DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[RTID 0648–XC218]

Takes of Marine Mammals Incidental to Specified Activities; Taking Marine Mammals Incidental to a Geophysical Survey in the Ross Sea, Antarctica

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice; proposed incidental harassment authorization; request for comments on proposed authorization and possible renewal.

SUMMARY: NMFS has received a request from the United States National Science Foundation (NSF) Office of Polar Programs for authorization to take marine mammals incidental to a geophysical survey in the Ross Sea, Antarctica. Pursuant to the Marine Mammal Protection Act (MMPA), NMFS is requesting comments on its proposal to issue an incidental harassment authorization (IHA) to incidentally take marine mammals during the specified activities. NMFS is also requesting comments on a possible one-year renewal that could be issued under certain circumstances and if all requirements are met, as described in Request for Public Comments at the end of this notice. NMFS will consider public comments prior to making any final decision on the issuance of the requested MMPA authorizations and agency responses will be summarized in the final notice of our decision.

DATES: Comments and information must be received no later than October 31, 2022.

ADDRESSES: Comments should be addressed to Jolie Harrison, Chief, Permits and Conservation Division, Office of Protected Resources, National Marine Fisheries Service. Physical comments should be sent to 1315 East-West Highway, Silver Spring, MD 20910 and electronic comments should be sent to *ITP.Harlacher@noaa.gov.*

Instructions: NMFS is not responsible for comments sent by any other method, to any other address or individual, or received after the end of the comment period. Comments received electronically, including all attachments, must not exceed a 25-megabyte file size. All comments received are a part of the public record and will generally be posted online at *https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act* without change. All personal identifying information (*e.g.,* name, address) voluntarily submitted by the commenter may be publicly accessible. Do not submit confidential business information or otherwise sensitive or protected information.

FOR FURTHER INFORMATION CONTACT: Jenna Harlacher, Office of Protected Resources, NMFS, (301) 427–8401. Electronic copies of the application and supporting documents, as well as a list of the references cited in this document, may be obtained online at: *https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act.* In case of problems accessing these documents, please call the contact listed above.

SUPPLEMENTARY INFORMATION:

Background

The MMPA prohibits the ''take'' of marine mammals, with certain exceptions. Sections 101(a)(5)(A) and (D) of the MMPA (16 U.S.C. 1361 *et seq.*) direct the Secretary of Commerce (as delegated to NMFS) to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region if certain findings are made and either regulations are issued or, if the taking is limited to harassment, a notice of a proposed incidental take authorization may be provided to the public for review.

Authorization for incidental takings shall be granted if NMFS finds that the taking will have a negligible impact on the species or stock(s) and will not have an unmitigable adverse impact on the availability of the species or stock(s) for taking for subsistence uses (where relevant). Further, NMFS must prescribe the permissible methods of taking and other ''means of effecting the least practicable adverse impact'' on the affected species or stocks and their habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance, and on the availability of the species or stocks for taking for certain subsistence uses (referred to in shorthand as ''mitigation''); and requirements pertaining to the mitigation, monitoring and reporting of the takings are set forth.

The definitions of all applicable MMPA statutory terms cited above are included in the relevant sections below.

National Environmental Policy Act

To comply with the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 *et seq.*) and NOAA Administrative Order (NAO) 216–6A, NMFS must review our proposed action (*i.e.,* the issuance of an incidental harassment authorization) with respect to potential impacts on the human environment.

This action is consistent with categories of activities identified in Categorical Exclusion B4 (incidental harassment authorizations with no anticipated serious injury or mortality) of the Companion Manual for NOAA Administrative Order 216–6A, which do not individually or cumulatively have the potential for significant impacts on the quality of the human environment and for which we have not identified any extraordinary circumstances that would preclude this categorical exclusion. Accordingly, NMFS has preliminarily determined that the issuance of the proposed IHA qualifies to be categorically excluded from further NEPA review.

Summary of Request

On May 26, 2022, NMFS received a request from NSF for an IHA to take marine mammals incidental to conducting a low energy seismic survey and icebreaking in the Ross Sea. The application was deemed adequate and complete on July 22, 2022. NSF's request is for take of small numbers of 17 species of marine mammals by Level B harassment only. Neither NSF nor NMFS expects serious injury or mortality to result from this activity and, therefore, an IHA is appropriate.

Description of Proposed Activity

Overview

Researchers from Louisiana State University, Texas A&M University, University of Texas at Austin, University of West Florida, and Dauphin Island Sea Lab, with funding from NSF, propose to conduct a two-part low-energy seismic survey from the Research Vessel/Icebreaker (RVIB) Nathaniel B. Palmer (NBP), in the Ross Sea during Austral Summer 2022–2023. The two-part proposed survey would include the Ross Bank and the Drygalski Trough areas. The proposed seismic survey would take place in International waters of the Southern Ocean, in water depths ranging from ~150 to 1100 meters (m).

The RVIB *Palmer* would deploy up to two 105-in^3 generator injector (GI) airguns at a depth of 1–4 m with a total maximum discharge volume for the largest, two-airgun array of 210 in^3 along predetermined track lines. During the Ross Bank survey, ~1920km of seismic data would be collected and during the Drygalski Trough survey, ~1800 km of seismic acquisition would occur, for a total of 3720 line km.

Although the proposed survey will occur in the Austral summer, some icebreaking activities are expected to be required during the cruise.

The proposed Ross Bank portion of activity is to determine if, how, when, and why the Ross Ice Shelf unpinned from Ross Bank in the recent geologic past, to assess to what degree that event caused a re-organization of ice sheet and ice shelf flow towards its current configuration. The Drygalski Trough activities are proposed to examine the gas hydrate contribution to the Ross Sea carbon budget. The Drygalski Trough activities would examine the warming and carbon cycling of the ephemeral reservoir of carbon at the extensive bottom ocean layer-sediment interface of the Ross Sea. This large carbon reserve appears to be sealed in the form of gas hydrate and is a thermogenic carbon source and carbon storage in deep sediment hydrates. The warming and ice melting coupled with high thermogenic gas hydrate loadings suggest the Ross Sea is an essential environment to determine contributions of current day and potential future methane, petroleum, and glacial carbon to shallow sediment and water column carbon cycles.

Dates and Duration

The RVIB *Palmer* would likely depart from Lyttelton, New Zealand, on December 18, 2022, and would return to McMurdo Station, Antarctica, on January 18, 2023, after the program is completed. The cruise is expected to consist of 31 days at sea, including approximately 19 days of seismic operations (including 2 days of sea trials and/or contingency), 1 day of ocean bottom seismometer (OBS) deployment/recovery, and approximately 11 days of transit. Some deviation in timing and ports of call could also result from unforeseen events such as weather or logistical issues.

Specific Geographic Region

The proposed survey would take place in the Ross Sea, Antarctica (continental shelf between ~75°–77.7° S and 171° E–173° E and Drygalski Trough between ~74°76.7° S and 163.6° E–170° E (Figure 1) in International waters of the Southern Ocean in water depths ranging from approximately 150 to 1100 m. Representative survey tracklines are shown in Figure 1; however, the actual survey effort could occur anywhere within the outlined study area as shown. The line locations for the survey area are preliminary and could be refined in light of information from data collected during the study and conditions within the survey area.

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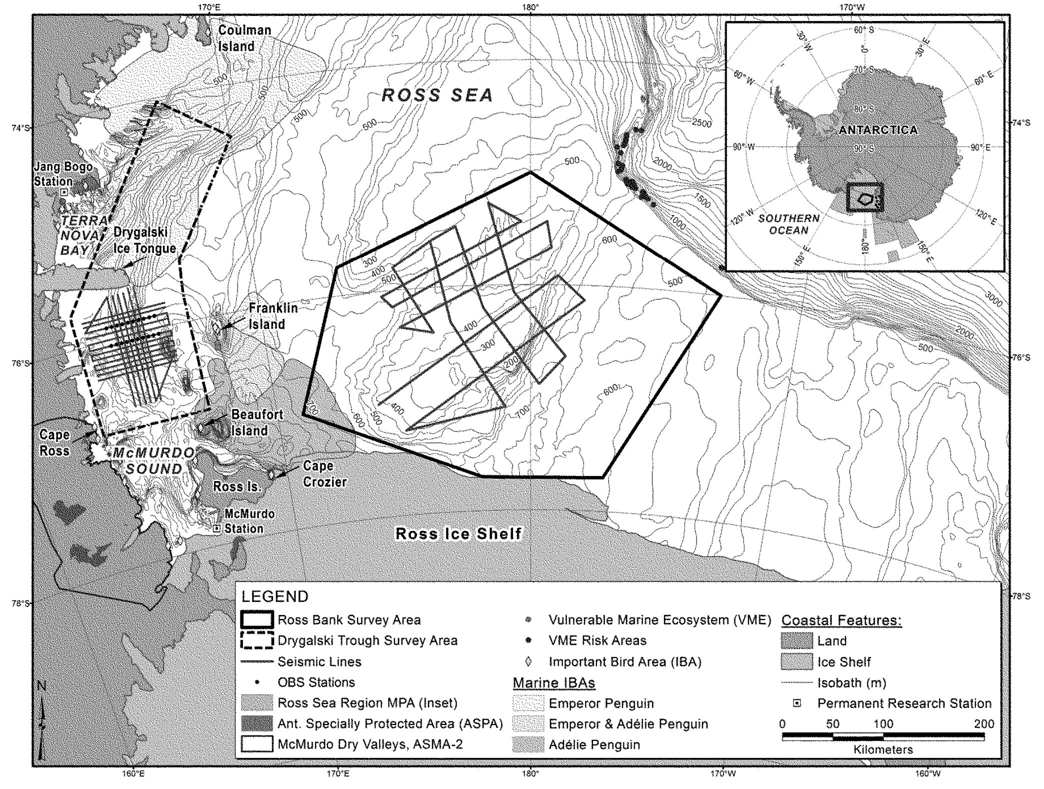

Figure 1 — Ross Sea Survey areas for the proposed low-energy seismic survey in the Ross Sea during austral summer 2022/2023*

*Showing representative transect lines and the protected areas. Ant. = Antarctic. ASMA = Antarctic Specially Managed Area. IBA = Important Bird Area. Sources: Davey (2013), CCAMLR (2017), Handley et al. (2021), and British Antarctic Survey (2022).

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Detailed Description of Specific Activity

The procedures to be used for the proposed survey would entail use of conventional seismic methodology. The survey would involve one source vessel, RVIB *Palmer* and the airgun array would be deployed at a depth of approximately 1–4 m below the surface, spaced approximately 2.4 m apart for the two-gun array. Seismic acquisition is proposed to begin with a standard sea trial to determine which configuration and mode of GI airgun(s) provide the best reflection signals, which depends on sea-state and subsurface conditions. A maximum of two GI airguns would be used. Four GI configurations (each using one or two GI airguns) would be tested during the sea trial (Table 1). The largest volume airgun configuration (configuration 4) was carried forward in our analysis and used for estimating the take numbers proposed for authorization.

The RVIB *Palmer* would deploy two 105 in^3 GI airguns as an energy source with a total volume of ~210 in^3. Seismic pulses would be emitted at intervals of 5 to 10 seconds from the GI airgun. The receiving system would consist of one hydrophone streamer, 75 m in length, with the vessel traveling at 8.3 km/hr (4.5 knots (kn)) to achieve high-quality seismic reflection data. As the airguns are towed along the survey lines, the hydrophone streamer would receive the returning acoustic signals and transfer the data to the on-board processing system. If sea-ice conditions permit, a multi-channel digital streamer would be used to improve signal-to-noise ratio by digital data processing; if ice is present, a single-channel digital steamer would be employed. When not towing seismic survey gear, the RVIB *Palmer* has a maximum speed of 26.9 km/h (14.5 kn), but cruises at an average speed of 18.7 km/h (10.1 kn). During the Ross Bank survey, ~1920km of seismic data would be collected and during the Drygalski Trough survey, ~1800 km of seismic acquisition would occur, for a total of 3720 line km.

During the Drygalski Trough survey, 2 deployments of 10 OBSs would occur along 2 different seismic refraction lines (see Fig. 1 for representative lines). Following refraction shooting of one line, OBSs on that line would be recovered, serviced, and redeployed on a subsequent refraction line. The spacing of OBSs on the initial refraction line would be 5 km apart, but OBSs could be deployed as close together as every 500 m on the subsequent refraction line. All OBSs would be recovered at the end of the survey. To retrieve the OBSs, the instrument is released via an acoustic release system to float to the surface from the wire and/or anchor, which are not retrieved.

TABLE 1—FOUR GI CONFIGURATIONS (EACH USING ONE OR TWO GI AIRGUNS) WOULD BE TESTED DURING THE SEA TRIAL

Configuration	Airgun array total volume (GI configuration)	Frequency between seismic shots	Streamer length
1	50 in^3 Harmonic Mode configured as 25 in^3 Generator + 25 Injector in^3.	5–10 seconds	75 m.
2	90 in^3 Harmonic Mode configured as 45 in^3 Generator + 45 Injector in^3.	5–10 seconds.	
3	50 in^3 True-GI Mode configured as 45 in^3 Generator + 105 Injector in^3.	5–10 seconds.	
4	210 in^3 Harmonic Mode configured as 105 in^3 Generator + 105 Injector in^3.	5–10 seconds.	

There could be additional seismic operations in the study area associated with equipment testing, re-acquisition due to reasons such as, but not limited to, equipment malfunction, data degradation during poor weather, or interruption due to shut down or track deviation in compliance with IHA requirements. To account for these additional seismic operations, 25 percent has been added in the form of operational days, which is equivalent to adding 25 percent to the proposed line km to be surveyed.

Along with the airgun and OBS operations, additional acoustical data acquisition systems and other equipment may be operated during the seismic survey at any time to meet scientific objectives. The ocean floor would be mapped with a Multibeam Ecosounder (MBES), Sub-bottom Profiler (SBP), and/or Acoustic Doppler Current Profiler (ADCP). Data acquisition in the survey area will occur in water depths ranging from 150 to 700 m. Take of marine mammals is not expected to occur incidental to use of these other sources, whether or not the airguns are operating simultaneously with the other sources. Given their characteristics (*e.g.,* narrow downward-directed beam), marine mammals would experience no more than one or two brief ping exposures, if any exposure were to occur. NMFS does not expect that the use of these sources presents any reasonable potential to cause take of marine mammals.

(1) *Single Beam Echo Sounder (Knudsen 3260)*—The hull-mounted compressed high-intensity radiated pulse (CHIRP) sonar is operated at 12 kilohertz (kHz) for bottom-tracking purposes or at 3.5 kHz in the sub-bottom profiling mode. The sonar emits energy in a 30° beam from the bottom of the ship and has a sound level of 224 dB re: 1 μPa m (rms).

(2) *Multibeam Sonar (Kongsberg EM122)*—The hull-mounted, multibeam sonar operates at a frequency of 12 kHz, has an estimated maximum source energy level of 242 dB re 1μPa (rms), and emits a very narrow (<2°) beam fore to aft and 150° in cross-track. The multibeam system emits a series of nine consecutive 15 millisecond (ms) pulses.

(3) *Acoustic Doppler Current Profiler (ADCP) (Teledyne RDI VM–150)*—The hull-mounted ADCP operates at a frequency of 150 kHz, with an estimated acoustic output level at the source of 223.6 dB re 1μPa (rms). Sound energy from the ADCP is emitted as a 30°, conically shaped beam.

(4) *ADCP (Ocean Surveyor OS–38)*—The characteristics of this backup, hull-mounted ADCP unit are similar to the Teledyne VM–150. The ADCP operates at a frequency of 150 kHz with an estimated acoustic output level at the source of 223.6 dB re 1μPa (rms). Sound energy from the ADCP is emitted as a 30° conically-shaped beam.

(5) *EK biological echo sounder (Simrad ES200–7C, ES38B, ES–120–7C)*—This echo sounder is a split-beam transducer with an estimated acoustic output level at the source of 183–185 dB

re 1μPa and emits a 7° beam. It can operate at 38 kHz, 120 kHz and 200 kHz.

(6) *Acoustic Release*—To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 7–15 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the wire and/or anchor which are not retrieved.

(7) *Oceanographic Sampling*—during the Drygalski Trough study, the researchers would also conduct opportunistic oceanographic sampling as time and scheduling allows, including conductivity, temperature and depth (CTD) measurements, box cores, and/or multi-cores.

Icebreaking

Icebreaking activities are expected to be limited during the proposed survey. The Ross Sea is generally clear of ice January through February, because of the large Ross Sea Polynya that occurs in front of the Ross Ice Shelf. Heavy ice conditions would hamper the proposed activities, as noise from icebreaking degrades the quality of the geophysical data to be acquired. If the RVIB *Palmer* would find itself in heavy ice conditions, it is unlikely that the airgun(s) and streamer could be towed, as this could damage the equipment and generate noise interference. The seismic survey could take place in low ice conditions if the RVIB *Palmer* were able to generate an open path behind the vessel. The RVIB *Palmer* is not rated for breaking multi-year ice and generally avoids transiting through ice two years or older and more than 1 m thick. If sea ice were to be encountered during the survey, the RVIB *Palmer* would likely proceed through one-year sea ice, and new, thin ice, but would follow leads wherever possible. Any time spent icebreaking would take away time from the proposed research activities, as the vessel would travel slower in ice-covered seas. Based on estimated transit to the survey area, it is estimated that the RVIB *Palmer* would break ice up to a distance of 500 km. Based on a ship speed of 5 kn under moderate ice conditions, this distance represents approximately 54 hours of icebreaking (or 2.2 days). Transit through areas of primarily open water containing brash ice or pancake ice is not considered icebreaking for the purposes of this assessment.

Proposed mitigation, monitoring, and reporting measures are described in detail later in this document (please see Proposed Mitigation and Proposed Monitoring and Reporting).

Description of Marine Mammals in the Area of Specified Activities

Sections 3 and 4 of the application summarize available information regarding status and trends, distribution and habitat preferences, and behavior and life history, of the potentially affected species. Additional information about these species (*e.g.,* physical and behavioral descriptions) may be found on NMFS's website (*https://www.fisheries.noaa.gov/find-species*).

The populations of marine mammals considered in this document do not occur within the U.S. Exclusive Economic Zone (EEZ) and are therefore not assigned to stocks and are not assessed in NMFS' Stock Assessment Reports (SAR). As such, information on potential biological removal (PBR; defined by the MMPA as the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population) and on annual levels of serious injury and mortality from anthropogenic sources are not available for these marine mammal populations. Abundance estimates for marine mammals in the survey location are lacking; therefore estimates of abundance presented here are based on a variety of other sources including International Whaling Commission (IWC) population estimates, the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species, and various literature estimates (see IHA application for further detail), as this is considered the best available information on potential abundance of marine mammals in the area.

Seventeen species of marine mammals could occur in the Ross Sea, including 5 mysticetes (baleen whales), 7 odontocetes (toothed whales) and 5 pinniped species (Table 2). Another seven species occur in the Sub-Antarctic but are unlikely to be encountered in the proposed survey areas, as they generally occur farther to the north than the project area. These species are not discussed further here but include: the southern right whale (*Eubalaena australis*), common (dwarf) minke whale (*Balaenoptera acutorostrata*), Cuvier's beaked (*Ziphius cavirostris*), Gray's beaked (*Mesoplodon grayi*), Hector's beaked (*Mesoplodon hectori*), and spade-toothed beaked (*Mesoplodon traversii*) whales, southern right whale dolphin (*Lissodelphis peronii*), and spectacled porpoise (*Phocoena dioptrica*). Table 2 lists all species with expected potential for occurrence in the Ross Sea, Antarctica, and summarizes information related to the population, including regulatory status under the MMPA and ESA.

TABLE 2—MARINE MAMMAL SPECIES POTENTIALLY PRESENT IN THE PROJECT AREA EXPECTED TO BE AFFECTED BY THE SPECIFIED ACTIVITIES

Common name	Scientific name	Stock[1]	ESA/MMPA status; strategic (Y/N)[2]	Stock abundance
Order Cetartiodactyla—Cetacea—Superfamily Mysticeti (baleen whales)				
Family Balaenopteridae (rorquals):				
Blue whale	*Balaenoptera musculus*	N/A	E/D;Y	10,000–25,000.[5] 1,700.[7]
Fin whale	*Balaenoptera physalus*	N/A	E/D;Y	140,000.[5] 38,200. [6]
Humpback whale	*Megaptera novaeangliae*	N/A		90,000.–100,000.[5] 80,000.[10] 42,000.[11]
Antarctic minke whale[6]	*Balaenoptera bonaerensis*	N/A		Several 100,000 [5] 515,000.[9]

TABLE 2—MARINE MAMMAL SPECIES POTENTIALLY PRESENT IN THE PROJECT AREA EXPECTED TO BE AFFECTED BY THE SPECIFIED ACTIVITIES—Continued

Common name	Scientific name	Stock[1]	ESA/ MMPA status; strategic (Y/N)[2]	Stock abundance
Sei whale	*Balaenoptera borealis*	N/A	E	70,000.[8]
Superfamily Odontoceti (toothed whales, dolphins, and porpoises)				
Family Physeteridae:				
Sperm whale	*Physeter macrocephalus*	N/A	E	360,000.[12] 12,069.[13]
Family Ziphiidae (beaked whales):				
Arnoux's beaked whale	*Berardius arnuxii*	N/A		599,300.[14]
Strap-toothed beaked whale	*Mesoplodon grayi*	N/A		599,300.[14]
Southern bottlenose whale	*Hyperoodon planifrons*	N/A		599,300.[14]
Family Delphinidae:				
Killer whale	*Orcinus orca*	N/A		50,000[16] 25,000.[17]
Long-finned pilot whale	*Globicephala macrorhynchus*	N/A		200,000.[15]
Hourglass dolphin	*Lagenorhynchus cruciger*	NA		144,300.[15]
Family Phocidae (earless seals):				
Crabeater seal	*Lobodon carcinophaga*	N/A		5–10 million[18] 1.7 million.[19]
Leopard seal	*Hydrurga leptonyx*	N/A		222,000–440,00.[5,20]
Southern elephant seal	*Mirounga leonina*	N/A		750,000.[23]
Ross seal	*Ommatophoca rossii*	N/A		250,000.[22]
Weddell seal	*Leptonychotes weddellii*	N/A		1 million.[5,21]

N.A. = data not available.

[1] Occurrence in area at the time of the proposed activities; based on professional opinion and available data.

[2] U.S. Endangered Species Act: EN = endangered, NL = not listed.

[5] Worldwide (Jefferson *et al.,* 2015).

[6] Antarctic (Aguilar and García-Vernet 2018).

[7] Antarctic (Branch *et al.,* 2007).

[8] Southern Hemisphere (Horwood 2018).

[9] Southern Hemisphere (IWC 2020).

[10] Southern Hemisphere (Clapham 2018).

[11] Antarctic feeding area (IWC 2020).

[12] Worldwide (Whitehead 2002).

[13] Antarctic south of 60° S (Whitehead 2002).

[14] All beaked whales south of the Antarctic Convergence; mostly southern bottlenose whales (Kasamatsu and Joyce 1995).

[15] Kasamatsu and Joyce (1995).

