Request by the University of Alaska Geophysics Institute for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during Marine Geophysical Surveys by R/V *Sikuliaq* in the Arctic Ocean, Summer 2021

submitted by

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to

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SUMMARY

Researchers from the University of Alaska Geophysics Institute, with funding from the U.S. National Science Foundation (NSF), and in collaboration with researchers from the Geological Survey of Denmark and Greenland, propose to conduct low- and high-energy seismic surveys from the Research Vessel (R/V) *Sikuliaq* in the Arctic Ocean during summer 2021. The NSF-owned R/V *Sikuliaq* is operated by the College of Fisheries and Ocean Sciences at University of Alaska Fairbanks under an existing Cooperative Agreement. A small portion of the proposed seismic survey activity would occur within the Exclusive Economic Zone (EEZ) of the U.S.; most of the survey activity would take place in International Waters. The surveys would use a towed array of two or six 520 in^3 G-airguns with a maximum total discharge volume of ~3120 in^3, and would occur in water depths ranging from 200 to 4000 m. This request is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371(a)(5).

Numerous species of marine mammals could occur in or near the proposed project area in the Arctic Ocean. Under the U.S. Endangered Species Act (ESA), several of these species are listed as ***endangered***, including the bowhead whale, fin whale, Western North Pacific Distinct Population Segment (DPS) of gray whale, and Western North Pacific DPS of humpback whale. The ***threatened*** polar bear, Mexico DPS of humpback whale, Beringia DPS of the Pacific bearded seal, and Arctic subspecies of ringed seal could also occur in or near the survey area. The polar bear and walrus are marine mammal species mentioned in this document that, in the U.S., are managed by the U.S. Fish and Wildlife Service (USFWS); all others are managed by the National Marine Fisheries Service (NMFS). Although Alaskan fish populations are not listed under the ESA, there are several ESA-listed fish species that spawn on the west coast of the Lower 48 U.S. that could occur in Alaskan waters during the marine phases of their life cycles, including several ***endangered*** and ***threatened*** evolutionary significant units (ESUs) of chinook, chum, coho, and sockeye salmon.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests", are set forth below. They include descriptions of the specific operations to be conducted, the marine mammals occurring in the survey area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on those marine mammals.

I. OPERATIONS TO BE CONDUCTED

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

Overview of the Activity

The proposed study would use two-dimensional (2-D) seismic surveying to document the history, structure, and stratigraphy of the Chukchi Borderland and adjacent Canada Basin, and to use ocean bottom seismometer (OBS) seismic refraction data in the Canada Basin to characterize the deep crustal structure associated with an extinct mid-ocean ridge in the central basin. The proposed surveys would occur within ~73.5–81.0°N, ~139.5–168°W and ≥300 km from the Alaska coastline; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual tracklines, including order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above and within the study area shown in Figure 1. However, deviations in tracklines are expected to be limited and would not be expected to substantially affect the ensuing analysis. A small portion of the surveys are proposed to occur within the EEZ of the U.S., and the majority would occur in International Waters; depths within the study area range from 200 to 4000 m. The proposed surveys would be expected to last for 45 days, including ~30 days of seismic operations, ~8 days of transit to and from the survey area, and 7 days for equipment deployment/recovery. R/V *Sikuliaq* would likely leave out of and return to port in Nome, AK, during summer (August/September) 2021.

The main goal of the seismic program proposed by the University of Alaska is to map the northern edge in the Chukchi Borderland and the adjacent Canada Basin. To achieve the project goals, the Principal Investigator (PI) Dr. B. Coakley proposes to utilize 2-D seismic reflection and OBS seismic refraction capabilities to address the following objectives:

1. Reveal the crustal structure of the Northern Chukchi Borderland, an extinct mid-ocean ridge and the adjacent extended continental crust.
2. Establish relations between continental Chukchi Borderland and transitional and oceanic crust in the Canada Basin.
3. Identify continuation of the mid-ocean ridge.
4. Link up lines collected by Canada for their Extended Continental Shelf program.
5. Sample distinct pieces of seafloor that have not previously been observed.
6. Image sites for proposed scientific ocean drilling.
7. Gather information that could be useful for a U.S. claim of an extended continental shelf for seabed resources under Article 76 of the Law of the Sea.

