Request by Scripps Institution of Oceanography for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V *Sikuliaq* in Greater Micronesia, December 2024–January 2025

submitted by

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SUMMARY

Researchers from the Woods Hole Oceanographic Institution (WHOI) and University of Houston, with funding from the U.S. National Science Foundation (NSF), propose to conduct marine geophysical research in the Nauru Basin of greater Micronesia in the Northwest Pacific Ocean, during December 2024–January 2025. The research would be conducted on the NSF-owned R/V *Sikuliaq* (operated by the College of Fisheries and Ocean Sciences at University of Alaska Fairbanks) using the portable multi-channel seismic (MCS) system operated by marine technicians from Scripps Institution of Oceanography (SIO). The proposed two-dimensional (2-D) seismic surveys would use four Generator-Injector (GI) airguns with a maximum discharge volume of ~420 in^3, in water depths ranging from 4000 to 6000 m deep. The surveys would take place within the Exclusive Economic Zone (EEZ) of the Republic of the Marshall Islands (RMI) and in international waters.

Numerous species of marine mammals inhabit the proposed survey area in greater Micronesia. Under the U.S. ESA, five of these species, managed by the National Marine Fisheries Service (NMFS), are listed as ***endangered***, including the Western North Pacific Distinct Population Segment (DPS) of the humpback whale, and the sperm, sei, fin, and blue whales. Thus, this request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5). The items required to be addressed pursuant to 50 C.F.R. § 216.104, “Submission of Requests”, are set forth below. They include descriptions of the specific operations to be conducted, the marine mammals occurring in the survey area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on those marine mammals.

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

Principal Investigator (PI) Dr. M. Tominaga (WHOI) and co-PIs Dr. H. Mark (WHOI) and W. Sager (University of Houston) propose to conduct seismic surveys using four GI airguns to examine magnetic reversals to help determine the processes that cause changes in the Earth's magnetic field. The Earth's geomagnetic field periodically reverses, with the north and south poles switching places. These reversals are preserved in ocean crust as linear magnetic anomalies. Because this process is like a magnetic tape recorder, studying the sequence of magnetic reversals has enabled scientists to develop a time scale used to determine ocean crustal age, plate tectonic movements, and the history of magnetic field evolution.

This project would examine magnetic reversals during a time known as the Jurassic Quiet Zone (JQZ) where the magnetic anomalies are small in amplitude. A magnetic sensor would be towed near the seafloor on a future cruise to measure these small anomalies. During the proposed JQZ surveys, a sea surface magnetometer would be towed by R/V *Sikuliaq*. The proposed seismic surveys are a prerequisite for processing these magnetic data, as they will provide crucial information on the structure of the oceanic crust that is used to model the source of the magnetic signals. The results of the seismic surveys, combined with the results of subsequently collected magnetic data, will help determine the processes that cause changes in the Earth's magnetic field.

To achieve the program goals, the PIs would use the capabilities of R/V *Sikuliaq* to conduct high-resolution profiles in Nauru Basin, greater Micronesia, in the Northwest Pacific Ocean. The proposed surveys would occur within ~6°–20°N and 154°E–167°E; representative survey tracklines are shown in Figure 1. The surveys are proposed to occur within the EEZ of the Republic of the Marshall Islands (RMI; herein also referred to as the Marshall Islands) and in international waters, where depths range from 4000 to 6000 m.

The surveys would involve one source vessel, R/V *Sikuliaq*. Marine technicians would deploy 4 GI airguns (2 arrays; 2 GI airguns per array) as an energy source, with a maximum discharge volume of ~420 in^3, from R/V *Sikuliaq*. The two arrays would be towed 11 m apart, at a speed of 5 kt and a depth of 3 m. The receiving system would consist of one 1200-m long hydrophone streamer. As the airguns are towed along the survey lines, the solid-state (solid flexible polymer made from extruded polyurethan, not gel or oil filled) hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

In addition to the operations of the airgun array, other acoustic sources, including a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and Acoustic Doppler Current Profilers (ADCP), would be operated from R/V *Sikuliaq* continuously during the seismic surveys. In addition, the R/V *Sikuliaq* would also tow a sea surface magnetometer and a shipboard gravitometer would also be used; the magnetometer is a passive system and would be towed taut behind the vessel. All planned marine-based geophysical data acquisition activities would be conducted by SIO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

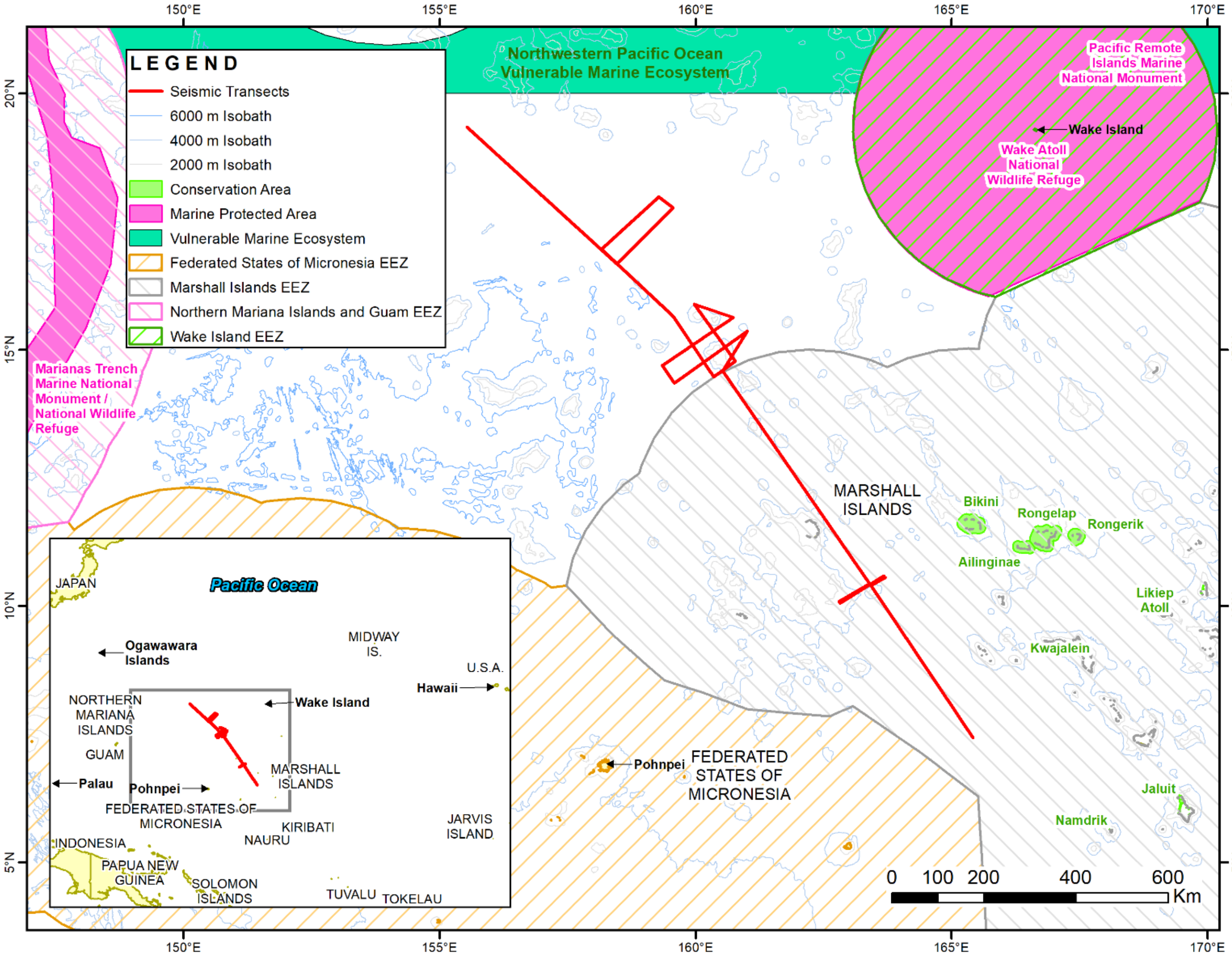

FIGURE 1. Survey area for the proposed seismic surveys in Nauru Basin, Greater Micronesia, during December 2024 to January 2025, showing representative transect lines and marine conservation and protected areas.

Source Vessel Specifications

R/V *Sikuliaq* is operated by the College of Fisheries and Ocean Sciences at University of Alaska Fairbanks under an existing Cooperative Agreement with NSF. R/V *Sikuliaq* has a length of 80 m, a beam of ~16 m, and a draft of ~6 m. The ship has diesel-electric engine with 5750 bhp. The cruising speed is 10 kt, and the range is 18,000 n.mi. with an endurance of 45 days. The vessel speed during seismic operations would be ~5 kt (~9.3 km/h). Other details of R/V *Sikuliaq* include the following:

Owner:	NSF
Operator:	University of Alaska
Flag:	U.S.
Date Built:	2014
Gross Tonnage:	3429
Accommodation Capacity:	46 including ~24 scientists

R/V *Sikuliaq* would also serve as the platform from which vessel-based protected species observers (PSO) would watch for marine species, including marine mammals, before and during airgun operations.

Airgun Description

R/V *Sikuliaq* would tow four GI airguns and one streamer containing hydrophones. The generator chamber of each GI gun, the one responsible for introducing the sound pulse into the ocean, would be 105 in^3. The injector chamber (105 in^3) injects air into the previously generated bubble to maintain its shape and does not introduce more sound into the water. The GI airgun(s) would be towed in two 2-GI gun clusters, with a fore-aft separation of 2 m. The two clusters would have a separation distance of 11 m and would be towed at a depth of 3 m, 25 m behind the vessel. Seismic pulses would be emitted at intervals of ~12 s (30 m) from the GI airgun(s).

GI Airgun Specifications

Energy Source:	Four GI airguns of 105 in^3 each
Gun positions used:	Inline airguns spaced ~2 m apart
Array separation distance:	11 m
Towing depth of energy source:	3 m
Source output*:	0-peak is 244.1 dB re 1 μPa; peak-peak is 248.4 dB re 1 μPa
Air discharge volume:	~420 in^3 (maximum volume to be used)
Dominant frequency components:	0–188 Hz
Gun volumes at each position (in^3):	105
Firing pressure:	2000 psi
Pulse duration:	0.113 s

*Source level is based on filtered farfield signature, using signatures filtered with DFS V out-256 Hz 72 dB/octave.

As the airguns are towed along the survey lines, the towed hydrophone array in the streamer would receive the reflected signals and transfer the data to the on-board processing system. The turning rate of the vessel with gear deployed would be ~5º. Thus, the maneuverability of the vessel would be limited during operations.

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

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

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

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

Mitigation zones for the proposed seismic surveys were not derived from the farfield signature but calculated based on modeling by Lamont-Doherty Earth Observatory (L-DEO) for both the full mitigation zones (160 dB re 1μPa_{rms}) for Level B takes and the exclusion zones (EZ) for Level A takes. The background information and methodology for this are provided in Appendix A and B, respectively. The proposed surveys would acquire data with four GI airguns (total discharge volume 420 in^3) at a tow depth of 3 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999).

Table 1 shows the distances at which the 160-dB re 1μPa_{rms} sound level is expected to be received for the 4-GI airgun array. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. Table 1 also shows the distance at which the 175-dB re 1μPa_{rms} sound level is expected to be received for the airgun source; this level is used by NMFS, based on U.S. DoN (2017), to determine behavioral disturbance for sea turtles.

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}). Different thresholds are available for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2016a, 2018), and sea turtles (DoN 2017). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances for marine mammals (Table 2).

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For recent low-energy seismic surveys supported by NSF, NMFS required PSOs to establish and monitor a 100-m EZ and a 200-m buffer zone beyond the EZ. In addition, a 500-m EZ was established for special circumstances, including observation of (1) beaked whales or right whales, (2) large whales with calf, and (3) aggregation of whales. Enforcement of mitigation zones via shut downs would be implemented as described in § XI or as otherwise required by regulators.

Description of Operations

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys by SIO and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Sikuliaq*, which would tow 4 GI airguns with a total discharge volume of ~420 in^3 at a depth of 3 m. The receiving system would consist of one 1200-m long hydrophone streamer. As the GI airguns are towed along the survey lines, the solid-state hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system.

TABLE 1. Predicted distances (based on L-DEO modeling) to behavioral disturbance sound levels ≥160-dB re 1 μPa$_{rms}$ and ≥175-dB re 1 μPa$_{rms}$ that could be received during the proposed surveys in Greater Micronesia. 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**	**Predicted distances (in m) to the 175-dB Received Sound Level**
Four 105-in^3 GI guns	3	>1000 m	1,408	251

TABLE 2. Level A (PTS) threshold distances for different marine mammal hearing groups for the 4-GI airguns based on a speed of 5 kts and a shot interval of ~12 s (30 m). Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SELcum or Peak SPLflat) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds***	**Sea Turtles***
PTS SEL$_{cum}$	**38.5**	0	0.1	0.5	0	**1.8**
PTS Peak	12.4	N.A/0	**85.8**	**14.0**	N.A./0	N.A./0

N.A. not applicable or available and assumed to be zero.

* For otariid pinnipeds and sea turtles, the 203 and 204 dB SELcum threshold does not exist in our modeling (maximum SEL$_{cum}$ = 202.2 dB), we then used the farfield SEL to compute the source factor.

The JQZ surveys would consist of ~3158 km of seismic acquisition (see Fig. 1). All effort would occur in water more than 4000 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 Section VII), 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed.

In addition to the operations of the airgun array, the ocean floor would be mapped with the Kongsberg EM304 (20–30 kHz) and Kongsberg EM710 (70–100 kHz), with a 0.5 degree x 1 degree transducer array. The Kongsberg TOPAS PS-18 SBP would be operated at frequencies of 0.5–6.0 kHz, 15–20 kHz, or 30–42 kHz. ADCPs would be used to measure water current velocities – the Teledyne RDI Ocean Surveyor ADCP has three available transducers which operate at frequencies of 38 kHz, 75 kHz, or 150 kHz; the Teledyne RDI Workhorse Sentinel ADCP operates at a frequency of 300 kHz. These sources are generally described in § 2.2.3.1 of the PEIS.

II. DATES, DURATION, AND REGION OF ACTIVITY

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

The proposed marine seismic surveys would occur within ~6°–20°N and 154°E–167°E; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, for the surveys, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within the EEZ of the RMI and in international waters, in water depths ranging from 4000 to 6000 m.