[16] Worldwide (Forney and Wade 2006).

[17] Minimum estimate for Southern Ocean (Branch and Butterworth 2001).

[18] Worldwide (Bengtson and Stewart 2018).

[19] Ross and Amundsen seas (Bengtson *et al.,* 2011).

[20] Rogers *et al.,* 2018.

[21] Hückstädt 2018a.

[22] Worldwide (Curtis *et al.,* 2011 in Hückstädt 2018b).

[23] Total world population (Hindell *et al.,* 2016).

All species that could potentially occur in the proposed survey areas are included in Table 2. As described below, all 17 species temporally and spatially co-occur with the activity to the degree that take is reasonably likely to occur, and we have proposed authorizing it.

We have reviewed NSF's species descriptions, including life history information, distribution, regional distribution, diving behavior, and acoustics and hearing, for accuracy and completeness. We refer the reader to Section 4 of NSF's IHA application for a complete description of the species, and offer a brief introduction to the species here, as well as information regarding population trends and threats, and describe information regarding local occurrence.

Mysticetes

Blue Whale

The blue whale has a cosmopolitan distribution, but tends to be mostly pelagic, only occurring nearshore to feed and possibly breed (Jefferson *et al.,* 2015). It is most often found in cool, productive waters where upwelling occurs (Reilly and Thayer 1990). 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). Seamounts and other deep ocean structures may be important habitat for blue whales (Lesage *et al.,* 2016).

Generally, blue whales are seasonal migrants between high latitudes in summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981).

Historically, blue whales were most abundant in the Southern Ocean. Although, the population structure of the Antarctic blue whale (*Balaenoptera musculus intermedia*) in the Southern Ocean is not well understood, there is evidence of discrete feeding stocks (Sears & Perrin 2018). Cooke (2018) explains that ''there are no complete estimates of recent or current abundance for the other regions, but plausible total numbers would be 1,000–3,000 in the North Atlantic, 3,000–5,000 in the North Pacific, and possibly 1,000–3,000 in the eastern South Pacific. The number of Pygmy Blue whales is very uncertain but may be in the range 2,000–5,000. Taken together with a range of 5,000–8,000 in the Antarctic, the global population size in 2018 is plausibly in the range 10,000–25,000 total or 5,000–15,000 mature, compared with a 1926 global population of at least 140,000 mature.'' Blue whales begin migrating north out of the Antarctic to winter breeding grounds earlier than fin and sei whales.

The Antarctic blue whale is typically found south of 55° S during summer, although some individuals do not migrate (Branch *et al.,* 2007a). The blue whale is considered to be rare in the Southern Ocean; up to 360,000 blue whales were harvested in the Southern Hemisphere in the early 20th century (Sears and Perrin 2018). Ainley (2010) noted that they were extirpated from the Ross Sea shelf break front in the 1920s. Smith *et al.* (2012) estimated that 30 blue whales may occur in the Ross Sea. Several sighting records were reported for the northern Ross Sea between 1978 and 2005 (Kasamatsu *et al.,* 1990; Nishiwaki *et al.,* 1997; Matsuoka *et al.,* 2006; Ainley *et al.,* 2010) as well as during a 2008 survey (Baird and Mormede 2014). Acoustic detections were also made in the northeastern Ross Sea between 1996 to 2010 (Shabangu *et al.,* 2018). Eight groups of 24 individuals were seen north of the Ross Sea during summer surveys in 2002–2003 (Ensor *et al.,* 2003). No blue whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Fin Whale

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 is not well known (Jefferson *et al.,* 2015). 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 the summer; they are known to use the shelf edge as a migration route (Evans 1987). 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).

They likely migrate beyond 60° S during the early to mid-austral summer, arriving at southern feeding grounds after blue whales. Overall, fin whale density tends to be higher outside the continental slope than inside it. During the austral summer, the distribution of fin whales ranges from 40° S–60° S in the southern Indian and South Atlantic oceans and 50° S–65° S in the South Pacific. Aguilar and García-Vernet (2018) found abundance estimates resulted in 38,200 individuals in the Antarctic south of 307° S.

Based on Edwards *et al.* (2015), densities in the Southern Ocean south of 60° S (including the northern part of the Ross Sea) are highest during December–February, with non-zero densities <0.003 whales/km^2. Pinkerton *et al.* (2010) assumed that ~200 fin whales use the Ross Sea during summer. Fin whale sightings have been reported for the Ross Sea by several authors (Nishiwaki *et al.,* 1997; Matsuoka *et al.,* 2006; Ainley *et al.,* 2010; Baird and Mormede 2014; MacDiarmid and Stewart 2015). During an NSF-funded seismic survey in the Ross Sea in January through February 2015, 13 sightings totaling 34 fin whales were made, including within the proposed survey area (RPS 2015a). Ensor *et al.* (2003) reported sightings north of the Ross Sea during summer surveys in 2002–2003.

Humpback Whale

The humpback whale is found in all ocean basins (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). The humpback whale is highly migratory, undertaking one of the world's longest mammalian migrations by traveling between mid- to high-latitude waters where it feeds during spring to fall and low-latitude wintering grounds over shallow banks, where it mates and calves (Winn and Reichley 1985; Bettridge *et al.,* 2015). Although considered to be mainly a coastal species, it often traverses deep pelagic areas while migrating (Baker *et al.,* 1998; Garrigue *et al.,* 2002; Zerbini *et al.,* 2011).

In the Southern Hemisphere, humpback whales migrate annually from summer foraging areas in the Antarctic to breeding grounds in tropical seas (Clapham 2018). The IWC recognizes seven breeding populations in the Southern Hemisphere that are linked to six foraging areas in the Antarctic (Bettridge *et al.,* 2015; Clapham 2018). Humpbacks that occur in the western Ross Sea (west of 170° W) are part of the Area V feeding stock (Schmitt *et al.,* 2014); these individuals are from the Oceania DPS that breeds in French Polynesia, Cook Islands, and Tonga, and from the East Australia DPS (Schmitt *et al.,* 2014; Bettridge *et al.,* 2015).

Humpback densities are high north of the Ross Sea (Branch 2011; Matsuoka and Hakamada 2020), but not within it (Ropert-Coudert *et al.,* 2014). Pinkerton *et al.* (2010) estimated that <5 percent (150 individuals) of the Southern Ocean population occurs in the Ross Sea in the austral summer. Humpback whales were seen in the northern Ross Sea during surveys conducted between 1987 and 2009 (Baird and Mormede 2014; MacDiarmid and Stewart 2015). However, none were seen in the Ross Sea during the International Whaling Commission-Southern Ocean Whale and Ecosystem Research (IDCR/SOWER) surveys from 1978/79 to 2004/05 (Branch 2011). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, two sightings totaling six individuals were made east of the proposed survey areas (RPS 2015a). Acoustic detections were also made in the northeastern Ross Sea between 1996 to 2010 (Shabangu *et al.,* 2018). Ensor *et al.* (2003) reported numerous humpback sightings and acoustic detections north of the Ross Sea during summer surveys in 2002–2003.

Antarctic Minke Whale

The Antarctic minke whale has a circumpolar distribution in coastal and offshore areas of the Southern Hemisphere from ~7 degrees S to the ice edge (Jefferson *et al.,* 2015). It is found between 60° S and the ice edge during the austral summer; in the austral winter, it is mainly found at mid-latitude breeding grounds, including off western South Africa and northeastern Brazil, where it is primarily oceanic, occurring beyond the shelf break (Perrin *et al.,* 2018). Antarctic minke whale densities are highest near pack ice edges, although they are also found amongst pack ice (Ainley *et al.,* 2012; Williams *et al.,* 2014), where they feed almost entirely on krill (Tamura and Konishi 2009). Murase *et al.* (2006, 2007) found that minke whale distribution was related to krill density in the Ross Sea, with the greatest number of pods in areas with a krill density of 1 g/m².

Minke whales were harvested heavily in the Southern Ocean during the 1970s and 1980s, with >13,000 harvested in the early 1980s; but the hunt ceased in 1986 under an IWC moratorium (Ainley 2002). However, Japanese whaling continued under scientific permit taking hundreds of minke whales in the Ross Sea since the late 1980s (Ainley 2002). During Japanese sighting surveys from 1976–1988, high encounter rates occurred in the Ross Sea (Kasamatsu *et al.,* 1996), where minke whales are known to form feeding aggregations (Kasamatsu *et al.,* 1998). Saino and Guglielmo (2002) reported a mean density of 0.13 whales/km² in the western Ross Sea. The minke whale is the most abundant species occupying the shelf waters in the Ross Sea (Waterhouse 2001; Smith *et al.,* 2007). Approximately six percent of Antarctic minke whales occur in the Ross Sea (Ainley *et a,l.* 2010; Smith *et al.,* 2012). The Ross Sea population was estimated at 14,300 by Ainley (2002) and 87,643 individuals by Matsuoka *et al.,* (2009).

Ainley *et al.* (2017) reported that minke whales started to arrive in the southwestern Ross Sea in mid-November, with decreasing ice conditions. Ainley *et al.* (2010, 2012) and Ballard *et al.* (2012) reported sightings around the northwestern and northeastern periphery of the proposed Ross Bank survey area and within the Drygalski Trough survey area. Although minke whales have a high likelihood of occurrence in the Ross Sea (*e.g.,* Ainley *et al.,* 2012; Ropert-Coudert *et al.,* 2014), habitat suitability for the proposed survey area in summer was modeled as relatively low (Ballard *et al.,* 2012). However, minke whales were seen in the Ross Sea during surveys conducted between 1978 and 2009, including within the proposed survey area (Kasamatsu *et al.,* 1990; Baird and Mormede 2014; MacDiarmid and Stewart 2015). They were also detected acoustically in the Ross Sea in 2004 (Dolman *et al.,* 2005). Minke whales were seen feeding (presumable on fish) in the southwestern Ross Sea (Lauriano *et al.,* 2007). During an NSF-funded seismic survey in the Ross Sea in January–February 2015, 224 sightings totaling 1023 minke whales were made, including within the proposed survey area and in McMurdo Sound (RPS 2015a). Ensor *et al.* (2003) reported numerous sightings north of the Ross Sea during summer surveys in 2002–2003.

Sei Whale

The sei whale occurs in all ocean basins (Horwood 2018), predominantly inhabiting deep waters throughout their range (Acevedo *et al.,* 2017a). It undertakes seasonal migrations to feed in sub-polar latitudes during summer, returning to lower latitudes during winter to calve (Horwood 2018). Recent observation records indicate that the sei whale may utilize the Vitória-Trindade Chain off Brazil as calving grounds (Heissler *et al.,* 2016). In the Southern Hemisphere, sei whales typically concentrate between the Subtropical and Antarctic convergences during the summer (Horwood 2018) between 40° S and 50° S, with larger, older whales typically travelling into the northern Antarctic zone while smaller, younger individuals remain in the lower latitudes (Acevedo *et al.,* 2017a). Pinkerton *et al.* (2010) assumed that approximately 100 animals may occur in the Ross Sea. Ensor *et al.* (2003) reported no sightings south of 54° S during a summer survey of the Southern Ocean in 2002–2003. No sei whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Odontocetes

Sperm Whale

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 greater than 1,000 m deep at latitudes less than 40° where sea surface temperatures are less than 15 °C; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds according to an unknown schedule (Whitehead 2018).

Few sperm whales are thought to occur in the Ross Sea (Smith *et al.,* 2012), although Pinkerton *et al.* (2010) assumed that 800 sperm whales could be using the Ross Sea. Sperm whales generally do not occur south of approximately 73–74° S in the Ross Sea (Matsuoka *et al.,* 1998; Ropert-Coudert *et al.,* 2014). Nonetheless, sperm whales have been reported there by several authors (Kasamatsu *et al.,* 1990; Baird and Mormede 2014). Ensor *et al.* (2003) reported numerous sightings and acoustic detections north of the Ross Sea during summer surveys in 2002–2003. No sperm whales were seen during an NSF-funded seismic survey in the Ross Sea in January through February 2015 (RPS 2015a).

Arnoux's Beaked Whale

Arnoux's beaked whale is distributed in deep, cold, temperate, and subpolar waters of the Southern Hemisphere, occurring between 24° S and Antarctica (Thewissen 2018), as far south as the Ross Sea at approximately 78° S (Perrin *et al,.* 2009). Most records exist for southeastern South America, Falkland Islands, Antarctic Peninsula, South Africa, New Zealand, and southern Australia (MacLeod *et al.,* 2006; Jefferson *et al.,* 2015).

Ainley *et al.* (2010) and Van Waerebeek *et al.* (2010), and Ropert-Coudert *et al.* (2014) reported their occurrence in the Ross Sea. Lauriano *et al.* (2011) reported two sightings of single individuals in Terra Nova Bay, western Ross Sea, during summer 2004 surveys. There may be 50 (Pinkerton *et al.,* 2010) to 150 (Smith *et al.,* 2012) Arnoux's beaked whales in the Ross Sea. No Arnoux's beaked whales were seen during an NSF-funded seismic survey in the Ross Sea in January through February 2015 (RPS 2015a).

Southern Bottlenose Whale

The southern bottlenose whale is found throughout the Southern Hemisphere from 30° S to the ice edge, with most sightings reported between approximately 57° S and 70° S (Jefferson *et al.,* 2015; Moors-Murphy 2018). Several sighting and stranding records exist for southeastern South America, Falkland Islands, South Georgia Island, southeastern Brazil, Argentina, South Africa, and numerous sightings have been reported for the Southern Ocean (Findlay *et al.,* 1992; MacLeod *et al.* 2006; Riccialdelli *et al.,* 2017). The population size of southern bottlenose whales in the Ross Sea was assumed to be 500 by Pinkerton *et al.* (2010). Ropert-Coudert *et al.* (2014) reported their occurrence in the Ross Sea, and Kasamatsu *et al.* (1990) reported sightings between 1978 and 1988. Southern bottlenose whales were also sighted in the northern Ross Sea and north of there during surveys of the Southern Ocean by Van Waerebeek *et al.* (2010). Several unidentified beaked whales have also been reported in the Ross Sea, including in the Ross Bank survey area and near the Drygalski Trough survey area (Baird and Mormede 2014; MacDiarmid and Stewart 2015; Matsuoka and Hakamada 2020). Ensor *et al.* (2003) and Matsuoka and Hakamada (2020) reported numerous sightings of southern bottlenose whales north of the Ross Sea. No bottlenose whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Strap-Toothed Beaked Whale

The strap-toothed beaked whale is thought to have a circumpolar distribution in temperate and subantarctic waters of the Southern Hemisphere, mostly between 32° and 63° S (MacLeod *et al.,* 2006; Jefferson *et al.,* 2015). It is likely quite common in the Southern Ocean (Pitman 2018). It may undertake limited migration to warmer waters during the austral winter (Pitman 2018). Strap-toothed beaked whales are thought to migrate northward from Antarctic and subantarctic latitudes during April–September (Sekiguchi *et al,.* 1995). One group of three strap-toothed beaked whales was seen north of the Ross Sea, north of 65° S, during a 2002 through 2003 summer survey (Ensor *et al.,* 2003). No strap-toothed beaked whales were seen during an NSF-funded seismic survey in the Ross Sea in January through February 2015 (RPS 2015a).

Killer Whale

The killer whale is cosmopolitan and globally abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters but also occurs in tropical waters (Heyning and Dahlheim 1988) and inhabits coastal and offshore regions (Budylenko 1981). Mikhalev *et al.* (1981) noted that it appears to migrate from warmer waters during the winter to higher latitudes during the summer. In the Antarctic, it commonly occurs up to the pack ice edge but may also find its way into ice-covered water (Ford 2018).

There are three ecotypes that occur in Antarctic waters: type A hunts marine mammals in open water, mainly seeking minke whales, type B hunt seals in loose pack ice, and type C feeds on fish in dense pack ice (Pitman and Ensor 2003); these types are likely different species (Morin *et al.,* 2010; Pitman *et al.,* 2017). Type D occurs in subantarctic waters and is also likely a separate species (Pitman *et al.,* 2011). Type B travels widely to hunt its prey, whereas type C is more resident (Andrews *et al.,* 2008). In fact, type Cs (Ross Sea killer whales) appear to have resident and transient groups in the Ross Sea (*e.g.,* Ainley *et al.,* 2017). In the Ross Sea, abundance has been estimated at 7500 individuals (Smith *et al.,* 2007). Ainley *et al.* (2010) and Smith *et al.* (2012) estimated that approximately 50 percent of Ross Sea killer whales use the Ross Sea during summer foraging. Smith *et al.* (2012) reported 3350 type C killer whales and 70 type A/B killer whales in the Ross Sea. Pitman *et al.* (2017) reported only two ecotypes in the Ross Sea (types B and C), but Ainley *et al.* (2010) noted that type A could occur along the slope.

Ainley *et al.* (2017) reported that type C and B killer whales start to arrive in the southwestern Ross Sea in mid-November, with decreasing ice conditions, with type Bs arriving earlier than type Cs. Type C killer whales have been seen feeding (presumable on fish) in the southwestern Ross Sea (Lauriano *et al.,* 2007), and type B and C killer whales were reported during summer 2004 surveys in Terra Nova Bay, western Ross Sea (Lauriano *et al.,* 2011). Eisert *et al.* (2014) reported Type C and B in McMurdo Sound. Type C killer whales have also been detected acoustically in McMurdo Sound (Wellard *et al.,* 2020). During an NSF-funded seismic survey in the Ross Sea in January through February 2015, 14 sightings totaling 254 killer whales were made, including within the survey area and in McMurdo Sound (RPS 2015a). Saino and Guglielmo (2002) reported a mean density of 0.05 whales/km^2 in the western Ross Sea. However, numbers of type C killer whales have apparently decreased in the southwestern Ross Sea, because of changes in prey distribution (Antarctic toothfish) likely brought on by fishing pressures (Ainley *et al.,* 2009; Ainley and Ballard 2012). However, Pitman *et al.* (2018) suggested that the presence of a mega-iceberg at Ross Island may have also impeded killer whale movement, thereby affecting the population size; they estimated a population size of 470 distinct individuals in McMurdo Sound. Type B killer whale numbers have not changed in the southern Ross Sea, where they hunt Weddell seals and emperor penguins (Ainley and Ballard 2012).

Type C killer whale appears to favor the Ross Sea shelf and slope (Ballard *et al.,* 2012). Sightings of type C killer whales within and west of the proposed study area have been reported during summer (Andrews *et al.,* 2008; Ballard *et al.,* 2012). The habitat suitability for the proposed survey area in summer for type C killer whales was modeled as relatively high, whereas it was lower for the Drygalski Trough survey area (Ballard *et al.,* 2012). Andrew *et al.* (2008) documented movement of a tagged type B killer whale to the west of the proposed study area. Aubrey *et al.* (1982) reported sightings of killer whales in the Ross Sea off Cape Adare and over Pennell Banks, and noted that killer whales were abundant off Ross Island. Killer whales were also reported in the Ross Sea by several other authors (*e.g.,* Kasamatsu *et al.,* 1990; Van Dam and Kooyman 2004; Van Waerebeek *et al.,* 2010; Baird and Mormede 2014; Ropert-Coudert *et al.,* 2014). Acoustic detections were also made in the northeastern Ross Sea between 1996 to 2010 (Shabangu *et al.,* 2018). Ensor *et al.* (2003) reported numerous sightings and acoustic detections north of the Ross Sea during summer surveys in 2002–2003.

Long-Finned Pilot Whales

The long-finned pilot whale is distributed antitropically in cold temperate waters, including the Southern Ocean, whereas the short-finned pilot whale is found in tropical and warm temperate waters (Olson 2018). The ranges of the two species show little overlap (Olson 2018). Long-finned pilot whales are geographically isolated and separated into two subspecies, *G. melas melas* and *G. melas edwardii* in the Northern and Southern hemispheres, respectively (Olson 2018). In the Southern Hemisphere, their range extends to the Antarctic Convergence and sometimes as far south as 68° S (Jefferson *et al.,* 2015). Although generally not seen south of 68° S, long-finned pilot whales were reported in the Ross Sea during observations from longliners between 1997 and 2009 (Baird and Mormede 2014). During summer surveys in 2002–2003, several sightings were made north of the Ross Sea (Ensor *et al.,* 2003). They were also reported north of the Ross Sea during surveys by Van Waerebeek *et al.* (2010). No pilot whales were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Hourglass Dolphin

The hourglass dolphin occurs in the Southern Ocean, with most sightings between approximately 45° S and 60° S (Cipriano 2018). However, some sightings have been made as far north as 33° S (Jefferson *et al.,* 2015). Hourglass dolphins were sighted near 45° S, north of the Ross Sea, during surveys of the Southern Ocean (Van Waerebeek *et al.,* 2010). Although it is pelagic, it is also sighted near banks and islands (Cipriano 2018). Ensor *et al.* (2003) reported numerous sightings of hourglass dolphins north of the Ross Sea, north of 65° S, during a summer survey in 2002–2003. No hourglass dolphins were seen during an NSF-funded seismic survey in the Ross Sea in January through February 2015 (RPS 2015a).

Phocids

Crabeater Seal

The crabeater seal has a circumpolar distribution off Antarctica and is the most abundant seal in the region, sometimes congregating in the hundreds (Bengtson and Stewart 2018). It generally spends the entire year in the advancing and retreating pack ice (Bengtson and Stewart 2018). However, outside of the breeding season, crabeater seals spend ~14 percent of their time in open water (reviewed in Southwell *et al.,* 2012); they mainly forage on krill. During the breeding season, crabeater seals are most likely to be present within 5° or less (~550 km) of the shelf break; non-breeding animals range farther north (Southwell *et al.,* 2012). Pupping season peaks in mid- to late-October, and adults are observed with their pups as late as mid-December (Bengtson and Stewart 2018).

Crabeater seals are most common in the pack ice of the northern Ross Sea (Waterhouse 2001). A population of approximately 204,000 has been estimated for the Ross Sea (Waterhouse 2001; Ainley 2002, 2010; Pinkerton and Bradford-Grieve 2010; Smith *et al.,* 2012). Crabeater seals have been reported for the Ross Sea by several authors (Stirling 1969; Van Dam and Kooyman 2004; Bester and Stewart 2006; Baird and Mormede 2014; Ropert-Coudert *et al.,* 2014). Crabeater seals have been sighted within the proposed survey area (*e.g.,* Saino and Guglielmo 2000; Ainley *et al.,* 2010; Ballard *et al.,* 2012), with greater habitat suitability in summer in the Drygalski Trough survey area than in the Ross Bank survey area (Ballard *et al.,* 2012). Similarly, Bengtson *et al.* (2011) reported relatively low densities in the Ross Bank area and higher densities in the Drygalski Trough area. Saino and Guglielmo (2002) showed increasing densities with increasing pack ice and distance from shore, with a mean density of 0.49 seals/km^2, in the western Ross Sea. In contrast, Bengtson *et al.* (2011) reported the highest density (1.3 seals/km^2) on the shelf at distances up to 200 km from the ice edge during surveys of the Ross and Amundsen seas; densities in the proposed survey area were estimated to be low. During an NSF-funded seismic survey in the Ross Sea in January through February 2015, 9 sightings of 14 individuals were made (RPS 2015a).