Although not funded through NSF, collaborator Dr. J.R. Hopper (Geological Survey of Denmark and Greenland), would work with the PI to achieve the research goals, providing assistance such as through logistical support, data acquisition, processing, and exchange. Some NSF funding would provide support for international engineer participation and equipment use.

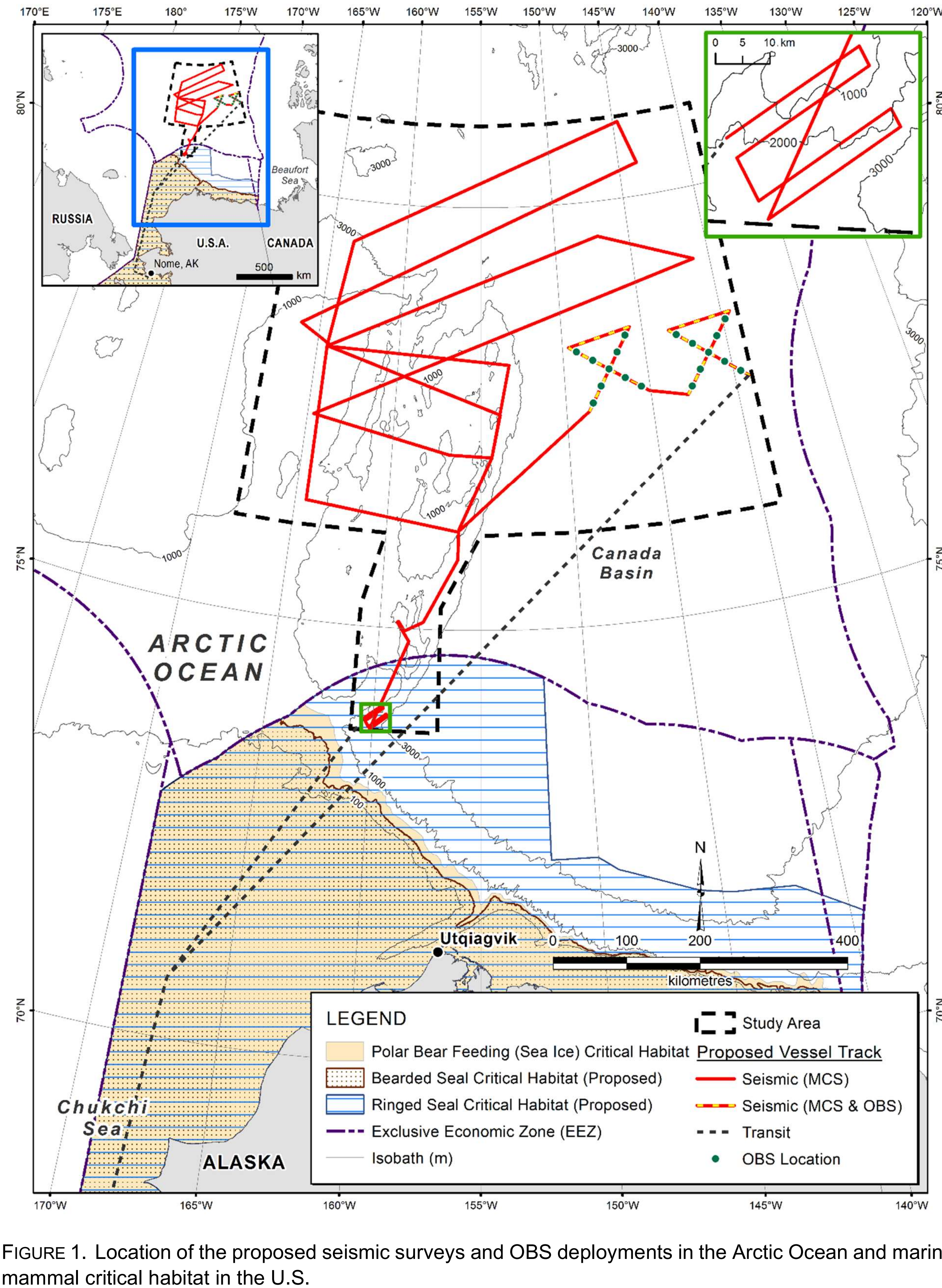

FIGURE 1. Location of the proposed seismic surveys and OBS deployments in the Arctic Ocean and marine mammal critical habitat in the U.S.

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous NSF-funded surveys and would use conventional seismic methodology. The survey would involve one source vessel, R/V *Sikuliaq*, which would tow an array with up to 6 G-airguns (520 in^3 each) and a total possible discharge volume of ~3120 in^3 at a depth of 9 m. During low-energy multi-channel seismic (MCS) reflection surveys, a 2-airgun array would be used with a total discharge volume of 1040 in^3, and a high-energy 6-airgun, 3120 in^3, array would be employed during OBS refraction surveys. During MCS surveys (~88% of total line km), a 1–3 km long hydrophone streamer (depending on ice conditions) would be employed as the receiving system, and refraction surveys (~12% of total line km) would employ nine OBS as the receiving system. As the airgun arrays are towed along the survey lines, the OBSs would receive and store the returning acoustic signals internally for later analysis, and the hydrophone streamer would transfer the data to the on-board processing system. The airguns would fire at a shot interval of 35 m (~15 s) during MCS surveys and at a 139-m (~60 s) interval during OBS refraction surveys.

In addition to numerous MCS transect lines, some lines would be acquired twice – once for MCS reflection and again for OBS refraction surveys. These MCS/OBS surveys would take place near the end of operations in the northeastern part of the survey area (Fig. 1); however, the location of these surveys could shift slightly to ensure one survey occurs over the extinct ridge axis and the other on hyper-extended continental crust. A