The proposed survey with the 4-GI airguns would be expected to take place during winter (December 2024 to January 2025) for a period of ~26.5 days, including ~13.5 days of seismic operations and 13 days of transit. R/V *Sikuliaq* would likely depart from Honolulu, Hawaii, on ~7 December 2024 and would return to Pohnpei, Federated States of Micronesia (FSM), on ~6 January 2025, after the program is completed.

III. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

Twenty-eight cetacean species (21 odontocetes and 7 mysticetes) could occur in or near the proposed survey area in greater Micronesia (Table 3). Five of the 28 marine mammal species are listed under the ESA as ***endangered***: the blue, fin, sei, and sperm whales, and the Western North Pacific DPS of the humpback whale.

No pinnipeds (seals or sea lions) are expected to occur there, although extralimital sightings of Hawaiian monk seals (*Neomonachus schauinslandi*) have been reported for Wake Island (Jefferson et al. 2015). To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of baleen and toothed whales are given in § 3.6.1 and § 3.7.1, of the PEIS. The Marianas qualitative analysis area (QAA) defined in the PEIS occurs in the Northwest Pacific Ocean, northwest of the proposed survey area. The general distribution of mysticetes and odontocetes in the Mariana Islands is discussed in § 3.6.3 and § 3.7.3 of the PEIS, respectively.

The following section details the species distributions in and near the proposed survey area in deep offshore waters of greater Micronesia.

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

Species	Occurrence in in Survey Area [1]	Habitat	Abundance in Mariana Islands[2]	Conservation Status		
				U.S. ESA[3]	IUCN[4]	CITES[5]
Mysticetes						
Humpback whale	Uncommon	Mainly nearshore, banks	2,673	EN/ NL[6]	LC	I
Common minke whale	Rare	Coastal, pelagic	450	NL	LC	I
Bryde's whale	Uncommon	Coastal, pelagic	1,596	NL	DD	I
Sei whale	Rare	Mostly pelagic	821	EN	EN	I
Omura's whale	Rare	Shelf waters	160	NL	DD	I
Fin whale	Rare	Slope, pelagic	46	EN	VU	I
Blue whale	Rare	Coastal, pelagic	150	EN	EN	I
Odontocetes						
Sperm whale	Uncommon	Pelagic, steep topography	5,146	EN	VU	I
Pygmy sperm whale	Uncommon	Deeper waters off shelf	11,168	NL	DD	II
Dwarf sperm whale	Uncommon	Deeper waters off shelf	27,395	NL	DD	II
Cuvier's beaked whale	Uncommon	Pelagic	2,642	NL	LC	II
Longman's beaked whale	Uncommon	Pelagic	11,253	NL	DD	II
Blainville's beaked whale	Uncommon	Pelagic	3,376	NL	DD	II
Ginkgo-toothed beaked whale	Uncommon	Pelagic	7,567	NL	DD	II
Deraniyagala's beaked whale	Rare	Pelagic	N.A.	NL	DD	II
Risso's dolphin	Uncommon	Shelf, slope, seamounts	17,184	NL	LC	II
Rough-toothed dolphin	Uncommon	Mainly pelagic	1,815	NL	LC	II
Common bottlenose dolphin	Uncommon	Coastal, shelf, pelagic	1,076	NL	LC	II
Pantropical spotted dolphin	Common	Coastal, pelagic	85,755	NL	LC	II
Spinner dolphin	Uncommon	Coastal. pelagic	5,232	NL	LC	II
Striped dolphin	Uncommon	Off continental shelf	24,528	NL	LC	II
Fraser's dolphin	Uncommon	Pelagic	76,476	NL	LC	II
Common dolphin	Rare	Costal, pelagic	N.A.	NL	LC	II
Short-finned pilot whale	Uncommon	Pelagic, high-relief	6,583	NL	LC	II
Killer whale	Rare	Widely distributed	253	EN	DD	II
False killer whale	Uncommon	Pelagic	4,218	NL	NT	II
Pygmy killer whale	Rare	Pelagic	527	NL	LC	II
Melon-headed whale	Uncommon	Pelagic	16,551	NL	LC	II

N.A. not available. [1] Occurrence in area at the time of the survey, based on densities provided in DoN (2018); rare is <0.0003 animals/km^2; uncommon is between 0.0003 animals/km^2 and 0.01 animals/km^2, common is >0.01 animals/km^2. [2] Abundance for the U.S. Navy Mariana Islands Training and Testing (MITT) area + Wake Island Transit Corridor (NMFS 2020a). [3] U.S. Endangered Species Act (ESA; NOAA 2024a): EN = Endangered; T = Threatened; DL = Delisted; NL = Not listed. [4] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, version 2023-1 (IUCN 2024); 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 and IUCN 2024): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled. [6] The Western North Pacific DPS is listed as endangered; the Oceania DPS is not listed.

Mysticetes

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).

Humpback whales occur throughout most of the Pacific, but are rare in the equatorial region (Jefferson et al. 2015). 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). They winter in four different breeding areas in the North Pacific: (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 North Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; Carretta et al. 2023). Breeding has also been documented in the Mariana Islands (Hill et al. 2020a,b). It is possible that animals that breed in the waters of the Philippines, Okinawa, and Ryukyu Archipelago comprise a different stock from those that breed off the Mariana Islands and Ogasawara (Bettridge et al. 2015; Hill et al. 2020b; Oleson et al. 2022). Andrews et al. (2023) hypothesized that breeding humpback whales may also occur in Palau, although sightings there have not been confirmed. If humpbacks are encountered during the proposed surveys during December to January, they would most likely be from the ***endangered*** Western North Pacific DPS; individuals from this DPS have been photographically identified in the Mariana Islands region (NMFS 2020a).

There appears to be a very low level of interchange between Asian wintering or feeding areas and those in the eastern and central Pacific (Calambokidis et al. 2008). However, several individuals have been seen in the wintering areas of Japan and Hawaii in separate years (Darling and Cerchio 1993; Salden et al. 1999; Calambokidis et al. 2001), and one individual was seen in both the wintering area of the Mariana Islands in February 2017 and in Mexico in February 2018 (Ransome et al. 2023). Whales from the central and eastern Pacific wintering areas travel to summer feeding areas in British Columbia, Canada, and Alaska (Darling et al. 1996; Calambokidis et al. 2001), but whales from the Western North Pacific DPS typically feed in Russian waters (Calambokidis et al. 2008; Ransome et al. 2023).

In the South Pacific Ocean, there are distinct breeding grounds off eastern Australia and Oceania (Anderson et al. 2010; Garrigue et al. 2011a). Although genetic evidence also indicates several discrete breeding grounds within Oceania, including New Caledonia, Tonga, and French Polynesia (Olavarría et al. 2003, 2007), some movement has been shown between breeding areas within Oceania (Garrigue et al. 2002, 2011a; Clapham et al. 2008) and between Oceania and eastern Australia (Anderson et al. 2010; Garrigue et al. 2011b). However, it is unlikely that whales from these breeding grounds and non-listed Oceania DPS would be encountered in the proposed survey area at the time of the study.

The breeding population of humpback whales in the Mariana Islands has been estimated to range from 34 to 126 individuals (Hill et al. 2020a). According to NOAA (2018), humpbacks occur in the Marianas from December through April, with an average density of 0.16 whales/km^2 (Hill et al. 2020a). At least five sightings of humpback whales were made from 1978 to 1996 in the Mariana Islands; group sizes were 2 to 6, and one sighting was of a mother-calf pair (Eldredge 2003). There were no humpback sightings during the January–April 2007 surveys in the Mariana Islands (DoN 2007; Norris et al. 2012). However, humpbacks were detected acoustically in the Mariana Islands, including just west of the proposed survey area, during January–April 2007 (DoN 2007; Norris et al. 2012), during acoustic recorder deployments in 2010–2013 (Oleson et al. 2015), and during glider surveys in the southern Mariana Trench region during September–November 2014 (Klink et al. 2015). Forty-two sightings were made during NOAA's Pacific Islands Fisheries Science Center (PIFSC) surveys of the southern Mariana Islands between 2010 and 2019 (Hill et al. 2020c) and in May 2021 (Yano et al. 2022). During surveys in February–March 1999–2001, Shimada and Miyashita (2001) did not report any sightings of humpback whales in the FSM, Mariana Islands, Solomon Islands, or Papua New Guinea. Similarly, there are no reports of humpback whales for Palau, Kiribati, or Naura (Wiles 2005; Miller 2023). However, records of humpback whales have been reported for RMI (Wiles 2005; Miller 2023), Solomon Islands (OBIS 2024), and Papua New Guinea (SPREP 2022; OBIS 2024). One whale that traveled between the Mariana Islands and Mexico may have traversed the proposed survey area (see Ransome et al. 2023).

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). The distribution of common whales in the South Pacific is not well known (Jefferson et al. 2015).

For the western Pacific stock, one group is thought to breed near the Ogasawara-Japan Trench during winter and could represent minke whales that are observed around the Mariana Islands (Smith et al. 2003). Despite a lack of visual detections during surveys of the southern Mariana Islands during 2007 (Fulling et al. 2011), minke whales were the baleen whale species most frequently detected acoustically during the January–April 2007 surveys in the Mariana Islands (DoN 2007; Norris et al. 2012, 2017), including just west of the proposed survey area. Acoustic detections were also made in the CNMI during 2010–2013 (Oleson et al. 2015). There has been one sighting along the eastern edge of the proposed survey area at 19.3°N, 166.6°E during the NOAA PIFSC cruise in January–February 2010 (PIFSC 2010a; Hill 2023a), and acoustic detections were made in the southern Mariana Islands during March–April 2010 (Hill et al. 2020c). There is also one record south of the proposed survey area at the Equator and 160°E (OBIS 2024) and an unconfirmed record for Palau (Miller 2023). Minke whales are known to occur in the RMI (Miller 2023), but there are no records for FSM, Kiribati, Solomon Islands or Papua New Guinea (SPREP 2022; Andrews et al. 2023; Miller 2023).

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 occur in both shallow coastal and deeper offshore waters (Jefferson et al. 2015). Bryde's whales in the eastern and western Pacific may comprise different stocks (Taguchi et al. 2023). Furthermore, whales in the East China Sea and coastal waters of Kochi, Japan, differ from the whales in offshore waters of the western North Pacific, perhaps at the subspecific level (Yoshida and Kato 1999). However, the reclassification of Bryde's whale remains unresolved (Jefferson et al. 2015).

Ohizumi et al. (2002) reported that Bryde's whales occur throughout the western North Pacific during winter, including the Mariana, Ogasawara, and Philippine islands. Bryde's whale sightings were made in the proposed survey area between 1998–2002, including during January to March (Shimada 2003; Shimada 2008 *in* Matsuoka et al. 2010). Sightings have also been made just north of the proposed survey area during 2014 (Matsuoka et al. 2015; Hakamada et al. 2017) and near Wake Island during January 2010 (Oleson and Hill 2010 *in* DoN 2020). Bryde's whales were taken in the FSM by the Philippine fishery during the 1980s (Perrin 2006). Additionally, Bryde's whale sightings were made during surveys in February to March 1999–2001 in the FSM, north of Papua New Guinea, Solomon Islands, and near the Mariana Islands (Shimada and Miyashita 2001).

Bryde's whales are considered the most common baleen whale in the Marianas region, with sightings occurring there from May to August (Kishiro 1996; Miyashita et al. 1996; Eldredge 2003). Similarly, Bryde's whale calls were reported in the Marianas during spring/summer 2018 and 2021 (Yano et al. 2022; Szesciorka et al. 2023). However, Tepp et al. (2021) reported year-round calls in the Mariana Islands. During January–April 2007 shipboard surveys in the waters of the Mariana Islands, Bryde's whale was one of the most frequently sighted baleen whales (DoN 2007; Fulling et al. 2011), including just west of the proposed survey area. Sightings were also made there during aerial surveys in August 2007 (Mobley 2007). Additionally, five sightings were made during surveys of the southern Mariana Islands during 2010–2019, three encounters were reported during the Mariana Archipelago Cetacean Survey (MACS) in 2015, and there were 10 sightings during MACS 2018 (Hill et al. 2020c). Bryde's whales are also known to occur in Palau (Andrews et al. 2023) and have been sighted during summer 2014 surveys in the RMI (Matsuoka et al. 2015). Additionally, Bryde's or Bryde's-like whales have also been reported off Wake Island and Nauru (Wiles 2005; Miller 2023). Ohsumi (1978) reported high densities of Bryde's whales along the Equator between 130°W and 180°W.

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). 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). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018).

In the Southern Hemisphere, sei whales are generally not found north of 30ºS (Reeves et al. 1999; Jefferson et al. 2015). 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. 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). Its winter distribution is concentrated at ~20°N (Rice 1998).

Three sightings of sei whales were made within the proposed survey area during the NOAA PIFSC transit from Hawaii to Guam during January–February 2010 (PIFSC 2010a; Hill 2023a). During January–April 2007 surveys of the Mariana Islands, the sei whale was one of the most frequently sighted baleen whales (DoN 2007; Fulling et al. 2011), including sightings just west of the proposed survey area. All sei whale sightings were south of Saipan in water >1000 m deep, with a number of sightings directly over the Mariana Trench; 32 acoustic detections were also recorded (Norris et al. 2012). No sei whales were detected during surveys of the southern Mariana Islands during 2010–2019 (Hill et al. 2020c). Sei whales have not been reported for Palau or the Solomon Islands, but there are sei whale records for RMI and Papua New Guinea (Wiles 2005; SPREP 2022; Andrews et al. 2023; Miller 2023).

Omura's Whale (*Balaenoptera omurai*)

Omura's whale is known to occur in the Indo-Pacific region, but its full distributional range remains uncertain (Cerchio and Yamada 2008). It was first described by Wada et al. (2003) based on records for the eastern Indian Ocean, Sea of Japan, and Solomon Sea (Wada et al. 2003). In the Pacific Ocean, there have also been two strandings in the Philippines between 1998 and 2009 (Aragones et al. 2010) and one stranding in Australia (Cerchio and Yamada 2008). Wada and Numachi (1991) and Yoshida and Kato (1999) had previously noted that whales in the Solomon Islands were distinct from Bryde's whales from offshore waters of the western North Pacific and the East China Sea. In fact, this species is not as closely related to Bryde's, Eden's, or sei whales as previously thought (Sasaki et al. 2006). Omura's whale mostly occurs over the continental shelf in nearshore waters and is generally seen alone or in pairs (Jefferson et al. 2008). Andrews et al. (2023) noted that Omura's whale probably occurs in Palau. However, there are no records of this species for the proposed survey area (Wada et al. 2003).