Leopard Seal

The leopard seal has a circumpolar distribution around the Antarctic continent where it is solitary and widely dispersed at low densities (Rogers 2018). It primarily occurs in pack ice, but when the sea ice extent is reduced, it can be found in coastal habitats (Meade *et al.,* 2015). Leopard seals are top predators, consuming everything from krill and fish to penguins and other seals (*e.g.,* Hall-Aspland and Rogers 2004). Pups are born during October to mid-November and weaned ~one month later (Rogers 2018). Mating occurs in the water during December and January. A population of ~8000 is thought to occur in the Ross Sea (Waterhouse 2001; Ainley 2002, 2010; Pinkerton and Bradford-Grieve 2010; Smith *et al.,* 2012). Bengtson *et al.* (2011) reported an abundance of 15,000 leopard seals for the Ross and Amundsen seas. Densities were highest (0.024 seals/km^2) in water <3000 m deep and <100 km from the ice edge; very low densities were estimated for the southern portion of the Ross Bank survey area, with low densities in the rest of the survey area and in the Drygalski Trough survey area (Bengtson *et al.,* 2011). Leopard seals have been documented to take Adélie penguins at several colonies in the Ross Sea, including Cape Crozier (south of the proposed survey areas), and in McMurdo Sound (Ainley *et al.,* 2005). Leopard seals have been reported within and near the Drygalski Trough survey area, no sightings have been reported within the Ross Bank survey area (Stirling 1969; Ackley *et al.,* 2003; Van Dam and Kooyman 2004; Bester and Stewart 2006; Ainley *et al.,* 2010; Baird and Mormede 2014; Ropert-Coudert *et al.,* 2014). No leopard seals were sighted during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a).

Southern Elephant Seal

The southern elephant seal has a near circumpolar distribution in the Southern Hemisphere (Jefferson *et al.,* 2015), with breeding sites located on islands throughout the subantarctic (Hindell 2018). Breeding colonies are generally island-based, with the occasional exception of the Antarctic mainland (Hindell 2018).

When not breeding (September–October) or molting (November–April), southern elephant seals range throughout the Southern Ocean from areas north of the Antarctic Polar Front to the pack ice of the Antarctic, spending >80 percent of their time at sea each year, up to 90 percent of which is spent submerged while hunting, travelling, and resting in water depths ≥200 m (Hindell 2018). Males generally feed in continental shelf waters, while females preferentially feed in ice-free Antarctic Polar Front waters or the marginal ice zone in accordance with winter ice expansion (Hindell 2018). Southern elephant seals tagged at South Georgia showed long-range movements from ~April through October into the open Southern Ocean and to the shelf of the Antarctic Peninsula (McConnell and Fedak 1996). Their occurrence in the Ross Sea is rare and only during the summer (Waterhouse 2001; Pinkerton and Bradford-Grieve 2010). The population size in the Ross Sea is estimated to number <100 individuals (Ainley 2010; Smith *et al.,* 2012). Ropert-Coudert *et al.* (2014) reported one record in the Ross Sea, in McMurdo Sound. No southern elephant seals were seen during an NSF-funded seismic survey in the Ross Sea in January–February 2015 (RPS 2015a)

Ross Seal

Ross seals are considered the rarest of all Antarctic seals; they are the least documented because they are infrequently observed. Ross seals have a circumpolar Antarctic distribution. They are pelagic through most of the year.

The population in the Ross Sea may number 500 (Smith *et al,.* 2012) to 5000 individuals (Waterhouse 2001; Ainley 2010; Pinkerton and Bradford-Grieve 2010). According to surveys by Bester *et al.* (2006), Ross seals are relatively abundant in the Ross Sea. Based on surveys of the Ross and Amundsen seas, Bengtson *et al.* (2011) estimated an abundance of 22,600, with the highest density (0.032 seals/km^2) in deep water (greater than 3000 m) within 200 km from the ice edge; low densities were estimated for the proposed survey area. Ross seals were seen in the western (Stirling 1969) and eastern Ross Sea during surveys (Stirling 1969; Ackley *et al.,* 2003; Bester and Stewart 2006). During an NSF-funded seismic survey in the Ross Sea in January through February 2015, two sightings of single Ross seals were made to the east of the proposed survey area (RPS 2015a).

Weddell Seal

The Weddell seal is the second most abundant species of Antarctic seal (Hückstädt 2018a). It occurs in the fast and pack ice around all of Antarctica, as well as on land along the coast, but is rarely found in ice-free water (Hückstädt 2018a). It occurs on the Ross Sea shelf and slope (Ballard *et al.,* 21012). It is the most southerly breeding mammal in the world, occurring as far south as the RIS (Hückstädt 2018a). Unlike other Antarctic ice seals, Weddell seals form colonies (Cameron *et al.,* 2007). There are numerous pupping locations throughout the western Ross Sea, including around Ross Island (Ainley *et al.,* 2010). Juveniles tend to disperse widely, resulting in genetic diversity in the population (Hückstädt 2018a). Seals outfitted with tags in the western Ross Sea were documented to disperse hundreds of kilometers, making their way into the proposed survey areas (Ainley *et al.,* 2010; Goetz 2015). However, some small colonies have been isolated from open water by ice sheets and therefore show inbreeding depression (Gelatt *et al.,* 2010). Weddell seals primarily feed on fish. Pups are born from October through November and are weaned after ~six to eight weeks (Hückstädt 2018a). Paterson *et al.* (2015) suggested that the timing of reproduction by Weddell seals in Erebus Bay, McMurdo Sound, is coupled with periods of high productivity in Ross Bay. After the breeding season, the ice breaks down and seals disperse into the sea to forage for one to two months and return to ice or land to molt in January and February (Hückstädt 2018a).

Ainley *et al.* (2010) estimated that 50 to 72 percent of the South Pacific sector of Weddell seals occur in the Ross Sea. The population in the Ross Sea has been estimated between 32,000 and 50,000 individuals (*e.g.,* Ainley 2002, 2010; Pinkerton and Bradford-Grieve 2010; Smith *et al.,* 2012). Bengtson *et al.* (2011) estimated the population in the Ross and Amundsen seas at 330,000 seals. The highest densities (up to 0.173 seals/km^2) were observed in water less than 3000 m deep; densities in the proposed survey area were estimated to be lower (Bengtson *et al.,* 2011). Populations at McMurdo Sound were permanently reduced by sealing in the 20th century (Ainley 2010). Sightings within the Ross Sea, including within and near the proposed survey area, have been reported by several sources (Stirling 1969; Saino and Guglielmo 2002; Ackley *et al.,* 2003; Van Dam and Kooyman 2004; Bester and Stewart 2006; Ainley *et al.,* 2010; Ropert-Coudert *et al.,* 2014; Baird and Mormede 2014). Ballard *et al.* (2012) relatively low habitat suitability for Weddell seals in the majority of the Ross Bank survey area, with higher suitability in the eastern portion of the Ross Bank survey area and within the Drygalski Trough survey area. During an NSF-funded seismic survey in the Ross Sea in January through February 2015, 17 sightings of Weddell seals were made, including within the proposed survey area (RPS 2015a).

Marine Mammal Hearing

Hearing is the most important sensory modality for marine mammals underwater, and exposure to anthropogenic sound can have deleterious effects. To appropriately assess the potential effects of exposure to sound, it is necessary to understand the frequency ranges marine mammals are able to hear. Current data indicate that not all marine mammal species have equal hearing capabilities (*e.g.,* Richardson *et al.,* 1995; Wartzok and Ketten, 1999; Au and Hastings, 2008). To reflect this, Southall *et al.,* (2007) recommended that marine mammals be divided into functional hearing groups based on directly measured or estimated hearing ranges on the basis of available behavioral response data, audiograms derived using auditory evoked potential techniques, anatomical modeling, and other data. Note that no direct measurements of hearing ability have been successfully completed for mysticetes (*i.e.,* low-frequency cetaceans). Subsequently, NMFS (2018) described generalized hearing ranges for these marine mammal hearing groups. Generalized hearing ranges were chosen based on the approximately 65 decibel (dB) threshold from the normalized composite audiograms, with the exception for lower limits for low-frequency cetaceans where the lower bound was deemed to be biologically implausible and the lower bound from Southall *et al.* (2007) retained. Marine mammal hearing groups and their associated hearing ranges are provided in Table 3.

TABLE 3—MARINE MAMMAL HEARING GROUPS (NMFS, 2018)

Hearing group	Generalized hearing range *
Low-frequency (LF) cetaceans (baleen whales)	7 Hz to 35 kHz.
Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz.
High-frequency (HF) cetaceans (true porpoises, *Kogia,* river dolphins, cephalorhynchid, *Lagenorhynchus cruciger* & *L. australis*).	275 Hz to 160 kHz.
Phocid pinnipeds (PW) (underwater) (true seals)	50 Hz to 86 kHz.
Otariid pinnipeds (OW) (underwater) (sea lions and fur seals)	60 Hz to 39 kHz.

* Represents the generalized hearing range for the entire group as a composite (*i.e.,* all species within the group), where individual species' hearing ranges are typically not as broad. Generalized hearing range chosen based on ~65 dB threshold from normalized composite audiogram, with the exception for lower limits for LF cetaceans (Southall *et al.,* 2007) and PW pinniped (approximation).

The pinniped functional hearing group was modified from Southall *et al.* (2007) on the basis of data indicating that phocid species have consistently demonstrated an extended frequency range of hearing compared to otariids, especially in the higher frequency range (Hemilä *et al.,* 2006; Kastelein *et al.,* 2009; Reichmuth & Holt, 2013).

For more detail concerning these groups and associated frequency ranges, please see NMFS (2018) for a review of available information.

Potential Effects of Specified Activities on Marine Mammals and Their Habitat

This section includes a summary and discussion of the ways that components of the specified activity may impact marine mammals and their habitat. The Estimated Take section later in this document includes a quantitative analysis of the number of individuals that are expected to be taken by this activity. The Negligible Impact Analysis and Determination section considers the content of this section, the Estimated Take section, and the Proposed Mitigation section, to draw conclusions regarding the likely impacts of these activities on the reproductive success or survivorship of individuals and how those impacts on individuals are likely to impact marine mammal species or stocks.

Description of Active Acoustic Sound Sources

This section contains a brief technical background on sound, the characteristics of certain sound types, and on metrics used in this proposal in as much as the information is relevant to the specified activity and to a discussion of the potential effects of the specified activity on marine mammals found later in this document.

Sound travels in waves, the basic components of which are frequency, wavelength, velocity, and amplitude. Frequency is the number of pressure waves that pass by a reference point per unit of time and is measured in hertz (Hz) or cycles per second. Wavelength is the distance between two peaks or corresponding points of a sound wave (length of one cycle). Higher frequency sounds have shorter wavelengths than lower frequency sounds, and typically attenuate (decrease) more rapidly, except in certain cases in shallower water. Amplitude is the height of the sound pressure wave or the ''loudness'' of a sound and is typically described using the relative unit of the dB. A sound pressure level (SPL) in dB is described as the ratio between a measured pressure and a reference pressure (for underwater sound, this is one microPascal (μPa)) and is a logarithmic unit that accounts for large variations in amplitude; therefore, a relatively small change in dB corresponds to large changes in sound pressure. The source level (SL) represents the SPL referenced at a distance of one m from the source (referenced to one μPa) while the received level is the SPL at the listener's position (referenced to one μPa).

Root mean square (rms) is the quadratic mean sound pressure over the duration of an impulse. Root mean square is calculated by squaring all of the sound amplitudes, averaging the squares, and then taking the square root of the average (Urick 1983). Root mean square accounts for both positive and negative values; squaring the pressures makes all values positive so that they may be accounted for in the summation of pressure levels (Hastings & Popper, 2005). This measurement is often used in the context of discussing behavioral effects, in part because behavioral effects, which often result from auditory cues, may be better expressed through averaged units than by peak pressures.

Sound exposure level (SEL; represented as dB re 1 μPa^2-s) represents the total energy contained within a pulse and considers both intensity and duration of exposure. Peak sound pressure (also referred to as zero-to-peak sound pressure or 0-p) is the maximum instantaneous sound pressure measurable in the water at a specified distance from the source and is represented in the same units as the rms sound pressure. Another common metric is peak-to-peak sound pressure (pk-pk), which is the algebraic difference between the peak positive and peak negative sound pressures. Peak-to-peak pressure is typically approximately six dB higher than peak pressure (Southall *et al.,* 2007).

When underwater objects vibrate or activity occurs, sound-pressure waves are created. These waves alternately compress and decompress the water as the sound wave travels. Underwater sound waves radiate in a manner similar to ripples on the surface of a pond and may be either directed in a beam or beams or may radiate in all directions (omnidirectional sources), as is the case for pulses produced by the airgun arrays considered here. The compressions and decompressions associated with sound waves are detected as changes in pressure by aquatic life and man-made sound receptors such as hydrophones.

Even in the absence of sound from the specified activity, the underwater environment is typically loud due to ambient sound. Ambient sound is defined as environmental background sound levels lacking a single source or point (Richardson *et al.,* 1995), and the sound level of a region is defined by the total acoustical energy being generated by known and unknown sources. These sources may include physical (*e.g.,* wind and waves, earthquakes, ice, atmospheric sound), biological (*e.g.,* sounds produced by marine mammals, fish, and invertebrates), and anthropogenic (*e.g.,* vessels, dredging, construction) sound. A number of sources contribute to ambient sound, including the following (Richardson *et al.,* 1995):

(1) Wind and waves: The complex interactions between wind and water surface, including processes such as breaking waves and wave-induced bubble oscillations and cavitation, are a main source of naturally occurring ambient sound for frequencies between 200 Hz and 50 kHz (Mitson, 1995). In general, ambient sound levels tend to increase with increasing wind speed and wave height. Surf sound becomes important near shore, with measurements collected at a distance of 8.5 km from shore showing an increase of 10 dB in the 100 to 700 Hz band during heavy surf conditions;

(2) Precipitation: Sound from rain and hail impacting the water surface can become an important component of total sound at frequencies above 500 Hz, and possibly down to 100 Hz during quiet times;

(3) Biological: Marine mammals can contribute significantly to ambient sound levels, as can some fish and snapping shrimp. The frequency band for biological contributions is from approximately 12 Hz to over 100 kHz; and

(4) Anthropogenic: Sources of ambient sound related to human activity include transportation (surface vessels), dredging and construction, oil and gas drilling and production, seismic surveys, sonar, explosions, and ocean acoustic studies. Vessel noise typically dominates the total ambient sound for frequencies between 20 and 300 Hz. In general, the frequencies of anthropogenic sounds are below one kHz and, if higher frequency sound levels are created, they attenuate rapidly. Sound from identifiable anthropogenic sources other than the activity of interest (*e.g.,* a passing vessel) is sometimes termed background sound, as opposed to ambient sound.

The sum of the various natural and anthropogenic sound sources at any given location and time—which comprise ''ambient'' or ''background'' sound—depends not only on the source levels (as determined by current weather conditions and levels of biological and human activity) but also on the ability of sound to propagate through the environment. In turn, sound propagation is dependent on the spatially and temporally varying properties of the water column and sea floor, and is frequency-dependent. As a result of the dependence on a large number of varying factors, ambient sound levels can be expected to vary widely over both coarse and fine spatial and temporal scales. Sound levels at a given frequency and location can vary by 10–20 dB from day to day (Richardson *et al.,* 1995). The result is that, depending on the source type and its intensity, sound from a given activity may be a negligible addition to the local environment or could form a distinctive signal that may affect marine mammals. Details of source types are described in the following text.

Sounds are often considered to fall into one of two general types: pulsed and non-pulsed (defined in the following). The distinction between these two sound types is important because they have differing potential to cause physical effects, particularly with regard to hearing (*e.g.,* Ward, 1997 in Southall *et al.,* 2007). Please see Southall *et al.* (2007) for an in-depth discussion of these concepts.

Pulsed sound sources (*e.g.,* airguns, explosions, gunshots, sonic booms, impact pile driving) produce signals that are brief (typically considered to be less than one second), broadband, atonal transients (ANSI, 1986, 2005; Harris, 1998; NIOSH, 1998; ISO, 2003) and occur either as isolated events or repeated in some succession. Pulsed sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a rapid decay period that may include a period of diminishing, oscillating maximal and minimal pressures, and generally have an increased capacity to induce physical injury as compared with sounds that lack these features.

Non-pulsed sounds can be tonal, narrowband, or broadband, brief or prolonged, and may be either continuous or non-continuous (ANSI, 1995; NIOSH, 1998). Some of these non-pulsed sounds can be transient signals of short duration but without the essential properties of pulses (*e.g.,* rapid rise time). Examples of non-pulsed sounds include those produced by vessels, aircraft, machinery operations such as drilling or dredging, vibratory pile driving, and active sonar systems (such as those used by the U.S. Navy). The duration of such sounds, as received at a distance, can be greatly extended in a highly reverberant environment.

Airgun arrays produce pulsed signals with energy in a frequency range from about 10–2,000 Hz, with most energy radiated at frequencies below 200 Hz. The amplitude of the acoustic wave emitted from the source is equal in all directions (*i.e.,* omnidirectional), but airgun arrays do possess some directionality due to different phase delays between guns in different directions. Airgun arrays are typically tuned to maximize functionality for data acquisition purposes, meaning that sound transmitted in horizontal directions and at higher frequencies is minimized to the extent possible.

As described above, hull-mounted MBESs, SBP, and ADCPs would also be operated from vessel continuously throughout the seismic surveys. Given the higher frequencies and relatively narrow beampatterns associated with these sources, in context of the movement and speed of the vessel, exposures of marine mammals are considered unlikely and, therefore, we do not expect take of marine mammals to result from use of these sources and do not consider them further in this analysis.

Acoustic Effects

Here, we discuss the effects of active acoustic sources on marine mammals.

Potential Effects of Underwater Sound—Please refer to the information given previously (*Description of Active Acoustic Sound Sources* section) regarding sound, characteristics of sound types, and metrics used in this document. Anthropogenic sounds cover a broad range of frequencies and sound levels and can have a range of highly variable impacts on marine life, from none or minor to potentially severe responses, depending on received levels, duration of exposure, behavioral context, and various other factors. The potential effects of underwater sound from active acoustic sources can potentially result in one or more of the following: temporary or permanent hearing impairment, non-auditory physical or physiological effects, behavioral disturbance, stress, and masking (Richardson *et al.,* 1995; Gordon *et al.,* 2004; Nowacek *et al.,* 2007; Southall *et al.,* 2007; Götz *et al.,* 2009). The degree of effect is intrinsically related to the signal characteristics, received level, distance from the source, and duration of the sound exposure. In general, sudden, high level sounds can cause hearing loss, as can longer exposures to lower level sounds. Temporary or permanent loss of hearing will occur almost exclusively for noise within an animal's hearing range. We first describe specific manifestations of acoustic effects before providing discussion specific to the use of airgun arrays.

Richardson *et al.* (1995) described zones of increasing intensity of effect that might be expected to occur, in relation to distance from a source and assuming that the signal is within an animal's hearing range. First is the area within which the acoustic signal would be audible (potentially perceived) to the animal, but not strong enough to elicit any overt behavioral or physiological response. The next zone corresponds with the area where the signal is audible to the animal and of sufficient intensity to elicit behavioral or physiological responsiveness. Third is a zone within which, for signals of high intensity, the received level is sufficient to potentially cause discomfort or tissue damage to auditory or other systems. Overlaying these zones to a certain extent is the area within which masking (*i.e.,* when a sound interferes with or masks the ability of an animal to detect a signal of interest that is above the absolute hearing threshold) may occur; the masking zone may be highly variable in size.

We describe the more severe effects of certain non-auditory physical or physiological effects only briefly as we do not expect that use of airgun arrays are reasonably likely to result in such effects (see below for further discussion). Potential effects from impulsive sound sources can range in severity from effects such as behavioral disturbance or tactile perception to physical discomfort, slight injury of the internal organs and the auditory system, or mortality (Yelverton *et al.,* 1973). Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to high level underwater sound or as a secondary effect of extreme behavioral reactions (*e.g.,* change in dive profile as a result of an avoidance reaction) caused by exposure to sound include neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage (Cox *et al.,* 2006; Southall *et al.,* 2007; Zimmer & Tyack, 2007; Tal *et al.,* 2015). The survey activities considered here do not involve the use of devices such as explosives or mid-frequency tactical sonar that are associated with these types of effects.

Threshold Shift—Marine mammals exposed to high-intensity sound, or to lower-intensity sound for prolonged periods, can experience hearing threshold shift (TS), which is the loss of hearing sensitivity at certain frequency ranges (Finneran, 2015). TS can be permanent (PTS), in which case the loss of hearing sensitivity is not fully recoverable, or temporary (TTS), in which case the animal's hearing threshold would recover over time (Southall *et al.,* 2007). Repeated sound exposure that leads to TTS could cause PTS. In severe cases of PTS, there can be total or partial deafness, while in most cases the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter, 1985).

When PTS occurs, there is physical damage to the sound receptors in the ear (*i.e.,* tissue damage), whereas TTS represents primarily tissue fatigue and is reversible (Southall *et al.,* 2007). In addition, other investigators have suggested that TTS is within the normal bounds of physiological variability and tolerance and does not represent physical injury (*e.g.,* Ward, 1997). Therefore, NMFS does not consider TTS to constitute auditory injury.

Relationships between TTS and PTS thresholds have not been studied in marine mammals, and there is no PTS data for cetaceans but such relationships are assumed to be similar to those in humans and other terrestrial mammals. PTS typically occurs at exposure levels at least several dBs above (a 40-dB threshold shift approximates PTS onset; *e.g.,* Kryter *et al.,* 1966; Miller, 1974) that inducing mild TTS (a 6-dB threshold shift approximates TTS onset;

e.g., Southall *et al.,* 2007). Based on data from terrestrial mammals, a precautionary assumption is that the PTS thresholds for impulse sounds (such as airgun pulses as received close to the source) are at least 6 dB higher than the TTS threshold on a peak-pressure basis and PTS cumulative sound exposure level thresholds are 15 to 20 dB higher than TTS cumulative sound exposure level thresholds (Southall *et al.,* 2007). Given the higher level of sound or longer exposure duration necessary to cause PTS as compared with TTS, it is considerably less likely that PTS could occur.

For mid-frequency cetaceans in particular, potential protective mechanisms may help limit onset of TTS or prevent onset of PTS. Such mechanisms include dampening of hearing, auditory adaptation, or behavioral amelioration (*e.g.,* Nachtigall and Supin, 2013; Miller *et al.,* 2012; Finneran *et al.,* 2015; Popov *et al.,* 2016).

TTS is the mildest form of hearing impairment that can occur during exposure to sound (Kryter, 1985). While experiencing TTS, the hearing threshold rises, and a sound must be at a higher level in order to be heard. In terrestrial and marine mammals, TTS can last from minutes or hours to days (in cases of strong TTS). In many cases, hearing sensitivity recovers rapidly after exposure to the sound ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals.

