).

3.4.5 Loggerhead Sea Turtle (*Carretta caretta*)

The loggerhead turtle is a widely distributed species occurring in coastal tropical and subtropical waters around the world. The global population is estimated at 43,320−44,560 nesting females (Spotila 2004). Loggerhead turtles (juveniles and adults) are suspected to take long migrations using warm water currents such as the Gulf Stream that bring them far from their breeding grounds. Loggerheads may be seen in the open seas during these migrations and may actually remain in pelagic existence for many years (e.g., for up to 12 years in the North Atlantic Gyre). Loggerheads prefer to feed in coastal bays and estuaries, and in the shallow waters along the continental shelves of the Atlantic, Pacific, and Indian oceans. Adult loggerheads feed on a variety of benthic fauna like conchs, crabs, shrimp, sea urchins, sponges, and fish. During the migration through the open sea, they eat jellyfish, pteropods, floating mollusks, floating egg clusters, flying fish, and squid.

Major nesting areas are located in the southeastern U.S., Yucatán Peninsula of Mexico, Columbia, Cuba, South Africa, eastern Australia, and Japan (Márquez 1990). During or shortly after the March−August breeding season, females disperse to distant feeding grounds via poorly delineated migration routes. While the loggerhead turtle is found in eastern Pacific waters, nesting in the Pacific is largely restricted to Japan and eastern Australia (Spotila 2004). The size structure of loggerheads in coastal and nearshore waters of the eastern and western Pacific suggest that Pacific loggerheads have a pelagic stage similar to that in the Atlantic (NMFS 2002); loggerheads spend the first 2−6 years of their lives at sea. Large aggregations (thousands) of mainly juveniles and subadult loggerheads are found off the southwestern coast of Baja California (Nichols et al. 2000). Pitman (1990) also reported sightings off Baja California. When they mature, they return to breed at the western Pacific beaches where they were hatched. Migratory routes across the Pacific appear to occur north of the proposed study area (SWOT 2018; Nichols et al. 2000). Telemetry data did not show any records of loggerheads within the proposed study area (SWOT 2018). There are no records in the OBIS database for the waters adjacent to the proposed study area (OBIS 2025).

3.5 Seabirds

One ESA-listed seabird species, the ***threatened*** Galápagos petrel, could occur in the proposed study area in the ETP. This species is listed as critically endangered on the IUCN Red List of Threatened Species (IUCN 2025).

3.5.1 Galápagos Petrel (*Pterodroma phaeopygia*)

The population of the Galápagos petrel has been reduced to an estimated 10,000−19,999 individuals (BirdLife International 2018). This decline is attributed to introduced predators and habitat destruction, the latter caused in part by introduced plant species and by herbivory and trampling from introduced livestock (Carboneras et al. 2020). Current threats include collisions with powerlines and towers, long-line fisheries, and climate change (BirdLife International 2018; Carboneras et al. 2020).

The Galápagos petrel nests in humid highlands on several of the islands of the Galápagos archipelago (Brooke 2004). The timing of the breeding season is variable and is occasionally drawn out (Carboneras et al. 2020). Egg laying usually takes place from May to October, but occasionally from November to March. This species is colonial, with nests in burrows excavated amongst dense vegetation (BirdLife International 2018). The single egg is incubated for 46 to 53 days and the nestling fledges 98 to 112 days after hatching (Carboneras et al. 2020). At sea, the Galápagos petrel occurs in the ETP east of 120°W and primarily between 20°N and 20°S (Bartle et al. 1993; Spear et al. 1995). During the breeding season it is found primarily within 500 km of the colonies (Carboneras et al. 2020). The Galápagos petrel could be encountered in small numbers in the proposed study area.

3.6 Fish of Conservation Concern

Three ESA-listed fish species could occur in the proposed study area in the ETP: the ***threatened*** oceanic whitetip shark and giant manta ray, and the ***endangered*** Eastern Pacific DPS of scalloped hammerhead shark (Table 6); these species are described below. No marine invertebrate species listed under the ESA occur within or near the proposed study area. There are currently no marine fish or invertebrate species proposed for listing under the ESA. However, the tope shark (*Galeorhinus galeus*) and smalltail shark (*Carcharhinus porosus*) are candidate species for listing, but are unlikely to occur in the deep offshore study area; thus, these two species are not discussed further.

3.6.1 Scalloped Hammerhead Shark (*Sphyrna lewini)*

The scalloped hammerhead shark inhabits warm temperate and tropical waters (Maguire et al. 2006; Miller et al. 2014). It occurs in coastal and estuarine waters, but also inhabits open water over continental and insular shelves, as well as deeper waters, with depths up to 1000 m (Miller et al. 2014). Reproduction occurs annually, with a gestation time of 9−12 months (Florida Museum 2025). Females move inshore to give birth to litters of 1–41 pups (Miller et al. 2014). The scalloped hammerhead shark is very mobile and partly migratory (Maguire et al. 2006), traveling distances up to 1941 km between aggregations of food sources (Bessudo et al. 2011), eventually returning to its original habitat, displaying site fidelity (Miller et al. 2014). Juveniles and adults can be solitary or travel in pairs; they also school in productive regions, such as over seamounts or near islands (Miller et al. 2014).

TABLE 6. The habitat and conservation status of ESA-listed fish species that could occur in or near the proposed study area in the Eastern Tropical Pacific.

Species	Habitat	ESA[1]	IUCN[2]	CITES[3]
Scalloped Hammerhead Shark	Coastal, shelf, pelagic; partly migratory	EN	CR	II
Giant Manta Ray	Coastal-pelagic; migratory; deep-diving	T	EN	II
Oceanic Whitetip Shark	Pelagic; migratory	T	CR	II

NL = Not listed/not listed in Mexico.

[1] U.S. Endangered Species Act (ESA): EN = Endangered, T = Threatened.

[2] International Union for the Conservation of Nature Red List of Threatened Species, version 2025-1 (IUCN 2025): CR = Critically Endangered, E = Endangered, VU = Vulnerable.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2025): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.

3.6.2 Oceanic White Tip Shark (*Carcharhinus longimanus)*

The oceanic white tip shark is an offshore pelagic species inhabiting surficial waters in the open ocean, occurring worldwide typically between 20ºN and 20ºS but also at higher latitudes during the summer months (Lessa et al. 1999). This species spends most of its time in waters <200 m but has been found down to 1082 m (Howey-Jordan et al. 2013). Oceanic whitetip sharks are aggressive and persistent and prey on bony fishes such as tunas, barracuda, white marlin, dolphinfish, lancetfish, oarfish, threadfish and swordfish, along with threadfins, stingrays, sea turtles, seabirds, gastropods, squid, crustaceans, and mammalian carrion (NOAA 2025a). Oceanic whitetip sharks can reach a maximum size of 395 cm (Lessa et al. 1999) and can live up to 18 years (D'Alberto et al. 2016).

3.6.3 Giant Manta Ray (*Mobula birostris)*

Giant manta rays are migratory and cold-water tolerant, with highly fragmented populations sparsely distributed in tropical, subtropical, and temperate waters of the world (NOAA 2025b) in water depths up to 1000 m deep (Marshall et al. 2008). Giant manta rays are the largest living ray in the world, reaching a disc width of 7 m (Marshall et al. 2008) and weighing >1300 kg (Bigelow and Schroeder 1953). Giant manta rays tend to be solitary (DoW 2015); however, aggregations can occur in predictable foraging grounds (NOAA 2025b). This species filter-feeds virtually exclusively on plankton (DoW 2015). Female maturity is reached at 8−10 years, and they can live up to 40 years (Marshall et al. 2008). Regional population sizes are small and have generally declined in known areas except where specifically protected (Miller and Klimovich 2017).

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$_{\text{rms}}$ 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 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 2024). 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; Zeddies et al. 2024) and may become less harmful over distance from the source (Hastie et al. 2019).

Temporary Threshold Shift (TTS) is not considered an injury as it is a temporary impairment of hearing (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, based on the information provided below, 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 (e.g., Richardson et al. 1995; Southall et al. 2021). 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 (see summaries below; Richardson et al. 1995; Southall et al. 2021). 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 (the portion of time the array is actively operating), 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 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); reverberation can presumably reduce 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. (2023) reported masking release at various frequencies in harbor seals exposed to noise with fluctuating amplitude; that is, masking was reduced when the noise had 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, 2023; 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. 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 northeastern 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 $\mu\text{Pa}^2 \cdot \text{s}$ (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 $\mu\text{Pa}^2 \cdot \text{s}$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000). Dunlop et al. (2020) found that humpback whales reduce their social interactions at greater distances and lower received levels than regulated by current mitigation practices.

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994−2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015; 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 $\text{CSEL}_{\text{10-min}}$ (SEL_{cum} over a 10-min period) of ~94 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$, decreased at $\text{CSEL}_{\text{10-min}}$ >127 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$, and whales were nearly silent at $\text{CSEL}_{\text{10-min}}$ >160 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$. Thode et al. (2020) reported similar changes in bowhead whale vocalizations when data were analyzed for the period 2008−2014. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 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; 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 America 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 America 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 America 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 America 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 America 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 $\mu Pa_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2−3 s intervals at ranges of 420−690 m and levels of 135−147 dB $\mu Pa^2 \cdot s$. 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) suggested 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. 2024a).

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*.—**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, 2019; 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; von Benda-Beckham et al. 2024). von Benda-Beckmann et al. (2022) suggested using kurtosis-corrected SELs to predict threshold shifts. 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 an $\mathrm{SEL_{cum}}$ of up to ~195 dB re 1 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$ (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 $\mu\mathrm{Pa}^2 \cdot \mathrm{s}$ 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. 2013c). 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 an unweighted $\mathrm{SEL_{cum}}$ 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. (2024b) 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 et al. 2007, 2008).

The noise exposure criteria for marine mammals that were released by NMFS (2016b, 2018) 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, 2018), 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 ($\mathrm{SEL_{cum}}$ over 24 hours) and Peak $\mathrm{SPL_{flat}}$. Onset of PTS is assumed to be 15 dB higher when considering $\mathrm{SEL_{cum}}$ and 6 dB higher when considering $\mathrm{SPL_{flat}}$. 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).

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 harbor 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. (NOAA 2025c). In a hearing to examine the Bureau of Ocean Energy Management's 2017−2022 OCS Oil and Gas Leasing Program (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 America, and the greater activity of oil and gas exploration in the Gulf of America. 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.