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). Jefferson et al. (2015) noted that fin whales are rare in tropical waters; equatorial waters are part of this species' secondary range. 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 in the eastern Pacific (Gambell 1985). The current distribution of fin whales in the western North Pacific is largely unknown, but they are known to winter in the Yellow, East China, and South China seas (Parsons et al. 1995; Rudolph and Smeenk 2002). They have also been detected in offshore waters off

Japan north of 35°N (Edwards et al. 2015; Tamura et al. 2015; Hakamada and Matsuoka 2016). 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), including the western North Pacific (Edwards et al. 2015). They were detected acoustically near Wake Island during January 2010 (Oleson and Hill 2010 *in* DoN 2020). However, no fin whales were sighted or detected acoustically during the January–April 2007 surveys in the waters of the Mariana Islands (DoN 2007; Fulling et al. 2011) or during NOAA surveys of the Mariana Islands (Hill et al. 2020c; Yano et al. 2022). Similarly, Edwards et al. (2015) reported densities of zero for the Mariana Islands during December–February and also did not report any records for the proposed survey area. However, acoustic detections were made on recorders deployed in the CNMI during 2010–2013 (Oleson et al. 2015). There are no records for Palau, Solomon Islands, or Papua New Guinea (SPREP 2022; Andrews et al. 2023; Miller 2023; OBIS 2024), but fin whales are known to occur in the RMI and Wake Island (Wiles 2005; SPREP 2022; Miller 2023).

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). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections.

Analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: the eastern and central (formerly western) stocks (NMFS 2020b; Carretta et al. 2023). 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; Busquets-Vass et al. 2021; Carretta et al. 2023). In the Northeast Pacific Ocean, blue whale calls are detected year-round (Stafford et al. 1999, 2001, 2009; Watkins et al. 2000; Moore et al. 2002; Stafford 2003; Monnahan et al. 2014).

The current distribution of blue whales in the western North Pacific is largely unknown. Nonetheless, the central North Pacific stock is known to feed 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. 2023). Few blue whales have been reported recently in the western North Pacific (Sears and Perrin 2018), but sightings have been made off Japan (Tamura et al. 2015; Branch et al. 2016; Hakamada and Matsuoka 2016; Katsumata and Matsuoka 2021; Takahashi et al. 2022). Branch et al. (2007) reported a sighting near the Equator and 175°E.

There is almost no information on the occurrence of blue whales in greater Micronesia (Reeves et al. 1999). No blue whales were sighted or detected acoustically during the January–April 2007 survey in the waters of the Mariana Islands (DoN 2007; Fulling et al. 2011) or during NOAA surveys of the Mariana Islands (Hill et al. 2020c; Yano et al. 2022). However, acoustic detections have been made at recorders deployed in the CNMI during 2010–2013 (Oleson et al. 2015). There is also one blue whale record for Guam for 1975 (OBIS 2024). In addition, there are confirmed records for the RMI, Wake Island, and unconfirmed records for Kiribati, but no records for the FSM (Wiles 2005; SPREP 2022; Miller 2023). It has not been confirmed for Palau (Andrews et al. 2023). The blue whale is also considered rare in the Southern Hemisphere (Sears and Perrin 2018). In the southwestern Pacific Ocean, but it has been reported near Papua New Guinea, Solomon Islands, Cook Islands, New Zealand, Australia, and New Caledonia (Reeves et al. 1999; SPREP 2022; Miller 2023).

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

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

The sperm whale is the most common large toothed whale in the Pacific Islands region (Reeves et al. 1999). There are historical whaling records throughout the region for April–September, including within the proposed survey area (Townsend 1935). Two sightings were made within the proposed survey area during a transit by NOAA from Hawaii to Guam during January–February 2010 (PIFSC 2010a; Hill 2023a), and three sightings were made east of the proposed survey area during a transit by NOAA from Guam to Hawaii in April–May 2010 (PIFSC 2010b; Hill 2023b). Additionally, sperm whales have been sighted just north of the proposed survey area during summer surveys in 2014 (Matsuoka et al. 2015). Sperm whales were also sighted during surveys in February–March 1999–2001 in the FSM, north of Papua New Guinea, and the Solomon Islands (Shimada and Miyashita 2001). Miyazaki and Wada (1978) also reported sperm whale sightings during surveys in January–March 1976 north of Papua New Guinea and in the Solomon Islands. The Bismarck Sea in Papua New Guinea appears to be an important breeding ground for sperm whales; mother/calf pairs and mature males have been seen in this area (Madsen et al. 2002).

The sperm whale was the most frequently sighted cetacean (21 sightings) during the January–April 2007 survey in the waters of the Mariana Island, and acoustic detections were three times higher than visual detections (DoN 2007; Fulling et al. 2011; Norris et al. 2012); sperm whales were detected in deep waters throughout most of Mariana Islands, as well as just west of the proposed survey area. During the 2007 surveys, there were multiple sightings of groups that included calves (DoN 2007). Observations were made of several large bulls with fresh tooth marks (one male rammed the survey ship) in 2007, which suggests that these males were engaged in competition for mates (Fulling and Salinas Vega 2009). Thus, there is evidence that this area is used for breeding and calving by sperm whales. Eldredge (2003) reported a sighting of a group of sperm whales including a newborn calf off the west coast of Guam. Additionally, acoustic detections were made on recorders in the CNMI during 2010–2013 (Oleson et al. 2015) and during glider surveys in the southern Mariana Trench during September–November 2014 (Klink et al. 2015). Seven sightings of sperm whales were made during surveys conducted in the southern Mariana Islands during 2010–2019, three encounters were made during MACS 2015, and two sightings were recorded during MACS 2018 (Hill et al. 2020c). Sperm whales were also seen and detected acoustically during May–July 2021 surveys in the Mariana Islands (Yano et al. 2022). Sightings have also been made during surveys off Palau (Andrews et al. 2023). Sperm whales are also known to occur in the RMI, Kiribati, and

Nauru (Wiles 2005; SPREP 2022; Baker et al. 2013; Murase et al. 2013; Miller 2023). There are numerous records for the FSM, RMI, Palau, Guam, CNMI, Solomon Islands, and Papua New Guinea in the OBIS database (OBIS 2024).

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 Eastern Tropical Pacific (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.

Kogia spp. are known to occur in tropical and warm temperate areas of the western Pacific Ocean. Although there were no sightings of either pygmy or dwarf sperm whales during the January–April 2007 shipboard surveys in the Mariana Islands (DoN 2007; Fulling et al. 2011), three *Kogia* sp. were seen during aerial surveys in August 2007 (Mobley 2007). Dwarf sperm whales were reported near Guam in May 2016 (Merkens et al. 2016). Five sightings of dwarf sperm whales were made during surveys conducted in the southern Mariana Islands in 2010–2019 (Hill et al. 2020c), one dwarf sperm whale was during MACS 2018, and another sighting was made during May 2021 (Yano et al. 2022). Acoustic detections of *Kogia* spp. were also made west of the Mariana Islands during July 2018 (McCullough et al. 2021). In addition, there are strandings records for Guam, including five strandings of dwarf sperm whales and one stranding of a pygmy sperm whale (Kami and Lujan 1976; Reeves et al. 1999; Eldredge 1991, 2003). The occurrence of *Kogia* spp. has been confirmed in the FSM (Buden and Bourgoin 2018), Papua New Guinea (SPREP 2022; Miller 2023), and there is a record of a dwarf sperm whale north of the Solomon Islands (OBIS 2024). Records of pygmy sperm whales (bone fragments) have also been reported for Kiribati (Baker et al. 2013). There are no records of *Kogia* spp. for Palau or the RMI (SPREP 2022; Miller 2023). However, Andrews et al. (2023) noted that *Kogia* spp. are likely to occur in the waters of Palau.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

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

Cuvier's beaked whale occurs throughout the deep waters of the western Pacific Ocean. In greater Micronesia, it is known to occur in the FSM and Wake Island (Wiles 2005), Palau (Andrews et al. 2023), Mariana Islands (SPREP 2022), and there are unconfirmed records for Nauru (SPREP 2022; Miller 2023). There are also two stranding records for the RMI (Bachara n.d.). Additionally, Cuvier's beaked whales were sighted on surveys during January–March 1976 off Papua New Guinea (Miyazaki and Wada 1978), and there are records for the Solomon Islands (Robards and Reeves 2011), and Kiribati (Baker et al. 2013). In the Mariana Islands, one sighting was made during NOAA's PIFSC surveys during 2010–2019, and one sighting of two individuals and acoustic detections were made during MACS 2018 (Hill et al. 2020c). Acoustic detections were also made off the Mariana Islands during 2010–2014 (Oleson et al. 2015; Simonis et al. 2020) and west of the Mariana Islands during July 2018 (McCullough et al. 2021). One ziphiid whale not identified to species was observed in deep water during the January–April 2007 survey in the Mariana Islands (DoN 2007; Fulling et al. 2011), and a confirmed Cuvier's beaked whale was seen during aerial surveys in 2007 (Mobley 2007). Cuvier's beaked whale has also been reported in the Ogasawara islands (Masaki 1972 *in* Eldredge 2003).

Longman's Beaked Whale (*Indopacetus pacificus*)

Longman's beaked whale, also known as Indo-Pacific beaked whale or tropical bottlenose whale, occurs in tropical waters throughout the Indo-Pacific, as well as Hawaii (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). Sightings of Longman's beaked whale have occurred at numerous locations in tropical waters of the Indo-Pacific region (Pitman 2018a; Jefferson et al. 2015). Records for this species exist for Japan (Yamada et al. 2004), Philippines (Acebes et al. 2005; Aragones et al. 2010), and Taiwan (Yang et al. 2008). There were no sightings during the January–April 2007 surveys in the waters of the Mariana Islands (DoN 2007; Fulling et al. 2011). However other studies reported one sighting during surveys of the southern Mariana Islands during 2010–2019 (Hill et al. 2020c), and two sightings as well as acoustic detections during MACS 2018 (Hill et al. 2020c). Acoustic detections were also made west of the Mariana Islands during July 2018 (McCullough et al. 2021), and two sightings and acoustic detections were recorded in the Mariana Islands during May 2021 (Yano et al. 2022). There are no records of this species for Palau, FSM, Papua New Guinea, or the Solomon Islands (Miller 2023). However, Andrews et al. (2023) noted that they are likely to occur in Palau.

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 greater Micronesia, records of this species have been reported for Kiribati (Baker et al. 2013) and the Mariana Islands (SPREP 2022; Miller 2023). Two sightings were made during surveys of the southern Mariana Islands during 2010–2019, and another two sightings and acoustic detections were made during MACS 2015 (Hill et al. 2020c). Acoustic detections were also made off the northern Mariana Islands during 2010–2014 (Oleson et al. 2015; Simonis et al. 2020), during MACS 2018 (Hill et al. 2020c), and west of the Mariana Islands during July 2018 (McCullough et al. 2021). There are no records for the FSM, RMI, or Palau (SPREP 2022; Miller 2023). Its occurrence in the Solomon Islands and Papua New Guinea is uncertain (SPREP 2022).

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 Galapagos 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 1996a). There is a report of a juvenile ginkgo-toothed whale that was caught near the proposed survey area in the FSM by a Taiwanese longliner at 4.43°N, 152.20°E (Dalebout et al. 2008).

However, there are no confirmed sightings for the RMI, Wake Islands, Guam, Palau, Nauru, Solomon Islands, or Papua New Guinea (SPREP 2022; Miller 2023), although they may have been detected acoustically during 2010–2013 in the CNMI (Oleson et al. 2015). Andrews et al. (2023) noted that they are likely to occur in Palau, and there are unconfirmed records for Kiribati (SPREP 2022).

Deraniyagala's Beaked Whale (*Mesoplodon hotaula*)

Deraniyagala's beaked whale occurs in the tropical Indo-Pacific 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). Acoustic detections have been made at Palmyra Atoll and Kingman Reef in the Line Islands (Baumann-Pickering et al. 2014), and possibly at the Mariana Islands (Hill et al. 2020c). 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).

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). In the western Pacific Ocean, Risso's dolphin ranges from the Kuril Islands to New Zealand and Australia (Jefferson et al. 2015), including Micronesia. Miyashita et al. (1996) reported sightings during surveys of the Mariana Islands in 1993–1995, and Miyazaki and Wada (1978) reported a sighting within the EEZ of Guam. Although DoN (2007) did not report any Risso's dolphins during surveys of the Mariana Islands in January–April 2007, two encounters were made during MACS 2015, and one pod of eight was seen during MACS 2018 (Hill et al. 2020c). Additionally, acoustic detections were made during glider surveys in the southern Mariana Trench during September–November 2014 (Klink et al. 2015). There are also confirmed records for Palau (Andrews et al. 2023; Miller 2023), but no records for FSM (Miller 2023). Sightings have also been made off Papua New Guinea, including the Bismarck Sea (Miyazaki and Wada 1978; Visser 2007). In addition, Risso's dolphin has been sighted during surveys in the Solomon Islands (Miyazaki and Wada 1978; Oremus 2011).

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 western Pacific, it occurs from central Japan to northern Australia, including greater Micronesia (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 July 2004, rough-toothed dolphins were seen off Rota, in the northern Mariana Islands (Jefferson et al. 2006). There were two sightings of rough-toothed dolphins during the January–April 2007 survey in the Mariana Islands (DoN 2007; Fulling et al. 2011), in groups of 7 and 15 with calves present in one of the sightings; both sightings occurred in deep (1000–4500 m) water. Additional sightings were made during August 2007 aerial surveys off the southern Mariana Islands (Mobley 2007), and they were also detected acoustically in 2007 (Norris et al. 2012). Nine sightings were made during surveys conducted in the southern Mariana Islands during 2010–2019, four encounters were reported during MACS 2015, and three sightings occurred during MACS 2018 (Hill et al. 2020c). There are also confirmed records for Kiribati (Miller 2023) and unconfirmed records for the RMI (SPREP 2022). However, there are no records for Palau or the FSM (SPREP 2022; Miller 2023), although Andrews et al. (2023) noted that it is likely to occur in Palau. A possible sighting of rough-toothed dolphin was made in the Bismarck Sea off Papua New Guinea (Visser 2007), and they are known to occur in the Solomon Islands (Robards and Reeves 2011; SPREP 2022; Miller 2023; OBIS 2024).