Marine mammal hearing plays a critical role in communication with conspecifics, and interpretation of environmental cues for purposes such as predator avoidance and prey capture. Depending on the degree (elevation of threshold in dB), duration (*i.e.,* recovery time), and frequency range of TTS, and the context in which it is experienced, TTS can have effects on marine mammals ranging from discountable to serious. For example, a marine mammal may be able to readily compensate for a brief, relatively small amount of TTS in a non-critical frequency range that occurs during a time where ambient noise is lower and there are not as many competing sounds present. Alternatively, a larger amount and longer duration of TTS sustained during time when communication is critical for successful mother/calf interactions could have more serious impacts.

Finneran *et al.* (2015) measured hearing thresholds in three captive bottlenose dolphins before and after exposure to ten pulses produced by a seismic airgun in order to study TTS induced after exposure to multiple pulses. Exposures began at relatively low levels and gradually increased over a period of several months, with the highest exposures at peak SPLs from 196 to 210 dB and cumulative (unweighted) SELs from 193–195 dB. No substantial TTS was observed. In addition, behavioral reactions were observed that indicated that animals can learn behaviors that effectively mitigate noise exposures (although exposure patterns must be learned, which is less likely in wild animals than for the captive animals considered in this study). The authors note that the failure to induce more significant auditory effects is likely due to the intermittent nature of exposure, the relatively low peak pressure produced by the acoustic source, and the low-frequency energy in airgun pulses as compared with the frequency range of best sensitivity for dolphins and other mid-frequency cetaceans.

Currently, TTS data only exist for four species of cetaceans (bottlenose dolphin, beluga whale, harbor porpoise, and Yangtze finless porpoise) exposed to a limited number of sound sources (*i.e.,* mostly tones and octave-band noise) in laboratory settings (Finneran, 2015). In general, harbor porpoises have a lower TTS onset than other measured cetacean species (Finneran, 2015). Additionally, the existing marine mammal TTS data come from a limited number of individuals within these species. There are no data available on noise-induced hearing loss for mysticetes.

Critical questions remain regarding the rate of TTS growth and recovery after exposure to intermittent noise and the effects of single and multiple pulses. Data at present are also insufficient to construct generalized models for recovery and determine the time necessary to treat subsequent exposures as independent events. More information is needed on the relationship between auditory evoked potential and behavioral measures of TTS for various stimuli. For summaries of data on TTS in marine mammals or for further discussion of TTS onset thresholds, please see Southall *et al.* (2007), Finneran and Jenkins (2012), Finneran (2015), and NMFS (2018).

Behavioral Effects—Behavioral disturbance may include a variety of effects, including subtle changes in behavior (*e.g.,* minor or brief avoidance of an area or changes in vocalizations), more conspicuous changes in similar behavioral activities, and more sustained and/or potentially severe reactions, such as displacement from or abandonment of high-quality habitat. Behavioral responses to sound are highly variable and context-specific and any reactions depend on numerous intrinsic and extrinsic factors (*e.g.,* species, state of maturity, experience, current activity, reproductive state, auditory sensitivity, time of day), as well as the interplay between factors (*e.g.,* Richardson *et al.,* 1995; Wartzok *et al.,* 2003; Southall *et al.,* 2007; Weilgart, 2007; Archer *et al.,* 2010). Behavioral reactions can vary not only among individuals but also within an individual, depending on previous experience with a sound source, context, and numerous other factors (Ellison *et al.,* 2012), and can vary depending on characteristics associated with the sound source (*e.g.,* whether it is moving or stationary, number of sources, distance from the source). Please see Appendices B–C of Southall *et al.* (2007) for a review of studies involving marine mammal behavioral responses to sound.

Habituation can occur when an animal's response to a stimulus wanes with repeated exposure, usually in the absence of unpleasant associated events (Wartzok *et al.,* 2003). Animals are most likely to habituate to sounds that are predictable and unvarying. It is important to note that habituation is appropriately considered as a ''progressive reduction in response to stimuli that are perceived as neither aversive nor beneficial,'' rather than as, more generally, moderation in response to human disturbance (Bejder *et al.,* 2009). The opposite process is sensitization, when an unpleasant experience leads to subsequent responses, often in the form of avoidance, at a lower level of exposure. As noted, behavioral state may affect the type of response. For example, animals that are resting may show greater behavioral change in response to disturbing sound levels than animals that are highly motivated to remain in an area for feeding (Richardson *et al.,* 1995; NRC, 2003; Wartzok *et al.,* 2003). Controlled experiments with captive marine mammals have shown pronounced behavioral reactions, including avoidance of loud sound sources (Ridgway *et al.,* 1997). Observed responses of wild marine mammals to loud pulsed sound sources (typically seismic airguns or acoustic harassment devices) have been varied but often consist of avoidance behavior or other behavioral changes suggesting discomfort (Morton & Symonds, 2002; see also Richardson *et al.,* 1995; Nowacek *et al.,* 2007). However, many delphinids approach acoustic source vessels with no apparent discomfort or obvious behavioral change (*e.g.,* Barkaszi *et al.,* 2012).

Available studies show wide variation in response to underwater sound; therefore, it is difficult to predict specifically how any given sound in a particular instance might affect marine mammals perceiving the signal. 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. 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 (*e.g.,* Lusseau & Bejder, 2007; Weilgart, 2007; NRC, 2005). However, there are broad categories of potential response, which we describe in greater detail here, that include alteration of dive behavior, alteration of foraging behavior, effects to breathing, interference with or alteration of vocalization, avoidance, and flight.

Changes in dive behavior can vary widely, and may consist of increased or decreased dive times and surface intervals as well as changes in the rates of ascent and descent during a dive (*e.g.,* Frankel & Clark, 2000; Ng & Leung, 2003; Nowacek *et al.,* 2004; Goldbogen *et al.,* 2013a, b). Variations in dive behavior may reflect interruptions in biologically significant activities (*e.g.,* foraging) or they may be of little biological significance. The impact of an alteration to dive behavior resulting from an acoustic exposure depends on what the animal is doing at the time of the exposure and the type and magnitude of the response.

Disruption of feeding behavior can be difficult to correlate with anthropogenic sound exposure, so it is usually inferred by observed displacement from known foraging areas, the appearance of secondary indicators (*e.g.,* bubble nets or sediment plumes), or changes in dive behavior. As for other types of behavioral response, the frequency, duration, and temporal pattern of signal presentation, as well as differences in species sensitivity, are likely contributing factors to differences in response in any given circumstance (*e.g.,* Croll *et al.,* 2001; Nowacek *et al.;* 2004; Madsen *et al.,* 2006; Yazvenko *et al.,* 2007). A determination of whether foraging disruptions incur fitness consequences would require information on or estimates of the energetic requirements of the affected individuals and the relationship between prey availability, foraging effort and success, and the life history stage of the animal.

Visual tracking, passive acoustic monitoring, and movement recording tags were used to quantify sperm whale behavior prior to, during, and following exposure to airgun arrays at received levels in the range 140–160 dB at distances of 7–13 km, following a phase-in of sound intensity and full array exposures at 1–13 km (Madsen *et al.,* 2006; Miller *et al.,* 2009). Sperm whales did not exhibit horizontal avoidance behavior at the surface. However, foraging behavior may have been affected. The sperm whales exhibited 19 percent less vocal (buzz) rate during full exposure relative to post exposure, and the whale that was approached most closely had an extended resting period and did not resume foraging until the airguns had ceased firing. The remaining whales continued to execute foraging dives throughout exposure; however, swimming movements during foraging dives were six percent lower during exposure than control periods (Miller *et al.,* 2009). These data raise concerns that seismic surveys may impact foraging behavior in sperm whales, although more data are required to understand whether the differences were due to exposure or natural variation in sperm whale behavior (Miller *et al.,* 2009).

Variations in respiration naturally vary with different behaviors and alterations to breathing rate as a function of acoustic exposure can be expected to co-occur with other behavioral reactions, such as a flight response or an alteration in diving. However, respiration rates in and of themselves may be representative of annoyance or an acute stress response. Various studies have shown that respiration rates may either be unaffected or could increase, depending on the species and signal characteristics, again highlighting the importance in understanding species differences in the tolerance of underwater noise when determining the potential for impacts resulting from anthropogenic sound exposure (*e.g.,* Kastelein *et al.,* 2001, 2005, 2006; Gailey *et al.,* 2007, 2016).

Marine mammals vocalize for different purposes and across multiple modes, such as whistling, echolocation click production, calling, and singing. Changes in vocalization behavior in response to anthropogenic noise can occur for any of these modes and may result from a need to compete with an increase in background noise or may reflect increased vigilance or a startle response. For example, in the presence of potentially masking signals, humpback whales and killer whales have been observed to increase the length of their songs (Miller *et al.,* 2000; Fristrup *et al.,* 2003; Foote *et al.,* 2004), while right whales have been observed to shift the frequency content of their calls upward while reducing the rate of calling in areas of increased anthropogenic noise (Parks *et al.,* 2007). In some cases, animals may cease sound production during production of aversive signals (Bowles *et al.,* 1994).

Cerchio *et al.* (2014) used passive acoustic monitoring to document the presence of singing humpback whales off the coast of northern Angola and to opportunistically test for the effect of seismic survey activity on the number of singing whales. Two recording units were deployed between March and December 2008 in the offshore environment; numbers of singers were counted every hour. Generalized Additive Mixed Models were used to assess the effect of survey day (seasonality), hour (diel variation), moon phase, and received levels of noise (measured from a single pulse during each 10 minute sampled period) on singer number. The number of singers significantly decreased with increasing received level of noise, suggesting that humpback whale breeding activity was disrupted to some extent by the survey activity.

Castellote *et al.* (2012) reported acoustic and behavioral changes by fin whales in response to shipping and airgun noise. Acoustic features of fin whale song notes recorded in the Mediterranean Sea and northeast Atlantic Ocean were compared for areas with different shipping noise levels and traffic intensities and during a seismic airgun survey. During the first 72 h of the survey, a steady decrease in song received levels and bearings to singers indicated that whales moved away from the acoustic source and out of the study area. This displacement persisted for a time period well beyond the 10-day duration of seismic airgun activity, providing evidence that fin whales may avoid an area for an extended period in the presence of increased noise. The authors hypothesize that fin whale acoustic communication is modified to compensate for increased background noise and that a sensitization process may play a role in the observed temporary displacement.

Seismic pulses at average received levels of 131 dB re 1 μPa^2-s caused blue whales to increase call production (Di Iorio and Clark, 2010). In contrast, McDonald *et al.* (1995) tracked a blue whale with seafloor seismometers and reported that it stopped vocalizing and changed its travel direction at a range of 10 km from the acoustic source vessel (estimated received level 143 dB pk-pk). Blackwell *et al.* (2013) found that bowhead whale call rates dropped significantly at onset of airgun use at sites with a median distance of 41–45 km from the survey. Blackwell *et al.* (2015) expanded this analysis to show that whales actually increased calling rates as soon as airgun signals were detectable before ultimately decreasing calling rates at higher received levels (*i.e.,* 10-minute $\mathrm{SEL}_{\mathrm{cum}}$ of ~127 dB). Overall, these results suggest that bowhead whales may adjust their vocal output in an effort to compensate for noise before ceasing vocalization effort and ultimately deflecting from the acoustic source (Blackwell *et al.,* 2013, 2015). These studies demonstrate that even low levels of noise received far from the source can induce changes in vocalization and/or behavior for mysticetes.

Avoidance is the displacement of an individual from an area or migration path as a result of the presence of a sound or other stressors, and is one of the most obvious manifestations of disturbance in marine mammals (Richardson *et al.,* 1995). For example, gray whales are known to change direction—deflecting from customary migratory paths—in order to avoid noise from seismic surveys (Malme *et al.,* 1984). Humpback whales showed avoidance behavior in the presence of an active seismic array during observational studies and controlled exposure experiments in western Australia (McCauley *et al.,* 2000). Avoidance may be short-term, with animals returning to the area once the noise has ceased (*e.g.,* Bowles *et al.,* 1994; Goold, 1996; Stone *et al.,* 2000; Morton and Symonds, 2002; Gailey *et al.,* 2007). Longer-term displacement is possible, however, which may lead to changes in abundance or distribution patterns of the affected species in the affected region if habituation to the presence of the sound does not occur (*e.g.,* Bejder *et al.,* 2006; Teilmann *et al.,* 2006).

A flight response is a dramatic change in normal movement to a directed and rapid movement away from the perceived location of a sound source. The flight response differs from other avoidance responses in the intensity of the response (*e.g.,* directed movement, rate of travel). Relatively little information on flight responses of marine mammals to anthropogenic signals exist, although observations of flight responses to the presence of predators have occurred (Connor & Heithaus, 1996). The result of a flight response could range from brief, temporary exertion and displacement from the area where the signal provokes flight to, in extreme cases, marine mammal strandings (Evans & England, 2001). However, it should be noted that response to a perceived predator does not necessarily invoke flight (Ford & Reeves, 2008), and whether individuals are solitary or in groups may influence the response.

Behavioral disturbance can also impact marine mammals in more subtle ways. Increased vigilance may result in costs related to diversion of focus and attention (*i.e.,* when a response consists of increased vigilance, it may come at the cost of decreased attention to other critical behaviors such as foraging or resting). These effects have generally not been demonstrated for marine mammals, but studies involving fish and terrestrial animals have shown that increased vigilance may substantially reduce feeding rates (*e.g.,* Beauchamp & Livoreil, 1997; Fritz *et al.,* 2002; Purser & Radford, 2011). In addition, chronic disturbance can cause population declines through reduction of fitness (*e.g.,* decline in body condition) and subsequent reduction in reproductive success, survival, or both (*e.g.,* Harrington & Veitch, 1992; Daan *et al.,* 1996; Bradshaw *et al.,* 1998). However, Ridgway *et al.* (2006) reported that increased vigilance in bottlenose dolphins exposed to sound over a five-day period did not cause any sleep deprivation or stress effects.

Many animals perform vital functions, such as feeding, resting, traveling, and socializing, on a diel cycle (24-hour cycle). Disruption of such functions resulting from reactions to stressors such as sound exposure are more likely to be significant if they last more than one diel cycle or recur on subsequent days (Southall *et al.,* 2007). Consequently, a behavioral response lasting less than one day and not recurring on subsequent days is not considered particularly severe unless it could directly affect reproduction or survival (Southall *et al.,* 2007). Note that there is a difference between multi-day substantive behavioral reactions and multi-day anthropogenic activities. For example, just because an activity lasts for multiple days does not necessarily mean that individual animals are either exposed to activity-related stressors for multiple days or, further, exposed in a manner resulting in sustained multi-day substantive behavioral responses.

Stone (2015) reported data from at-sea observations during 1,196 seismic surveys from 1994 to 2010. When large arrays of airguns (considered to be 500 in^3 or more) were firing, lateral displacement, more localized avoidance, or other changes in behavior were evident for most odontocetes. However, significant responses to large arrays were found only for the minke whale and fin whale. Behavioral responses observed included changes in swimming or surfacing behavior, with indications that cetaceans remained near the water surface at these times. Cetaceans were recorded as feeding less often when large arrays were active. Behavioral observations of gray whales during a seismic survey monitored whale movements and respirations pre-, during and post-seismic survey (Gailey *et al.,* 2016). Behavioral state and water depth were the best 'natural' predictors of whale movements and respiration and, after considering natural variation, none of the response variables were significantly associated with seismic survey or vessel sounds.

Stress Responses—An animal's perception of a threat may be sufficient to trigger stress responses consisting of some combination of behavioral responses, autonomic nervous system responses, neuroendocrine responses, or immune responses (*e.g.,* Seyle, 1950; Moberg, 2000). In many cases, an animal's first and sometimes most economical (in terms of energetic costs) response is behavioral avoidance of the potential stressor. Autonomic nervous system responses to stress typically involve changes in heart rate, blood pressure, and gastrointestinal activity. These responses have a relatively short duration and may or may not have a significant long-term effect on an animal's fitness.

Neuroendocrine stress responses often involve the hypothalamus-pituitary-adrenal system. Virtually all neuroendocrine functions that are affected by stress—including immune competence, reproduction, metabolism, and behavior—are regulated by pituitary hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction, altered metabolism, reduced immune competence, and behavioral disturbance (*e.g.,* Moberg, 1987; Blecha, 2000). Increases in the circulation of glucocorticoids are also equated with stress (Romano *et al.,* 2004).

The primary distinction between stress (which is adaptive and does not normally place an animal at risk) and ''distress'' is the cost of the response. During a stress response, an animal uses glycogen stores that can be quickly replenished once the stress is alleviated. In such circumstances, the cost of the stress response would not pose serious fitness consequences. However, when an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other functions. This state of distress will last until the animal replenishes its energetic reserves sufficiently to restore normal function.

Relationships between these physiological mechanisms, animal behavior, and the costs of stress responses are well-studied through controlled experiments and for both laboratory and free-ranging animals (*e.g.,* Holberton *et al.,* 1996; Hood *et al.,* 1998; Jessop *et al.,* 2003; Krausman *et al.,* 2004; Lankford *et al.,* 2005). Stress responses due to exposure to anthropogenic sounds or other stressors and their effects on marine mammals have also been reviewed (Fair & Becker, 2000; Romano *et al.,* 2002b) and, more rarely, studied in wild populations (*e.g.,* Romano *et al.,* 2002a). For example, Rolland *et al.* (2012) found that noise reduction from reduced ship traffic in the Bay of Fundy was associated with decreased stress in North Atlantic right whales. These and other studies lead to a reasonable expectation that some marine mammals will experience physiological stress responses upon exposure to acoustic stressors and that it is possible that some of these would be classified as ''distress.'' In addition, any animal experiencing TTS would likely also experience stress responses (NRC, 2003).

Auditory Masking—Sound can disrupt behavior through masking, or interfering with, an animal's ability to detect, recognize, or discriminate between acoustic signals of interest (*e.g.,* those used for intraspecific communication and social interactions, prey detection, predator avoidance, navigation) (Richardson *et al.,* 1995; Erbe *et al.,* 2016). Masking occurs when the receipt of a sound is interfered with by another coincident sound at similar frequencies and at similar or higher intensity, and may occur whether the sound is natural (*e.g.,* snapping shrimp, wind, waves, precipitation) or anthropogenic (*e.g.,* shipping, sonar, seismic exploration) in origin. The ability of a noise source to mask biologically important sounds depends on the characteristics of both the noise source and the signal of interest (*e.g.,* signal-to-noise ratio, temporal variability, direction), in relation to each other and to an animal's hearing abilities (*e.g.,* sensitivity, frequency range, critical ratios, frequency discrimination, directional discrimination, age or TTS hearing loss), and existing ambient noise and propagation conditions.

Under certain circumstances, marine mammals experiencing significant masking could also be impaired from maximizing their performance fitness in survival and reproduction. Therefore, when the coincident (masking) sound is man-made, it may be considered harassment when disrupting or altering critical behaviors. It is important to distinguish TTS and PTS, which persist after the sound exposure, from masking, which occurs during the sound exposure. Because masking (without resulting in TS) is not associated with abnormal physiological function, it is not considered a physiological effect, but rather a potential behavioral effect.

The frequency range of the potentially masking sound is important in determining any potential behavioral impacts. For example, low-frequency signals may have less effect on high-frequency echolocation sounds produced by odontocetes but are more likely to affect detection of mysticete communication calls and other potentially important natural sounds such as those produced by surf and some prey species. The masking of communication signals by anthropogenic noise may be considered as a reduction in the communication space of animals (*e.g.,* Clark *et al.,* 2009) and may result in energetic or other costs as animals change their vocalization behavior (*e.g.,* Miller *et al.,* 2000; Foote *et al.,* 2004; Parks *et al.,* 2007; Di Iorio and Clark, 2009; Holt *et al.,* 2009). Masking can be reduced in situations where the signal and noise come from different directions (Richardson *et al.,* 1995), through amplitude modulation of the signal, or through other compensatory behaviors (Houser and Moore, 2014). Masking can be tested directly in captive species (*e.g.,* Erbe, 2008), but in wild populations it must be either modeled or inferred from evidence of masking compensation. There are few studies addressing real-world masking sounds likely to be experienced by marine mammals in the wild (*e.g.,* Branstetter *et al.,* 2013).

Masking affects both senders and receivers of acoustic signals and can potentially have long-term chronic effects on marine mammals at the population level as well as at the individual level. Low-frequency ambient sound levels have increased by as much as 20 dB (more than three times in terms of SPL) in the world's ocean from pre-industrial periods, with most of the increase from distant commercial shipping (Hildebrand, 2009). All anthropogenic sound sources, but especially chronic and lower-frequency signals (*e.g.,* from vessel traffic), contribute to elevated ambient sound levels, thus intensifying 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 & 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 percent when a seismic survey was operating 450–2,800 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. Nieukirk *et al.* (2012) and Blackwell *et al.* (2015) 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). As noted above, Cerchio *et al.* (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (*e.g.,* Di Iorio and Clark 2010; Castellote *et al.,* 2012; Blackwell *et al.,* 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (*e.g.,* MacGillivray *et al.,* 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses.

Icebreaking

Icebreakers produce more noise while breaking ice than ships of comparable size due, primarily, to the sounds of propeller cavitation (Richardson *et al.,* 1995). Icebreakers commonly back and ram into heavy ice until losing momentum to make way. The highest noise levels usually occur while backing full astern in preparation to ram forward through the ice. Overall the noise generated by an icebreaker pushing ice was 10 to 15 dB greater than the noise produced by the ship underway in open water (Richardson *et al.,* 1995). In general, the Antarctic and Southern Ocean is a noisy environment. Calving and grounding icebergs as well as the break-up of ice sheets, can produce a large amount of underwater noise. Little information is available about the increased sound levels due to icebreaking.

Cetaceans—Few studies have been conducted to evaluate the potential interference of icebreaking noise with marine mammal vocalizations. Erbe and Farmer (1998) measured masked hearing thresholds of a captive beluga whale. They reported that the recording of a Canadian Coast Guard Ship (CCGS) *Henry Larsen,* ramming ice in the Beaufort Sea, masked recordings of beluga vocalizations at a noise to signal pressure ratio of 18 dB, when the noise pressure level was eight times as high as the call pressure. Erbe and Farmer (2000) also predicted when icebreaker noise would affect beluga whales through software that combined a sound propagation model and beluga whale impact threshold models. They again used the data from the recording of the *Henry Larsen* in the Beaufort Sea and predicted that masking of beluga whale vocalizations could extend between 40 and 71 km (21.6 and 38.3 nmi) near the surface. Lesage *et al.* (1999) report that beluga whales changed their call type and call frequency when exposed to boat noise. It is possible that the whales adapt to the ambient noise levels and are able to communicate despite the sound. Given the documented reaction of belugas to ships and icebreakers it is highly unlikely that beluga whales would remain in the proximity of vessels where vocalizations would be masked.

Beluga whales have been documented swimming rapidly away from ships and icebreakers in the Canadian high Arctic when a ship approaches to within 35 to 50 km (18.9 to 27 nmi), and they may travel up to 80 km (43.2 nmi) from the vessel's track (Richardson *et al.,* 1995). It is expected that belugas avoid icebreakers as soon as they detect the ships (Cosens and Dueck, 1993). However, the reactions of beluga whales to ships vary greatly and some animals may become habituated to high levels of ambient noise (Erbe and Farmer, 2000).