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). Studies of freshwater turtles have also shown that exposure to underwater sounds can cause TTS in turtles. Based on TTS from exposure to continuous broad-band in-air sound, Mannes et al. (2024) surmised that a freshwater turtle, the red-eared slider (*Trachemys scripta elegans*), would likely exhibit TTS when exposed to SEL of 160 dB re 1 $\mu Pa^2 \cdot s$ for an underwater sound. In fact, when Salas et al. (2023) used auditory evoked potentials measured at 400 Hz, they found a TTS in the red-eared slider when exposed to underwater noise (50−1000 Hz) at SELs varying from 155 to 193 dB re 1 $\mu Pa^2 \cdot s$. Shifts of up to 40 dB were observed; shift magnitude was positively related to exposure duration, amplitude, and SEL. Recovery rates from TTS varied from less than 1 h to greater than 2 days after exposure; recovery rates were usually greater after TTS of higher magnitude. In a later study on the eastern painted turtle (*Chrysemys picta picta*), Salas et al. (2024) found that this species experienced a TTS when exposed to noise (50−1000 Hz) at SELs ranging from 151 to 171 dB re 1 $\mu Pa^2 \cdot s$. TTS occurred in all individuals at both 400 Hz and 600 Hz, with shifts ranging from 6.1 to 41.4 dB; greater shifts were recorded at 600 Hz than at 400 Hz. The patterns of TTS growth and recovery were similar to that in the red-eared slider.

These studies suggest 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 2017a). 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 *Langseth* 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 EM 122 MBES and Knudsen Chirp 3260 SBP would be operated from the source vessel during the proposed surveys. Information about this equipment was provided in § 2.2.3.1 of the

PEIS. A review of the expected potential effects (or lack thereof) of MBESs, SBPs, and pingers on marine mammals 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 R/V *Maurice Ewing* (Malakoff 2002, Cox et al. 2006 *in* PEIS:3-136), which used a similar MBES system. As noted in the PEIS, however, “The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence” (Hogarth 2002, Yoder 2002 *in* PEIS:3-190).

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on R/V *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for $\mathrm{SEL}_{\mathrm{cum}}$ 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. 2024a). 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 *Langseth* could affect marine animals in the proposed study area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. During seismic operations, R/V *Langseth* would be traveling at ~4.5 kt (8.3 km/h). Typical cruising speed during transit to and from port is 10−13 kt (~20−24 km/h); vessel speed is reduced to 10 kt or less when mother/calf pairs, pods, or large assemblages of cetaceans are observed near a vessel.

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) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015, 2018; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2017; 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. (2024) 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; Radtke et al. 2023; Brown et al. 2024).

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 study 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 sea floor. A free-swimming green sea turtle fitted with a data logger, camera, and a hydrophone reacted to increasing ship noise when travelling; it exhibited increasing amounts of vigilance (visual scanning, i.e., extending the neck, raising the head and moving it from side to side) (Parra Díaz et al. 2024). However, when at rest on the seabed, the turtle did not alter its scanning behavior in response to increasing noise levels.

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. At least 11 cetacean species are known to be hit by ships, with fin whales being most frequently struck, but right, humpback, sperm, and gray whales are also regularly reported in collisions (Laist et al. 2001). There are less frequent records of collisions with blue, sei, and minke whales (Laist et al. 2001). The rate of collision mortality varies by species (Garrison et al. 2025), but can also vary by age class due to age-specific behavior, with juvenile whales representing a higher proportion of strikes (Stepanuk et al. 2021).

Reducing ship speed has been shown to be an effective mitigation measure to reduce mortality and/or avoid ship strikes (Wiley et al. 2016; Currie et al. 2017; Garrison et al. 2025). Garrison et al. (2025) found that large vessels (≥20−107 m) had a predicted lethality for large whales of 38% at 5 knots, 54% at 10 knots, and 69% at 15 knots. 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 with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing*.

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 *Langseth*. 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 R/V *Langseth*, which has been conducting seismic surveys since 2008, or for its predecessor, R/V *Maurice Ewing*, during 2003−2007. 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 activity. These measures include the following: ramp ups; two dedicated observers maintaining a visual watch during all daytime airgun operations; two PSOs for 30 min before and during ramp ups; PAM during the day and night to complement visual monitoring (unless the system and back-up systems are damaged during operations); 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. These mitigation measures are described in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § II (2.1.3). The fact that the airgun array, because of its design, would 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 activity without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activity and would be implemented under the Proposed Action.

4.1.1.5 Potential Numbers of Takes for Marine Mammals and Sea Turtle Exposures

All marine mammals takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for marine mammals. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels for the high-energy surveys, and we present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys (additional details are provided in Appendix B). The estimates are based on consideration of the number of marine mammals that could be harassed by sound (Level B takes) produced by the seismic surveys in the ETP.

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 density of animals in the area. This method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting representative seismic tracklines that could be surveyed on one day (~200 km at 4.5 kt) that have the same or similar proportion of water depths to be surveyed as during the entire survey (in this case, >1000 m deep). The area expected to be ensonified on a single day was determined by "drawing" the applicable Level B and PTS threshold buffers around the representative lines for the racetrack surveys, as well as around the 210-km long seismic transect. The ensonified areas, increased by 25%, were then multiplied by the number of seismic days (18 days for the racetrack surveys; 2 days for the single 210-km long seismic transect line). This is equivalent to adding an additional 25% to the proposed line km (Appendix C). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches. The same approach was used to determine the number of sea turtles that could be exposed to airguns sounds with received levels of ≥175 dB re 1 µPa$_{rms}$.

We used habitat-based stratified marine mammal densities for summer for the ETP when available (Barlow et al. 2009) and densities for the ETP from NMFS (2015) for all other species (Table 7). For the sei whale, for which NMFS (2015) reported a density of zero, we used the spring density for Baja from DoN (2017b). The habitat-based density models based on Barlow et al. (2009) consisted of 100 km x 100 km grid cells; densities in the grid cells that overlapped the proposed study area were averaged. The density for olive ridley sea turtles was obtained from Eguchi et al. (2007) for 2006 for the offshore northern stratum in the ETP. Densities for all other sea turtle species were derived from winter data collected in offshore waters off Mexico (Zepeda-Borja et al. 2017).

There is uncertainty about the representativeness of the data and the assumptions used to estimate exposures. Thus, for some species, the densities derived from the abundance models described above may not precisely represent the densities that would be encountered during the proposed seismic surveys. The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 µPa$_{rms}$ 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 8 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 µPa$_{rms}$ during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details), along with the *Requested Take Authorization*.

TABLE 7. Densities of marine mammals in the ETP from Barlow et al. (2009) and NMFS (2015), as well as sea turtle densities. Densities in bold were used to estimate Level B and Level A takes for marine mammals and exposures of sea turtles.

	Density (#/km^2) in Study Area [Barlow et al. 2009]	**Density (#/km^2) in wider ETP [NMSF 2015]**	**Density (#/km^2)**
Baleen Whales			
Humpback whale		**0.00013**	
Minke whale		**0.00001**	
Bryde's whale	**0.00051**	0.00049	
Fin whale		**0.00003**	
Sei whale[1]		0	**0.00005**
Blue whale	**0.00008**	0.00019	
Odontocetes			
Sperm whale		**0.00019**	
Cuvier's beaked whale	**0.00084**	0.00094	
Longman's beaked whale		**0.00004**	
Mesplodon spp.	**0.00031**	0.00119	
Blaineville's beaked whale[2]			
Ginkgo-toothed beaked whale[2]			
Deraniyagala's beaked whale[2]			
Pygmy beaked whale[2]			
Risso's dolphin	**0.00455**	0.00517	
Rough-toothed dolphin	**0.00620**	0.00504	
Common bottlenose dolphin	**0.01308**	0.01573	
Pantropical spotted dolphin[3]	**0.07258**	0.12263	
Spinner dolphin (whitebelly)	**0.00889**	0.04978	
Spinner dolphin (eastern)	**0.08000**		
Striped dolphin	**0.08099**	0.04516	
Common dolphin	**0.03980**	0.14645	
Fraser's dolphin		**0.01355**	
Short-finned pilot whale[4]	**0.00867**	0.02760	
Killer whale		**0.00040**	
False killer whale		**0.00186**	
Pygmy killer whale		**0.00183**	
Melon-headed whale		**0.00213**	
Dwarf sperm whale		0.00053	
Kogia spp.	**0.00003**		
Sea Turtles			
Olive Ridley Sea Turtle[5]			**0.16000**
Green Sea Turtle[6]			**0**
Loggerhead Sea Turtle[6]			**0.03333**
Hawksbill Sea Turtle[6]			**0.00667**
Leatherback Sea Turtle[6]			**0.00667**

[1] Spring density for Baja (DoN 2019).
[2] Density not available.
[3] Bold density for offshore stock only.
[4] Bold density for *Globicephala* spp.
[5] Density for 2006 for the northern offshore stratum in the ETP (Eguchi et al. 2007).
[6] Density for winter for waters offshore Mexico (Zepeda-Borja et al. 2017).

TABLE 8. Estimates of the possible numbers of individual marine mammals that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the ETP.

Species	**Level B Takes**[1]	**Level A Takes**[2]	**% of Pop. in ETP (Total Takes)**[3]	**Requested Level A+B Take Authorization**[4]
LF Cetaceans				
Humpback whale[5]	2	0	0.07	2
Minke whale	0	0	0.87	***1***
Bryde's whale	5	1	0.06	6
Fin whale	0	0	0.17	***1***
Sei whale	1	0	<0.01	1
Blue whale	1	0	0.14	**2**
HF Cetaceans				
Sperm whale	3	0	0.19	**8**
Cuvier's beaked whale	12	0	0.06	12
Longman's beaked whale	1	0	1.99	**20**
Mesoplodon spp.	5	0	N.A.	N.A.
Blainville's beaked whale	N.A.	N.A.	0.01	**3**
Ginkgo-toothed beaked whale	N.A.	N.A.	0.01	**3**
Deraniyagala's beaked whale	N.A.	N.A.	0.01	**3**
Pygmy beaked whale	N.A.	N.A.	0.01	**3**
Risso's dolphin	66	0	0.06	66
Rough-toothed dolphin	69	1	0.07	70
Common bottlenose dolphin	148	1	0.04	149
Pantropical spotted dolphin	1,050	7	0.12	1,057
Spinner dolphin (whitebelly)	129	1	0.02	**135**
Spinner dolphin (eastern)	1,157	8	0.11	1,165
Striped dolphin	1,171	8	0.12	1,179
Common dolphin	576	4	0.02	580
Fraser's dolphin	196	1	0.14	**395**
Short-finned pilot whale	125	1	0.02	126
Killer whale	6	0	0.07	6
False killer whale	27	0	0.07	27
Pygmy killer whale	26	0	0.07	**28**
Melon-headed whale	31	0	0.44	**200**
VHF Cetaceans				
Dwarf and pygmy sperm whales	0	0	0.02	**2**

N.A. means not applicable or not available.