total of nine OBSs would be deployed twice for a total of 18 deployment sites. Nine OBSs would be deployed while MCS data would be acquired between OBS drops, then OBS refraction data would be acquired along these same lines, followed by retrieval of the OBSs, before R/V *Sikuliaq* would travel to the next site to deploy all nine OBSs again. Approximately 5850 line km would be surveyed, including 5170 km of MCS surveys, and 680 km of OBS surveys. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the calculations (see § VII), 25% has been added in the form of operational days, which is equivalent to adding 25% to the proposed line km to be surveyed. Most of the survey (80%) would occur in deep water (>1000 m), and 20% would occur in intermediate water (100–1000 m deep); there would be no effort in shallow water <100 m deep.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), sub-bottom profiler (SBP), and Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Sikuliaq* during the seismic surveys. All planned geophysical data acquisition activities would be conducted by the University of Alaska with on-board assistance by the scientists and engineers who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

Vessel Specifications

R/V *Sikuliaq* has a length of 80 m, a beam of ~16 m, and a draft of ~6 m. The ship has diesel-electric engine with 5750 bhp, and can break through ice up to 1 m thick. The cruising speed is 10 kt, and the range is 18,000 n.mi. with an endurance of 45 days. The vessel speed during seismic operations would be ~4.5 kt (~8.3 km/h).

Other details of R/V *Sikuliaq* include the following:

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

Airgun Description

During the surveys, R/V *Sikuliaq* would tow up to 6 G-airguns. During MCS surveys, 2 G-airguns with a total discharge volume of 1040 in^3 would be used; during OBS surveys, a 6-airgun 3120 in^3 array would be employed. Various airgun arrays were described in § 2.2.3.1 of the PEIS. The array would be towed at a depth of 9 m, and the shot interval would be 35 m (~15 s) during MCS surveys, 139 m (60 s) during refraction surveys.