There is little information about the effects of icebreaking ships on baleen whales. Migrating bowhead whales appeared to avoid an area around a drill site by greater than 25 km (13.5 mi) where an icebreaker was working in the Beaufort Sea. There was intensive icebreaking daily in support of the drilling activities (Brewer *et al.,* 1993). Migrating bowheads also avoided a nearby drill site at the same time of year where little icebreaking was being conducted (LGL and Greeneridge, 1987). It is unclear as to whether the drilling activities, icebreaking operations, or the ice itself might have been the cause for the whale's diversion. Bowhead whales are not expected to occur in the proximity of the proposed action area.

Pinnipeds—Brueggeman *et al.* (1992) reported on the reactions of seals to an icebreaker during activities at two prospects in the Chukchi Sea. Reactions of seals to the icebreakers varied between the two prospects. Most (67 percent) seals did not react to the icebreaker at either prospect. Reaction at one prospect was greatest during icebreaking activity (running/maneuvering/jogging) and was 0.23 km (0.12 nmi) of the vessel and lowest for animals beyond 0.93 km (0.5 nmi). At the second prospect however, seal reaction was lowest during icebreaking activity with higher and similar levels of response during general (non-icebreaking) vessel operations and when the vessel was at anchor or drifting. The frequency of seal reaction generally declined with increasing distance from the vessel except during general vessel activity where it remained consistently high to about 0.46 km (0.25 nmi) from the vessel before declining.

Similarly, Kanik *et al.* (1980) found that ringed (*Pusa hispida*) and harp seals (*Pagophilus groenlandicus*) often dove into the water when an icebreaker was breaking ice within 1 km (0.5 nmi) of the animals. Most seals remained on the ice when the ship was breaking ice 1 to 2 km (0.5 to 1.1 nmi) away.

Sea ice is important for pinniped life functions such as resting, breeding, and molting. Icebreaking activities may damage seal breathing holes and would also reduce the haulout area in the immediate vicinity of the ship's track. Icebreaking along a maximum of 500 km of tracklines would alter local ice conditions in the immediate vicinity of the vessel. This has the potential to temporarily lead to a reduction of suitable seal haulout habitat. However, the dynamic sea-ice environment requires that seals be able to adapt to changes in sea, ice, and snow conditions, and they therefore create new breathing holes and lairs throughout the winter and spring (Hammill and Smith, 1989). In addition, seals often use open leads and cracks in the ice to surface and breathe (Smith and Stirling, 1975). Disturbance of the ice would occur in a very small area relative to the Southern Ocean ice-pack and no significant impact on marine mammals is anticipated by icebreaking during the proposed low-energy seismic survey.

Ship Noise

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

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (*e.g.,* Richardson *et al.,* 1995; Clark *et al,.* 2009; Jensen *et al.,* 2009; Gervaise *et al.,* 2012; Hatch *et al.,* 2012; Rice *et al.,* 2014; Dunlop 2015; Erbe *et al.,* 2016; Jones *et al,.* 2017; Putland *et al.,* 2017). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter *et al.,* 2013, 2016; Finneran and Branstetter 2013; Sills *et al.,* 2017). Branstetter *et al.* (2013)

reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (*e.g.,* Parks *et al.,* 2011, 2012, 2016a,b; Castellote *et al.,* 2012; Melcón *et al.,* 2012; Azzara *et al.,* 2013; Tyack and Janik 2013; Luís *et al.,* 2014; Sairanen 2014; Papale *et al.,* 2015; Bittencourt *et al.,* 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley *et al.,* 2016; Heiler *et al.,* 2016; Martins *et al.,* 2016; O'Brien *et al.,* 2016; Tenessen & Parks 2016). Harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016). Holt *et al.* (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (*e.g.,* Campana *et al.,* 2015; Culloch *et al.,* 2016).

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

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or if they 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). Pirotta *et al.* (2015) noted that the physical presence of vessels, not just ship noise, disturbed the foraging activity of bottlenose dolphins. Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana *et al.,* 2015).

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

Sounds emitted by the *Palmer* are low frequency and continuous, but would be widely dispersed in both space and time. 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 (NSF–USGS 2011).

In summary, 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.

Ship Strike

Vessel collisions with marine mammals, or ship strikes, can result in death or serious injury of the animal. Wounds resulting from ship strike may include massive trauma, hemorrhaging, broken bones, or propeller lacerations (Knowlton and Kraus, 2001). An animal at the surface may be struck directly by a vessel, a surfacing animal may hit the bottom of a vessel, or an animal just below the surface may be cut by a vessel's propeller. Superficial strikes may not kill or result in the death of the animal. These interactions are typically associated with large whales (*e.g.,* fin whales), which are occasionally found draped across the bulbous bow of large commercial ships upon arrival in port. Although smaller cetaceans are more maneuverable in relation to large vessels than are large whales, they may also be susceptible to strike. The severity of injuries typically depends on the size and speed of the vessel, with the probability of death or serious injury increasing as vessel speed increases (Knowlton and Kraus, 2001; Laist *et al.,* 2001; Vanderlaan and Taggart, 2007; Conn and Silber, 2013). Impact forces increase with speed, as does the probability of a strike at a given distance (Silber *et al.,* 2010; Gende *et al.,* 2011).

Pace and Silber (2005) also found that the probability of death or serious injury increased rapidly with increasing vessel speed. Specifically, the predicted probability of serious injury or death increased from 45 to 75 percent as vessel speed increased from 10 to 14 kn, and exceeded 90 percent at 17 kn. Higher speeds during collisions result in greater force of impact, but higher speeds also appear to increase the chance of severe injuries or death through increased likelihood of collision by pulling whales toward the vessel (Clyne, 1999; Knowlton *et al.,* 1995). In a separate study, Vanderlaan and Taggart (2007) analyzed the probability of lethal mortality of large whales at a given speed, showing that the greatest rate of change in the probability of a lethal injury to a large whale as a function of vessel speed occurs between 8.6 and 15 kn. The chances of a lethal injury decline from approximately 80 percent at 15 kn to approximately 20 percent at 8.6 kn. At speeds below 11.8 kn, the chances of lethal injury drop below 50 percent, while the probability asymptotically increases toward one hundred percent above 15 kn.

The RVIB *Palmer* travels at a speed of 4.5 kn (8.3 km/hour) when towing seismic survey gear, or at an average speed of 18.7 km/h (10.1 kn) while cruising. At these speeds, both the possibility of striking a marine mammal and the possibility of a strike resulting in serious injury or mortality are discountable. At average transit speed, the probability of serious injury or mortality resulting from a strike is less than 50 percent. However, the likelihood of a strike actually happening is again discountable. Ship strikes, as analyzed in the studies cited above, generally involve commercial shipping, which is much more common in both space and time than is geophysical survey activity. Jensen and Silber (2004) summarized ship strikes of large whales worldwide from 1975–2003 and found that most collisions occurred in the open ocean and involved large vessels (*e.g.,* commercial shipping). No such incidents were reported for geophysical survey vessels during that time period.

It is possible for ship strikes to occur while traveling at slow speeds. For example, a hydrographic survey vessel traveling at low speed (5.5 kn) while conducting mapping surveys off the central California coast struck and killed a blue whale in 2009. The State of California determined that the whale had suddenly and unexpectedly surfaced beneath the hull, with the result that the propeller severed the whale's vertebrae, and that this was an unavoidable event. This strike represents the only such incident in approximately 540,000 hours of similar coastal mapping activity ($p = 1.9 \times 10^{-6}$; 95 percent CI = $0–5.5 \times 10^{-6}$; NMFS, 2013b). In addition, a research vessel reported a fatal strike in 2011 of a dolphin in the Atlantic, demonstrating that it is possible for strikes involving smaller cetaceans to occur. In that case, the incident report indicated that an animal apparently was struck by the vessel's propeller as it was intentionally swimming near the vessel. While indicative of the type of unusual events that cannot be ruled out, neither of these instances represents a circumstance that would be considered reasonably foreseeable or that would be considered preventable.

Although the likelihood of the vessel striking a marine mammal is low, we require a robust ship strike avoidance protocol (see Proposed Mitigation), which we believe eliminates any foreseeable risk of ship strike. We anticipate that vessel collisions involving a seismic data acquisition vessel towing gear, while not impossible, represent unlikely, unpredictable events for which there are no preventive measures. Given the required mitigation measures, the relatively slow speed of the vessel towing gear, the presence of bridge crew watching for obstacles at all times (including marine mammals), and the presence of marine mammal observers, we believe that the possibility of ship strike is discountable and, further, that were a strike of a large whale to occur, it would be unlikely to result in serious injury or mortality. No incidental take resulting from ship strike is anticipated, and this potential effect of the specified activity will not be discussed further in the following analysis.

Stranding—When a living or dead marine mammal swims or floats onto shore and becomes ''beached'' or incapable of returning to sea, the event is a ''stranding'' (Geraci *et al.,* 1999; Perrin and Geraci, 2002; Geraci and Lounsbury, 2005; NMFS, 2007). The legal definition for a ''stranding'' under the MMPA is an event in the wild in which (A) a marine mammal is dead and is (i) on a beach or shore of the United States; or (ii) in waters under the jurisdiction of the United States (including any navigable waters); or (B) a marine mammal is alive and is (i) on a beach or shore of the United States and unable to return to the water; (ii) on a beach or shore of the United States and, although able to return to the water, is in need of apparent medical attention; or (iii) in the waters under the jurisdiction of the United States (including any navigable waters), but is unable to return to its natural habitat under its own power or without assistance (16 U.S.C. 1421h(3)).

Marine mammals strand for a variety of reasons, such as infectious agents, biotoxicosis, starvation, fishery interaction, ship strike, unusual oceanographic or weather events, sound exposure, or combinations of these stressors sustained concurrently or in series. However, the cause or causes of most strandings are unknown (Geraci *et al.,* 1976; Eaton, 1979; Odell *et al.,* 1980; Best, 1982). Numerous studies suggest that the physiology, behavior, habitat relationships, age, or condition of cetaceans may cause them to strand or might pre-dispose them to strand when exposed to another phenomenon. These suggestions are consistent with the conclusions of numerous other studies that have demonstrated that combinations of dissimilar stressors commonly combine to kill an animal or dramatically reduce its fitness, even though one exposure without the other does not produce the same result (Chrousos, 2000; Creel, 2005; DeVries *et al.,* 2003; Fair & Becker, 2000; Foley *et al.,* 2001; Moberg, 2000; Relyea, 2005a; 2005b, Romero, 2004; Sih *et al.,* 2004).

There is no conclusive evidence that exposure to airgun noise results in behaviorally-mediated forms of injury. Behaviorally-mediated injury (*i.e.,* mass stranding events) has been primarily associated with beaked whales exposed to mid-frequency active (MFA) naval sonar. Tactical sonar and the alerting stimulus used in Nowacek *et al.* (2004) are very different from the noise produced by airguns. One should therefore not expect the same reaction to airgun noise as to these other sources. As explained below, military MFA sonar is very different from airguns, and one should not assume that airguns will cause the same effects as MFA sonar (including strandings).

To understand why Navy MFA sonar affects beaked whales differently than airguns do, it is important to note the distinction between behavioral sensitivity and susceptibility to auditory injury. To understand the potential for auditory injury in a particular marine mammal species in relation to a given acoustic signal, the frequency range the species is able to hear is critical, as well as the species' auditory sensitivity to frequencies within that range. Current data indicate that not all marine mammal species have equal hearing capabilities across all frequencies and, therefore, species are grouped into hearing groups with generalized hearing ranges assigned on the basis of available data (Southall *et al.,* 2007, 2019). Hearing ranges as well as auditory sensitivity/susceptibility to frequencies within those ranges vary across the different groups. For example, in terms of hearing range, the high-frequency cetaceans (*e.g., Kogia* spp.) have a generalized hearing range of frequencies between 275 Hz and 160 kHz, while mid-frequency cetaceans—such as dolphins and beaked whales—have a generalized hearing range between 150 Hz to 160 kHz. Regarding auditory susceptibility within the hearing range, while mid-frequency cetaceans and high-frequency cetaceans have roughly similar hearing ranges, the high-frequency group is much more susceptible to noise-induced hearing loss during sound exposure, *i.e.,* these species have lower thresholds for these effects than other hearing groups (NMFS, 2018). Referring to a species as behaviorally sensitive to noise simply means that an animal of that species is more likely to respond to lower received levels of sound than an animal of another species that is considered less behaviorally sensitive. So, while dolphin species and beaked whale species—both in the mid-frequency cetacean hearing group—are assumed to generally hear the same sounds equally well and be equally susceptible to noise-induced hearing loss (auditory injury), the best available information indicates that a beaked whale is more likely to behaviorally respond to that sound at a lower received level compared to an animal from other mid-frequency cetacean species that are less behaviorally sensitive. This distinction is important because, while beaked whales are more likely to respond behaviorally to sounds than are many other species (even at lower levels), they cannot hear the predominant, lower frequency sounds from seismic airguns as well as sounds that have more energy at frequencies that beaked whales can hear better (such as military MFA sonar).

Navy MFA sonar affects beaked whales differently than airguns do because it produces energy at different frequencies than airguns. Mid-frequency cetacean hearing is generically thought to be best between 8.8 to 110 kHz, *i.e.,* these cutoff values define the range above and below which a species in the group is assumed to have declining auditory sensitivity, until reaching frequencies that cannot be heard (NMFS, 2018). However, beaked whale hearing is likely best within a higher, narrower range (20–80 kHz, with best sensitivity around 40 kHz), based on a few measurements of hearing in stranded beaked whales (Cook *et al.,* 2006; Finneran *et al.,* 2009; Pacini *et al.,* 2011) and several studies of acoustic signals produced by beaked whales (*e.g.,* Frantzis *et al.,* 2002; Johnson *et al.,* 2004, 2006; Zimmer *et al.,* 2005). While precaution requires that the full range of audibility be considered when assessing risks associated with noise exposure (Southall *et al.,* 2007, 2019a, 2019), animals typically produce sound at frequencies where they hear best. More recently, Southall *et al.* (2019) suggested that certain species in the historical mid-frequency hearing group (beaked whales, sperm whales, and killer whales) are likely more sensitive to lower frequencies within the group's generalized hearing range than are other species within the group, and state that the data for beaked whales suggest sensitivity to approximately 5 kHz. However, this information is consistent with the general conclusion that beaked whales (and other mid-frequency cetaceans) are relatively insensitive to the frequencies where most energy of an airgun signal is found. Military MFA sonar is typically considered to operate in the frequency range of approximately 3–14 kHz (D'Amico *et al.,* 2009), *i.e.,* outside the range of likely best hearing for beaked whales but within or close to the lower bounds, whereas most energy in an airgun signal is radiated at much lower frequencies, below 500 Hz (Dragoset, 1990).

It is important to distinguish between energy (loudness, measured in dB) and frequency (pitch, measured in Hz). In considering the potential impacts of mid-frequency components of airgun noise (1–10 kHz, where beaked whales can be expected to hear) on marine mammal hearing, one needs to account for the energy associated with these higher frequencies and determine what energy is truly ''significant.'' Although there is mid-frequency energy associated with airgun noise (as expected from a broadband source), airgun sound is predominantly below 1 kHz (Breitzke *et al.,* 2008; Tashmukhambetov *et al.,* 2008; Tolstoy *et al.,* 2009). As stated by Richardson *et al.* (1995), ''[. . .] most emitted [seismic airgun] energy is at 10–120 Hz, but the pulses contain some energy up to 500–1,000 Hz.'' Tolstoy *et al.* (2009) conducted empirical measurements, demonstrating that sound energy levels associated with airguns were at least 20 decibels (dB) lower at 1 kHz (considered ''mid-frequency'') compared to higher energy levels associated with lower frequencies (below 300 Hz) (''all but a small fraction of the total energy being concentrated in the 10–300 Hz range'' [Tolstoy *et al.,* 2009]), and at higher frequencies (*e.g.,* 2.6–4 kHz), power might be less than 10 percent of the peak power at 10 Hz (Yoder, 2002). Energy levels measured by Tolstoy *et al.* (2009) were even lower at frequencies above 1 kHz. In addition, as sound propagates away from the source, it tends to lose higher-frequency components faster than low-frequency components (*i.e.,* low-frequency sounds typically propagate longer distances than high-frequency sounds) (Diebold *et al.,* 2010). Although higher-frequency components of airgun signals have been recorded, it is typically in surface-ducting conditions (*e.g.,* DeRuiter *et al.,* 2006; Madsen *et al.,* 2006) or in shallow water, where there are advantageous propagation conditions for the higher frequency (but low-energy) components of the airgun signal (Hermannsen *et al.,* 2015). This should not be of concern because the likely behavioral reactions of beaked whales that can result in acute physical injury would result from noise exposure at depth (because of the potentially greater consequences of severe behavioral reactions). In summary, the frequency content of airgun signals is such that beaked whales will not be able to hear the signals well (compared to MFA sonar), especially at depth where we expect the consequences of noise exposure could be more severe.

Aside from frequency content, there are other significant differences between MFA sonar signals and the sounds produced by airguns that minimize the risk of severe behavioral reactions that could lead to strandings or deaths at sea, *e.g.,* significantly longer signal duration, horizontal sound direction, typical fast and unpredictable source movement. All of these characteristics of MFA sonar tend towards greater potential to cause severe behavioral or physiological reactions in exposed beaked whales that may contribute to stranding. Although both sources are powerful, MFA sonar contains significantly greater energy in the mid-frequency range, where beaked whales hear better. Short-duration, high energy pulses—such as those produced by airguns—have greater potential to cause damage to auditory structures (though this is unlikely for mid-frequency cetaceans, as explained later in this document), but it is longer duration signals that have been implicated in the vast majority of beaked whale strandings. Faster, less predictable movements in combination with multiple source vessels are more likely to elicit a severe, potentially anti-predator response. Of additional interest in assessing the divergent characteristics of MFA sonar and airgun signals and their relative potential to cause stranding events or deaths at sea is the similarity between the MFA sonar signals and stereotyped calls of beaked whales' primary predator: the killer whale (Zimmer and Tyack, 2007). Although generic disturbance stimuli—as airgun noise may be considered in this case for beaked whales—may also trigger antipredator responses, stronger responses should generally be expected when perceived risk is greater, as when the stimulus is confused for a known predator (Frid and Dill, 2002). In addition, because the source of the perceived predator (*i.e.,* MFA sonar) will likely be closer to the whales (because attenuation limits the range of detection of mid-frequencies) and moving faster (because it will be on faster-moving vessels), any antipredator response would be more likely to be severe (with greater perceived predation risk, an animal is more likely to disregard the cost of the response; Frid and Dill, 2002). Indeed, when analyzing movements of a beaked whale exposed to playback of killer whale predation calls, Allen *et al.* (2014) found that the whale engaged in a prolonged, directed avoidance response, suggesting a behavioral reaction that could pose a risk factor for stranding. Overall, these significant differences between sound from MFA sonar and the mid-frequency sound component from airguns and the likelihood that MFA sonar signals will be interpreted in error as a predator are critical to understanding the likely risk of behaviorally-mediated injury due to seismic surveys.

The available scientific literature also provides a useful contrast between airgun noise and MFA sonar regarding the likely risk of behaviorally-mediated injury. There is strong evidence for the association of beaked whale stranding events with MFA sonar use, and particularly detailed accounting of several events is available (*e.g.,* a 2000 Bahamas stranding event for which investigators concluded that MFA sonar use was responsible; Evans and England, 2001). D'Amico *et al.* (2009) reviewed 126 beaked whale mass stranding events over the period from 1950 (*i.e.,* from the development of modern MFA sonar systems) through 2004. Of these, there were two events where detailed information was available on both the timing and location of the stranding and the concurrent nearby naval activity, including verification of active MFA sonar usage, with no evidence for an alternative cause of stranding. An additional ten events were at minimum spatially and temporally coincident with naval activity likely to have included MFA sonar use and, despite incomplete knowledge of timing and location of the stranding or the naval activity in some cases, there was no evidence for an alternative cause of stranding. The U.S. Navy has publicly stated agreement that five such events since 1996 were associated in time and space with MFA sonar use, either by the U.S. Navy alone or in joint training exercises with the North Atlantic Treaty Organization. The U.S. Navy additionally noted that, as of 2017, a 2014 beaked whale stranding event in Crete coincident with naval exercises was under review and had not yet been determined to be linked to sonar activities (U.S. Navy, 2017). Separately, the International Council for the Exploration of the Sea reported in 2005 that, worldwide, there have been about 50 known strandings, consisting mostly of beaked whales, with a potential causal link to MFA sonar (ICES, 2005). In contrast, very few such associations have been made to seismic surveys, despite widespread use of airguns as a geophysical sound source in numerous locations around the world.

A more recent review of possible stranding associations with seismic surveys (Castellote and Llorens, 2016) states plainly that, ''[s]peculation concerning possible links between seismic survey noise and cetacean strandings is available for a dozen events but without convincing causal evidence.'' The authors' ''exhaustive'' search of available information found ten events worth further investigation via a ranking system representing a rough metric of the relative level of confidence offered by the data for inferences about the possible role of the seismic survey in a given stranding event. Only three of these events involved beaked whales. Whereas D'Amico *et al.* (2009) used a 1–5 ranking system, in which ''1'' represented the most robust evidence connecting the event to MFA sonar use, Castellote and Llorens (2016) used a 1–6 ranking system, in which ''6'' represented the most robust evidence connecting the event to the seismic survey. As described above, D'Amico *et al.* (2009) found that two events were ranked ''1'' and ten events were ranked ''2'' (*i.e.,* 12 beaked whale stranding events were found to be associated with MFA sonar use). In contrast, Castellote and Llorens (2016) found that none of the three beaked whale stranding events achieved their highest ranks of 5 or 6. Of the ten total events, none achieved the highest rank of 6. Two events were ranked as 5: one stranding in Peru involving dolphins and porpoises and a 2008 stranding in Madagascar. This latter ranking can only broadly be associated with the survey itself, as opposed to use of seismic airguns. An exhaustive investigation of this stranding event, which did not involve beaked whales, concluded that use of a high-frequency mapping system (12-kHz multibeam echosounder) was the most plausible and likely initial behavioral trigger of the event, which was likely exacerbated by several site- and situation-specific secondary factors. The review panel found that seismic airguns were used after the initial strandings and animals entering a lagoon system, that airgun use clearly had no role as an initial trigger, and that there was no evidence that airgun use dissuaded animals from leaving (Southall *et al.,* 2013).

However, one of these stranding events, involving two Cuvier's beaked whales, was contemporaneous with and reasonably associated spatially with a 2002 seismic survey in the Gulf of California conducted by Lamont-Doherty Earth Observatory (L–DEO), as was the case for the 2007 Gulf of Cadiz seismic survey discussed by Castellote and Llorens (also involving two Cuvier's beaked whales). However, neither event was considered a ''true atypical mass stranding'' (according to Frantzis [1998]) as used in the analysis of Castellote and Llorens (2016). While we agree with the authors that this lack of evidence should not be considered conclusive, it is clear that there is very little evidence that seismic surveys should be considered as posing a significant risk of acute harm to beaked whales or other mid-frequency cetaceans. We have considered the potential for the proposed survey to result in marine mammal stranding and have concluded that, based on the best available information, stranding is not expected to occur.