[1] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds.

[2] Level A takes if there were no mitigation measures.

[3] Requested take authorization expressed as % of population in the ETP, if available (see Table 4).

[4] Requested take authorization is Level A plus Level B calculated takes. Numbers in bold (without italics) are based on mean group sizes; numbers in bold italics have been rounded up to 1 (see text for details).

[5] One take each are requested for the Central America and Mexico DPSs.

It should be noted that the exposure estimates assume that the proposed surveys would be completed; in fact, the calculated takes for marine mammals ***have been increased by 25%***. Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are pre-cautionary and probably overestimate the actual numbers of marine mammals that could be involved. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

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

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 2013; 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 note that use of a single threshold can lead to large errors in prediction impacts due to variability in responses between and within species.

Estimates of the numbers of marine mammals that could be exposed to seismic sounds from the 18-airgun array with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs observe animals approaching or inside the EZs), are also given in Table 8. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed study area.

Table 9 shows the estimates of the numbers of sea turtles that potentially could be exposed to various sound thresholds (behavioral disturbance and PTS onset (see Appendix B for more details) during the proposed seismic surveys, based on densities provided in Table 7. Although the density for green sea turtles for the study area was zero based on data for offshore waters during winter (Zepeda-Burja et al. 2017), it is possible that some individuals could be encountered during the proposed surveys.

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".

TABLE 9. Estimates of the possible numbers of sea turtle exposures during the proposed seismic surveys in the ETP.

	Behavioral Disturbance	PTS Onset Threshold
Olive Ridley Sea Turtle	472	54
Green Sea Turtle	0	0
Loggerhead Sea Turtle	98	11
Hawksbill Sea Turtle	20	2
Leatherback Sea Turtle	20	2

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, and that Level A effects were highly unlikely. Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for the Proposed Action involving the high-energy survey; however, following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys. For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g., NMFS 2019a,b).

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 marine mammals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes (Table 4). The proposed activities are likely to adversely affect ESA-listed marine mammal species for which takes are being requested (Table 10). However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

TABLE 10. ESA determination for marine mammal species that could potentially be encountered during the proposed surveys in the ETP.

	ESA Determination		
Species	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Humpback Whale (Central America DPS)			√
Humpback Whale (Mexico DPS)			√
Sei Whale			√
Fin Whale			√
Blue Whale			√
Sperm Whale			√

In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Maurice Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by R/V *Langseth* off the coast of North Carolina in September−October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by R/V *Langseth* along the U.S. east coast in August−September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 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. Nonetheless, the proposed activities are likely to adversely affect ESA-listed sea turtles that could be encountered in the proposed study area (Table 11). However, in decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Maurice Ewing*, PSOs and other crew members have seen no seismic sound-related sea turtle injuries or mortality.

4.1.2 Direct Effects on Marine Invertebrates, Fish, 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; Popper et al. 2022; Pieniazek et al. 2023; Solé et al. 2023; Cones et al. 2024; Vereide and Kühn 2024), 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. 2024). 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. Wang et al. (2024) showed that the pumping behavior of epibenthic polycheate worms can be affected by sound. 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.

TABLE 11. ESA determination for sea turtle species that could be encountered during the proposed surveys in the ETP.

Species	ESA Determination 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 (Mexico Pacific coastal breeding population)			√
Hawksbill Turtle			√

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; Prosnier 2024; Vereide and Kühn 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. (2024) 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 dB re 1 μPa^2 · s SEL. Increases in alarm responses were seen at SELs >147−151 dB re 1 μPa^2 · 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 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. (2023) 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 Pa^{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 $\mu\text{Pa}^2 \cdot \text{s}$ 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 rock 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 SEL_{cum} source levels were 189−199 dB re 1 $\mu\text{Pa}^2 \cdot \text{s}$. 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). Day et al. (2019, 2021, 2022) exposed rock lobster to the equivalent of a full-scale commercial seismic survey passing within 500 m, adult and juvenile 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, 2022). Day et al. (2021, 2022) noted that there was indication for slowed growth and physiological stress in 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.

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). 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.

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$_{\text{rms}}$ 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 heptapancreas. 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$_{\text{rms}}$, 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.

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 µPa^2·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 5−8 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 crabs 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 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 the effects of seismic exposure on the behavior 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 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 an airgun 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 coelemic 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.

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 et al. (2024); 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. (2024) 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, temporary threshold shift, 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) and Borland et al. (2024) examined the behavior of rockfish and lingcod during a seismic survey off southern Oregon in 2021. They 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 $\mu Pa^2 \cdot s$). 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 North west 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 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen in the fish at SELs >147−151 dB re 1 $\mu Pa^2 \cdot s$; 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 auditory evoked potentials (AEP) were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at water depth of 5 m, there was no evidence of TTS in any of the fish examined, even though the SEL_{cum} had reached 190 dB re 1 $\mu Pa^2 \cdot s$. Wei and McCauley (2022) determined that the angle of sound energy arrival at the otolith (a pathway for sound transmittance between a sound source and the inner ear) affects the extent of potential injury from noise. de Jong et al. (2020) conducted a study on the predicted effects of anthropogenic noise on fish reproduction and found that continuous sounds with irregular amplitudes and/or frequency-content such as heavy ship traffic were likely to induce masking or hearing loss. The vulnerability of a species to noise-induced stressors was dependent on its ability to reallocate reproduction to a quieter location or time, and whether or not their reproductive strategy relied on sound communication. Although TTS has been demonstrated in some fish species, it is unlikely to occur in free-swimming fish (Smith and Popper 2024).

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. Although cod had a reduced hear rate in response to the sound exposure, there was no behavioral startle response. However, 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. Davidsen et al. (2019) concluded that the sound exposures over a 3-day period were unlikely to lead to long-term alterations in physiology or behavior.

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 SEL_{cum} over the 3.5-day survey period at the receiver position was 186.3 dB re 1 µPa^{2}s 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 ($SPL_{0\text{-}p}$) 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 during 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; they exhibited more transiting behavior (i.e., swimming at high speed with a low turning angle) during and after exposure. Similar results were obtained during an experiment that exposed wild-caught Atlantic cod to airgun playbacks in an experimental tank with an SPL of 150 dB re 1 µ$Pa_{0\text{-}p}$; although the cod did not change the time spent foraging, they did increase the time spent swimming during exposure (Hubert et al. 2019; Hubert 2021).

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 behavior (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 $\mathrm{SEL}_{\mathrm{cum}}$.

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 $\mu\mathrm{Pa}_{0\text{-p}}$. 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 $\mu\mathrm{Pa}_{0\text{-p}}$, they swam rapidly. This suggests that the threshold between subtle reactions and avoidance responses occurs between 178 and 184 dB re 1 $\mu\mathrm{Pa}_{0\text{-p}}$, 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 $\mu\mathrm{Pa}^2$/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 $\mu\mathrm{Pa}_{\mathrm{rms}}$. 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 fish.

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 $\mu Pa_{0\text{-}p}$. 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.

4.1.2.3 Conclusions for Fish and Marine Invertebrates

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 survey. Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect (including ESA-listed) marine fish (Table 12). In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Maurice Ewing*, 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 seabirds (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.

TABLE 12. ESA determination for marine fish species that could potentially be encountered during the proposed surveys in the ETP.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Scalloped Hammerhead Shark		√	
Oceanic Whitetip Shark		√	
Giant Manta Ray		√	

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 unlikely event an ESA-listed seabird was observed diving or foraging within the designated EZ. However, ESA-listed seabirds that could be present forage at the ocean surface rather than diving and would not be affected by the airgun operations below the water surface. Given the proposed activities, avoidance measures and unlikelihood of encounter, no effects to ESA-listed seabirds would be anticipated from the proposed action (Table 13). In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, the R/V *Maurice Ewing*, PSOs and other crew members have seen no seismic sound-related seabird injuries or mortality.

TABLE 13. ESA determination for seabird species that could be encountered during the proposed surveys in the ETP.

	ESA Determination		
Species	**No Effect**	**May Affect – Not Likely to Adversely Affect**	**May Affect – Likely to Adversely Affect**
Galápagos Petrel	√		

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

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

4.1.5 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 proposed study 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 study 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 (e.g., research, vessel traffic, and fisheries) that could impact animals specifically in the proposed study area. However, the combination of the proposed activities with the existing operations in the region would be expected to produce only a negligible increase in overall disturbance effects on marine mammals. For these reasons, significant impacts to marine resources are not anticipated from the proposed surveys.

4.1.6.1 Past and Future Research Activities

The SWFSC has been conducting systematic marine mammal surveys in the wider ETP region since 1986. Ferguson and Barlow (2001) reported on data collected from 1986−1996, and Forney et al. (2012) used SWFSC data collected during 1986−2006 to develop species-habitat models for the ETP. Initial systematic studies of cetaceans in the ETP were prompted by the incidental killing of dolphins in the purse-seine fishery for yellowfin tuna in the area (Smith 1983). As it is currently unknown whether the dolphin populations have recovered, Oedekoven et al. (2021) conducted a trial survey for ETP dolphins off the west coast of Mexico in November 2019. A second trial survey using drones was conducted in November 2023, but the results are not available yet (IATTC 2024).

Other research activities may have been conducted in the past or may be conducted in the study area in the future. As mentioned earlier, seismic data were collected in the area during 2008. More recently, the study area was visited during NSF-funded expedition AT50-33 in January-February 2025 and again in April 2025, where RV *Atlantis* and HOV *Alvin* and AUV *Sentry* were used to survey and sample deep-sea vents. In fact, there was an underwater volcanic eruption within the proposed study area at the Tica vent, in April 2025. There may be an expedition using ROV Jason to the study site in 2026.

4.1.6.2 Vessel Traffic

Vessel traffic in the proposed study area would consist mainly of commercial fishing vessels, cargo vessels, and tankers. Based on the data available through the Automated Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard (USCG), the monthly density plot totals for the shipping lanes that intersect the study area had 4 or fewer vessels within 60' latitude by 60' longitude cells during January and February 2025 (USCG 2025). When live vessel traffic information for the area was accessed during April 2025, there were two cargo vessels, one tug/special craft, and one pleasure craft within the proposed study area (MarineTraffic 2025). The total transit time by R/V *Langseth* (~5 days) would be significant relative to the number of other vessels operating in the proposed study area. Thus, the combination of R/V *Langseth*'s operations with the existing shipping operations is expected to produce a significant increase in overall ship disturbance effects on marine mammals.