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 western Pacific, the bottlenose dolphin is distributed from Japan to Australia and New Zealand (Jefferson et al. 2015), including greater Micronesia. Bottlenose dolphins were sighted three times during the January–April 2007 surveys in the Mariana Islands (DoN 2007; Fulling et al. 2011), including just west of the proposed survey area. Forty sightings were made during surveys conducted in the southern Mariana Islands during 2010–2019, three encounters were recorded during MACS 2015, and four sightings were reported during MACS 2018 (Hill et al. 2020c). Trianni and Kessler (2002) also reported bottlenose dolphins in coastal waters of Guam. Sightings have also been reported for Palau (Andrews et al. 2023), and their occurrence has been reported in the RMI, FSM, and Kiribati (SPREP 2022; Miller 2023). Additionally, sightings have been made in Papua New Guinea, including the Bismarck Sea (Miyazaki and Wada 1978; Visser 2007) and during surveys in the Solomon Islands (Miyazaki and Wada 1978; Oremus 2011).

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 western Pacific Ocean, the pantropical spotted dolphin occurs from Japan south to Australia (Jefferson et al. 2015), including greater Micronesia. Miyashita (1993) reported sightings within the proposed survey area during 1983–1991 surveys. During surveys in January–March 1976, Miyazaki and Wada (1978) reported sightings of pantropical spotted dolphins near the FSM and off Papua New Guinea and the Solomon Islands. Oremus (2011) also reported sightings of pantropical spotted dolphins in the Solomon Islands. Pantropical spotted dolphins were seen in the waters of the Mariana Islands during January–April 2007 shipboard surveys (DoN 2007; Fulling et al. 2011) and August 2007 aerial surveys (Mobley 2007), including just west of the proposed survey area. Most (11 of 17) sightings were in deep (>3000 m) water, and there were multiple sightings that included calves (DoN 2007). Fifty-three sightings were made during surveys conducted in the southern Mariana Islands during 2010–2019, and nine sightings were made during MACS 2018 (Hill et al. 2020c). Additionally, this species has been sighted during dedicated surveys off Palau (Andrews et al. 2023). There are also records for the RMI, FSM, and Kiribati (Wiles 2005; SPREP 2022; Miller 2023).

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). Two subspecies of spinner dolphin occur in the western Pacific Ocean: the widespread, offshore spinner dolphin (*Stenella longirostris longirostris*) and the dwarf spinner dolphin (*S. l. roseiventris*). There is little or no genetic interchange between the two subspecies (Dizon et al. 1991). *S. l. longirostris* is pantropical, occurring from Japan, through to the Philippines, and south to Australia, including Micronesia; *S. l. roseiventris* only inhabits the shallow waters of inner Southeast Asia (Perrin et al. 1999).

The spinner dolphin is expected to occur throughout the Mariana Islands (Trianni and Kessler 2002), but only one sighting was made during January–April 2007 surveys in the area (DoN 2007; Fulling et al. 2011). The pod was encountered northeast of Saipan in 425 m of water and was estimated to contain 98 individuals; acoustic detections were also recorded (Norris et al. 2012). Spinner dolphins were encountered 161 times during surveys conducted in the southern Mariana Islands during 2010–2019, 12 encounters were reported during MACS 2015, and 7 sightings were made during MACS 2018 (Hill et al. 2020c). Miller et al. (2016) also reported spinner dolphin sightings in the coastal waters of Guam. Spinner dolphins have also been sighted during surveys off Palau (Andrews et al. 2023). Additionally, spinner dolphins are also known to occur in the FSM and RMI (Wiles 2005; SPREP 2022; Miller 2023), and Kiribati (Murase et al. 2013). Spinner dolphins have also been sighted in Papua New Guinea during surveys by Visser and Bonoccorso (2003) and Visser (2007); sometimes they were seen in association with killer whales (Visser and Bonoccorso 2003). Miyazaki and Wada (1978) also reported sightings of spinner dolphins off Papua New Guinea, and there were two sightings southwest of the proposed survey area near 2°N, 140°E. Spinner dolphins have also been sighted during surveys in the Solomon Islands (Miyazaki and Wada 1978; Oremus 2011).

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). The striped dolphin occurs in temperate and tropical regions of the western Pacific, ranging from Russian waters south to Australia and New Zealand (Jefferson et al. 2015), including greater Micronesia. Sightings have been made during surveys in the FSM (Miyazaki and Wada 1978), and Miyashita (1993) reported sightings just north of the proposed survey area during 1983–1991 surveys. Striped dolphins were sighted 10 times during the January–April 2007 surveys in the waters of the Mariana Islands (DoN 2007; Fulling et al. 2011), including just west of the proposed survey area; they were also detected acoustically (Norris et al. 2012). Detections were made in water depths ~2350–7600 m, and several groups included calves. Additionally, one pod of 20 spinner dolphins was encountered during MACS 2018 (Hill et al. 2020c). Striped dolphins are also known to occur in the RMI, Palau, Kiribati, and the Solomon Islands, but there are no records for Papua New Guinea (Wiles 2005; SPREP 2022; Andrews et al. 2023; Miller 2023; OBIS 2024).

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). In the western Pacific Ocean, their distributional range extends from Japan down to Australia, including greater Micronesia (Jefferson et al. 2015). Fraser’s dolphins have been sighted in the FSM and Papua New Guinea during surveys by Miyazaki and Wada (1978). They are also known to occur in Nauru, Kiribati, and the Solomon Islands (Robards and Reeves 2011; Miller 2023) and off Palau (Andrews et al. 2023). However, there are no records for the Mariana Islands (SPREP 2022; Miller 2023).

Common Dolphin (*Delphinus delphis*)

The common dolphin is distributed in tropical to cool temperate waters of the Atlantic and the Pacific oceans from 60ºN to ~50ºS (Jefferson et al. 2015). It is the most abundant dolphin species in offshore areas of warm-temperate regions in the Atlantic and Pacific (Perrin 2018c). It is common in coastal waters 200–300 m deep (Evans 1994), but it can also occur thousands of kilometers offshore (Jefferson et al. 2015). In the western Pacific Ocean, it is known to occur from Japan south to Australia and New Zealand (Jefferson et al. 2015). Although neither Jefferson et al. (2015) nor Perrin (2018c) included Micronesia to be within this species' distributional range, SPREP (2022) and Miller (2023) report its occurrence in the RMI and one record has been reported for the Mariana Islands (OBIS 2024). Fulling et al. (2011) noted that its occurrence in the Mariana Islands is rare. Sightings have been made north of the proposed survey area, north of 35°N (Katsumata and Matsuoka 2021, 2022).

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. (2017) suggested that two types of short-finned pilot whales occur in the Pacific – one in the western and central Pacific, and one in the Eastern Pacific; they hypothesized that prey distribution rather than sea surface temperature determine their latitudinal ranges. In Japanese waters, two stocks have been identified based on pigmentation patterns and head shape differences of adult males (Kasuya et al. 1988). The southern stock of short-finned pilot whales (Kasuya et al. 1988) is likely associated with the Marianas Islands area (Miyashita 1993).

The range of the short-finned pilot whale in the western Pacific includes the waters from Sakhalin Island, Russia, south to Australia and New Zealand, including greater Micronesia. There were four sightings of short-finned pilot whales during a January–April 2007 survey in the Mariana Islands, which were sighted in water depths of ~900–4500 m (DoN 2007; Fulling et al. 2011). Pilot whales were also detected acoustically northwest of the Mariana Islands in 2007 (Norris et al. 2012). In addition, 23 sightings were made during surveys conducted in the southern Mariana Islands during 2010–2019, and three encounters were made during MACS 2018 (Hill et al. 2020c). Pilot whales have been sighted during surveys in coastal waters of Guam from 1963 to 2012 (Martins et al. 2016). A group of more than 30 was sighted in late April 1977 near Uruno Point, off the northwest coast of Guam (Birkeland 1977), and a stranding occurred on Guam in July 1980 (Schulz 1980; Kami and Hosmer 1982; Donaldson 1983). Short-finned pilot whales have also been sighted during surveys in the Solomon Islands (Oremus 2011) and Papua New Guinea (Miyazaki and Wada 1978). The presence of short-finned pilot whales has also been confirmed in the FSM (Buden and Bourgoin 2018), Palau (Andrews et al. 2023), as well as the RMI and Kiribati (SPREP 2022; Miller 2023).

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). In greater Micronesia, killer whales are known to occur in the RMI, FSM, Kiribati, and off Palau (Wiles 2005; Murase et al. 2013; Buden and Bourgoin 2018; SPREP 2022; Andrews et al. 2023; Miller 2023). They may also occur in Nauru (SPREP 2022; Miller 2023). There are a few records (most unconfirmed) of killer whales off Guam (Eldredge 1991, 2003), including a badly decomposed killer whale found stranded on Guam in August 1981 (Kami and Hosmer 1982). No killer whales were sighted during the January–April 2007 surveys in the waters of the Mariana Islands (DoN 2007; Fulling et al. 2011) or during PIFSC surveys of the southern Mariana Islands or MACS (Hill et al. 2020c). However, acoustic detections were made during glider surveys in the southern Mariana Trench during September–November 2014 (Klink et al. 2015). Off Papua New Guinea, killer whales have been reported for 10 months of the year there, with group sizes ranging from one to ~20 individuals (Visser and Bonoccorso 2003); calves were mostly seen during April (Visser 2007).

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 western Pacific Ocean, the false killer whale is distributed from Japan south to Australia and New Zealand (Jefferson et al. 2015), including greater Micronesia. Five sightings have been reported during surveys in January–April 2007 in the Mariana Islands (DoN 2007; Fulling et al. 2011), including just west of the proposed survey area; some pods included calves. False killer whales were also detected acoustically during the 2007 surveys (Norris et al. 2012). Six sightings were made during surveys conducted in the southern Mariana Islands during 2010–2019, and two encounters were recorded during MACS 2015 (Hill et al. 2020c). Additionally, one sighting was made just west of the proposed survey area at ~15.8°N, 153.2°E during a transit by NOAA from Hawaii to Guam in January–February 2010 (PIFSC 2010a; Hill 2023a), and one sighting was made southwest of the proposed survey area at ~4.9°N, 138.6°E (Miyazaki and Wada 1978). DoN (2020) also noted that Oleson and Hill (2010) reported a sighting of five false killer whales near Wake Islands during 2010. There are additional sightings for the FSM (Buden and Bourgoin 2018), Palau (Andrews et al. 2023), and Kiribati (Murase et al. 2013), and other records for the RMI (Wiles 2005). Sightings have also been reported for Papua New Guinea, including the Bismarck Sea (Miyazaki and Wada 1978; Visser 2007), and during surveys in the Solomon Islands (Oremus 2011).

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 warmer water, it is usually seen close to the coast (Wade and Gerrodette 1993), but it is also found in deep waters. In the western Pacific Ocean, it occurs from Japan southward to Australia, including greater Micronesia (Jefferson et al. 2015). There was one sighting of a group of six pygmy killer whales during surveys in January–April 2007 in the Mariana Islands south of Guam where the bottom depth was ~4400 m (DoN 2007; Fulling et al. 2011). Five sightings of pygmy killer whales were seen during surveys conducted in the southern Mariana Islands during 2010–2019, and a group of 22 pygmy killer whales was encountered during MACS 2018 (Hill et al. 2020c). They are also known to occur in Palau (Andrews et al. 2023) and the Solomon Islands (Robards and Reeves 2011; OBIS 2024). It may occur in Papua New Guinea, but there are no records for the RMI or FSM (SPREP 2022).

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 western Pacific Ocean, it is distributed south of central Japan to Australia, including Micronesia (Jefferson et al. 2015). One detection was made east of the proposed survey area during a transit by NOAA from Guam to Hawaii in April–May 2010 (PIFSC 2010b; Hill 2023b), and two sightings were made near Wake Island (Oleson and Hill 2010 *in* DoN 2020). In July 2004, a pod of 500–700 melon-headed whales were seen off Rota, in the northern Mariana Islands (Jefferson et al. 2006). There were two sightings of melon-headed whales with group sizes estimated at 80 and 109 during the January–April 2007 survey in the waters of the Mariana

Islands (DoN 2007; Fulling et al. 2011); the groups were sighted in water depths ~3200–3900 m, both southwest of Guam. Acoustic detections were also made off Guam in 2007 (Norris et al. 2012). Three sightings were made during surveys conducted in the southern Mariana Islands during 2010–2019, four encounters were made during MACS 2015, and a group of 399 melon-headed whales was seen during MACS 2018 (Hill et al. 2020c). Additionally, there was a live stranding at Inarajan Bay, Guam, in April 1980 (Kami and Hosmer 1982; Donaldson 1983). There have also been sightings in the FSM (Miyazaki and Wada 1978), Palau (SPREP 2022; Andrews et al. 2023), and in the Bismarck Sea off Papua New Guinea (Visser 2007). Additionally, there are records of this species for Kiribati and the RMI (Robards and Reeves 2011), as well as Nauru and the Solomon Islands (SPREP 2022; Miller 2023).

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

SIO requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys in greater Micronesia during winter (December 2024 to January 2025). The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the surveys, by echosounders, and by general vessel operations. "Takes" by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS. Although NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes, no take by serious injury or lethal takes is expected, given the nature of the planned operations, the mitigation measures that are planned (see § XI, MITIGATION MEASURES), in addition to the general avoidance by marine mammals of loud sound.

VI. NUMBERS OF MARINE MAMMALS THAT COULD BE TAKEN

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

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

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

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

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in § VII. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Then we summarize the potential impacts of operations by the echosounders. A more comprehensive review of the relevant background information appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.
- Finally, we estimate the numbers of marine mammals that could be affected by the proposed surveys in greater Micronesia. As called for in § VI, this section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned surveys, including Level A "takes".

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 2017; Bröker 2019; Rako-Gospić and Picciulin 2019; Burnham 2023). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent (Hastie et al. 2019; Martin et al. 2020) and may become less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016; Houser 2021). Although the possibility cannot be entirely excluded, it would be unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals were encountered during an active survey, some behavioral disturbance could result, but this would be localized and short-term.