Predicted Sound Levels

Mitigation zones for the proposed marine seismic surveys were not derived from the farfield signature, but based on modeling by Lamont-Doherty Earth Observatory (L-DEO) of Columbia University for the exclusion zones (EZ) for Level A takes and for the Level B (160 dB re 1µPa_{rms}) threshold. The background information and methodology for this are provided in Appendix A. The proposed surveys would acquire MCS data with a 2 G-airguns and OBS refraction data with a 6 G-airgun array, at a maximum tow depth of 9 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the airgun arrays at a 9-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. Table 1 shows the distances at which the 160-dB re 1µPa_{rms} sound levels are expected to be received for the 2- and 6-airgun arrays. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW; polar bears and walrus fall within this hearing group) (NMFS 2016a, 2018). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances for marine mammals. Here, SEL_{cum} is used for LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups for the 2 G-airguns (Table 2) and 6 G-airguns (Table 3).

This document has been prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For other recent NSF-funded, high-energy seismic surveys, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for shut downs and to monitor an additional 500-m buffer zone beyond the EZ. Enforcement of mitigation zones via shut downs would be implemented as described below. Enforcement of mitigation zones via shut downs would be implemented as described in § XI.

OBS Description and Deployment

Nine OBSs would be deployed at two sites within the Canada Basin in the northeastern portion of the survey area (Fig. 1). The OBSs would be deployed 25 km apart along two lines; after seismic acquisition at the first site, they would be retrieved and redeployed at the second site. The OBSs used would be Sercel MicrOBS. OBSs have a height and diameter of ~1 m and an anchor weighing ~80 kg. All OBSs would be recovered upon conclusion of the survey.

TABLE 1. Level B. Predicted distances to which sound levels ≥160-dB could be received during the proposed surveys in the Arctic Ocean. The 160-dB criterion applies to all hearing groups of marine mammals.

Source and Volume[1]	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level
Two 520 in^3 G-airguns, 1040 in^3	9	>1000 m	1604[2]
		100–1000 m	2406[3]
Six 520 in^3 G-airguns, 3120 in^3	9	>1000 m	4640[2]
		100–1000 m	6960[3]

[1] Modeled at 2540 psi.
[2] Distance is based on L-DEO model results.
[3] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

TABLE 2. Level A threshold distances for different marine mammal hearing groups for the 2 G-airguns and shot interval of 15 s. Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds and other Non-phocid Carnivores
PTS SEL_{cum}	**17.2**	0	0	0.2	0
PTS Peak	10.3	**2.9**	**72.8**	**11.6**	**2.3**

TABLE 3. Level A threshold distances for different marine mammal hearing groups for the 6 G-airguns and a shot interval of 60 s. Consistent with NMFS (2016a, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups				
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds and other Non-phocid Carnivores
PTS SEL_{cum}	**50.6**	0	0	0.4	0
PTS Peak	29.8	**7.2**	**211.5**	**33.6**	**5.1**

Description of Operations

The procedures to be used for the proposed surveys would be similar to those used during other recent NSF-funded, high-energy seismic surveys, and would use conventional seismic methodology. The surveys would involve one source vessel, R/V *Sikuliaq*, which is owned by NSF and operated on its behalf by the College of Fisheries and Ocean Sciences at University of Alaska Fairbanks under an existing Cooperative Agreement. R/V *Sikuliaq* would deploy a towed array of two or six 520 in^3 G-airguns with a maximum total discharge volume of ~3120 in^3. The receiving system would consist of a 1–3 km long hydrophone streamer and nine OBSs.

As the airgun arrays are towed along the survey lines, the OBSs would receive and store the returning acoustic signals internally for later analysis, and the hydrophone streamer would transfer the data to the on-board processing system. Approximately 5850 km of transect lines would be surveyed. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the take calculations, 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. Most of the survey (80%) would occur in deep water (>1000 m), and 20% would occur in intermediate water (100–1000 m deep); there would be no effort in shallow water <100 m deep.