4.1.6.3 Fisheries

The proposed study area is located in the eastern Central Pacific Ocean. In 2019, nearly 900,000 tons of fish were harvested in this region (Sea Around Us 2024). Most of the catch (44%) consisted of skipjack tuna, followed by yellowfin tuna (20%), big eye tuna (14%), and blue shark (6%); other species landed included albacore tuna, swordfish, striped marlin, common dolphinfish, and mackerels (Sea Around Us 2024). Most catches were taken by purse seine by fishing vessels based out of Ecuador, followed by Taiwan, and the U.S. (Sea Around Us 2024).

The primary contributions of fishing to potential reasonably foreseeable impacts on marine mammals and sea turtles involve direct removal of prey items and noise (Reeves et al. 2003).

***Marine Mammals*.—**Entanglement in fishing gear can lead to serious injury or mortality of some marine mammals and high numbers of bycatch. Hundreds of thousands of dolphins used to be killed in the tuna fishery annually in the ETP (Ballance et al. 2021). The main cetacean species that were affected by the fishery include pantropical spotted and spinner dolphins (Smith 1983; Ballance et al. 2021). Short-beaked common, striped, bottlenose, Fraser's, and rough-toothed dolphins, as well as short-finned pilot whales, have also been killed in the fishery (e.g., Hall and Boyer 1989). Dolphin mortality was high at the onset of the fishery (Allen 1985), but has since dropped considerably (Ballance et al. 2021). During the 1960s, it was estimated that 200,000−500,000 dolphins per year were killed by the fishery (Wade 1995). Since 2000, ~1000 dolphins are killed in the ETP tuna purse-seine fishery annually (Ballance et al. 2021).

In 1992, the La Jolla Agreement provided a framework to reduce the mortality by setting dolphin mortality limits (DML) for fishing vessels (AIDCP 2024). The Agreement on the International Dolphin Conservation Program (AIDCP) formalized the provisions of the La Jolla Agreement and entered into force in 1999. The Parties to the AIDCP "committed to ensure the sustainability of tuna stocks in the eastern Pacific Ocean and to progressively reduce the incidental dolphin mortalities in the tuna fishery of the eastern Pacific Ocean to levels approaching zero and to avoid, reduce and minimize the incidental catch and the discard of juvenile tuna and the incidental catch of non-target species, taking into consideration the interrelationship among species in the ecosystem".

The total DML was 5000 animals for 2023 and 2020 (AIDCP 2024). The bycatch was reported as 828 animals in 2023 and has been <1000 since 2011 (AIDCP 2024). Populations of offshore spotted dolphins and eastern spinner dolphins had not recovered by the early 2000s (Gerrodette and Forcada 2005; Wade et al. 2007). It is currently unknown whether these populations have recovered, as current population estimates are unknown (Leslie and Morin 2016; Ballance et al. 2021); no systematic surveys have taken place since 2006 (Scott et al. 2018; Ballance et al. 2021). However, Oedekoven et al. (2021) conducted a trial survey for ETP dolphins off the west coast of Mexico in November 2019, and a second trial survey was conducted in November 2023 (IATTC 2024). The goal of a future main survey is to estimate the current abundance of dolphins in the ETP. The trial surveys mainly tested the use of a drone to assess whether they can be used to detect dolphin schools ahead of the vessel and whether they can be used to determine school size and species composition.

Sea Turtles.—Lewison et al. (2004) estimated that 30,000−75,000 loggerheads are taken as bycatch in longlines in 2000 in the Pacific; the estimate for leatherbacks was lower (20,000−40,000). Although Lewison et al. (2014) reported relatively high bycatch of sea turtles during longlining operations in the ETP 1990−2008. Roe et al. (2014) reported limited bycatch risk for leatherbacks in the proposed study area. Sea turtles are also occasionally caught in the tropical purse-seine fishery. A mean of 85 sea turtles per year are caught in the eastern Pacific, of which most (86%) are olive ridleys, followed by green, loggerhead, and hawksbill turtles (Hall and Roman 2013). Montero et al. (2016) indicated some bycatch risk for olive ridleys in the purse-seine fishery within the proposed study area, and Lopez et al. (2024) indicated limited bycatch vulnerability for leatherbacks from all fishery types within the proposed study area. Entanglement of sea turtles in seismic gear is also a concern; there have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore of West Africa (Weir 2007). The probability of entanglements would be a function of turtle density in the study area. 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*.—**Entanglement in fishing gear and hooking can also lead to mortality of seabirds. In the fisheries in the ETP, Huang et al. (2011) reported a bycatch of 22 to 109 white-chinned petrels (*Procellaria* *aequinoctialis*) annually whereas Hall and Roman (2013), Lewison et al. (2014), and Wang et al. (2021) reported no bycatch.

4.1.6 Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and sea turtles occurring in the proposed study area would be limited to short-term, localized changes in behavior of individuals. For marine mammals, some of the changes in behavior may be considered 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 that does not involve injury, 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 request 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 has been prepared by LGL Limited on behalf of L-DEO and NSF pursuant to Executive Order 12114. 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 processes with NMFS and other U.S. and international regulatory processes as appropriate. This document will also be used as supporting documentation for an IHA application submitted by L-DEO, on behalf of itself, NSF, UCSD, and WHOI, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic surveys.

4.2 No Action Alternative

An alternative to conducting the proposed activity 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 species attributable to the proposed activity; however, valuable data about the marine environment would be lost. Geological data of scientific value, with the aim to examine a timelapse of crustal mantle body changes within or between volcanic cycles, 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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APPENDIX A: DETERMINATION OF MITIGATION ZONES

APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for Level A and Level B (160 dB re 1µPa$_{\mathrm{rms}}$) thresholds. 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 18-airgun array at a 7.5 m tow depth. The 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). Propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have also been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of America 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

Typically, for deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at the sites in the Gulf of America, the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth for marine mammals of ~2000 m (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep and slope sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The 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 Gulf of America 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 Gulf of America 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 the 18-airgun array at a maximum tow depth of 7.5 m in deep water. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. A-1). Table A-1 shows the distances at which the 160-dB and 175-dB re 1µPa$_{\mathrm{rms}}$ sound levels are expected to be received for the 18-airgun array. The 160-dB level is the behavioral disturbance criteria (Level B) that is used by NMFS to estimate anticipated takes for marine mammal. The 175-dB level is used by NMFS, based on data from the DoN (2017), to determine behavioral disturbance for turtles. A 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 levels[3] have confirmed that the L-DEO model generated conservative exclusion zones (EZs), resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The noise exposure criteria for marine mammals accounted for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat}, respectively. Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 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. A-2) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}).

Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), high-frequency (HF) cetaceans (e.g., most delphinids), very high-frequency (VHF) cetaceans (e.g., porpoise and *Kogia* spp.), phocid pinnipeds underwater (PW), and otariid pinnipeds underwater (OW). The largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances. The dual criteria for sea turtles (DoN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re $1\mu Pa_{rms}$, for Level B harassment (behavior). It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise. Tougaard et al. (2024) noted that TTS-onset thresholds 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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[3] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of America 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).

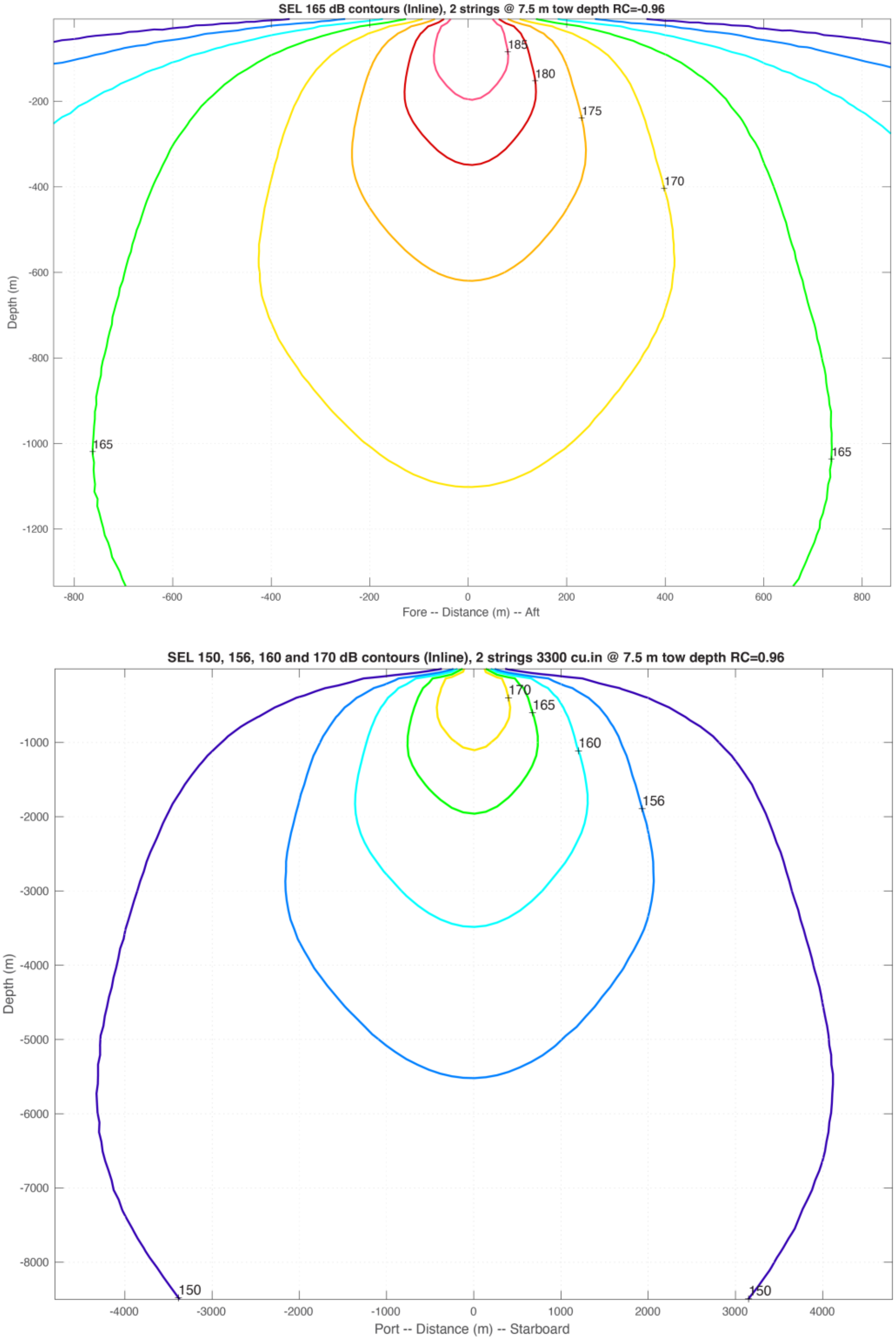


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 18-airgun array at a 7.5-m tow depth planned for use during the proposed surveys. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-14. Predicted distances 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 with the 18-airgun array in the Eastern Tropical Pacific. 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 distances (in m) to the 160-dB Received Sound Level[1]	Predicted distances (in m) to the 175-dB Received Sound Level[1]
2 strings, 18 airguns, 3300 in^3	7.5	>1000 m	3,526	763

[1] Distance is based on L-DEO model results.