Tolerance

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

Masking

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

Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012, 2020; Blackwell et al. 2013, 2015; Thode et al. 2020; Fernandez-Betelu et al. 2021). 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. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Disturbance Reactions

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

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Kastelein et al. (2019a) surmised that if disturbance by noise would displace harbor porpoises from a feeding area or otherwise impair foraging ability for a short period of time (e.g., 1 day), they would be able to compensate by increasing their food consumption following the disturbance.

Southall et al. (2023) proposed data collection and analysis methods to examine the potential effects, including at the population level, of seismic surveys on whales. There have been several studies have attempted modeling to assess consequences of effects from underwater noise at the population level; this has proven to be complicated by numerous factors including variability in responses between individuals (e.g., New et al. 2013b; King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017; 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). 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 $CSEL_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu Pa^2 \cdot s$, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 $\mu Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 $\mu Pa^2 \cdot s$. 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). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

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

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

Toothed Whales.—Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). 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). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther (>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015).

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

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland, (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment. However, Heide-Jørgensen et al. (2021) did report avoidance reaction at distances >11 km from an active seismic vessel, as well as an increase in travel speed and changes in direction of travel at distances up to 24 km from a seismic source; however, no long-term effects were reported. Tervo et al. (2021) reported that narwhal buzzing rates decreased in response to concurrent ship noise and airgun pulses (being 50% at 12 km from ship) and that the whales discontinued to forage at 7–8 km from the vessel. Tervo et al. (2023) also noted that narwhals showed increased shallow diving activity and avoided deeper diving, resulting in a reduction in foraging, when exposed to combined ship sounds and airgun pulses. Both studies found that exposure effects could still be detected >40 km from the vessel (Tervo et al. 2021, 2023).

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

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). Winsor et al. (2017) outfitted sperm whales in the Gulf of Mexico with satellite tags to examine their spatial distribution in relation to seismic surveys. They found no evidence of avoidance or changes in orientation by sperm whales to active seismic vessels. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2017), could have significant consequences on individual fitness. Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it 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). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 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 µPa$_{0\text{-peak}}$. 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 µPa$^2 \cdot$ 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). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of gray or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 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.

Hearing Impairment and Other Physical Effects

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

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is 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).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 µPa^2 · s (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015; Schlundt et al. 2016). Bottlenose dolphins exposed to 10-ms impulses at 8 kHz with SELs of 182–183 dB re 1 µPa^2 · s produced a TTS of up to 35 dB (Mulsow et al. 2023).

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012; Mulsow et al. 2023). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL$_{cum}$ of 188 and 191 µPa^2 · 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).

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 a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). Kastelein et al. (2021b) found that susceptibility of TTS of California sea lions exposed to one-sixth-octave noise bands centered at 2 and 4 kHz is similar to that of harbor seals.

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

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

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

It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016a, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups. Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise. Tougaard et al. (2022) indicate that there is empirical evidence to support the thresholds for very-high frequency cetaceans and pinnipeds in water, but caution that above 10 kHz for porpoise and outside of 3–16 kHz for seals, there are differences between the TTS thresholds and empirical data. Tougaard et al. (2023) also noted that TTS-onset thresholds for harbor porpoise are likely impacted by the experimental methods used (e.g., behavioral vs. brain stem recordings, and stationary vs. free-swimming animals), in particular for noise exposure >10 kHz.

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. 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. (2020) describe new methodology that visualizes scars in the cochlea to detect hearing loss in stranded marine mammals.

Since 1991, there have been 72 Marine Mammal Unusual Mortality Events (UME) in the U.S., including the currently active UMEs of North Atlantic right whales and Atlantic humpback whales (NOAA 2024b). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

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

Possible Effects of Other Acoustic Sources

An MBES, SBP, and ADCP 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 these acoustic sources on marine mammals appears in § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

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

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

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2016:209). However, Ruppel et al. (2022) found that MBESs, SBPs, sidescan sonars, ADCPs, and pingers are unlikely to result in take of marine mammals as these sources typically operate at frequencies inaudible to marine mammals, have low source and received levels, narrow beams, downward directed transmission, and/or have low exposure (e.g., short pulse lengths, intermittency of pulses).

There is little information available on marine mammal behavioral responses to MBES sounds (Southall et al. 2013). 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).

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

Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear. Vessel noise from R/V *Sikuliaq* could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2018) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014; Veirs et al. 2016; Kyhn et al. 2019; Landrø and Langhammer 2020); low levels of high-frequency sound from vessels have been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have also been shown to affect foraging behavior (Teilmann et al. 2015; Wisniewska et al. 2018; Tervo et al. 2023), habitat use (e.g., Rako et al. 2013; Carome et al. 2022; Gannier et al. 2022), and swim speeds and movement (e.g., Sprogis et al. 2020; Martin et al. 2022) 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; et al. 2018; Cholewiak et al. 2018; Putland et al. 2018). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017; Popov et al. 2020; Branstetter and Sills 2022). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. Yurk et al. (2023) suggested that killer whales could avoid masking by using adaptive call design or vocalizing at different frequencies depending on noise levels in their environment.

In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from vessels, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Bittencourt et al. 2017; Fornet et al. 2018; Laute et al. 2022; Brown et al. 2023; Radtke et al. 2023). Similarly, 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). However, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals.

In addition to masking, Erbe et al. (2019) noted that ship noise can elicit physical and behavioral responses in marine mammals, as well as stress. For example, Rolland et al. (2012) showed that baseline levels of stress-related faecal hormone metabolites decreased in North Atlantic right whales with a 6-dB decrease in underwater noise from vessels. However, shipping noise is typically not thought to produce sounds capable of eliciting hearing damage. Trigg et al. (2020) noted that gray seals are not at risk of TTS from shipping noise, based on modeling. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016; Oakley et al. 2017). Based on modeling, Halliday et al. (2017) suggested that shipping noise can be audible more than 100 km away and could affect the behavior of a marine mammal at a distance of 52 km in the case of tankers.

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey area during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Martin et al. (2023) 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.

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

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

Numbers of Marine Mammals that could be "Taken by Harassment"

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. No injurious takes (Level A) would be expected. Nonetheless, consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.)

In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels, and we present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys (additional details are provided in Appendix C). The estimates are based on consideration of the number of marine mammals that could be harassed by sound (Level B takes) produced by the proposed seismic surveys in greater Micronesia.

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

Basis for Estimating "Takes"

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

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 seismic tracklines that could be surveyed on one day (~222 km) that have the same or similar proportion of water depths to be surveyed as during the entire survey (>1000 m for this survey).

The area expected to be ensonified on a single day was then calculated using the representative line length and multiplying by two times the Level B (or PTS) radii, and adding endcaps. The ensonified areas, increased by 25%, were then multiplied by the number of seismic days (13.5). 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 *Sikuliaq* approaches.

We used density data from the U.S. Navy's Marine Species Density Database Phase III for the Mariana Islands Training and Testing (MITT) Study Area (DoN 2018), as no density estimates are available for the proposed survey area. The U.S. Navy modeled densities for two areas within the MITT: the Mariana Islands Training and Testing Representative Study Area to the west of the proposed survey area, and the Transit Corridor Representative Study Area surrounding Wake Island, to the east of the proposed survey area (DoN 2018). The proposed survey area lies between the two MITT modelled areas and does not overlap. As the proposed tracklines are located closer to Wake Island than the Mariana Islands, the MITT seasonal density estimates for the Transit Corridor Representative Study Area were used here. As the surveys are proposed for December 2024 to January 2025, the densities for winter (December through February) were used to calculate takes for marine mammals. No densities were available for Deraniyagala's beaked whale or the common dolphin. However, the density for ginkgo-toothed beaked whale was applied to *M. ginkgodens* and *M. Hotaula* as a combined group, as these two species are difficult to distinguish. Table 4 shows estimated densities for cetacean species that could occur in the proposed survey area.

Table 5 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 C for more details), along with the *Requested Take Authorization*. 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 precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

TABLE 4. Densities of marine mammals during winter (December through February) for the proposed survey area in Greater Micronesia. Based on U.S. Navy MITT cetacean densities for the Transit Corridor Representative Study Area surrounding Wake Island (DoN 2018).

Species	**Density (#/km^2) in Survey Area**
LF Cetaceans	
Humpback whale	8.90E-04
Bryde's whale	3.00E-04
Minke whale	1.50E-04
Fin whale	6.00E-05
Sei whale	1.30E-04
Blue whale	5.00E-05
Omura's whale	4.00E-05
MF Cetaceans	
Sperm whale	2.22E-03
Longman's beaked whale	2.50E-04
Cuvier's beaked whale	3.74E-03
Blaineville's beaked whale	7.00E-04
Ginkgo-toothed beaked whale	1.89E-03
Deraniyagala's beaked whale	N.A.
Risso's dolphin	4.60E-04
Rough-toothed dolphin	1.85E-03
Bottlenose dolphin	7.70E-04
Pantropical spotted dolphin	1.13E-02
Spinner dolphin	1.87E-03
Striped dolphin	5.84E-03
Fraser's dolphin	2.52E-03
Common dolphin	N.A.
Short-finned pilot whale	2.11E-03
Melon-headed whale	2.67E-03
False killer whale	5.70E-04
Pygmy killer whale	6.00E-05
Killer whale	9.00E-05
HF Cetaceans	
Pygmy sperm whale	1.76E-03
Dwarf sperm whale	4.30E-03

N.A. = Not available.

TABLE 5. 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 Greater Micronesia.

Species	**Level B Takes**[1]	**Level A Takes**[2]	**% of Pop. (Total Takes)**[3]	**Requested Level A+B Take Authorization**[4]
LF Cetaceans				
Humpback whale[5]	9	0	0.35	9
Bryde's whale	3	0	0.20	3
Minke whale	2	0	0.36	2
Fin whale	1	0	1.39	1
Sei whale	1	0	0.24	**2**
Blue whale	1	0	0.36	1
Omura's whale	0	0	0.63	**1**
MF Cetaceans				
Sperm whale	24	0	0.46	24
Longman's beaked whale	3	0	0.02	3
Cuvier's beaked whale	40	0	1.51	40
Blaineville's beaked whale	7	0	0.22	7
Ginkgo-toothed beaked whale[6]	20	0	0.13	10
Deraniyagala's beaked whale[6]	N.A.	0	N.A.	10
Risso's dolphin	5	0	0.16	**27**
Rough-toothed dolphin	20	0	1.09	20
Bottlenose dolphin	8	0	0.76	8
Pantropical spotted dolphin	121	0	0.14	121
Spinner dolphin	20	0	1.87	**98**
Striped dolphin	62	0	0.25	62
Fraser's dolphin	27	0	0.04	27
Common Dolphin	N.A.	0	N.A.	*10*
Short-finned pilot whale	22	0	0.34	22
Melon-headed whale	28	0	0.57	**95**
False killer whale	6	0	0.24	**10**
Pygmy killer whale	1	0	1.14	**6**
Killer whale	1	0	1.98	**5**
HF Cetaceans				
Pygmy sperm whale	18	1	0.17	19
Dwarf sperm whale	43	3	0.17	46

N.A. means not applicable or 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 MITT including the Wake Island Transit Corridor (NMFS 2020a). [4] Requested take authorization for marine mammals is Level A plus Level B calculated takes. Takes in bold have been increased to mean group size for the Mariana Islands based on Fulling et al. (2011) where available or for Hawaii (e.g., Risso's dolphin and killer whale) as reported by Bradford et al. (2017); takes in italics have been increased to minimum group sizes provided in Jefferson et al. (2015). [5] All takes are assumed to be from the endangered Western North Pacific DPS. [6] Takes based on density for ginkgo-toothed beaked whale divided equally between the two species.

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".

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 4 GI 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 5. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

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

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

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

IX. ANTICIPATED IMPACT ON HABITAT

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

The proposed seismic surveys would not result in any permanent impact on habitats used by marine mammals or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VII, above. Effects of seismic sound on marine invertebrates, marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations.

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

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

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

XI. MITIGATION MEASURES

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

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

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity. The procedures described here are based on protocols used during previous SIO seismic research cruises as approved by NMFS, and on best practices recommended in

Richardson et al. (1995), Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017).

Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed surveys was to evaluate what source level was necessary to meet the research objectives. The surveys would be conducted in deep water, necessitating a sufficiently large source to overcome energy loss through the water column. Based on the results of previous surveys using the SIO portable system (in particular, the USGS-led MATRIX experiment[2]), the PIs have determined that four GI airguns would be the minimum source level necessary to reach the target depths.
2. *Survey Location and Timing*—The PIs worked with NSF and its contractors to identify potential times to carry out the surveys, taking into consideration key factors such as environmental conditions (e.g., seasonal presence of marine mammals), weather conditions, equipment, and optimal timing for other proposed research cruises. The schedule (December–January) is proposed because the safe weather window for working in the western Pacific Ocean spans late fall to early spring, thereby avoiding the main part of the typhoon season. Although baleen whales are more likely to occur in this region during the winter, they are expected to be uncommon in the proposed survey area. Most other marine mammals, including toothed whales and delphinids, are expected to occur in the survey area year-round. The December–January period was determined to be the most practical timing for the proposed surveys based on weather conditions, operational requirements, and availability of researchers.
3. *Mitigation Zones*—During the planning phase, mitigation zones for the proposed marine seismic surveys using the 4-GI airgun array (at a tow depth of 3 m) were not derived from the farfield signature but based on modeling by L-DEO for both the full mitigation zones (160 dB re 1µPa$_{rms}$) for Level B takes and the EZ for Level A takes. The background information and methodology for this are provided in Appendix A and B, respectively. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the airgun array in deep water (>1000 m) down to a maximum water depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999).

Mitigation During Operations

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities are expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include (1) monitoring by PSOs for marine mammals, ESA-listed sea turtles and seabirds (diving/foraging) near the vessel, and observing for potential impacts of acoustic sources on fish; (2) PSO data and documentation; and (3) mitigation during operations (speed or course alteration; shut

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[2] https://www.usgs.gov/centers/whcmsc/science/mid-atlantic-resource-imaging-experiment-matrix

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. Mitigation measures that would be adopted during the proposed surveys include(1) shut downs and (2) ramp ups. These measures are proposed by SIO based on past experience and for consistency with the PEIS.