In addition to the operations of the airgun array, the ocean floor would be mapped with the Kongsberg EM 302 MBES and a Kongsberg TOPAS PS-18 SBP. A Teledyne RDI Ocean Surveyor ADCP that operates at frequencies of 75 kHz and 150 kHz would be used to measure water current velocities. Similar sound sources are described in § 2.2.3.1 of the PEIS. To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 10–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor which is not retrieved.

II. Dates, Duration, and Region of Activity

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

The proposed surveys would occur within ~73.5–81.0°N, ~139.5–168°W, ≥300 km north of Utqiaġvik; representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, subsistence, or mechanical issues with the research vessel and/or equipment. Thus, the tracklines could occur anywhere within the coordinates noted above and within the study area shown in Figure 1. The surveys are proposed to occur within the EEZ of the U.S. and in International Waters, ranging in depth from 200 to 4000 m. The proposed surveys would be expected to last for 45 days, including ~30 days of seismic operations, ~8 days of transit to and from the survey area, and 7 days for equipment deployment/recovery. R/V *Sikuliaq* would likely leave out of and return to port in Nome, AK, during late summer (August/September) 2021. The ensuing analysis focuses on the time of the survey (summer); the best available species densities for that time of year have been used.

III. Species and Numbers of Marine Mammals in Area

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

A total of nine cetacean species, five species of pinnipeds, and one marine fissiped could occur in or near the proposed study area (Table 4).

TABLE 4. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed study area in the Arctic Ocean.

Species	Occurrence in Area*	Habitat	Regional Abundance	ESA[1]	IUCN[2]	CITES[3]
Mysticetes						
Bowhead whale *Balaena mysticetus*	Uncommon	Pack ice, coastal	16,820[4] 27,133[5]	EN	LC	I
Gray whale *Eschrichtius robustus*	Rare	Coastal, lagoons	26,960[6]	DL/EN[25]	LC	I
Humpback whale *Megaptera novaeangliae*	Rare	Shelf, coastal	10,103[7] 1,107[8]	T/EN[26]	LC	I
Common minke whale *Balaenoptera acutorostrata scammoni*	Rare	Shelf, coastal	20,000[9]	NL	LC	I
Fin whale *Balaenoptera physalus physalus*	Rare	Slope, mostly pelagic	13,620-18,680[10]	EN	VU	I
Odontocetes						
Beluga whale *Delphinapterus leucas*	Common	Offshore, coastal, ice edges	20,752[11] 39,258[12]	NL	LC	II
Narwhal *Monodon monoceros*	Rare	Offshore, ice edges	N.A.[13]	NL	LC	II
Killer whale *Orcinus orca*	Rare	Widely distributed	2,347[14] 587[15]	NL	DD	II
Harbor porpoise *Phocoena phocoena vomerina*	Rare	Coastal, inland waters, shallow offshore waters	48,215[16]	NL	LC	II
Pinnipeds						
Pacific walrus *Odobenus rosmarus divergens*	Uncommon	Coastal, pack ice, ice floes	129,000[17]	NL	DD	III
Bearded seal *Erignathus barbatus nauticus*	Uncommon	Pack ice, open water	125,000[18] 301,836[19]	T	LC	–
Spotted seal *Phoca largha*	Uncommon	Pack ice, open water, coastal haulouts	461,625[19]	NL	LC	–
Arctic ringed seal *Phoca (pusa) hispida*	Common	Landfast ice, pack ice, open water	171,418[19] 119,000[18] 300,000[20] 208,000[21]	T	LC	–
Ribbon seal *Histriophoca fasciata*	Uncommon	Pack ice, open water	184,697[19]	NL	LC	–
Marine Fissiped						
Polar bear *Ursus maritimus*	Uncommon	Pack ice	2937[22]; 980[23]; 907[24]	T	VU	II