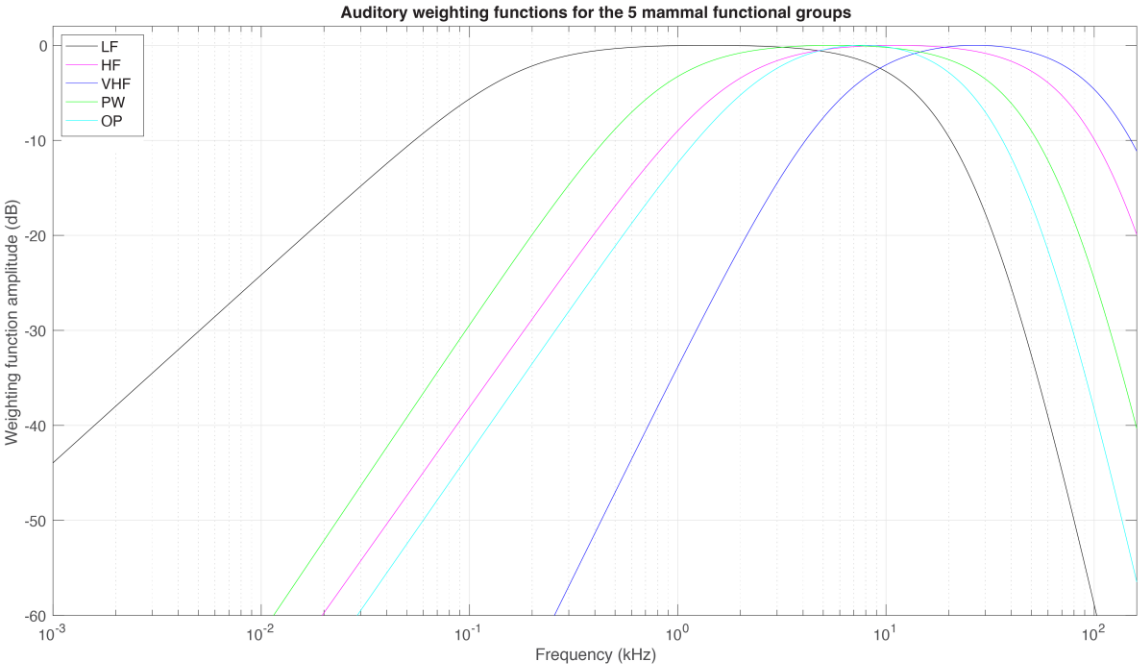


FIGURE A-2. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet. LF = low frequency cetaceans, HF = high frequency cetaceans, VHF = very high frequency cetaceans, PW = phocid pinnipeds underwater, OP = otariid pinnipeds underwater.

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

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

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

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

For LF cetaceans during operations with the 18-airgun array, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor assuming a propagation of $20\log_{10}$(Radial distance) (Table A-2).

However, for MF and HF cetaceans (and OW and PW pinnipeds, if applicable), the modeling for a single shot with the weighted function applied leads to 0-m isopleths; the adjustment factors thus cannot be derived the same way as for LF cetaceans. Hence, for MF and HF cetaceans (and OW and PW pinnipeds, if applicable), 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 18-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 18-airgun array are shown in Table A-3. Figure A-3 shows the impact of weighting functions by hearing group. Figures A-4–A-6 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-7 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

The thresholds for Peak SPL_{flat} for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-8–A-10 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

TABLE A-2. Results for modified farfield SEL source level modeling for the 18-airgun array with and without applying weighting functions to various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**193**	**159**	**183**	**185**	**184***
Radial Distance (m) (no weighting function)	162.78	38.25	2602	162.78	126.42	141.92
Modified Farfield SEL	227.23	224.65	227.31	227.23	126.42	227.04
Radial Distance (m) (with weighting function)	43.36	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-11.26	N.A.	N.A.	N.A.	N.A.	N.A.

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

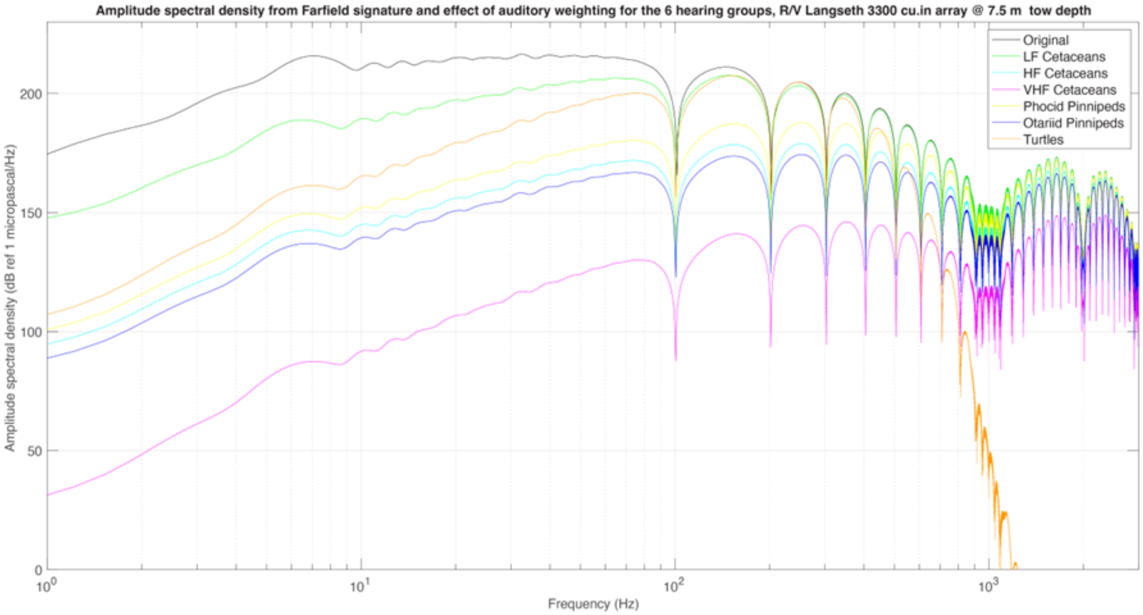
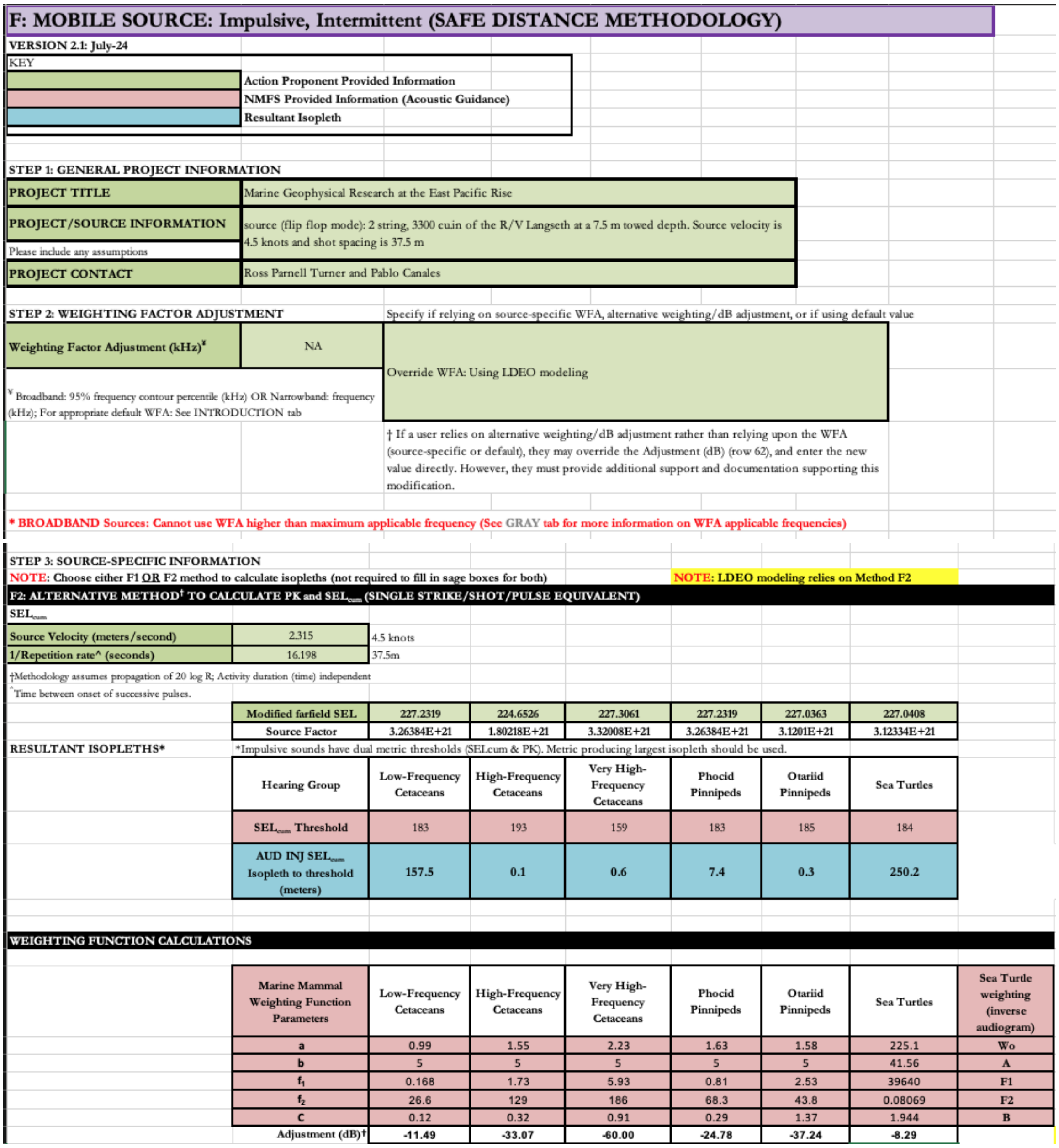


FIGURE A-3. Modeled amplitude spectral density of the 18-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, HF, and VHF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-3. Results for single shot SEL source level modeling for the 18-airgun array, at a speed of 4.5 kt and shot spacing of 37.5 m, with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various hearing groups.