Use of military tactical sonar has been implicated in a majority of investigated stranding events. Most known stranding events have involved beaked whales, though a small number have involved deep-diving delphinids or sperm whales (*e.g.,* Mazzariol *et al.,* 2010; Southall *et al.,* 2013). In general, long duration (approximately 1 second) and high-intensity sounds (greater than 235 dB SPL) have been implicated in stranding events (Hildebrand, 2004). With regard to beaked whales, mid-frequency sound is typically implicated (when causation can be determined) (Hildebrand, 2004). Although seismic airguns create predominantly low-frequency energy, the signal does include a mid-frequency component. We have considered the potential for the proposed survey to result in marine mammal stranding and have concluded that, based on the best available information, stranding is not expected to occur.

Entanglement—Entanglements occur when marine mammals become wrapped around cables, lines, nets, or other objects suspended in the water column. During seismic operations, numerous cables, lines, and other objects primarily associated with the airgun array and hydrophone streamers will be towed behind the *Palmer* near the water's surface. No incidents of entanglement of marine mammals with seismic survey gear have been documented in over 54,000 kt (100,000 km) of previous NSF-funded seismic surveys when observers were aboard (*e.g.,* Smultea and Holst 2003; Haley and Koski 2004; Holst 2004; Smultea *et al.,* 2004; Holst *et al.,* 2005a; Haley and Ireland 2006; SIO and NSF 2006b; Hauser *et al.,* 2008; Holst and Smultea 2008). Although entanglement with the streamer is theoretically possible, it has not been documented during tens of thousands of miles of NSF-sponsored seismic cruises or, to our knowledge, during hundreds of thousands of miles of industrial seismic cruises. There are a relative few deployed devices, and no interaction between marine mammals and any such device has been recorded during prior NSF surveys using the devices. There are no meaningful entanglement risks posed by the proposed survey, and entanglement risks are not discussed further in this document.

Anticipated Effects on Marine Mammal Habitat

Physical Disturbance—Sources of seafloor disturbance related to geophysical surveys that may impact marine mammal habitat include placement of anchors, nodes, cables, sensors, or other equipment on or in the seafloor for various activities. Equipment deployed on the seafloor has the potential to cause direct physical damage and could affect bottom-associated fish resources.

Placement of equipment, such as the heat flow probe in the seafloor, could damage areas of hard bottom where direct contact with the seafloor occurs and could crush epifauna (organisms that live on the seafloor or surface of other organisms). Damage to unknown or unseen hard bottom could occur, but because of the small area covered by most bottom-founded equipment and the patchy distribution of hard bottom habitat, contact with unknown hard bottom is expected to be rare and impacts minor. Seafloor disturbance in areas of soft bottom can cause loss of small patches of epifauna and infauna due to burial or crushing, and bottom-feeding fishes could be temporarily displaced from feeding areas. Overall, any effects of physical damage to habitat are expected to be minor and temporary.

Effects to Prey—Marine mammal prey varies by species, season, and location and, for some, is not well documented. Fish react to sounds which are especially strong and/or intermittent low-frequency sounds. Short duration, sharp sounds can cause overt or subtle changes in fish behavior and local distribution. Hastings and Popper (2005) identified several studies that suggest fish may relocate to avoid certain areas of sound energy. Additional studies have documented effects of pulsed sound on fish, although several are based on studies in support of construction projects (*e.g.,* Scholik and Yan, 2001, 2002; Popper and Hastings, 2009). Sound pulses at received levels of 160 dB may cause subtle changes in fish behavior. SPLs of 180 dB may cause noticeable changes in behavior (Pearson *et al.,* 1992; Skalski *et al.,* 1992). SPLs of sufficient strength have been known to cause injury to fish and fish mortality. The most likely impact to fish from survey activities at the project area would be temporary avoidance of the area. The duration of fish avoidance of a given area after survey effort stops is unknown, but a rapid return to normal recruitment, distribution and behavior is anticipated.

Marine mammal prey varies by species, season, and location and, for some, is not well documented. Fish react to sounds which are especially strong and/or intermittent low-frequency sounds, and behavioral responses such as flight or avoidance are the most likely effects. However, the reaction of fish to airguns depends on the physiological state of the fish, past exposures, motivation (*e.g.,* feeding, spawning, migration), and other environmental factors. Several studies have demonstrated that airgun sounds might affect the distribution and behavior of some fishes, potentially impacting foraging opportunities or increasing energetic costs (*e.g.,* Fewtrell and McCauley, 2012; Pearson *et al.,* 1992; Skalski *et al.,* 1992; Santulli *et al.,* 1999; Paxton *et al.,* 2017), though the bulk of studies indicate no or slight reaction to noise (*e.g.,* Miller and Cripps, 2013; Dalen and Knutsen, 1987; Pena *et al.,* 2013; Chapman and Hawkins, 1969; Wardle *et al.,* 2001; Sara *et al.,* 2007; Jorgenson and Gyselman, 2009; Blaxter *et al.,* 1981; Cott *et al.,* 2012; Boeger *et al.,* 2006), and that, most commonly, while there are likely to be impacts to fish as a result of noise from nearby airguns, such effects will be temporary. For example, investigators reported significant, short-term declines in commercial fishing catch rate of gadid fishes during and for up to five days after seismic survey operations, but the catch rate subsequently returned to normal (Engas *et al.,* 1996; Engas and Lokkeborg, 2002). Other studies have reported similar findings (Hassel *et al.,* 2004). Skalski *et al.,* (1992) also found a reduction in catch rates—for rockfish (*Sebastes* spp.) in response to controlled airgun exposure—but suggested that the mechanism underlying the decline was not dispersal but rather decreased responsiveness to baited hooks associated with an alarm behavioral response. A companion study showed that alarm and startle responses were not sustained following the removal of the sound source (Pearson *et al.,* 1992). Therefore, Skalski *et al.* (1992) suggested that the effects on fish abundance may be transitory, primarily occurring during the sound exposure itself. In some cases, effects on catch rates are variable within a study, which may be more broadly representative of temporary displacement of fish in response to airgun noise (*i.e.,* catch rates may increase in some locations and decrease in others) than any long-term damage to the fish themselves (Streever *et al.,* 2016).

SPLs of sufficient strength have been known to cause injury to fish and fish mortality and, in some studies, fish auditory systems have been damaged by airgun noise (McCauley *et al.,* 2003; Popper *et al.,* 2005; Song *et al.,* 2008). However, in most fish species, hair cells in the ear continuously regenerate and loss of auditory function likely is restored when damaged cells are replaced with new cells. Halvorsen *et al.* (2012b. (2012) showed that a TTS of 4–6 dB was recoverable within 24 hours for one species. Impacts would be most severe when the individual fish is close to the source and when the duration of exposure is long—both of which are conditions unlikely to occur for this survey that is necessarily transient in any given location and likely result in brief, infrequent noise exposure to prey species in any given area. For this survey, the sound source is constantly moving, and most fish would likely avoid the sound source prior to receiving sound of sufficient intensity to cause physiological or anatomical damage. In addition, ramp-up may allow certain fish species the opportunity to move further away from the sound source.

A recent comprehensive review (Carroll *et al.,* 2017) found that results are mixed as to the effects of airgun noise on the prey of marine mammals. While some studies suggest a change in prey distribution and/or a reduction in prey abundance following the use of seismic airguns, others suggest no effects or even positive effects in prey abundance. As one specific example, Paxton *et al.* (2017), which describes findings related to the effects of a 2014 seismic survey on a reef off of North Carolina, showed a 78 percent decrease in observed nighttime abundance for certain species. It is important to note that the evening hours during which the decline in fish habitat use was recorded (via video recording) occurred on the same day that the seismic survey passed, and no subsequent data is presented to support an inference that the response was long-lasting. Additionally, given that the finding is based on video images, the lack of recorded fish presence does not support a conclusion that the fish actually moved away from the site or suffered any serious impairment. In summary, this particular study corroborates prior studies indicating that a startle response or short-term displacement should be expected.

Available data suggest that cephalopods are capable of sensing the particle motion of sounds and detect low frequencies up to 1–1.5 kHz, depending on the species, and so are likely to detect airgun noise (Kaifu *et al.,* 2008; Hu *et al.,* 2009; Mooney *et al.,* 2010; Samson *et al.,* 2014). Auditory injuries (lesions occurring on the statocyst sensory hair cells) have been reported upon controlled exposure to low-frequency sounds, suggesting that cephalopods are particularly sensitive to low-frequency sound (Andre *et al.,* 2011; Sole *et al.,* 2013). Behavioral responses, such as inking and jetting, have also been reported upon exposure to low-frequency sound (McCauley *et al.,* 2000b; Samson *et al.,* 2014). Similar to fish, however, the transient nature of the survey leads to an expectation that effects will be largely limited to behavioral reactions and would occur as a result of brief, infrequent exposures.

With regard to potential impacts on zooplankton, McCauley *et al.* (2017) found that exposure to airgun noise resulted in significant depletion for more than half the taxa present and that there were two to three times more dead zooplankton after airgun exposure compared with controls for all taxa, within 1 km of the airguns. However, the authors also stated that in order to have significant impacts on r-selected species (*i.e.,* those with high growth rates and that produce many offspring) such as plankton, the spatial or temporal scale of impact must be large in comparison with the ecosystem concerned, and it is possible that the findings reflect avoidance by zooplankton rather than mortality (McCauley *et al.,* 2017). In addition, the results of this study are inconsistent with a large body of research that generally finds limited spatial and temporal impacts to zooplankton as a result of exposure to airgun noise (*e.g.,* Dalen and Knutsen, 1987; Payne, 2004; Stanley *et al.,* 2011). Most prior research on this topic, which has focused on relatively small spatial scales, has showed minimal effects (*e.g.,* Kostyuchenko, 1973; Booman *et al.,* 1996; Sætre and Ona, 1996; Pearson *et al.,* 1994; Bolle *et al.,* 2012).

A modeling exercise was conducted as a follow-up to the McCauley *et al.* (2017) study (as recommended by McCauley *et al.*), in order to assess the potential for impacts on ocean ecosystem dynamics and zooplankton population dynamics (Richardson *et al.,* 2017). Richardson *et al.* (2017) found that for copepods with a short life cycle in a high-energy environment, a full-scale airgun survey would impact copepod abundance up to three days following the end of the survey, suggesting that effects such as those found by McCauley *et al.* (2017) would not be expected to be detectable downstream of the survey areas, either spatially or temporally.

Notably, a recently described study produced results inconsistent with those of McCauley *et al.* (2017). Researchers conducted a field and laboratory study to assess if exposure to airgun noise affects mortality, predator escape response, or gene expression of the copepod *Calanus finmarchicus* (Fields *et al.,* 2019). Immediate mortality of copepods was significantly higher, relative to controls, at distances of 5 m or less from the airguns. Mortality one week after the airgun blast was significantly higher in the copepods placed 10 m from the airgun but was not significantly different from the controls at a distance of 20 m from the airgun. The increase in mortality, relative to controls, did not exceed 30 percent at any distance from the airgun. Moreover, the authors caution that even this higher mortality in the immediate vicinity of the airguns may be more pronounced than what would be observed in free-swimming animals due to increased flow speed of fluid inside bags containing the experimental animals. There were no sublethal effects on the escape performance or the sensory threshold needed to initiate an escape response at any of the distances from the airgun that were tested. Whereas McCauley *et al.* (2017) reported an SEL of 156 dB at a range of 509–658 m, with zooplankton mortality observed at that range, Fields *et al.* (2019) reported an SEL of 186 dB at a range of 25 m, with no reported mortality at that distance. Regardless, if we assume a worst-case likelihood of severe impacts to zooplankton within approximately 1 km of the acoustic source, the typically wide dispersal of survey vessels and brief time to regeneration of the potentially affected zooplankton populations does not lead us to expect any meaningful follow-on effects to the prey base for odontocete predators.

A recent review article concluded that, while laboratory results provide scientific evidence for high-intensity and low-frequency sound-induced physical trauma and other negative effects on some fish and invertebrates, the sound exposure scenarios in some cases are not realistic to those encountered by marine organisms during routine seismic operations (Carroll *et al.,* 2017). The review finds that there has been no evidence of reduced catch or abundance following seismic activities for invertebrates, and that there is conflicting evidence for fish with catch observed to increase, decrease, or remain the same. Further, where there is evidence for decreased catch rates in response to airgun noise, these findings provide no information about the underlying biological cause of catch rate reduction (Carroll *et al.,* 2017).

In summary, impacts of the specified activity on marine mammal prey species will likely be limited to behavioral responses, the majority of prey species will be capable of moving out of the area during the survey, a rapid return to normal recruitment, distribution, and behavior for prey species is anticipated, and, overall, impacts to prey species will be minor and temporary. Prey species exposed to sound might move away from the sound source, experience TTS, experience masking of biologically relevant sounds, or show no obvious direct effects. Mortality from decompression injuries is possible in close proximity to a sound, but only limited data on mortality in response to airgun noise exposure are available (Hawkins *et al.,* 2014). The most likely impacts for most prey species in the survey area would be temporary avoidance of the area. The proposed survey would move through an area relatively quickly, limiting exposure to multiple impulsive sounds. In all cases, sound levels would return to ambient once the survey moves out of the area or ends and the noise source is shut down and, when exposure to sound ends, behavioral and/or physiological responses are expected to end relatively quickly (McCauley *et al.,* 2000b). The duration of fish avoidance of a given area after survey effort stops is unknown, but a rapid return to normal recruitment, distribution, and behavior is anticipated. While the potential for disruption of spawning aggregations or schools of important prey species can be meaningful on a local scale, the mobile and temporary nature of this survey and the likelihood of temporary avoidance behavior suggest that impacts would be minor.

In general, impacts to marine mammal prey are expected to be limited due to the relatively small temporal and spatial overlap between the proposed survey and any areas used by marine mammal prey species. The proposed use of airguns as part of an active seismic array survey would occur over a relatively short time period (approximately 25 days at sea) and would occur over a very small area relative to the area available as marine mammal habitat in the Ross Sea. We believe any impacts to marine mammals due to adverse effects to their prey would be insignificant due to the limited spatial and temporal impact of the proposed survey. However, adverse impacts may occur to a few species of fish and to zooplankton.

Acoustic Habitat—Acoustic habitat is the soundscape—which encompasses all of the sound present in a particular location and time, as a whole—when considered from the perspective of the animals experiencing it. Animals produce sound for, or listen for sounds produced by, conspecifics (communication during feeding, mating, and other social activities), other animals (finding prey or avoiding predators), and the physical environment (finding suitable habitats, navigating). Together, sounds made by animals and the geophysical environment (*e.g.,* produced by earthquakes, lightning, wind, rain, waves) make up the natural contributions to the total acoustics of a place. These acoustic conditions, termed acoustic habitat, are one attribute of an animal's total habitat.

Soundscapes are also defined by, and acoustic habitat influenced by, the total contribution of anthropogenic sound. This may include incidental emissions from sources such as vessel traffic, or may be intentionally introduced to the marine environment for data acquisition purposes (as in the use of airgun arrays). Anthropogenic noise varies widely in its frequency content, duration, and loudness and these characteristics greatly influence the potential habitat-mediated effects to marine mammals (please see also the previous discussion on masking under *Acoustic Effects*), which may range from local effects for brief periods of time to chronic effects over large areas and for long durations. Depending on the extent of effects to habitat, animals may alter their communications signals (thereby potentially expending additional energy) or miss acoustic cues (either conspecific or adventitious). For more detail on these concepts see, *e.g.,* Barber *et al.,* 2010; Pijanowski *et al.,* 2011; Francis and Barber, 2013; Lillis *et al.,* 2014.

Problems arising from a failure to detect cues are more likely to occur when noise stimuli are chronic and overlap with biologically relevant cues used for communication, orientation, and predator/prey detection (Francis and Barber, 2013). Although the signals emitted by seismic airgun arrays are generally low frequency, they would also likely be of short duration and transient in any given area due to the nature of these surveys. As described previously, exploratory surveys such as this one cover a large area but would be transient rather than focused in a given location over time and therefore would not be considered chronic in any given location.

Based on the information discussed herein, we conclude that impacts of the specified activity are not likely to have more than short-term adverse effects on any prey habitat or populations of prey species. Further, any impacts to marine mammal habitat are not expected to result in significant or long-term consequences for individual marine mammals, or to contribute to adverse impacts on their populations.

Estimated Take

This section provides an estimate of the number of incidental takes proposed for authorization through this IHA, which will inform both NMFS' consideration of ''small numbers'' and the negligible impact determination.

Harassment is the only type of take expected to result from these activities. Except with respect to certain activities not pertinent here, section 3(18) of the MMPA defines ''harassment'' as any act of pursuit, torment, or annoyance, which (i) has the potential to injure a marine mammal or marine mammal stock in the wild (Level A harassment); or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B harassment).

All proposed takes are by Level B harassment, involving temporary changes in behavior. No Level A harassment is expected or proposed for authorization. In the sections below, we describe methods to estimate the number of Level B harassment events. The main sources of distributional and numerical data used in deriving the estimates are summarized below.

Generally speaking, we estimate take by considering: (1) acoustic thresholds above which NMFS believes the best available science indicates marine mammals will be behaviorally harassed or incur some degree of hearing impairment; (2) the area or volume of water that will be ensonified above these levels in a day; (3) the density or occurrence of marine mammals within these ensonified areas; and (4) the number of days of activities. We note that while these basic factors can contribute to a basic calculation to provide an initial prediction of takes, additional information that can qualitatively inform take estimates is also sometimes available (*e.g.,* previous monitoring results or average group size). Below, we describe the factors considered here in more detail and present the proposed take estimate.

Acoustic Thresholds

NMFS recommends the use of acoustic thresholds that identify the received level of underwater sound above which exposed marine mammals would be reasonably expected to be behaviorally harassed (equated to Level B harassment) or to incur PTS of some degree (equated to Level A harassment).

Level B Harassment for non-explosive sources—Though significantly driven by received level, the onset of behavioral disturbance from anthropogenic noise exposure is also informed to varying degrees by other factors related to the source (*e.g.,* frequency, predictability, duty cycle), the environment (*e.g.,* bathymetry), and the receiving animals (hearing, motivation, experience, demography, behavioral context) and can be difficult to predict (Southall *et al.,* 2007, Ellison *et al.,* 2012). Based on what the available science indicates and the practical need to use a threshold based on a factor that is both predictable and measurable for most activities, NMFS uses a generalized acoustic threshold based on received level to estimate the onset of behavioral harassment. NMFS predicts that marine mammals are likely to be behaviorally harassed in a manner we consider Level B harassment when exposed to underwater anthropogenic noise above received levels of 120 dB re 1 μPa (rms) for continuous (*e.g.,* vibratory pile-driving, drilling) and above 160 dB re 1 μPa (rms) for non-explosive impulsive (*e.g.,* seismic airguns) or intermittent (*e.g.,* scientific sonar) sources.

The proposed activities include the use of continuous icebreaking and impulsive seismic sources and, and therefore the 120 and 160 dB re 1 μPa (rms) are applicable.

Level A harassment for non-explosive sources—NMFS' Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0) (Technical Guidance, 2018) identifies dual criteria to assess auditory injury (Level A harassment) to five different marine mammal groups (based on hearing sensitivity) as a result of exposure to noise from two different types of sources (impulsive or non-impulsive). The proposed activity includes the use of impulsive seismic and continuous non-impulsive icebreaking sources.

These thresholds are provided in the table below. The references, analysis, and methodology used in the development of the thresholds are described in NMFS 2018 Technical Guidance, which may be accessed at *https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-acoustic-technical-guidance.*

TABLE 4—THRESHOLDS IDENTIFYING THE ONSET OF PERMANENT THRESHOLD SHIFT

Hearing group	PTS onset acoustic thresholds* (received level)	
	Impulsive	Non-impulsive
Low-Frequency (LF) Cetaceans	*Cell 1:* $L_{pk,flat}$: 219 dB; $L_{E,LF,24h}$: 183 dB	*Cell 2:* $L_{E,LF,24h}$: 199 dB.
Mid-Frequency (MF) Cetaceans	*Cell 3:* $L_{pk,flat}$: 230 dB; $L_{E,MF,24h}$: 185 dB	*Cell 4:* $L_{E,MF,24h}$: 198 dB.
High-Frequency (HF) Cetaceans	*Cell 5:* $L_{pk,flat}$: 202 dB; $L_{E,HF,24h}$: 155 dB	*Cell 6:* $L_{E,HF,24h}$: 173 dB.
Phocid Pinnipeds (PW) (Underwater)	*Cell 7:* $L_{pk,flat}$: 218 dB; $L_{E,PW,24h}$: 185 dB	*Cell 8:* $L_{E,PW,24h}$: 201 dB.
Otariid Pinnipeds (OW) (Underwater)	*Cell 9:* $L_{pk,flat}$: 232 dB; $L_{E,OW,24h}$: 203 dB	*Cell 10:* $L_{E,OW,24h}$: 219 dB.

* Dual metric acoustic thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

Note: Peak sound pressure (L_{pk}) has a reference value of 1 μPa, and cumulative sound exposure level (L_E) has a reference value of $1 \mu Pa^2 s$. In this Table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this Technical Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the generalized hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (LF, MF, and HF cetaceans, and PW and OW pinnipeds) and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in a multitude of ways (*i.e.,* varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these acoustic thresholds will be exceeded.

Ensonified Area

Here, we describe operational and environmental parameters of the activity that will feed into identifying the area ensonified above the acoustic thresholds, which include source levels and transmission loss coefficient.

When the NMFS Technical Guidance (2016) was published, in recognition of the fact that ensonified area/volume could be more technically challenging to predict because of the duration component in the new thresholds, we developed a User Spreadsheet that includes tools to help predict a simple isopleth that can be used in conjunction with marine mammal density or occurrence to help predict takes. We note that because of some of the assumptions included in the methods used for these tools, we anticipate that isopleths produced are typically going to be overestimates of some degree, which may result in some degree of overestimate of Level A harassment take. However, these tools offer the best way to predict appropriate isopleths when more sophisticated 3D modeling methods are not available, and NMFS continues to develop ways to quantitatively refine these tools, and will qualitatively address the output where appropriate. For mobile sources (*e.g.,* icebreaking), the User Spreadsheet predicts the closest distance at which a stationary animal would not incur PTS if the sound source traveled by the animal in a straight line at a constant speed.

The proposed survey would entail the use of a 2-airgun array with a total discharge of 210 in^3 at a tow depth of 1–4 m (with the worst-case scenario of 4 m assumed for purposes of modeling). L–DEO model results are used to determine the 160 dB_{rms} radius for the 2-airgun array water depth ranging from 150–700 m. Received sound levels were predicted by L–DEO's model (Diebold *et al.,* 2010) as a function of distance from the airguns, for the two 105 in^3 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 homogenous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from a 36-airgun array at a tow depth of 6 m have been reported in deep water (~1,600 m), intermediate water depth on the slope (~600–1,100 m), and shallow water (~50 m) in the Gulf of Mexico 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 the Level A and Level B harassment isopleths, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–550 m, which may not intersect all the SPL isopleths at their widest point from the sea surface down to the maximum relevant water depth (~2,000 m) for marine mammals. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data 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 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 at short ranges, sound levels for direct arrivals recorded by the calibration hydrophone and L–DEO model results for the same array tow depth are in good alignment (see Figures 12 and 14 in Appendix H of NSF–USGS 2011). 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 (see Figures 11, 12, and 16 in Appendix H of NSF–USGS 2011). Aside from local topography effects, the region around the critical distance is where the observed levels rise closest to the model curve. However, the observed sound levels are found to fall almost entirely below the model curve. Thus, analysis of the Gulf of Mexico calibration measurements demonstrates that although simple, the L–DEO model is a robust tool for conservatively estimating isopleths.