N.A. = not available. * Based on literature and professional judgement. [1] U.S. Endangered Species Act (ESA; NOAA 2021a): EN = Endangered, T = Threatened, NL = Not listed, DL = Delisted. [2] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2020); EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient. [3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2020): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled; Appendix III: protected in at least one country, which has asked other CITES Parties for assistance in controlling the trade. [4] Western Arctic stock based on 2011 aerial surveys (Givens et al. 2016 *in* Muto et al. 2020). [5] Western Arctic stock based on 2011 photo-identification data (Givens et al. 2018 in Muto et al. 2020). [6] Eastern North Pacific population (Durban et al. 2017 *in* Carretta et al. 2020); Western North Pacific population is estimated at 290 animals (Carretta et al. 2020). [7] Central North Pacific stock (Muto et al. 2020). [8] Western North Pacific stock (Muto et al. 2020). [9] Northwest Pacific and Okhotsk Sea (IWC 2021). [10] North Pacific (Ohsumi and Wada 1974). [11] Eastern Chukchi Sea stock (Muto et al. 2020). [12] Beaufort Sea stock (Muto et al. 2020). [13] Baffin Bay and Canadian Arctic archipelago population (COSEWIC 2004). [14] Alaska Resident stock (Muto et al. 2020). [15] Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock (Muto et al. 2020). [16] Bering Sea stock (Muto et al. 2020). [17] 129,000 with a 95% CV of 55,000-507,000 (Speckman et al. 2011 *in* Muto et al. 2020). [18] 2013 estimate for U.S. portion of the Bering Sea (Boveng et al. 2017). [19] Alaska stock based on limited sub-sample from the Bering Sea (Conn et al. 2014 *in* Muto et al. 2020). [20] Chukchi and Beaufort seas (Kelly et al. 2010a). [21] Chukchi Sea (Bengtson et al. 2005). [22] Chukchi Sea population (IUCN/SCC PBSG 2020). [23] Northern Beaufort Sea population (IUCN/SCC PBSG 2020). [24] Southern Beaufort Sea population (IUCN/SCC PBSG 2020). [25] Although the Eastern North Pacific DPS was delisted under the ESA, the Western North Pacific DPS is listed as endangered. [26] The Western North Pacific DPS and Central America DPS are listed as endangered, and the Mexico DPS is listed as threatened; the Hawaii DPS is not at risk.

The marine mammals that could be encountered in the proposed survey area belong to three taxonomic groups: odontocetes (toothed cetaceans, such as beluga whale), mysticetes (baleen whales), and carnivora (pinnipeds and polar bears). Four of these species/populations, including the bowhead whale, fin whale, Western North Pacific DPS of gray whale, and Western North Pacific DPS of humpback whale are listed as ***endangered*** under the ESA. The ***threatened*** polar bear, Mexico DPS of humpback whale, Beringia DPS of bearded seal, and Arctic subspecies of ringed seal could also occur in or near the survey area. Cetaceans and pinnipeds (except walrus) are the subject of the IHA Application to NMFS; in the U.S., the walrus and polar bear are managed by USFWS.

The marine mammal species most likely to be encountered during the seismic survey include the beluga whale and ringed seal. The bowhead whale and bearded seal likely occur in low numbers and are most common within 100 km of shore, where no seismic work is proposed. Seven additional cetacean species—narwhal, killer whale, harbor porpoise, gray whale, minke whale, fin whale, and humpback whale—could potentially occur in the project area but are unlikely to be encountered during the survey because they are primarily coastal species or rare because they are outside of their normal range in the survey area in the Arctic Ocean. Nonetheless, these seven species have been included here for the sake of completeness. The gray whale is a coastal species that occurs regularly in continental shelf waters along the Chukchi Sea coast in summer and to a lesser extent along the Beaufort Sea coast. Monitoring activities in the Chukchi and Beaufort seas during industry seismic surveys suggest that the harbor porpoise, also a coastal species, and the minke whale, both of which have been considered uncommon or rare in the Chukchi and Beaufort seas, may be increasing in numbers in these areas (e.g., Funk et al. 2010). Similarly, Brower et al. (2018) also noted that sightings of sub-Arctic species like minke, fin, and humpback whales are increasing in the eastern Chukchi Sea. Small numbers of killer whales have also been recorded during industry surveys in the Chukchi Sea, along with a few sightings of fin and humpback whales. The narwhal occurs in Canadian waters and occasionally in the Beaufort Sea, but is rare there and not expected to be encountered. It is very unlikely that a North Pacific right, blue, or sei whale would be encountered during the survey, although one sei whale was seen during U.S. Navy (2019) research activities on 9 September 2019 just south of the survey area at 74.1°N, 166.5°W; these three species are not discussed further.