F: MOBILE SOURCE: Impulsive, Intermittent (SAFE DISTANCE METHODOLOGY)

VERSION 2.1: July-24

KEY	
🟩	**Action Proponent Provided Information**
🟥	**NMFS Provided Information (Acoustic Guidance)**
🟦	**Resultant Isopleth**

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Marine Geophysical Research at the East Pacific Rise
PROJECT/SOURCE INFORMATION Please include any assumptions	source (flip flop mode): 2 string, 3300 cu.in of the R/V Langseth at a 7.5 m towed depth. Source velocity is 4.5 knots and shot spacing is 37.5 m
PROJECT CONTACT	Ross Parnell Turner and Pablo Canales

STEP 2: WEIGHTING FACTOR ADJUSTMENT Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

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

SEL_{cum}

Source Velocity (meters/second)	2.315	4.5 knots
1/Repetition rate^ (seconds)	16.198	37.5m

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

^Time between onset of successive pulses.

Modified farfield SEL	227.2319	224.6526	227.3061	227.2319	227.0363	227.0408
Source Factor	3.26384E+21	1.80218E+21	3.32008E+21	3.26384E+21	3.1201E+21	3.12334E+21

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	184
AUD INJ SEL_{cum} Isopleth to threshold (meters)	157.5	0.1	0.6	7.4	0.3	250.2

WEIGHTING FUNCTION CALCULATIONS

Marine Mammal Weighting Function Parameters	Low-Frequency Cetaceans	High-Frequency Cetaceans	Very High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles	Sea Turtle weighting (inverse audiogram)
a	0.99	1.55	2.23	1.63	1.58	225.1	Wo
b	5	5	5	5	5	41.56	A
f_1	0.168	1.73	5.93	0.81	2.53	39640	F1
f_2	26.6	129	186	68.3	43.8	0.08069	F2
C	0.12	0.32	0.91	0.29	1.37	1.944	B
Adjustment (dB)†	-11.49	-33.07	-60.00	-24.78	-37.24	-8.29	

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of $20*\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-3).

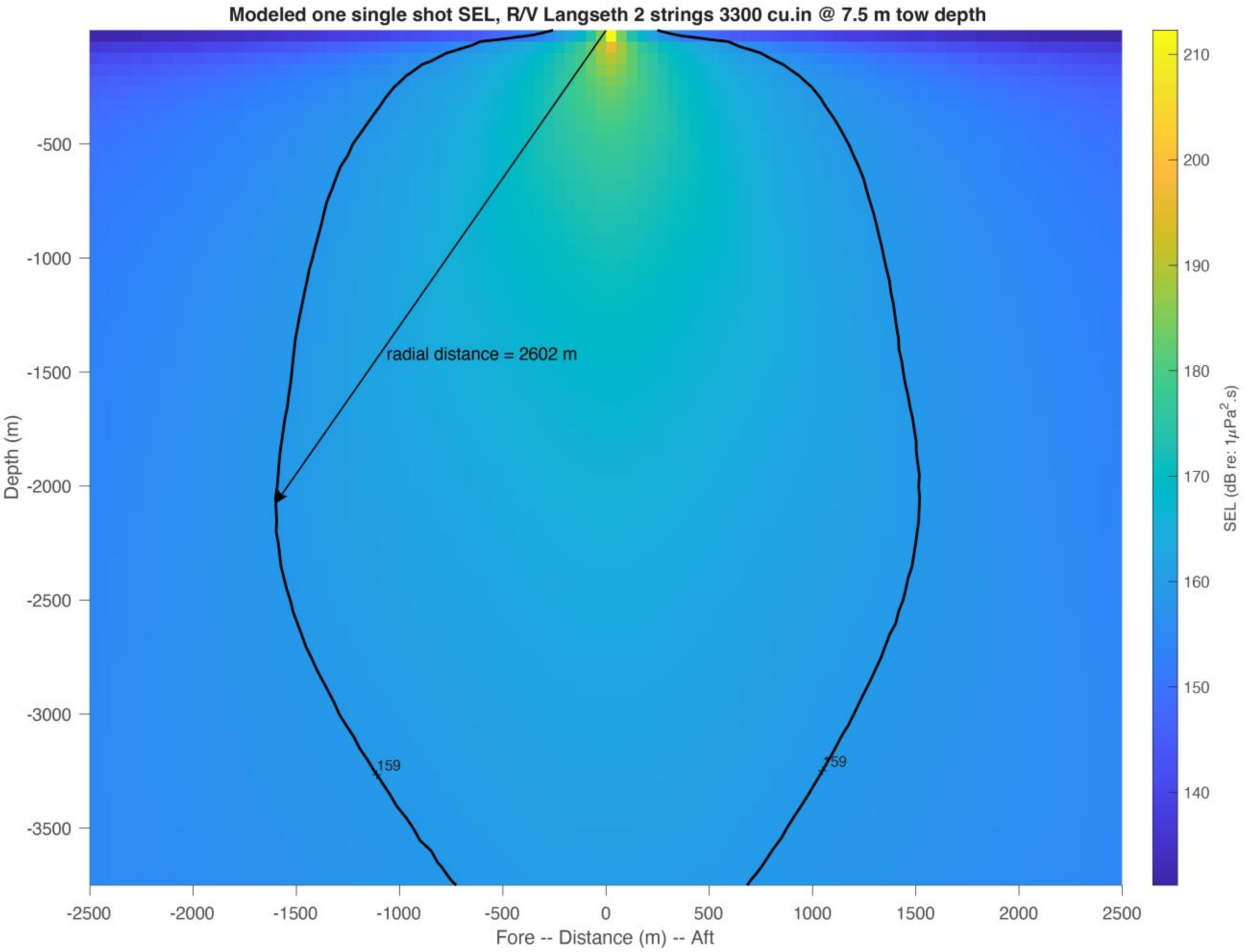


FIGURE A-4. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 159-dB SEL isopleth. Radial distance allows us to determine the modified farfield SEL using a propagation of 20log10(radial distance).

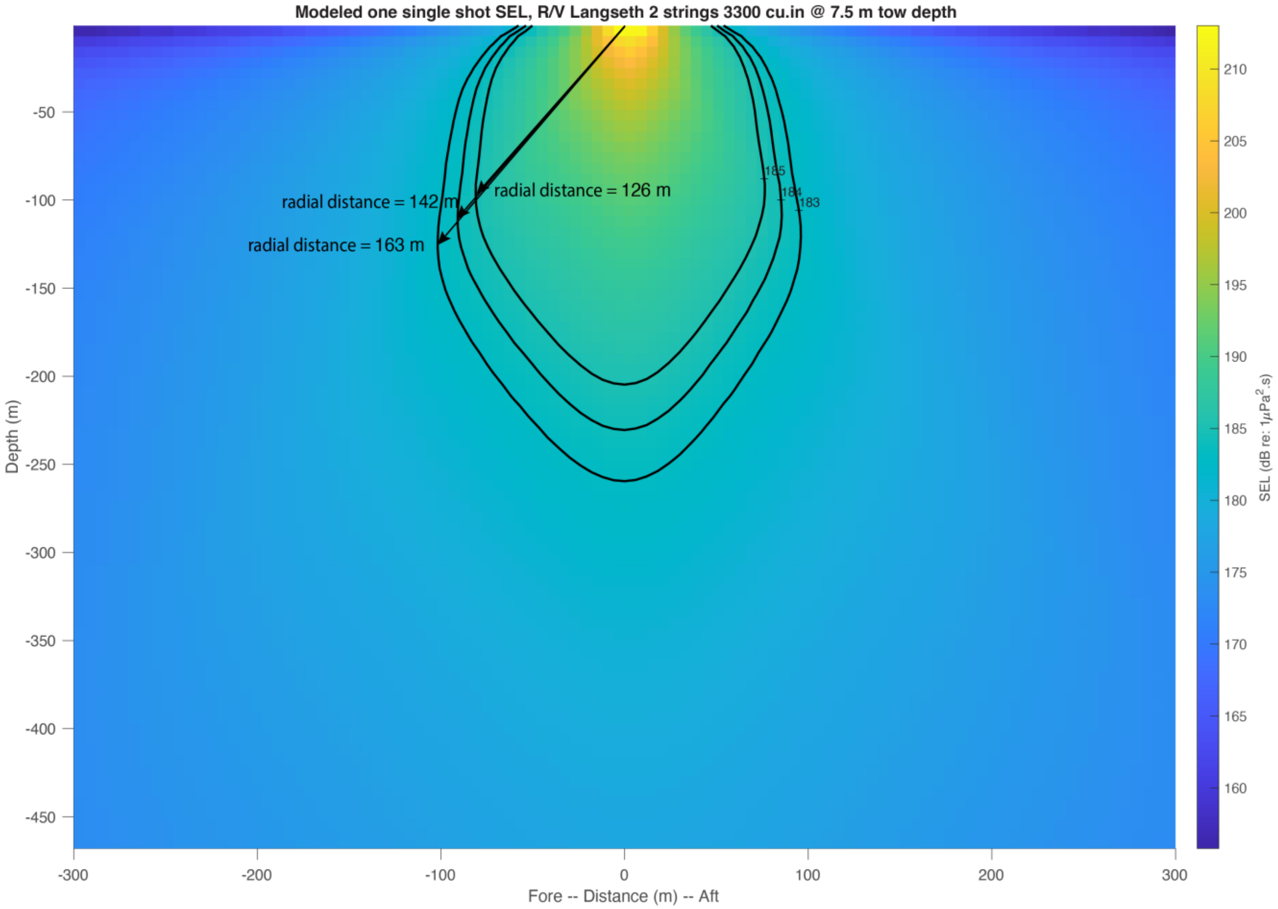


FIGURE A-5. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths.