The proposed survey would acquire data with two 105-in^3 guns at a tow depth of 1–4 m. For deep water (>1000 m), we use the deep-water radii obtained from L–DEO model results down to a maximum water depth of 2,000 m for the airgun array. The radii for intermediate water depths (100–1,000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (see Figure 16 in Appendix H of NSF–USGS 2011).

L–DEO's modeling methodology is described in greater detail in NSF's IHA application. The estimated distances to the Level B harassment isopleth for the proposed airgun configuration are shown in Table 5.

TABLE 5—PREDICTED RADIAL DISTANCES FROM THE RVIB *Palmer* SEISMIC SOURCE TO ISOPLETHS CORRESPONDING TO LEVEL B HARASSMENT THRESHOLD

Airgun configuration	Water depth (m) [a]	Predicted distances (m) to 160 dB received sound level
Two 105-in^3 GI guns	>1,000	726 [b]
	100–1,000	1,089 [c]

[a] No survey effort would occur in water >1000 m; the distance for this water depth is included for informational purposes only.
[b] Distance is based on L–DEO model results.
[c] Distance is based on L–DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

Table 6 presents the modeled PTS isopleths for each marine mammal hearing group based on the L–DEO modeling incorporated in the companion User Spreadsheet (NMFS 2018).

TABLE 6—MODELED RADIAL DISTANCES TO ISOPLETHS CORRESPONDING TO LEVEL A HARASSMENT THRESHOLDS

Hearing group	SEL cumulative PTS threshold (dB) [1]	SEL cumulative PTS distance (m) [1]	Pk PTS threshold (dB) [1]	Pk PTS distance (m) [1]
Low-frequency cetaceans	183	25.4	219	6.69
Mid-frequency cetaceans	185	0.0	230	1.50
High-frequency cetaceans	155	0.0	202	47.02
Phocid pinnipeds	185	0.3	218	7.53
Otariid pinnpeds	203	0.0	232	0.92

[1] Cumulative sound exposure level for PTS (SEL$_{cum}$PTS) or Peak (SPLflat) resulting in Level A harassment (*i.e.,* injury). Based on 2018 NMFS Acoustic Technical Guidance (NMFS 2018).

Predicted distances to Level A harassment isopleths, which vary based on marine mammal hearing groups, were calculated based on modeling performed by L–DEO using the Nucleus software program and the NMFS User Spreadsheet, described below. The acoustic thresholds for impulsive sounds (*e.g.,* airguns) contained in the Technical Guidance were presented as dual metric acoustic thresholds using both SEL$_{cum}$ and peak sound pressure metrics (NMFS 2016a). As dual metrics, NMFS considers onset of PTS (Level A harassment) to have occurred when either one of the two metrics is exceeded (*i.e.,* metric resulting in the largest isopleth). The SEL$_{cum}$ metric considers both level and duration of exposure, as well as auditory weighting functions by marine mammal hearing group. In recognition of the fact that the requirement to calculate Level A harassment ensonified areas could be more technically challenging to predict due to the duration component and the use of weighting functions in the new SEL$_{cum}$ thresholds, NMFS developed an optional User Spreadsheet that includes tools to help predict a simple isopleth that can be used in conjunction with marine mammal density or occurrence to facilitate the estimation of take numbers.

The SEL$_{cum}$ for the two-GI airgun array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance (right) below the array (*e.g.,* 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy *et al.,* 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy *et al.,* 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the interactions of the two airguns that occur near the source center and is calculated as a point source (single airgun), the modified farfield signature is a more appropriate measure of the sound source level for large arrays. For this smaller array, the modified farfield changes will be correspondingly smaller as well, but this method is used for consistency across all array sizes.

The Level B harassment 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 μParms 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.

Marine Mammal Occurrence

In this section we provide the information about the presence, density, or group dynamics of marine mammals that will inform the take calculations.

For the proposed survey area, NSF provided density data for marine mammal species that might be encountered in the project area. NMFS concurred that these data are the best available. Sightings data from the 2002–2003 (IWC–SOWER) Circumpolar Cruise, Area V (Ensor *et al.* 2003) were used to estimate densities for four mysticete (*i.e.,* humpback whale, Antarctic minke whale, fin whale, and blue whale) and six odontocete species (*i.e.,* sperm whale, southern bottlenose whale, strap-toothed beaked whale, killer whale, long-finned pilot whale and hourglass dolphin). Densities for sei and Arnoux's beaked whales were based on those reported in the Naval Marine Species Density Database (NMSDD) (Department of Navy 2012). NMFS finds NMSDD a reasonable representation of the lower likelihood of encountering these species, as evidenced by previous monitoring reports from projects in the same or similar area (85 FR 5619; January 31, 2020 & 0648–XD705;January 29, 2015) and primary literature on whale species density distribution in the Antarctic (Cetacean Population Studies Vol.2, 2020). Densities of pinnipeds were estimated using best available data (Waterhouse 2001; Pinkerton and Bradford-Grieve 2010) and dividing the estimated population of pinnipeds (number of animals) by the area of the Ross Sea (300,000 km²). Estimated densities used and Level B harassment ensonified areas to inform take estimates are presented in Table 7.

TABLE 7—MARINE MAMMAL DENSITIES AND TOTAL ENSONIFIED AREA OF ACTIVITIES IN THE PROPOSED SURVEY AREA

Species	Estimated density (#/km²)	Ross bank level B ensonified area (km²)	Drygalski tough level B ensonified area (km²)	Icebreaking level B ensonified area (km²)
Fin whale	0.0306570			
Blue whale	0.0065132			
Sei whale	0.0046340			
Antarctic minke whale	0.0845595			
Humpback whale	0.0321169			
Sperm whale	0.0098821			
Southern bottlenose whale	0.0117912			
Arnoux's beaked whale	0.0134420			
Strap-toothed beaked whale	0.0044919	5,272	4,942	8,278
Killer whale	0.0208872			
Long-finned pilot whale	0.0399777			
Hourglass dolphin	0.0189782			
Crabeater seal	0.6800000			
Leopard seal	0.0266700			
Ross seal	0.0166700			
Weddell seal	0.1066700			
Southern elephant seal	0.0001300			

Take Calculation and Estimation

Here we describe how the information provided above is brought together to produce a quantitative take estimate.

Seismic Surveys

In order to estimate the number of marine mammals predicted to be exposed to sound levels that would result in Level B harassment, the radial distance from the airgun array to the predicted isopleth corresponding to the Level B harassment threshold is calculated, as described above. The radial distance is then used to calculate the area around the airgun array predicted to be ensonified to the sound level that exceed the Level B harassment threshold. The area estimated to be ensonified in a single day of the survey is then calculated (Table 8), based on the area predicted to be ensonified around the array and the estimated trackline distance traveled per day. The daily ensonified area was then multiplied by the number of estimated seismic acquisition days –9.6 days for the Ross Bay survey and 9 days for the Drygalski Trough survey. The product is then multiplied by 1.25 to account for the additional 25 percent contingency, as described above. This results in an estimate of the total area (km²) expected to be ensonified to the Level B harassment threshold.

TABLE 8—AREA (KM²) TO BE ENSONIFIED TO THE LEVEL B HARASSMENT THRESHOLD

Survey area	Distance/day (km)	Threshold distance (km)	Daily ensonified area with endcap (km²)	Number of survey days	Plus 25% (contingency)	Total ensonified area (km²)
Ross Bank	200	1.089	439	9.6	12	5,272
Drygaiski Trough	200	1.089	439	9	11.25	4,942

Based on the small Level A harassment isopleths (as shown in Table 6) and in consideration of the proposed mitigation measures (see Proposed Mitigation section below), take by Level A harassment is not expected to occur and is not proposed for authorization.

The marine mammals predicted to occur within the respective areas, based on estimated densities (Table 7), are assumed to be incidentally taken. Estimated take, and percentages of the stocks estimated to be taken, for the proposed survey are shown in Table 10.

Icebreaking

Applying the maximum estimated amount of icebreaking expected by NSF, *i.e.,* 500 km, we calculate the total ensonified area of icebreaking (Table 9). Estimates of exposures assume that there would be approximately 2 days of icebreaking activities; the calculated takes have been increased by 25 percent (2.75 days).

TABLE 9—ENSONIFIED AREA FOR ICEBREAKING ACTIVITIES

Criteria	Distance/day (km)	Threshold distance (km)	Daily ensonified area with endcap (km²)	Number of survey days	Plus 25% (contingency)	Total ensonified area (km²)
120 dB	223	6,456	3,010	2.2	2.75	8,278

Estimated take from icebreaking for the proposed survey are shown in Table 10. As most cetaceans do not occur in pack ice, the estimates of the numbers of marine mammals potentially exposed to sounds greater than the Level B harassment threshold (120 dB re 1 µPa rms) are precautionary and probably overestimate the actual numbers of marine mammals that could be involved. No takes by Level A harassment are expected or proposed for authorization. The estimated number of takes for pinnipeds accounts for both seals that may be in the water and those hauled out on ice surfaces. Few cetaceans are expected to be seen during icebreaking activities, although some could occur along the ice margin.

TABLE 10—TOTAL MARINE MAMMAL TAKE ESTIMATED FOR THE PROPOSED SURVEY IN THE ROSS SEA

Species	Level B take		Total take proposed for authorization	Population abundance	Percent of population
	All seismic	Icebreaking			
Fin whale	313	254	567	38,200	1.48
Blue whale	67	54	120	1,700	7.09
Sei whale	47	38	86	10,000	0.86
Antarctic minke whale	864	700	1,564	515,000	0.3
Humpback whale	328	266	594	42,000	1.41
Sperm whale	101	82	183	12,069	1.51
Southern bottlenose whale	120	98	218	599,300	0.04
Arnoux's beaked whale	137	111	249	599,300	0.04
Strap-toothed beaked whale	46	37	83	599,300	0.01
Killer whale	213	173	386	25,000	1.55
Long-finned pilot whale	408	331	739	200,000	0.37
Hourglass dolphin	194	157	351	144,300	0.24
Crabeater seal	6,946	5,629	12,575	1,700,000	1
Leopard seal	272	221	493	220,000	0.22
Ross seal	170	138	308	250,000	0.12
Weddell seal	1,090	883	1,973	1,000,000	0.2
Southern elephant seal	2	1	3	750,000	<0.01

Proposed Mitigation

In order to issue an IHA under Section 101(a)(5)(D) of the MMPA, NMFS must set forth the permissible methods of taking pursuant to the activity, and other means of effecting the least practicable impact on the species or stock and its habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance, and on the availability of the species or stock for taking for certain subsistence uses (latter not applicable for this action). NMFS regulations require applicants for incidental take authorizations to include information about the availability and feasibility (economic and technological) of equipment, methods, and manner of conducting the activity or other means of effecting the least practicable adverse impact upon the affected species or stocks and their habitat (50 CFR 216.104(a)(11)).

In evaluating how mitigation may or may not be appropriate to ensure the least practicable adverse impact on species or stocks and their habitat, as well as subsistence uses where applicable, we carefully consider two primary factors:

(1) the manner in which, and the degree to which, the successful implementation of the measure(s) is expected to reduce impacts to marine mammals, marine mammal species or stocks, and their habitat. This considers the nature of the potential adverse impact being mitigated (likelihood, scope, range). It further considers the likelihood that the measure will be effective if implemented (probability of accomplishing the mitigating result if implemented as planned), the likelihood of effective implementation (probability implemented as planned), and;

(2) the practicability of the measures for applicant implementation, which may consider such things as cost, impact on operations, and, in the case of a military readiness activity, personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity.

Mitigation measures that would be adopted during the planned survey include, but are not limited to: (1)

Vessel speed or course alteration, provided that doing so would not compromise operation safety requirements. (2) GI-airgun shut down within exclusion zones (EZ)s, and (3) ramp-up procedures.

Vessel-Visual Based Mitigation Monitoring

Visual monitoring requires the use of trained observers (herein referred to as visual protected species observers (PSOs)) to scan the ocean surface visually for the presence of marine mammals. The area to be scanned visually includes primarily the exclusion zone, within which observation of certain marine mammals requires shutdown of the acoustic source, but also the buffer zone. The buffer zone means an area beyond the exclusion zone to be monitored for the presence of marine mammals that may enter the exclusion zone. During pre-start clearance (*i.e.,* before ramp-up begins), the buffer zone also acts as an extension of the exclusion zone in that observations of marine mammals within the buffer zone would also prevent airgun operations from beginning (*i.e.,* ramp-up). The buffer zone encompasses the area at and below the sea surface from the edge of the 100 m exclusion zone measured from the edges of the airgun array. Visual monitoring of the exclusion zone and adjacent waters is intended to establish and, when visual conditions allow, maintain zones around the sound source that are clear of marine mammals, thereby reducing or eliminating the potential for injury and minimizing the potential for more severe behavioral reactions for animals occurring closer to the vessel. Visual monitoring of the buffer zone is intended to (1) provide additional protection to naïve marine mammals that may be in the area during pre-clearance, and (2) during airgun use, aid in establishing and maintaining the exclusion zone by altering the visual observer and crew of marine mammals that are outside of, but may approach and enter, the exclusion zone.

NSF must use independent, dedicated, trained visual PSOs, meaning that the PSOs must be employed by a third-party observer provider, must not have tasks other than to conduct observational effort, collect data, and communicate with and instruct relevant vessel crew with regard to the presence of protected species and mitigation requirements, and must have successfully completed an approved PSO training course. PSO resumes shall be provided to NMFS for approval.

At least one visual PSO must have a minimum of 90 days at-sea experience working in that role during a shallow penetration or low-energy survey, with no more than 18 months elapsed since the conclusion of the at-sea experience. One PSO with such experience shall be designated as the lead for the entire protected species observation team. The lead PSO shall serve as primary point of contact for the vessel operator and ensure all PSO requirements per the IHA are met. To the maximum extent practicable, the experienced PSOs should be scheduled to be on duty with those PSOs with the appropriate training but who have not yet gained relevant experience.

During survey operations (*e.g.,* any day on which use of the acoustic source is planned to occur, and whenever the acoustic source is in the water, whether activated or not), a minimum of two PSOs must be on duty and conducting visual observations at all times during daylight hours (*i.e.,* from 30 minutes prior to sunrise through 30 minutes following sunset) and 30 minutes prior to and during ramp-up of the airgun array. Visual monitoring of the exclusion and buffer zones must begin no less than 30 minutes prior to ramp-up and must continue until one hour after use of the acoustic source ceases or until 30 minutes past sunset. Visual PSOs must coordinate to ensure 360 degree visual coverage around the vessel from the most appropriate observation posts, and must conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner.

PSOs shall establish and monitor the exclusion and buffer zones. These zones shall be based upon the radial distance from the edges of the acoustic source (rather than being based on the center of the array or around the vessel itself). During use of the acoustic source (*i.e.,* anytime airguns are active, including ramp-up) shall be communicated to the operator to prepare for the potential shutdown of the acoustic source.

During use of the airgun, detections of marine mammals within the buffer zone (but outside the exclusion zone) should be communicated to the operator to prepare for the potential shutdown of the acoustic source. Visual PSOs will immediately communicate all observations to the on duty acoustic PSO(s), including any determination by the PSO regarding species identification, distance, and bearing and the degree of confidence in the determination. Any observations of marine mammals by crew members shall be relayed to the PSO team. During good conditions (*e.g.,* daylight hours; Beaufort sea state (BSS) 3 or less), visual PSOs shall conduct observations when the acoustic source is not operating for comparison of sightings rates and behavior with and without use of the acoustic source and between acquisition periods, to the maximum extent practicable.

Visual PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period.

Exclusion Zone and Buffer Zone

An exclusion zone (EZ) is a defined area within which occurrence of a marine mammal triggers mitigation action intended to reduce the potential for certain outcome, *e.g.,* auditory injury, disruption of critical behaviors. The PSOs would establish a minimum EZ with a 100 m radius with an additional 100 m buffer zone (total of 200 m). The 200m zone would be based on radial distance from the edge of the airgun array (rather than being based on the center of the array or around the vessel itself). With certain exceptions (described below), if a marine mammal appears within or enters this zone, the acoustic source would be shut down.

The 100 m EZ, with additional 100 m buffer zone, is intended to be precautionary in the sense that it would be expected to contain sound exceeding the injury criteria for all cetacean hearing groups, (based on the dual criteria of $\mathrm{SEL_{cum}}$ and peak SPL), while also providing a consistent, reasonably observable zone within which PSOs would typically be able to conduct effective observational effort. Additionally, a 100 m EZ is expected to minimize the likelihood that marine mammals will be exposed to levels likely to result in more severe behavioral responses. Although significantly greater distances may be observed from an elevated platform under good conditions, we believe that 100 m is regularly attainable for PSOs using the naked eye during typical conditions.

An extended 500 m exclusion zone must be established for beaked whales, large whales with a calf, and an aggregation of whales during all survey effort. No buffer zone is required.

Pre-Clearance and Ramp-Up

Ramp-up (sometimes referred to as ‘‘soft start’’) is the gradual and systematic increase of emitted sound levels from an airgun array. Ramp-up would begin with one GI airgun 45 cu in first being activated, followed by the second after 5 minutes. The intent of pre-clearance observation (30 minutes) is to ensure no marine mammals are observed within the buffer zone prior to the beginning of ramp-up. During pre-clearance is the only time observations of marine mammals in the buffer zone would prevent operations (*i.e.,* the beginning of ramp-up). The intent of ramp-up is to warn protected species of pending seismic operations and to allow sufficient time for those animals to leave the immediate vicinity. A ramp-up procedure, involving a stepwise increase in the number of airguns are activated and the full volume is achieve, is required at all times as part of the activation of the acoustic source. All operators must adhere to the following pre-clearance and ramp-up requirements:

(1) The operator must notify a designated PSO of the planned start of ramp-up as agreed upon with the lead PSO; the notification time should not be less than 60 minutes prior to the planned ramp-up in order to allow PSOs time to monitor the exclusion and buffer zones for 30 minutes prior to the initiation of ramp-up (pre-clearance);

- Ramp-ups shall be scheduled so as to minimize the time spent with the source activated prior to reaching the designated run-in;
- One of the PSOs conducting pre-clearance observations must be notified again immediately prior to initiating ramp-up procedures and the operator must receive confirmation from the PSO to proceed;
- Ramp-up may not be initiated if any marine mammal is within the applicable exclusion or buffer zone. If a marine mammal is observed within the applicable exclusion zone or the buffer zone during the 30 minutes pre-clearance period, ramp-up may not begin until the animal(s) has been observed exiting the zones or until an additional time period has elapsed with no further sightings (15 minutes for small odontocetes and pinnipeds, and 30 minutes for Mysticetes and all other odontocetes, including sperm whales and beaked whales);
- PSOs must monitor the exclusion and buffer zones during ramp-up, and ramp-up must cease and the source must be shut down upon detection of a marine mammal within the applicable exclusion zone. Once ramp-up has begun, detections of marine mammals within the buffer zone do not require shutdown, but such observation shall be communicated to the operator to prepare for the potential shutdown.

(2) If the acoustic source is shut down for brief periods (*i.e.,* less than 30 minutes) for reasons other than that described for shutdown (*e.g.,* mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant observation and no detections of marine mammals have occurred within the applicable exclusion zone. For any longer shutdown, pre-start clearance observation and ramp-up are required. For any shutdown at night or in periods of poor visibility (*e.g.,* BSS 4 or greater), ramp-up is required, but if the shutdown period was brief and constant observation was maintained, pre-start clearance watch is not required.

- Testing of the acoustic source involving all elements requires ramp-up. Testing limited to individual source elements or strings does not require ramp-up but does require pre-start clearance watch.

Shutdown Procedures

The shutdown of an airgun array requires the immediate de-activation of all individual airgun elements of the array. Any PSO on duty will have the authority to delay the start of survey operations or to call for shutdown of the acoustic source if a marine mammal is detected within the applicable exclusion zone. The operator must also establish and maintain clear lines of communication directly between PSOs on duty and crew controlling the acoustic source to ensure that shutdown commands are conveyed swiftly while allowing PSOs to maintain watch. When both visual and acoustic PSOs are on duty, all detections will be immediately communicated to the remainder of the on-duty PSO team for potential verification of visual observations by the acoustic PSO or of acoustic detections by visual PSOs. When the airgun array is active (*i.e.,* anytime one or more airguns is active, including during ramp-up) and (1) a marine mammal appears within or enters the applicable exclusion zone and/or (2) a marine mammal (other than delphinids, see below) is detected acoustically and localized within the applicable exclusion zone, the acoustic source will be shut down. When shutdown is called for by a PSO, the acoustic source will be immediately deactivated and any dispute resolved only following deactivation.

Following a shutdown, airgun activity would not resume until the marine mammal has cleared the EZ. The animal would be considered to have cleared the EZ if it is visually observed to have departed the EZ, or it has not been seen within the EZ for 15 minutes in the case of small odontocetes and pinnipeds, and 30 minutes for Mysticetes and all other odontocetes, including sperm and beaked whales, with no further observation of the marine mammal(s).

Upon implementation of shutdown, the source may be reactivated after the marine mammal(s) has been observed exiting the applicable exclusion zone (*i.e.,* animal is not required to fully exit the buffer zone where applicable) or following a clearance period (15 minutes for small odontocetes and pinnipeds, and 30 minutes for mysticetes and all other odontocetes, including sperm whales, beaked whales, pilot whales, killer whales, and Risso's dolphin) with no further observation of the marine mammal(s).

NSF must implement shutdown if a marine mammal species for which take was not authorized, or a species for which authorization was granted but the takes have been met, approaches the Level B harassment zones.

Vessel Strike Avoidance Measures

These measures apply to all vessels associated with the planned survey activity; however, we note that these requirements do not apply in any case where compliance would create an imminent and serious threat to a person or vessel or to the extent that a vessel is restricted in its ability to maneuver and, because of the restriction, cannot comply. These measures include the following:

(1) Vessel operators and crews must maintain a vigilant watch for all marine mammals and slow down, stop their vessel, or alter course, as appropriate and regardless of vessel size, to avoid striking any marine mammal. A single marine mammal at the surface may indicate the presence of submerged animals in the vicinity of the vessel; therefore, precautionary measures should be exercised when an animal is observed. A visual observer aboard the vessel must monitor a vessel strike avoidance zone around the vessel (specific distances detailed below), to ensure the potential for strike is minimized. Visual observers monitoring the vessel strike avoidance zone can be either third-party observers or crew members, but crew members responsible for these duties must be provided sufficient training to distinguish marine mammals from other phenomena and broadly to identify a marine mammal to broad taxonomic group (*i.e.,* as a large whale or other marine mammal);

(2) Vessel speeds must be reduced to 10 kn or less when mother/calf pairs, pods, or large assemblages of any marine mammal are observed near a vessel;

(3) All vessels must maintain a minimum separation distance of 100 m from large whales (*i.e.,* sperm whales and all mysticetes);

(4) All vessels must attempt to maintain a minimum separation distance of 50 m from all other marine mammals, with an exception made for those animals that approach the vessel; and

(5) When marine mammals are sighted while a vessel is underway, the vessel should take action as necessary to avoid violating the relevant separation distance (*e.g.,* attempt to remain parallel to the animal's course, avoid excessive speed or abrupt changes in direction until the animal has left the area). If marine mammals are sighted within the relevant separation distance, the vessel should reduce speed and shift the engine to neutral, not engaging the engines until animals are clear of the area. This recommendation does not apply to any vessel towing gear.