Shut Down Procedures

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

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

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

Ramp Up Procedures

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

Ramp up would begin with one GI airgun, and the second GI airgun would be added after 5 min. During ramp up, the PSOs would monitor the EZ, and if marine mammals or ESA-listed seabirds (diving/foraging) are sighted, a shut down would be implemented as though the full array were operational. If the EZ has not been monitored by PSOs for at least 30 min prior to the start of operations, ramp up would not commence. A ramp up from a shut down may occur in poor visibility/darkness as long as the EZ has been continually monitored by PSOs for 30 minutes prior to ramp up with no marine mammal detections. Ramp up of the GI airguns would not be initiated if a marine mammal is sighted within or near the EZ.

The proposed operational mitigation measures are standard for seismic cruises, per the PEIS. Independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours. A monitoring report would be provided to NMFS, both the Permits and Conservation Division and the ESA Interagency Cooperation Division.

With the proposed monitoring and mitigation provisions, potential effects on most, if not all, individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals 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.

XII. PLAN OF COOPERATION

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

(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;

(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;

(iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and

(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activity would take place in greater Micronesia, and no activities would take place in traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

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

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

Vessel-based Visual Monitoring

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

All PSOs would be appointed by SIO with NMFS concurrence. Two PSOs would monitor for marine mammals around the seismic vessel. Use of two simultaneous observers increases the effectiveness of detecting animals around the source vessel. PSO(s) would be on duty in shifts of duration no longer than 4 h, or per the IHA. Other crew would also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic surveys, the crew would be given additional instruction regarding how to do so.

R/V *Sikuliaq* is a suitable platform from which PSOs would watch for marine mammals, ESA-listed seabirds, and turtles. Standard equipment for marine mammal observers would be 7 x 50 reticle binoculars and optical range finders. At night, night-vision equipment would be available. The observers would be in communication with ship's officers on the bridge and scientists in the vessel's operations laboratory, so they can advise promptly of the need for avoidance maneuvers or seismic source shut down.

PSO Data and Documentation

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

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

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

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

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

Results from the vessel-based observations would provide

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

A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring and would summarize the dates and locations of seismic operations and all marine mammal observations. The report would also include estimates of the number and nature of exposures that could result in "takes" of marine mammals by harassment or in other ways.

XIV. COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL TAKE

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

SIO and NSF would coordinate with applicable U.S. agencies (e.g., NMFS) and foreign agencies, and would comply with their requirements.

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LIST OF APPENDICES

APPENDIX A: DETERMINATION OF MITIGATION ZONES
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APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for the Level B (160 dB re 1µPa$_{\mathrm{rms}}$) threshold. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the airguns, for the four 105-in^3 GI airguns. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor).

Propagation measurements of pulses from the R/V *Langseth's* 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the GoM in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010). For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth (~2000 m) for marine mammals (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant.

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

The proposed surveys would acquire data with four 105-in^3 GI guns configured in two 2-GI gun clusters, separated by 11 m, and towed at a depth of 3 m. Table A-1 shows the distances at which the 160-dB re 1µPa$_{\mathrm{rms}}$ sound level is expected to be received for the 4-GI airgun configuration (totaling 420 in^3) at a 3-m tow depth. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. A-1).

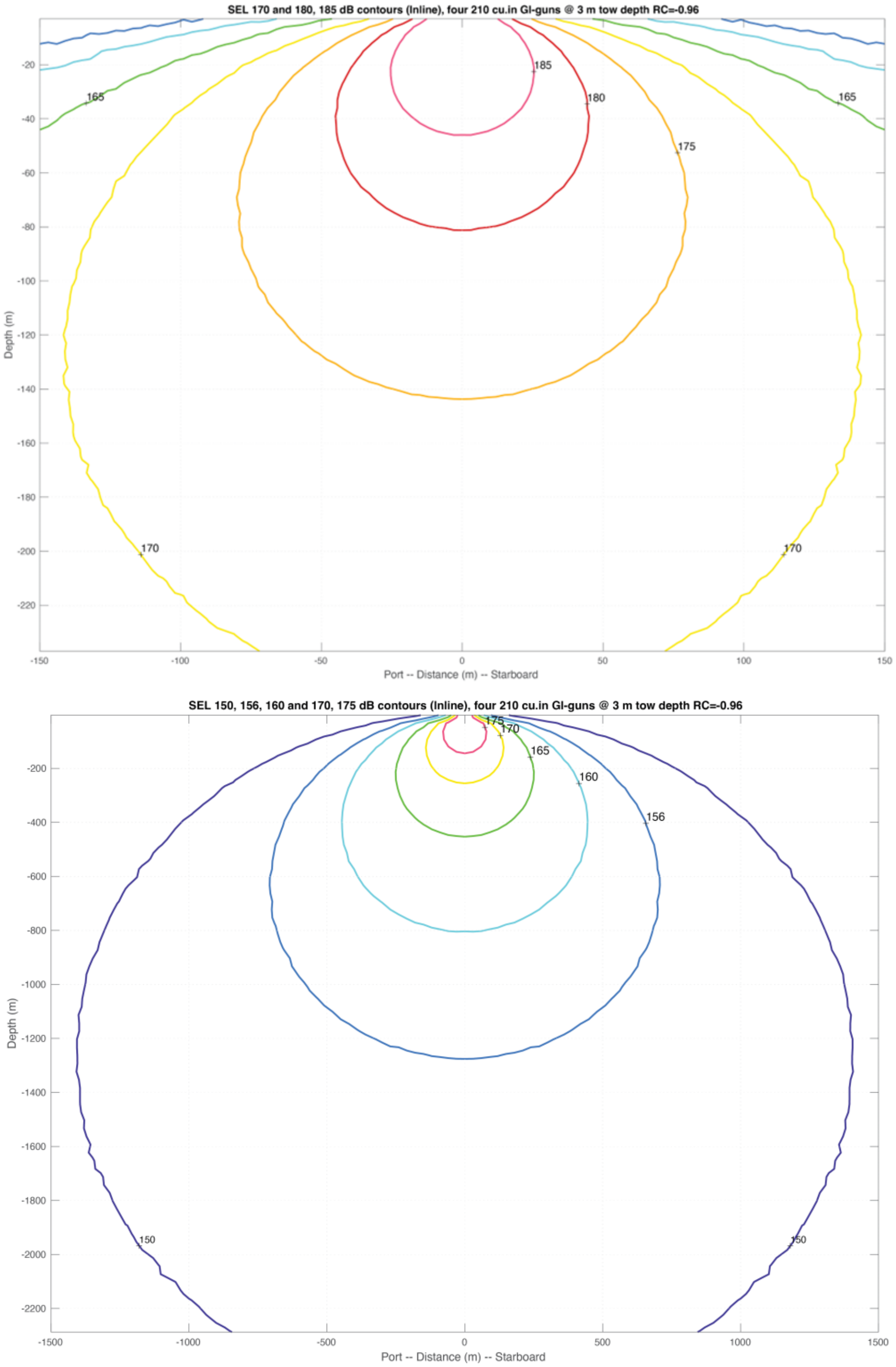

FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the four 105-in^3 GI guns at a 3-m tow depth, planned for use during the proposed surveys in Greater Micronesia. Received rms levels (SPLs) are expected to be ~10 dB higher. The radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-6. Predicted distances (based on L-DEO modeling) to behavioral disturbance sound levels ≥160-dB re 1 µPa$_{rms}$ and ≥175-dB re 1 µPa$_{rms}$ that could be received during the proposed surveys in Greater Micronesia. 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**	**Predicted distances (in m) to the 175-dB Received Sound Level**
Four 105-in^3 GI guns	3	>1000 m	1,408	251

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

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species, but did not establish new thresholds for Level B Harassment. The new noise exposure criteria for marine mammals account for newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). The Draft EA has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), and Wright and Cosentino (2015).

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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 Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

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APPENDIX B: DETERMINATION OF LEVEL A RADII

Here we provide the methodology for determining the Level A radii for the 4-210 in^3 GI gun array, with 2-m aft-fore separation between GI guns and 11-m separation in the port-starboard direction between the two 2-GI gun clusters. The array would be towed at a depth of 3 m.

SEL$_{cum}$ methodology† (spreadsheet – Sivle et al. 2014)

Source Velocity (meters/second)	2.5722 *
1/Repetition rate^ (seconds)	12 **

† Methodology assumes propagation of 20 log R; activity duration (time) independent.
^ Time between onset of successive pulses.
* 5 kts
** shot interval of 12 s, shot spacing of 30 m

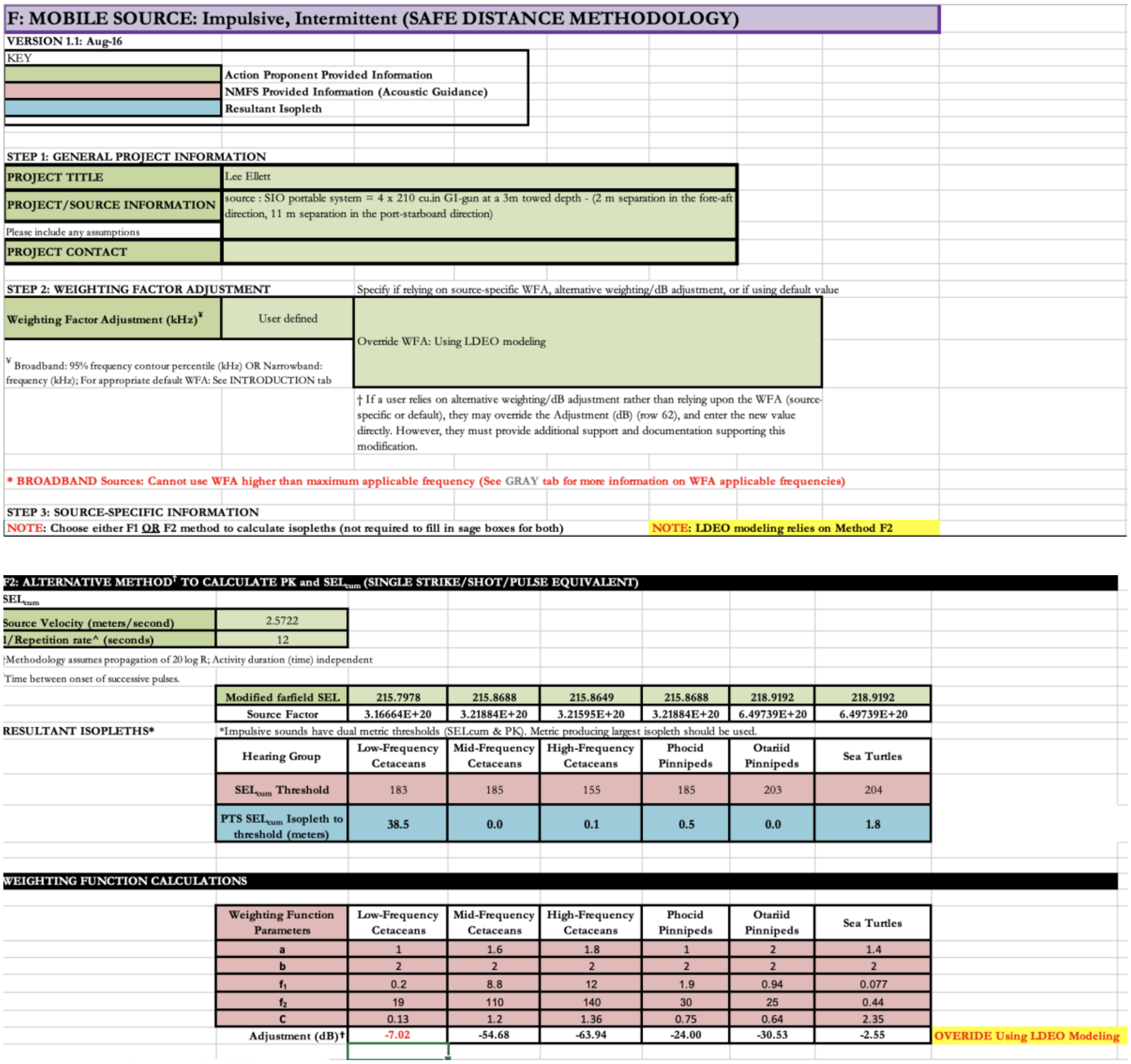
TABLE B-1. One single SEL SL modeling without and with applying weighting function to the 5 hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL$_{cum}$ threshold is the largest. A propagation of 20 log10 (Radial distance)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

SEL$_{cum}$ Threshold	**183**	**185**	**155**	**185**	**203**
Distance(m) (no weighting function)	43.6	34.9	1104.7	34.9	N/A
Modified Farfield SEL*	215.8	215.9	215.9	215.9	N/A
Distance (m) (with weighting function)	19.5	N/A	N/A	N/A	N/A
Adjustment (dB)	-7.0	N/A	N/A	N/A	N/A

* Propagation of 20 log R

For the Low Frequency Cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183dB SEL cum isopleth is the largest. We first run the modeling for one single shot without applying any weighting function. The maximum 183dB SEL cum isopleth is located at 43.64 m from the source. We then run the modeling for one single shot with the low frequency Cetaceans weighting function applied to the full spectrum. The maximum 183 dB SEL cum isopleth is located at 19.45 m from the source. Difference between 19.45 m and 43.64 m gives an adjustment factor of -7.02 dB assuming a propagation of 20log10(R).

TABLE B-2. Results for single shot SEL source level modeling for the four 105 in^3 airguns with weighting function calculations for SEL$_{cum}$ criteria.



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

VERSION 1.1: Aug-16

KEY

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

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Lee Ellett
PROJECT/SOURCE INFORMATION	source : SIO portable system = 4 x 210 cu.in GI-gun at a 3m towed depth - (2 m separation in the fore-aft direction, 11 m separation in the port-starboard direction)
Please include any assumptions	
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

Weighting Factor Adjustment (kHz)$^¥$	User defined	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 <u>OR</u> F2 method to calculate isopleths (not required to fill in sage boxes for both)

NOTE: LDEO modeling relies on Method F2

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

SEL$_{cum}$

Source Velocity (meters/second)	2.5722
1/Repetition rate^ (seconds)	12

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

^Time between onset of successive pulses.