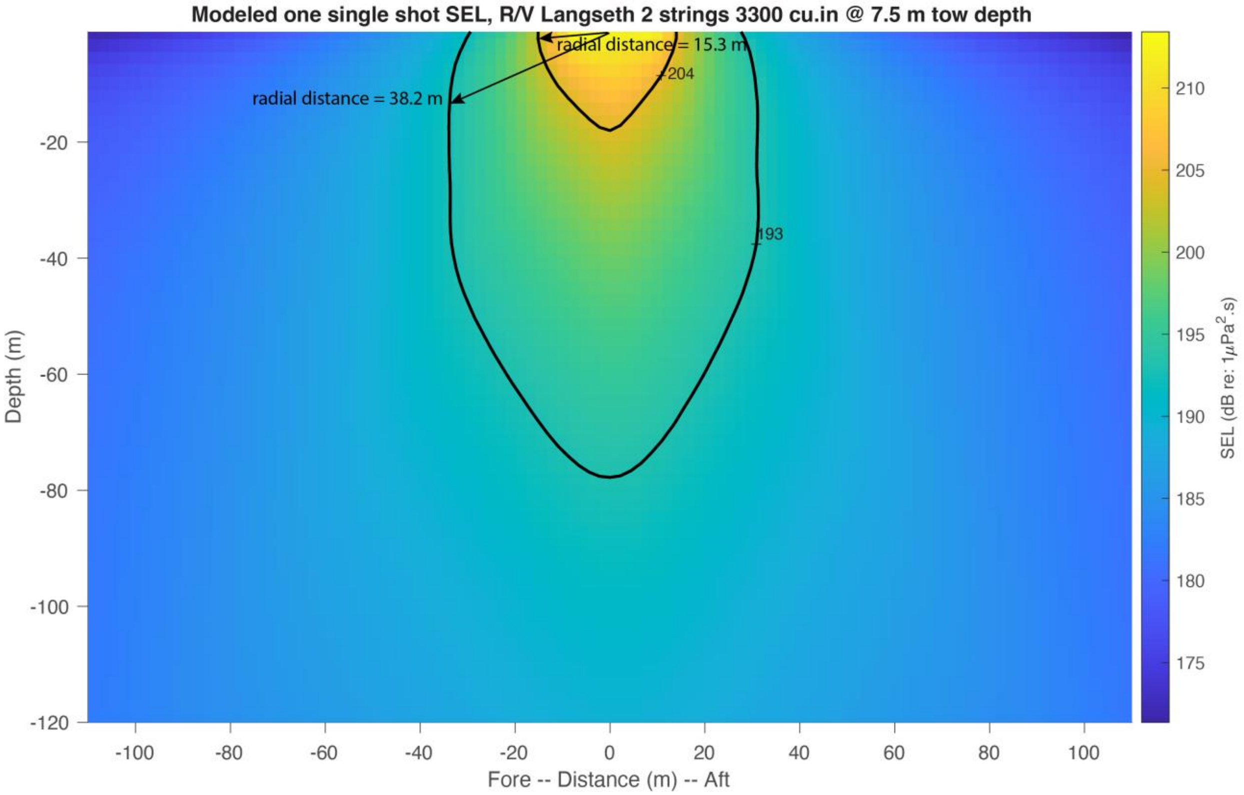


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 18-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 193-dB SEL isopleth.

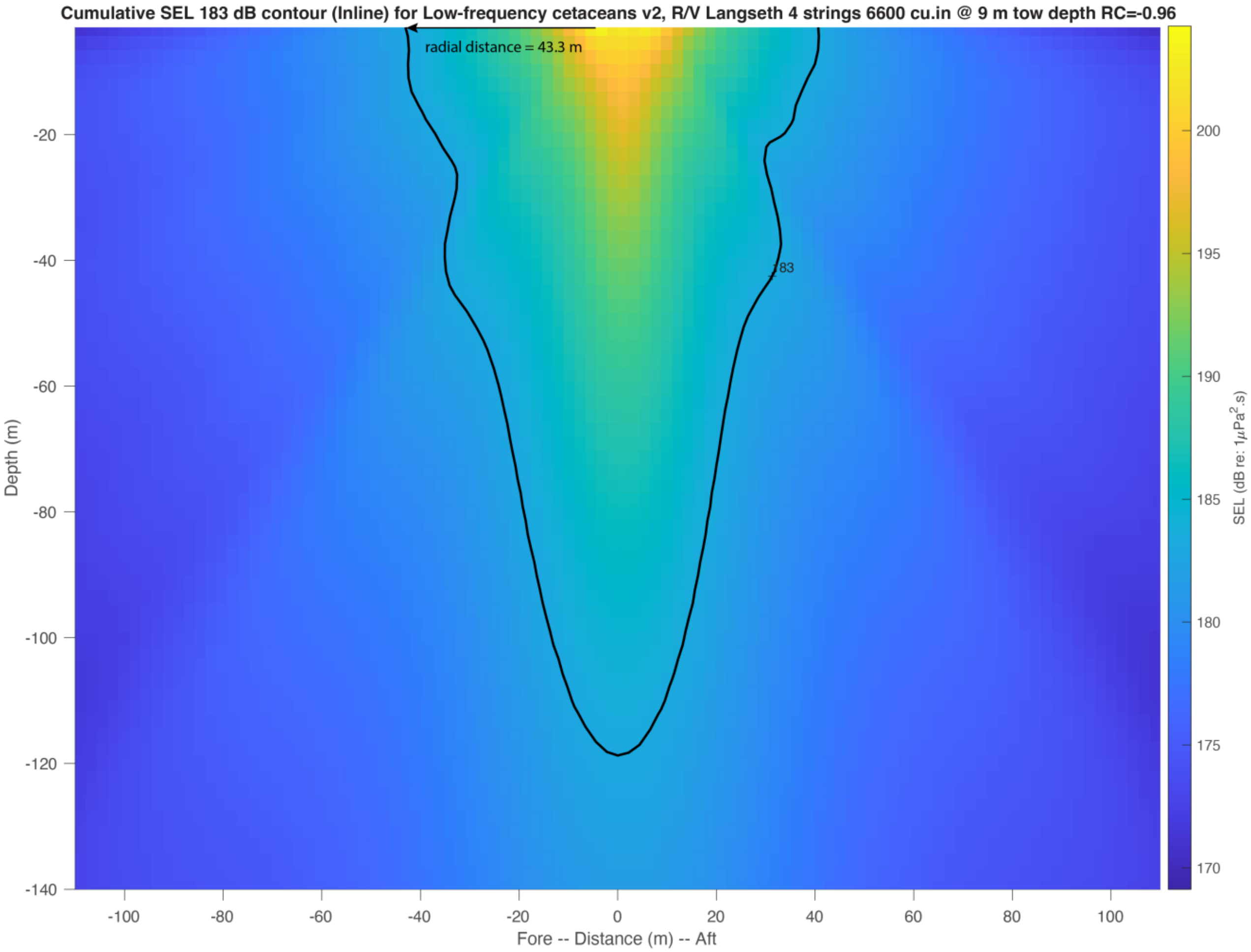


FIGURE A-7. Modeled received sound exposure levels (SELs) from the 18-airgun array at a 7.5-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-5 and this figure allows us to estimate the adjustment in dB.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and sea turtles and predicted distances to Level A thresholds for various hearing groups that could be received from the 18-airgun array during the proposed surveys.

Hearing Group	Low-Frequency Cetaceans	High-Frequency Cetaceans	Very High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Turtles
Peak Threshold	**222**	**230**	**202**	**223**	**230**	**232**
Radial Distance to Threshold (m)	23.4	13.4	166.5	21.6	13.4	11.9
PTS Peak Isopleth (Radius) to Threshold (m)	23.4	13.4	164.6	21.6	13.4	11.9

N.A. means not applicable or not available.

TABLE A-5. Level A (PTS) threshold distances for different marine mammal hearing groups for the 18-airgun array in the Eastern Tropical Pacific. Consistent with NMFS (2024), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances. PTS threshold distances for sea turtles are also shown.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	High-Frequency Cetaceans	Very High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PTS SEL_{cum}	**157.5**	0.1	0.6	7.4	0.3	**250.2**
PTS Peak	23.4	**13.4**	**164.6**	**21.6**	**13.4**	11.9

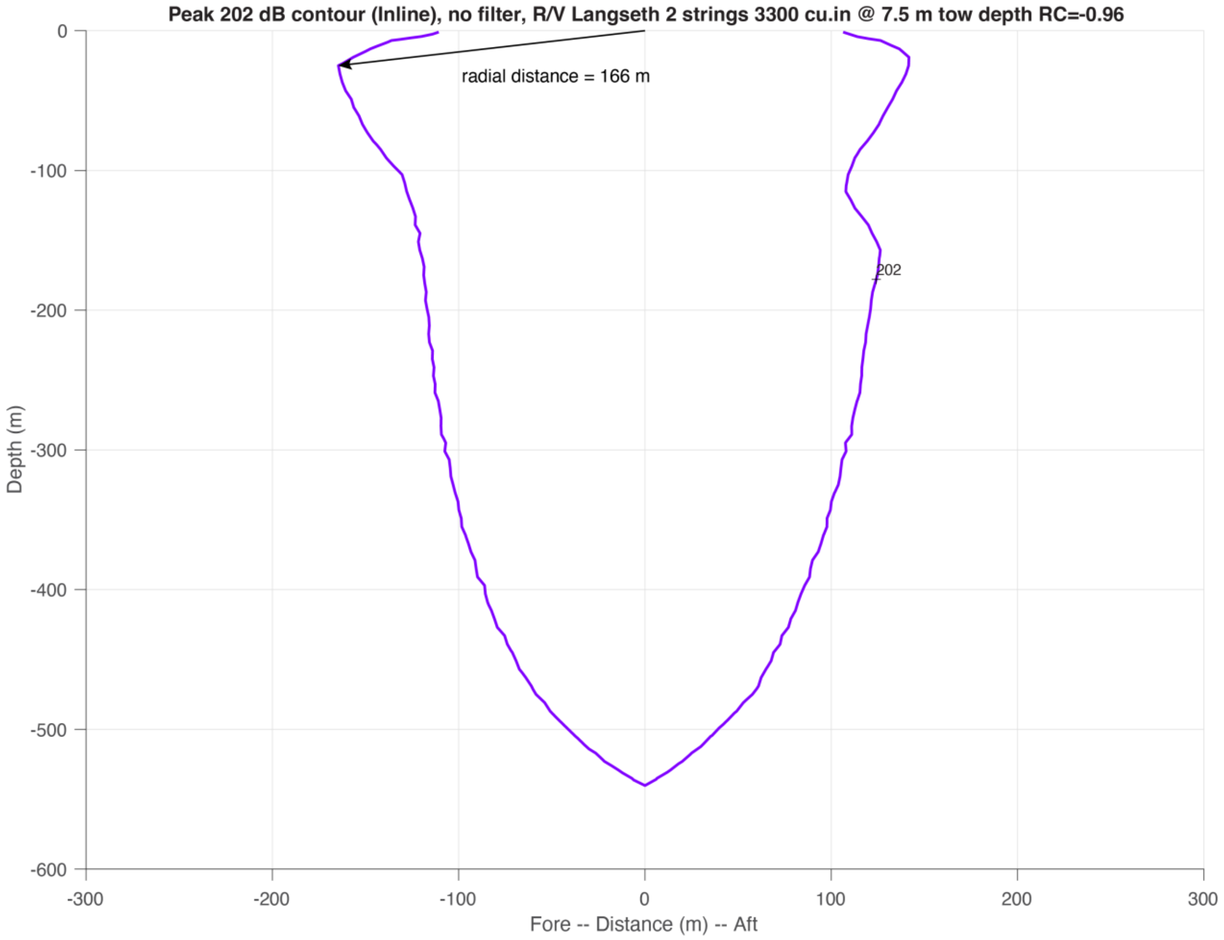


FIGURE A-8. Modeled deep-water received Peak SPL from the 18-airgun array at a 7.5-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

FIGURE A-9. Modeled deep-water received Peak SPL from the 18-airgun array at a 7.5 m tow depth. The plot provides the distances to the 222- and 223-dB Peak isopleths.