Based on our evaluation of the applicant's proposed measures, NMFS has preliminarily determined that the proposed mitigation measures provide the means of effecting the least practicable impact on the affected species or stocks and their habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance.

Proposed Monitoring and Reporting

In order to issue an IHA for an activity, Section 101(a)(5)(D) of the MMPA states that NMFS must set forth requirements pertaining to the monitoring and reporting of such taking. The MMPA implementing regulations at 50 CFR 216.104 (a)(13) indicate that requests for authorizations must include the suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species and of the level of taking or impacts on populations of marine mammals that are expected to be present in the proposed action area. Effective reporting is critical both to compliance as well as ensuring that the most value is obtained from the required monitoring.

Monitoring and reporting requirements prescribed by NMFS should contribute to improved understanding of one or more of the following:

(1) Occurrence of marine mammal species or stocks in the area in which take is anticipated (*e.g.,* presence, abundance, distribution, density).

(2) Nature, scope, or context of likely marine mammal exposure to potential stressors/impacts (individual or cumulative, acute or chronic), through better understanding of: (1) action or environment (*e.g.,* source characterization, propagation, ambient noise); (2) affected species (*e.g.,* life history, dive patterns); (3) co-occurrence of marine mammal species with the action; or (4) biological or behavioral context of exposure (*e.g.,* age, calving or feeding areas).

(3) Individual marine mammal responses (behavioral or physiological) to acoustic stressors (acute, chronic, or cumulative), other stressors, or cumulative impacts from multiple stressors.

(4) How anticipated responses to stressors impact either: (1) long-term fitness and survival of individual marine mammals; or (2) populations, species, or stocks.

(5) Effects on marine mammal habitat (*e.g.,* marine mammal prey species, acoustic habitat, or other important physical components of marine mammal habitat).

(6) Mitigation and monitoring effectiveness.

Vessel-Based Visual Monitoring

As described above, PSO observations would take place during daytime airgun operations. During seismic operations, at least three visual PSO would be based aboard the *Palmer,* with a minimum of one on duty at all times during daylight hours. NMFS' typical requirements for surveys of this type include a minimum of two PSOs on duty at all times during daylight hours. However, NSF stated in communications with NMFS that the requirement is not practicable in this circumstance due to the remote location of the proposed survey and associated logistical issues, including limited capacity to fly PSOs into and out of McMurdo Station in Antarctica and limited berth space on the *Palmer,* and requested an exception to the requirement. NMFS agrees that, in this circumstance, the requirement to have a minimum of two PSOs on duty during all daylight hours would be impracticable and, therefore, proposes that a minimum of one PSO be on duty. NSF must employ two PSOs on duty during all daylight hours to the maximum extent practicable. NSF Monitoring shall be conducted in accordance with the following requirements:

(1) PSOs shall be independent, dedicated and trained and must be employed by a third-party observer provider;

(2) PSOs shall have no tasks other than to conduct visual observational effort, collect data, and communicate with and instruct relevant vessel crew with regard to the presence of protected species and mitigation requirements (including brief alerts regarding maritime hazards);

(3) PSOs shall have successfully completed an approved PSO training course appropriate for their designated task (visual or acoustic);

(4) NMFS must review and approve PSO resumes accompanied by a relevant training course information packet that includes the name and qualifications (*i.e.,* experience, training completed, or educational background) of the instructor(s), the course outline or syllabus, and course reference material as well as a document stating successful completion of the course;

(5) NMFS shall have one week to approve PSOs from the time that the necessary information is submitted, after which PSOs meeting the minimum requirements shall automatically be considered approved;

(6) PSOs must successfully complete relevant training, including completion of all required coursework and passing (80 percent or greater) a written and/or oral examination developed for the training program;

(7) PSOs must have successfully attained a bachelor's degree from an accredited college or university with a major in one of the natural sciences, a minimum of 30 semester hours or equivalent in the biological sciences, and at least one undergraduate course in math or statistics; and

(8) The educational requirements may be waived if the PSO has acquired the relevant skills through alternate experience. Requests for such a waiver shall be submitted to NMFS and must include written justification. Requests shall be granted or denied (with justification) by NMFS within one week of receipt of submitted information. Alternate experience that may be considered includes, but is not limited to

- secondary education and/or experience comparable to PSO duties;
- previous work experience conducting academic, commercial, or government-sponsored protected species surveys; or
- previous work experience as a PSO; the PSO should demonstrate good standing and consistently good performance of PSO duties.

PSOs must use standardized data collection forms, whether hard copy or electronic. PSOs must record detailed information about any implementation of mitigation requirements, including the distance of animals to the acoustic source and description of specific actions that ensued, the behavior of the animal(s), any observed changes in behavior before and after implementation of mitigation, and if shutdown was implemented, the length of time before any subsequent ramp-up of the acoustic source. If required mitigation was not implemented, PSOs should record a description of the circumstances. At a minimum, the following information must be recorded:

- Vessel name and call sign;
- PSO names and affiliations;
- Date and participants of PSO briefings (as discussed in General Requirement);
- Dates of departure and return to port with port name;
- Dates and times (Greenwich Mean Time) of survey effort and times corresponding with PSO effort;
- Vessel location (latitude/longitude) when survey effort began and ended and vessel location at beginning and end of visual PSO duty shifts;
- Vessel heading and speed at beginning and end of visual PSO duty shifts and upon any line change;
- Environmental conditions while on visual survey (at beginning and end of PSO shift and whenever conditions changed significantly), including BSS and any other relevant weather conditions including cloud cover, fog, sun glare, and overall visibility to the horizon;
- Factors that may have contributed to impaired observations during each PSO shift change or as needed as environmental conditions changed (*e.g.,* vessel traffic, equipment malfunctions); and
- Survey activity information, such as acoustic source power output while in operation, number and volume of airguns operating in the array, tow depth of the array, and any other notes of significance (*i.e.,* pre-start clearance, ramp-up, shutdown, testing, shooting, ramp-up completion, end of operations, streamers, *etc.*).

The following information should be recorded upon visual observation of any marine mammal:

- Watch status (sighting made by PSO on/off effort, opportunistic, crew, alternate vessel/platform);
- PSO who sighted the animal;
- Time of sighting;
- Vessel location at time of sighting;
- Water depth;
- Direction of vessel's travel (compass direction);
- Direction of animal's travel relative to the vessel;
- Pace of the animal;
- Estimated distance to the animal and its heading relative to vessel at initial sighting;
- Identification of the animal (*e.g.,* genus/species, lowest possible taxonomic level, or unidentified) and the composition of the group if there is a mix of species;
- Estimated number of animals (high/low/best);
- Estimated number of animals by cohort (adults, yearlings, juveniles, calves, group composition, *etc.*);
- Description (as many distinguishing features as possible of each individual seen, including length, shape, color, pattern, scars or markings, shape and size of dorsal fin, shape of head, and blow characteristics);
- Detailed behavior observations (*e.g.,* number of blows/breaths, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible; note any observed changes in behavior);
- Animal's closest point of approach (CPA) and/or closest distance from any element of the acoustic source;
- Platform activity at time of sighting (*e.g.,* deploying, recovering, testing, shooting, data acquisition, other); and
- Description of any actions implemented in response to the sighting (*e.g.,* delays, shutdown, ramp-up) and time and location of the action.

Reporting

NSF must submit a draft comprehensive report to NMFS on all activities and monitoring results within 90 days of the completion of the survey or expiration of the IHA, whichever comes sooner. A final report must be submitted within 30 days following resolution of any comments on the draft report. The report would describe the operations that were conducted and sightings of marine mammals near the operations. The report would provide full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report would summarize the dates and locations of seismic operations, and all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities). The report would also include estimates of the number and nature of exposures that occurred above the harassment threshold based on PSO observations and including an estimate of those that were not detected, in consideration of both the characteristics and behaviors of the species of marine mammals that affect detectability, as well as the environmental factors that affect detectability.

The draft report shall also include geo-referenced time-stamped vessel tracklines for all time periods during which airguns were operating. Tracklines should include points recording any change in airgun status (*e.g.,* when the airguns began operating, when they were turned off, or when they changed from full array to single gun or vice versa). Geographic Information System (GIS) files shall be provided in Environmental Systems Research Institute (ESRI) shapefile format and include the Coordinated Universal Time (UTC) date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates shall be referenced to the WGS84 geographic coordinate system. In addition to the report, all raw observational data shall be made available to NMFS. The report must summarize the information submitted in interim monthly reports as well as additional data collected as described above and in the IHA. A final report must be submitted within 30 days following resolution of any comments on the draft report.

Reporting Injured or Dead Marine Mammals

Discovery of injured or dead marine mammals—In the event that personnel involved in survey activities covered by the authorization discover an injured or dead marine mammal, the NSF shall report the incident to the Office of Protected Resources (OPR), NMFS as soon as feasible. The report must include the following information:

- Time, date, and location (latitude/longitude) of the first discovery (and updated location information if known and applicable);
- Species identification (if known) or description of the animal(s) involved;
- Condition of the animal(s) (including carcass condition if the animal is dead);
- Observed behaviors of the animal(s), if alive;
- If available, photographs or video footage of the animal(s); and
- General circumstances under which the animal was discovered.

Vessel strike—In the event of a ship strike of a marine mammal by any vessel involved in the activities covered by the authorization, L–DEO shall report the incident to Office of Protected Resources (OPR), NMFS and to the NMFS West Coast Regional Stranding Coordinator as soon as feasible. The report must include the following information:

- Time, date, and location (latitude/longitude) of the incident;
- Vessel's speed during and leading up to the incident;
- Vessel's course/heading and what operations were being conducted (if applicable);
- Status of all sound sources in use;
- Description of avoidance measures/requirements that were in place at the time of the strike and what additional measure were taken, if any, to avoid strike;
- Environmental conditions (*e.g.,* wind speed and direction, Beaufort sea

state, cloud cover, visibility) immediately preceding the strike;

- Species identification (if known) or description of the animal(s) involved;
- Estimated size and length of the animal that was struck;
- Description of the behavior of the animal immediately preceding and following the strike;
- If available, description of the presence and behavior of any other marine mammals present immediately preceding the strike;
- Estimated fate of the animal (*e.g.,* dead, injured but alive, injured and moving, blood or tissue observed in the water, status unknown, disappeared); and To the extent practicable, photographs or video footage of the animal(s).

Negligible Impact Analysis and Determination

NMFS has defined negligible impact as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival (50 CFR 216.103). A negligible impact finding is based on the lack of likely adverse effects on annual rates of recruitment or survival (*i.e.,* population-level effects). An estimate of the number of takes alone is not enough information on which to base an impact determination. In addition to considering estimates of the number of marine mammals that might be ''taken'' through harassment, NMFS considers other factors, such as the likely nature of any responses (*e.g.,* intensity, duration), the context of any responses (*e.g.,* critical reproductive time or location, migration), as well as effects on habitat, and the likely effectiveness of the mitigation. We also assess the number, intensity, and context of estimated takes by evaluating this information relative to population status. Consistent with the 1989 preamble for NMFS's implementing regulations (54 FR 40338; September 29, 1989), the impacts from other past and ongoing anthropogenic activities are incorporated into this analysis via their impacts on the environmental baseline (*e.g.,* as reflected in the regulatory status of the species, population size and growth rate where known, ongoing sources of human-caused mortality, or ambient noise levels).

To avoid repetition, the discussion of our analysis applies to all the species listed in Table 2 given that the anticipated effects of this activity on these different marine mammal stocks are expected to be similar, except where a species- or stock-specific discussion is warranted. NMFS does not anticipate that serious injury or mortality would occur as a result from low-energy survey, even in the absence of mitigation, and no serious injury or mortality is proposed to be authorized. As discussed in the Potential Effects of Specified Activities on Marine Mammals and their Habitat section, non-auditory physical effects and vessel strike are not expected to occur. NMFS expects that all potential take would be in the form of Level B behavioral harassment in the form of temporary avoidance of the area or decreased foraging (if such activity was occurring), responses that are considered to be of low severity, and with no lasting biological consequences (*e.g.,* Southall *et al.,* 2007, 2021). These low-level impacts of behavioral harassment are not likely to impact the overall fitness of any individual or lead to population level effects of any species. As described above, Level A harassment is not expected to occur given the estimated small size of the Level A harassment zones.

In addition to being temporary, the maximum expected Level B harassment zone around the survey vessel is 1,089 m (and as much a 6,456 m for icebreaking activities). Therefore, the ensonified area surrounding the vessel is relatively small compared to the overall distribution of animals in the area and their use of the habitat. Feeding behavior is not likely to be significantly impacted as prey species are mobile and are broadly distributed throughout the survey area; therefore, marine mammals that may be temporarily displaced during survey activities are expected to be able to resume foraging once they have moved away from areas with disturbing levels of underwater noise. Because of the short duration (19 days) and temporary nature of the disturbance and the availability of similar habitat and resources in the surrounding area, the impacts to marine mammals and the food sources that they utilize are not expected to cause significant or long-term consequences for individual marine mammals or their populations.

NMFS does not anticipate that serious injury or mortality would occur as a result of NSF's proposed seismic survey, even in the absence of proposed mitigation. Thus, the proposed authorization does not authorize any serious injury or mortality. As discussed in the Potential Effects of Specified Activities on Marine Mammals and their Habitat section, non-auditory physical effects, stranding, and vessel strike are not expected to occur.

No takes by Level A harassment are proposed to be authorized. The 100-m EZ encompasses the Level A harassment isopleths for all marine mammal hearing groups, and is expected to prevent animals from being exposed to sound levels that would cause PTS. Also, as described above, we expect that marine mammals would be likely to move away from a sound source that represents an aversive stimulus, especially at levels that would be expected to result in PTS, given sufficient notice of the RVIB *Palmer's* approach due to the vessel's relatively low speed when conducting seismic survey. We expect that any instances of take would be in the form of short-term Level B behavioral harassment in the form of temporary avoidance of the area or decreased foraging (if such activity were occurring), reactions that are considered to be of low severity and with no lasting biological consequences (*e.g.,* Southall *et al.,* 2007).

Potential impacts to marine mammal habitat were discussed previously in this document (see Potential Effects of Specified Activities on Marine Mammals and their Habitat). Marine mammal habitat may be impacted by elevated sound levels, but these impacts would be temporary. Feeding behavior is not likely to be significantly impacted, as marine mammals appear to be less likely to exhibit behavioral reactions or avoidance responses while engaged in feeding activities (Richardson *et al.,* 1995). Prey species are mobile and are broadly distributed throughout the project area; therefore, marine mammals that may be temporarily displaced during survey activities are expected to be able to resume foraging once they have moved away from areas with disturbing levels of underwater noise. Because of the temporary nature of the disturbance, the availability of similar habitat and resources in the surrounding area, and the lack of important or unique marine mammal habitat, the impacts to marine mammals and the food sources that they utilize are not expected to cause significant or long-term consequences for individual marine mammals or their populations. In addition, there are no feeding, mating or calving areas known to be biologically important to marine mammals within the proposed project area.

As explained above in the Description of Marine Mammals in the Area of Specified Activities section, marine mammals in the survey area are not assigned to NMFS stocks. Therefore, we rely on the best available information on the abundance estimates for the species of marine mammals that could be taken.

The activity is expected to impact a very small percentage of all marine mammal populations that would be affected by NSF's proposed survey (approximately three percent or less each for all marine mammal populations where abundance estimates exist). Additionally, the acoustic ''footprint'' of the proposed survey would be very small relative to the ranges of all marine mammal species that would potentially be affected. Sound levels would increase in the marine environment in a relatively small area surrounding the vessel compared to the range of the marine mammals within the proposed survey area. The seismic array would be active 24 hours per day throughout the duration of the proposed survey. However, the very brief overall duration of the proposed survey (19 days) would further limit potential impacts that may occur as a result of the proposed activity.

The proposed mitigation measures are expected to reduce the number and/or severity of takes by allowing for detection of marine mammals in the vicinity of the vessel by visual observers, and by minimizing the severity of any potential exposures via ramp-ups and shutdowns of the airgun array.

Of the marine mammal species that are likely to occur in the project area, the following species are listed as endangered under the ESA: blue, fin, sei, and sperm whales. We are proposing to authorize very small numbers of takes for these species (Table 9), relative to their population sizes (again, for species where population abundance estimates exist), therefore we do not expect population-level impacts to any of these species. The other marine mammal species that may be taken by harassment during NSF's seismic survey are not listed as threatened or endangered under the ESA. There is no designated critical habitat for any ESA-listed marine mammals within the project area.

NMFS concludes that exposures of marine mammals due to NSF's proposed seismic survey would result in only short-term (temporary and short in duration) effects to individuals exposed. Marine mammals may temporarily avoid the immediate area, but are not expected to permanently abandon the area. Major shifts in habitat use, distribution, or foraging success are not expected. NMFS does not anticipate the proposed take estimates to impact annual rates of recruitment or survival.

In summary and as described above, the following factors primarily support our preliminary determination that the impacts resulting from this activity are not expected to adversely affect the species or stock through effects on annual rates of recruitment or survival:

(1) No mortality, serious injury or Level A harassment is anticipated or proposed to be authorized;

(2) The anticipated impacts of the proposed activity on marine mammals would primarily be temporary behavioral changes of small percentages of the affected species due to avoidance of the area around the survey vessel. The relatively short duration of the proposed survey (19 days) would further limit the potential impacts of any temporary behavioral changes that would occur;

(3) The availability of alternate areas of similar habitat value for marine mammals to temporarily vacate the survey area during the proposed survey to avoid exposure to sounds from the activity;

(4) The potential adverse effects of the proposed survey on fish or invertebrate species that serve as prey species for marine mammals would be temporary and spatially limited; and

(5) The proposed mitigation measures, including visual monitoring, ramp-ups, and shutdowns, are expected to minimize potential impacts to marine mammals.

Based on the analysis contained herein of the likely effects of the specified activity on marine mammals and their habitat, and taking into consideration the implementation of the proposed monitoring and mitigation measures, NMFS preliminarily finds that the total marine mammal take from the proposed activity would have a negligible impact on all affected marine mammal species or stocks.

Small Numbers

As noted above, only small numbers of incidental take may be authorized under sections 101(a)(5)(A) and (D) of the MMPA for specified activities other than military readiness activities. The MMPA does not define small numbers and so, in practice, where estimated numbers are available, NMFS compares the number of individuals taken to the most appropriate estimation of abundance of the relevant species or stock in our determination of whether an authorization is limited to small numbers of marine mammals. When the predicted number of individuals to be taken is fewer than one-third of the species or stock abundance, the take is considered to be of small numbers. Additionally, other qualitative factors may be considered in the analysis, such as the temporal or spatial scale of the activities.

The amount of take NMFS proposes to authorize is below one third of the estimated stock abundance for all species (in fact, take of individuals is less than ten percent of the abundance of the affected stocks, see Table 10). This is likely a conservative estimate because we assume all takes are of different individual animals, which is likely not the case. Some individuals may be encountered multiple times in a day, but PSOs would count them as separate individuals if they cannot be identified.

Based on the analysis contained herein of the proposed activity (including the proposed mitigation and monitoring measures) and the anticipated take of marine mammals, NMFS preliminarily finds that small numbers of marine mammals will be taken relative to the population sizes of the affected species.

Unmitigable Adverse Impact Analysis and Determination

There are no relevant subsistence uses of the affected marine mammal species or stocks implicated by this action. Therefore, NMFS has determined that the total taking of affected species or stocks would not have an unmitigable adverse impact on the availability of such species or stocks for taking for subsistence purposes.

Endangered Species Act (ESA)

Section 7(a)(2) of the Endangered Species Act of 1973 (ESA: 16 U.S.C. 1531 *et seq.*) requires that each Federal agency insure that any action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat. To ensure ESA compliance for the issuance of IHAs, NMFS consults internally whenever we propose to authorize take for endangered or threatened species.

We propose to authorize take of blue, fin, sei, and sperm whales, which are listed under the ESA, and have requested initiation of Section 7 consultation for the issuance of this IHA. NMFS will conclude the ESA consultation prior to reaching a determination regarding the proposed issuance of the authorization.

Proposed Authorization

As a result of these preliminary determinations, NMFS proposes to issue an IHA to NSF for conducting seismic survey and icebreaking in the Ross Sea, in January through February 2023, provided the previously mentioned mitigation, monitoring, and reporting requirements are incorporated. A draft of the proposed IHA can be found at *https://www.fisheries.noaa.gov/permit/incidental-take-authorizations-under-marine-mammal-protection-act.*

Request for Public Comments

We request comment on our analyses, the proposed authorization, and any other aspect of this Notice of Proposed IHA for the proposed low-energy marine geophysical survey and icebreaking activity in the Ross Sea. We also request at this time comment on the potential renewal of this proposed IHA as described in the paragraph below. Please include with your comments any supporting data or literature citations to help inform decisions on the request for this IHA or a subsequent Renewal.

On a case-by-case basis, NMFS may issue a one-year IHA renewal with an additional 15 days for public comments when (1) another year of identical or nearly identical activities as described in the Potential Effects of Specified Activities on Marine Mammals and their Habitat section of this notice is planned or (2) the activities as described in the Specified Activities section of this notice would not be completed by the time the IHA expires and a Renewal would allow for completion of the activities beyond that described in the *Dates and Duration* section of this notice, provided all of the following conditions are met:

(1) A request for renewal is received no later than 60 days prior to expiration of the current IHA.

(2) The request for renewal must include the following:

- An explanation that the activities to be conducted under the requested Renewal are identical to the activities analyzed under the initial IHA, are a subset of the activities, or include changes so minor (*e.g.,* reduction in pile size) that the changes do not affect the previous analyses, mitigation and monitoring requirements, or take estimates (with the exception of reducing the type or amount of take because only a subset of the initially analyzed activities remain to be completed under the Renewal).
- A preliminary monitoring report showing the results of the required monitoring to date and an explanation showing that the monitoring results do not indicate impacts of a scale or nature not previously analyzed or authorized.
- Upon review of the request for Renewal, the status of the affected species or stocks, and any other pertinent information, NMFS determines that there are no more than minor changes in the activities, the mitigation and monitoring measures will remain the same and appropriate, and the findings in the initial IHA remain valid.

Dated: September 22, 2022.

Kimberly Damon-Randall,

Director, Office of Protected Resources, National Marine Fisheries Service.

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