Modified farfield SEL	**215.7978**	**215.8688**	**215.8649**	**215.8688**	**218.9192**	**218.9192**
Source Factor	**3.16664E+20**	**3.21884E+20**	**3.21595E+20**	**3.21884E+20**	**6.49739E+20**	**6.49739E+20**

RESULTANT ISOPLETHS*

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

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**
SEL$_{cum}$ Threshold	183	185	155	185	203	204
PTS SEL$_{cum}$ Isopleth to threshold (meters)	**38.5**	**0.0**	**0.1**	**0.5**	**0.0**	**1.8**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**	**Sea Turtles**	
a	1	1.6	1.8	1	2	1.4	
b	2	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	0.077	
f_2	19	110	140	30	25	0.44	
C	0.13	1.2	1.36	0.75	0.64	2.35	
Adjustment (dB)†	-7.02	-54.68	-63.94	-24.00	-30.53	-2.55	**OVERIDE Using LDEO Modeling**

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds***	**Sea Turtles***
SEL$_{cum}$ Threshold	183	185	155	185	203	204
PTS SEL$_{cum}$ Isopleth to threshold (meters)	**38.5**	**0.0**	**0.1**	**0.5**	**0.0**	**1.8**

* For Otarriid Pinnipeds and Sea Turtles, the 203 and 204 dB SEL$_{cum}$ threshold does not exist in our modeling (maximum SEL$_{cum}$ = 202.2 dB); we used the farfield SEL to compute the source factor.

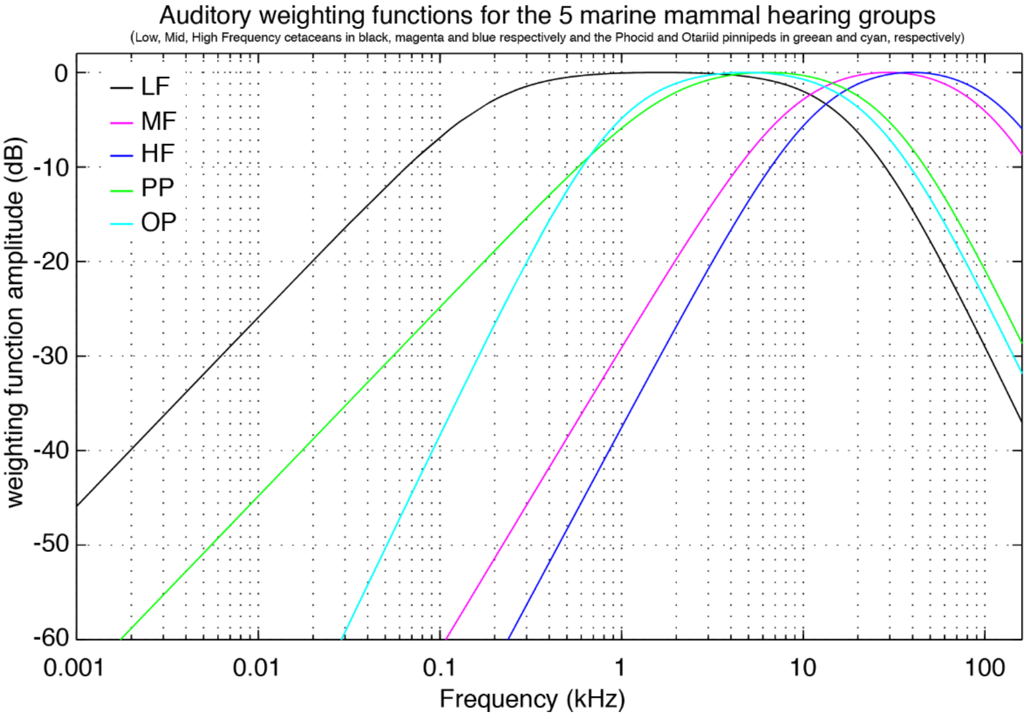


FIGURE B-1. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

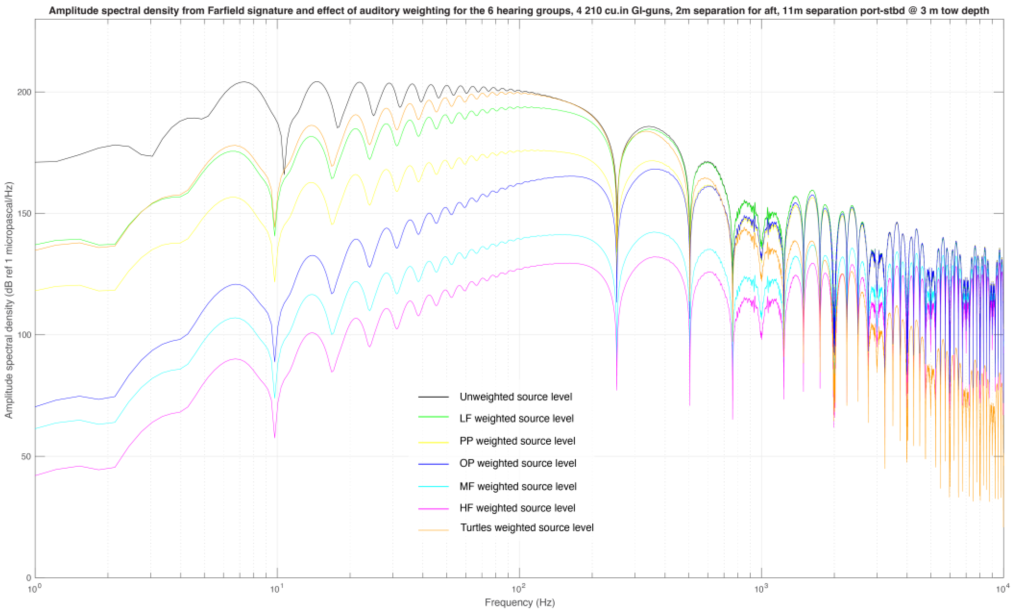


FIGURE B-2. Modeled amplitude spectral density of the four 105 in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting function for the low- frequency cetaceans, phocid pinnipeds, otariid pinnipeds, mid-frequency cetaceans, high-frequency cetaceans, respectively. Modeled spectral levels in micropascals are used to calculate the difference between the un-weighted and weighted source level at each frequency and to derive the adjustment factors for the phocid pinnipeds, otariid pinnipeds, mid-frequency cetaceans, and high-frequency cetaceans as inputs into the NMFS user spreadsheet.

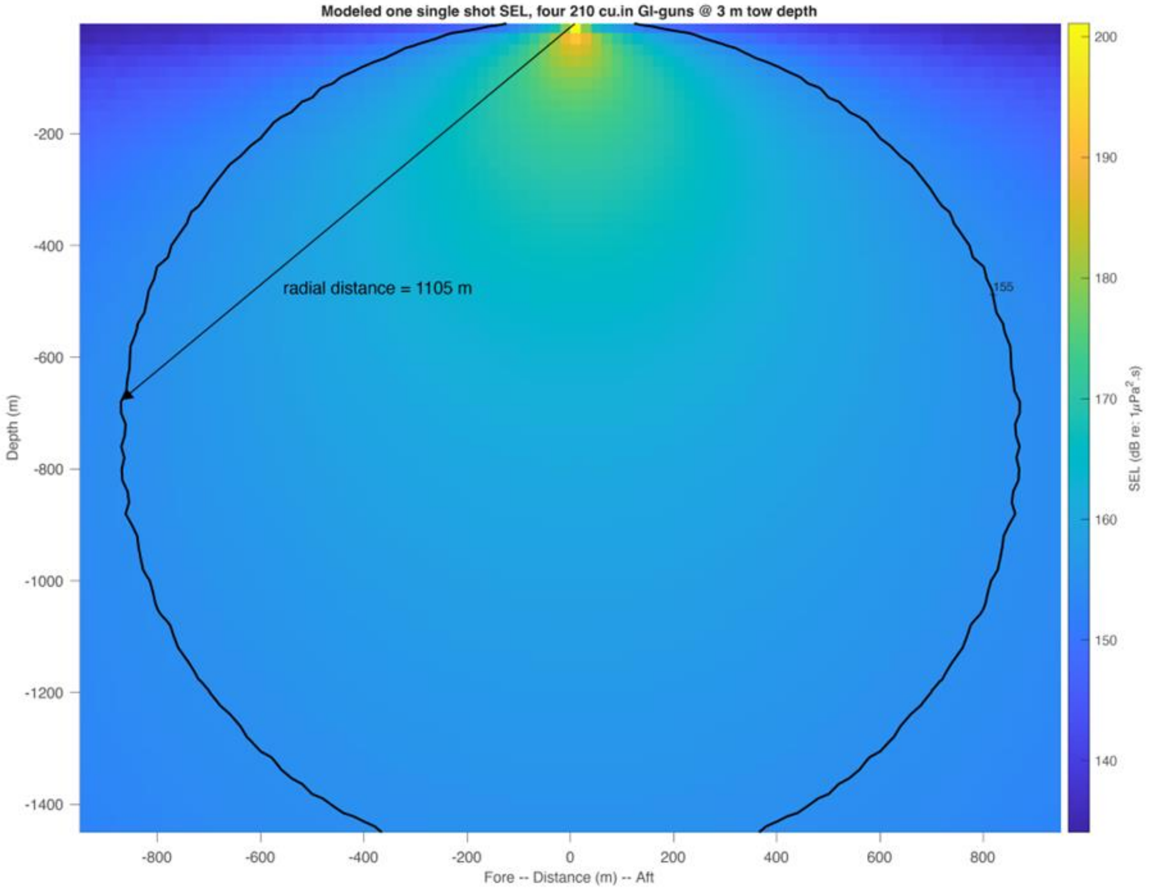


FIGURE B-3. Modeled received sound levels (SELs) in deep water from the four 105 in^3 GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (1105 m).

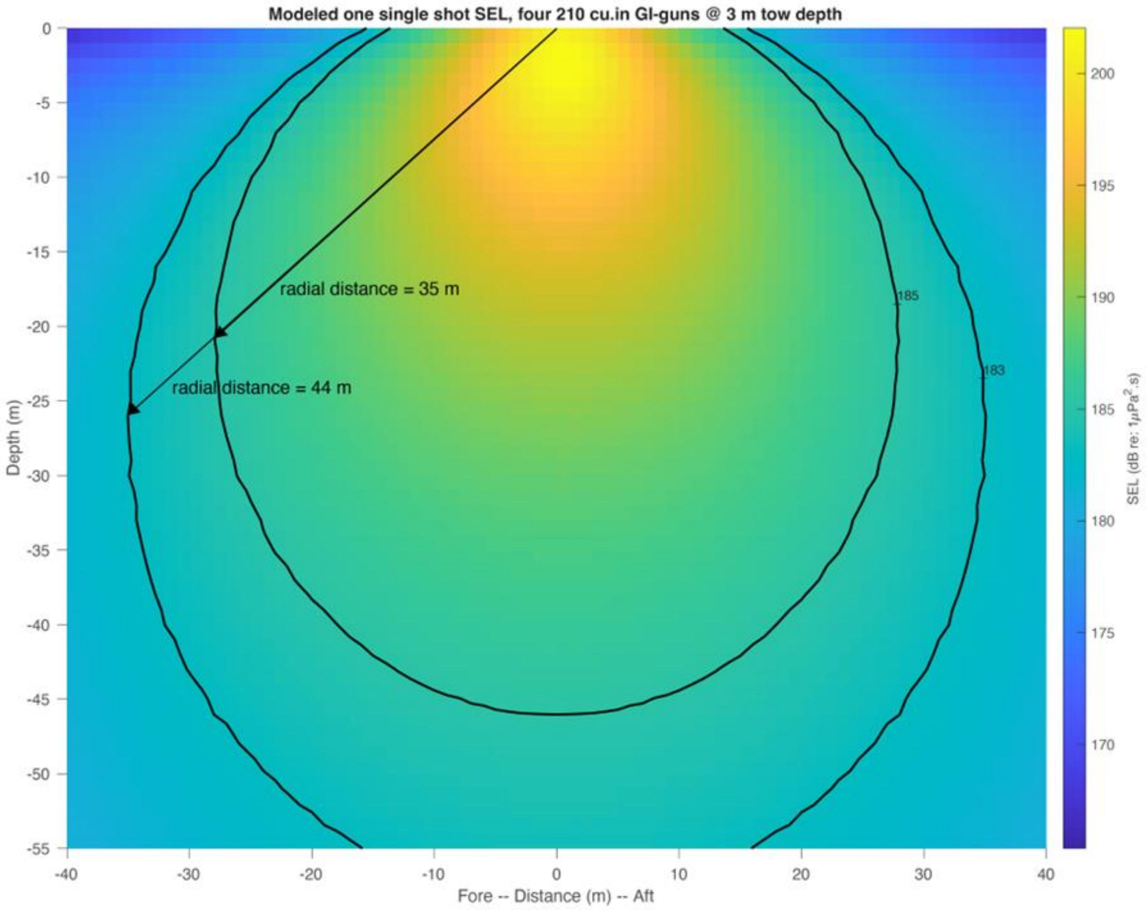


FIGURE B-4 : Modeled received sound levels (SELs) in deep water from the four 105 in^3 GI-guns at a 3-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183 and 185 dB isopleths; the 203 dB SEL isopleth does not exist.