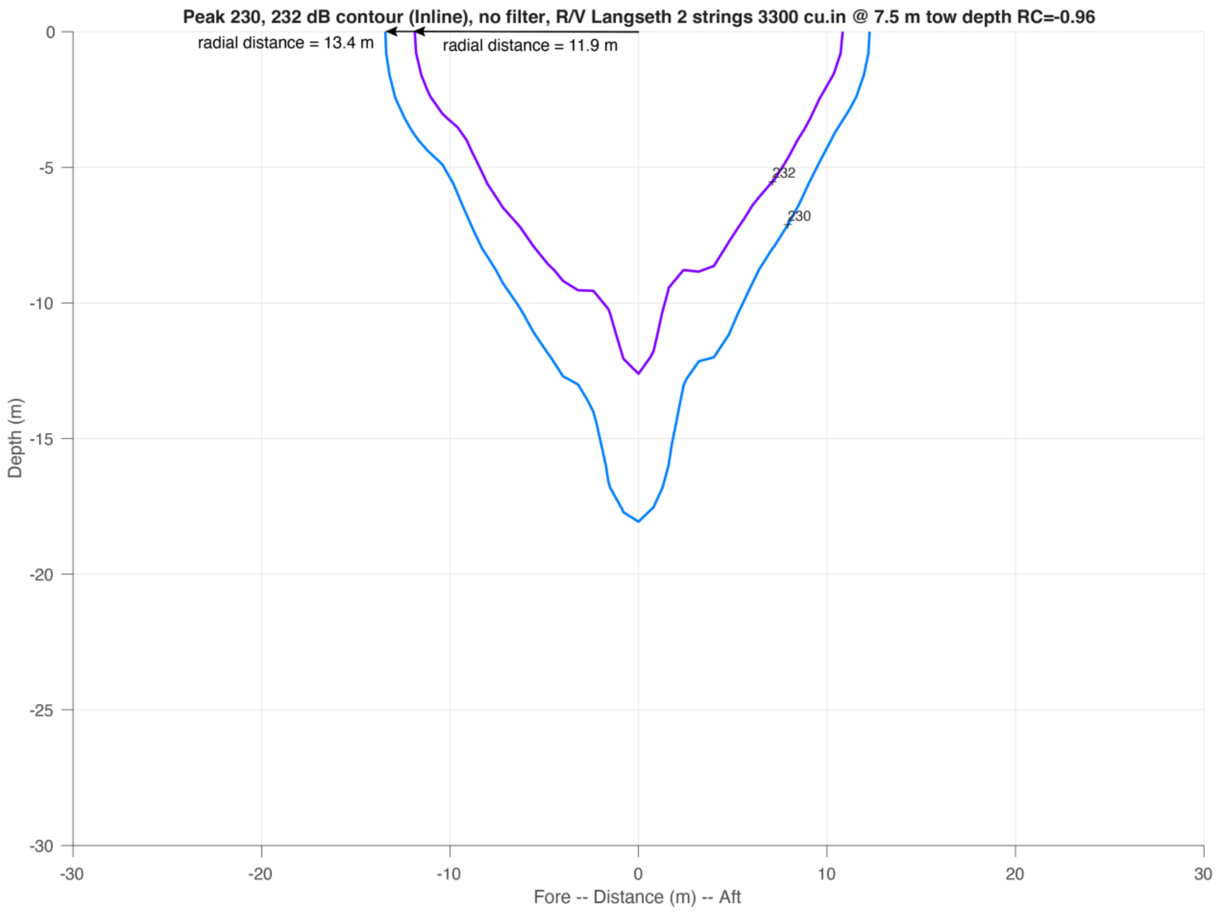


FIGURE A-10. Modeled deep-water received Peak SPL from the 18-airgun array at a 7.5 m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

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APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

APPENDIX B: MARINE MAMMAL TAKE CALCULATIONS

Level A and Level B takes were determined for the seismic surveys; the detailed take calculations are shown in Table B-1. The ensonified areas that were used to calculate Level A and B takes are provided in Appendix C.

TABLE B-1. Take estimates for the proposed surveys in the ETP.

Species	Estimated Density (#/km^2)	Population Size in ETP[1]	Level B Ensonified Area (km^2)	Level A Ensonified Area (km^2)	Level B Takes[1]	Level A Takes[2]	% of Pop. in ETP (Total Takes)[3]	Requested Level A+B Take Authorization[4]
LF Cetaceans								
Humpback whale[5]	0.00013	2,566	14,558	1,122	2	0	0.07	2
Minke whale	0.00001	115	14,558	1,122	0	0	0.87	***1***
Bryde's whale	0.00051	10,411	14,558	1,122	5	1	0.06	6
Fin whale	0.00003	574	14,558	1,122	0	0	0.17	***1***
Sei whale	0.00005	*29,600*	14,558	1,122	1	0	<0.01	1
Blue whale	0.00008	1,415	14,558	1,122	1	0	0.14	**2**
HF Cetaceans								
Sperm whale	0.00019	4,145	14,558	97	3	0	0.19	**8**
Cuvier's beaked whale	0.00084	20,000	14,558	97	12	0	0.06	12
Longman's beaked whale	0.00004	1,007	14,558	97	1	0	1.99	**20**
Mesoplodon spp.	0.00031	25,300	14,558	97	5	0	N.A.	N.A.
Blainville's beaked whale	N.A.	25,300	14,558	97	N.A.	N.A.	0.01	**3**
Ginkgo-toothed beaked whale	N.A.	25,300	14,558	97	N.A.	N.A.	0.01	**3**
Deraniyagala's beaked whale	N.A.	25,300	14,558	97	N.A.	N.A.	0.01	**3**
Pygmy beaked whale	N.A.	25,300	14,558	97	N.A.	N.A.	0.01	**3**
Risso's dolphin	0.00455	110,457	14,558	97	66	0	0.06	66
Rough-toothed dolphin	0.00620	107,663	14,558	97	69	1	0.07	70
Common bottlenose dolphin	0.01308	335,834	14,558	97	148	1	0.04	149
Pantropical spotted dolphin	0.07258	857,884	14,558	97	1,050	7	0.12	1,057
Spinner dolphin (whitebelly)	0.00889	734,837	14,558	97	129	1	0.02	**135**
Spinner dolphin (eastern)	0.08000	1,062,879	14,558	97	1,157	8	0.11	1,165
Striped dolphin	0.08099	964,362	14,558	97	1,171	8	0.12	1,179
Common dolphin	0.03980	3,127,203	14,558	97	576	4	0.02	580
Fraser's dolphin	0.01355	289,300	14,558	97	196	1	0.14	**395**
Short-finned pilot whale	0.00867	589,315	14,558	97	125	1	0.02	126
Killer whale	0.00040	8,500	14,558	97	6	0	0.07	6
False killer whale	0.00186	39,800	14,558	97	27	0	0.07	27
Pygmy killer whale	0.00183	38,900	14,558	97	26	0	0.07	**28**
Melon-headed whale	0.00213	45,400	14,558	97	31	0	0.44	**200**
VHF Cetaceans								
Dwarf and pygmy sperm whales	0.00003	11,200	14,558	1,147	0	0	0.02	**2**

N.A. means not available.

[1] Level B takes, based on the 160-dB criterion for marine mammals, excluding exposures to sound levels equivalent to PTS thresholds.

[2] Level A takes if there were no mitigation measures.

[3] Requested take authorization is expressed as % of population for the EPT (see Table 4).

[4] Requested take authorization is Level A plus Level B calculated takes. Takes in bold (not italics) are based on mean group size; numbers in bold italics are rounded up to 1.

APPENDIX C: ENSONIFIED AREA CALCULATIONS

APPENDIX C: ENSONIFIED AREA CALCULATIONS

The ensonified areas that were used to calculate takes for sea turtles and Level A and Level B takes for marine mammals for the proposed surveys in the ETP.

TABLE C-1. Areas expected to ensonified during the proposed surveys.

	Criterion	Daily Ensonified Area (km^2)	Total Survey Days	25% Increase	Total Ensonified Area (km^2)	Relevant Isopleth (m)
Marine Mammals						
Racetrack Survey	160 dB	478.1	18	1.25	10757.9	3,526
Long Transect Line	160 dB	1520.0	2	1.25	3799.9	3,526
Total					**14557.8**	
Sea Turtles						
Racetrack Survey	175 dB	110.4	18	1.25	2483.5	763
Long Transect Line	175 dB	322.3	2	1.25	805.7	763
Total					**3289.2**	
PTS						
Racetrack Survey	**LF**	42.5	18	1.25	956.1	157.5
Long Transect Line	**LF**	66.2	2	1.25	165.6	157.5
Total	**LF**	**108.7**			**1121.7**	
Racetrack Survey	**HF**	3.7	18	1.25	83.0	13.0
Long Transect Line	**HF**	5.6	2	1.25	14.1	13.0
Total	**HF**	**9.3**			**97.1**	
Racetrack Survey	**VHF**	43.3	18	1.25	973.5	164.6
Long Transect Line	**VHF**	69.2	2	1.25	173.0	164.6
Total	**VHF**	**112.5**			**1146.6**	
Racetrack Survey	**Sea turtles**	3.3	18	1.25	73.7	11.9
Long Transect Line	**Sea turtles**	105.3	2	1.25	263.2	11.9
Total	**Sea turtles**	**108.6**			**336.9**	