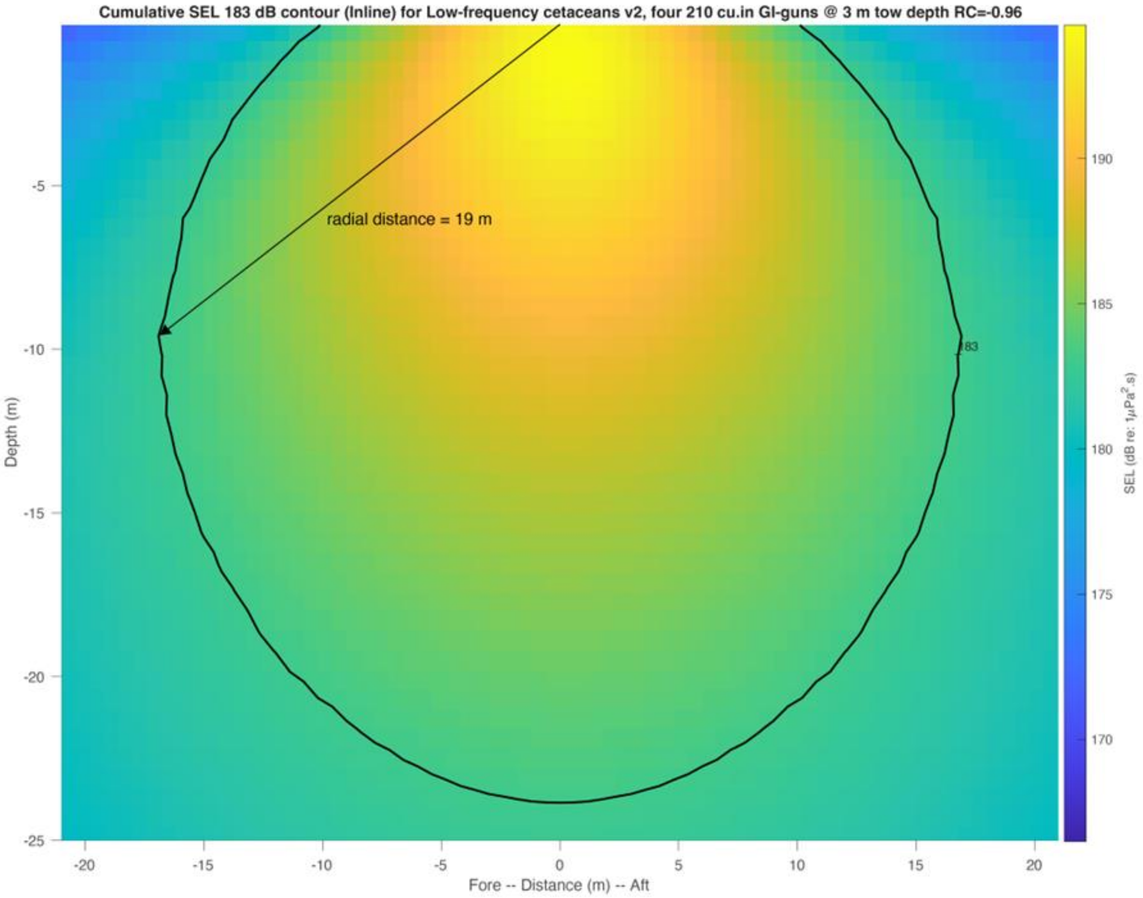


FIGURE B-5: Modeled received sound exposure levels (SELs) from the four 105 in^3 GI-guns at a 3-m tow depth, after applying the auditory weighting function for the low-frequency cetaceans hearing group following to the new technical guidance. The plot provides the radial distance to the 183-dB SELcum isopleth for one shot. The difference in radial distances between Fig. B-4 (43.64 m) and this figure (19.45 m) allows us to estimate the adjustment in dB.

Peak Sound Pressure Level

TABLE B-3. Level A. NMFS Level A acoustic thresholds (Peak SPL$_{\text{flat}}$) for impulsive sources for marine mammals and predicted radial distances to Level A thresholds for various marine mammal hearing groups that could be received from the four 105 in^3 airguns at a 3 m tow depth during the proposed seismic surveys.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PK Threshold	219	230	202	218	232	232
Radius to threshold (meters)	**12.44**	**N/A (0)**	**85.76**	**13.97**	**N/A (0)**	**N/A(0)**

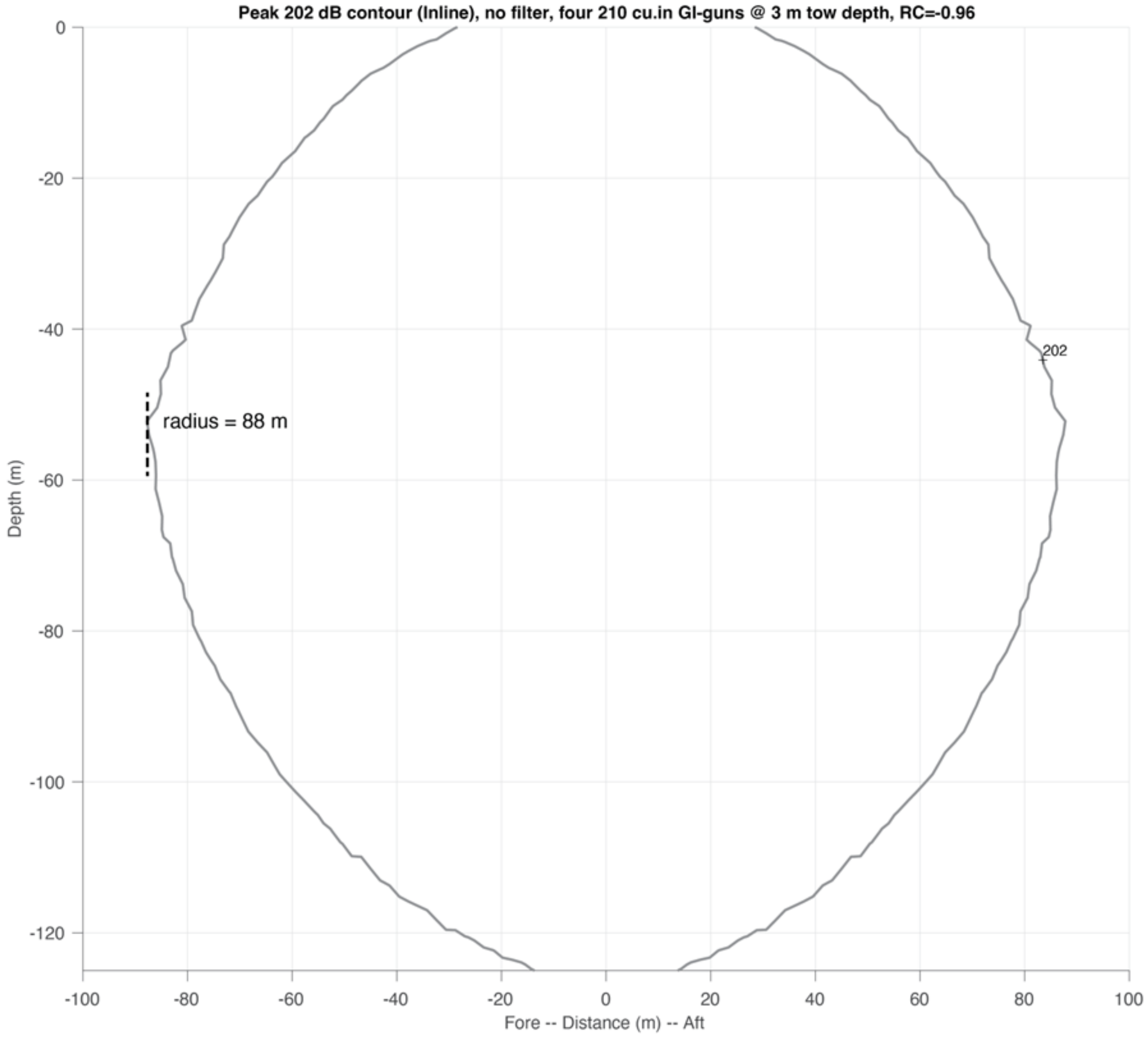


FIGURE B-6: Modeled deep-water received Peak SPL from four 105 in^3 airguns at a 3-m tow depth. The plot provides the radius of the 202-dB peak isopleth (88 m).

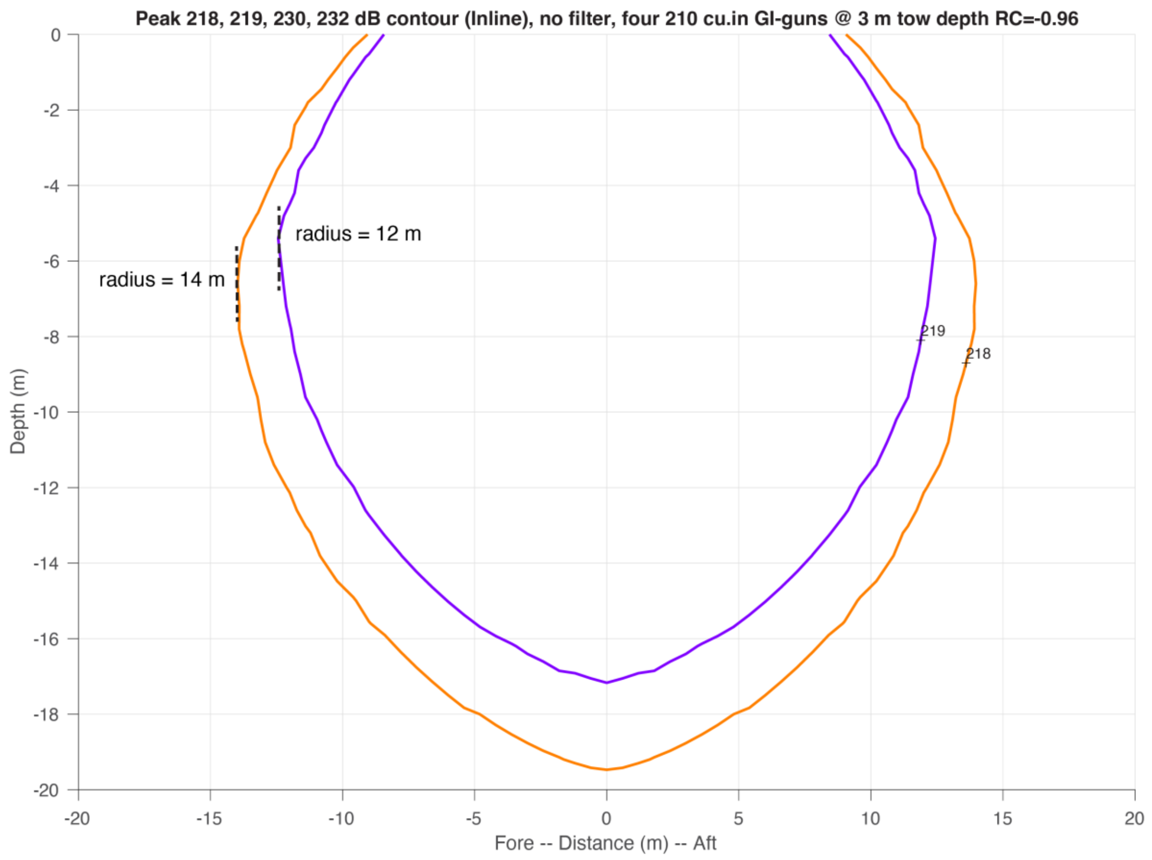


FIGURE B-7: Modeled deep-water received Peak SPL from four 105 in^3 airguns at a 4-m tow depth. The plot provides the radius of the 218 and 219 dB peak isopleths.

Literature Cited

Sivle, L.D., P.H., Kvadsheim, and M.A. Ainslie. 2014. Potential for population-level disturbance by active sonar in herring. **ICES J. Mar. Sci.** 72:558-567.

APPENDIX C: POTENTIAL MARINE MAMMAL TAKES

Species	Estimated Density (#/km^2)	Population Size for MITT Area+Transit Corridor	Hearing Group	Level B Ensonified Area (km^2)	Level A Ensonified Area (km^2)	All Takes	Only Level B Takes minus Level A[1]	Level A Takes[2]	% of Pop. (Total Takes)[3]	Requested Level A+B Take Authorization[4]
LF Cetaceans										
Humpback whale	8.90E-04	2,673	LF	10,655	289	9	9	0	0.35	9
Bryde's whale	3.00E-04	1596	LF	10,655	289	3	3	0	0.20	3
Minke whale	1.50E-04	450	LF	10,655	289	2	2	0	0.36	2
Fin whale	6.00E-05	46	LF	10,655	289	1	1	0	1.39	1
Sei whale	1.30E-04	821	LF	10,655	289	1	1	0	0.24	**2**
Blue whale	5.00E-05	150	LF	10,655	289	1	1	0	0.36	1
Omura's whale	4.00E-05	160	LF	10,655	289	0	0	0	0.63	**1**
MF Cetaceans										
Sperm whale	2.22E-03	5,146	MF	10,655	0	24	24	0	0.46	24
Longman's beaked whale	2.50E-04	11,253	MF	10,655	0	3	3	0	0.02	3
Cuvier's beaked whale	3.74E-03	2,642	MF	10,655	0	40	40	0	1.51	40
Blainevile's beaked whale	7.00E-04	3,376	MF	10,655	0	7	7	0	0.22	7
Ginkgo-toothed beaked whale	1.89E-03	7,567	MF	10,655	0	20	20	0	0.13	10
Deraniyagala's beaked whale	N.A.	N.A.	MF	10,655	0	N.A.	N.A.	0	N.A.	10
Risso's dolphin	4.60E-04	17,184	MF	10,655	0	5	5	0	0.16	**27**
Rough-toothed dolphin	1.85E-03	1,815	MF	10,655	0	20	20	0	1.09	20
Bottlenose dolphin	7.70E-04	1,076	MF	10,655	0	8	8	0	0.76	8
Pantropical spotted dolphin	1.13E-02	85,755	MF	10,655	0	121	121	0	0.14	121
Spinner dolphin	1.87E-03	5,232	MF	10,655	0	20	20	0	1.87	**98**
Striped dolphin	5.84E-03	24,528	MF	10,655	0	62	62	0	0.25	62
Fraser's dolphin	2.52E-03	76,476	MF	10,655	0	27	27	0	0.04	27
Common Dolphin	N.A.	N.A.	MF	10,655	0	N.A.	N.A.	0	N.A.	*10*
Short-finned pilot whale	2.11E-03	6,583	MF	10,655	0	22	22	0	0.34	22
Melon-headed whale	2.67E-03	16,551	MF	10,655	0	28	28	0	0.57	**95**
False killer whale	5.70E-04	4,218	MF	10,655	0	6	6	0	0.24	**10**
Pygmy killer whale	6.00E-05	527	MF	10,655	0	1	1	0	1.14	**6**
Killer whale	9.00E-05	253	MF	10,655	0	1	1	0	1.98	**5**
HF Cetaceans										
Pygmy sperm whale	1.76E-03	11,168	HF	10,655	643	19	18	1	0.17	19
Dwarf sperm whale	4.30E-03	27,395	HF	10,655	643	46	43	3	0.17	46

N.A. means not applicable or 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 MITT including the Wake Island Transit Corridor (NMFS 2020a). [4]Requested take authorization is Level A plus Level B calculated takes. Takes in bold have been increased to mean group size for cetaceans in the Mariana Islands based on Fulling et al. (2011) where available, for Hawaii (e.g., Risso's dolphin and killer whale) as reported by Bradford et al. (2017). Takes in italics have been increased to minimum group size reported in Jefferson et al. (2015).