In addition to ringed and bearded seals, other pinniped species that could be encountered during the proposed survey include the spotted seal, ribbon seal, and Pacific walrus. Spotted seals are more abundant in the Chukchi Sea and occur in small numbers in the Beaufort Sea. The ribbon seal is uncommon in the Chukchi Sea, and there are few sightings in the Beaufort Sea. The Pacific walrus is common in the Chukchi Sea but uncommon in the Beaufort Sea, and not likely to occur in the far offshore waters of the proposed survey area in the Arctic Ocean. None of these species would likely be encountered during the proposed cruise other than perhaps during transit periods to or from the survey area. Polar bears occur on the pack ice in low densities. As the vessel will avoid the ice edge, it is unlikely that polar bears would be encountered in the open-water study area.

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in § IV, below.

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

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

Sections III and IV are integrated here to minimize repetition. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. The rest of this section deals specifically with species distribution in the proposed survey area.

Mysticetes

Bowhead Whale (*Balaena mysticetus*)

The bowhead whale has a disjunct circumpolar distribution in arctic and subantarctic waters (Jefferson et al. 2015). Of four stocks recognized worldwide by the International Whaling Commission (IWC), the Bering-Chukchi-Beaufort (BCB) stock is the only one that could occur in the proposed survey area. The BCB stock winters in the central and western Bering Sea and summers in the Canadian Beaufort Sea and Amundsen Gulf (Moore and Reeves 1993; Quakenbush et al. 2018). However, some individuals spend the entire summer in the Chukchi Sea (Citta et al. 2012; Quakenbush et al. 2018). The eastern Bering Strait has been shown to be a Biologically Important Area (BIA) for the spring northbound migration in March–June (Ferguson et al. 2015a). Spring migration through the western Beaufort Sea occurs through offshore ice leads, generally from mid-April through mid-June (Braham et al. 1984; Moore and Reeves 1993).

The whales make the return migration west through the Alaskan Beaufort Sea in the fall to wintering areas in the Bering Sea. Some bowhead whales continue migrating west past Utqiaġvik (formerly Barrow) and through the Chukchi Sea to Russian waters before turning south toward the Bering Sea (Quakenbush 2007; Citta et al. 2018a). Some bowheads may reach ~75°N latitude during the westward fall migration (Quakenbush et al. 2010a; Citta et al. 2018a). Other researchers have also reported a westward movement of bowhead whales through the northern Chukchi Sea during fall migration (Moore et al. 1995, 2000a; Mate et al. 2000). Fall migration into Alaskan waters is primarily during September and October; westbound bowheads typically reach the Utqiaġvik area in mid-September (e.g., Brower 1996). However, small numbers of bowheads have been seen or heard offshore from the Prudhoe Bay region and seen near Utqiaġvik in August (e.g., Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999, 2007; Blackwell et al. 2004, 2010; Huntington and Quakenbush 2009).

Bowheads tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice (Moore 2000; Treacy et al. 2006). Treacy et al. (2006) found that the migration corridor ranges from ~30 km offshore during light ice years to ~80 km offshore during heavy ice years; sighting rate tends to be lower in heavy ice years (Treacy 1997). During fall migration, most bowheads migrate west in water ranging from 15 to 200 m deep over the continental shelf (Miller et al. 2002). Some individuals enter shallower water, particularly in light ice years, but very few whales are ever seen shoreward of the barrier islands in the Alaskan Beaufort Sea. Clarke et al. (2016) reported that there was no defined migratory corridor in the Chukchi Sea, and that bowheads occurred up to 300 km offshore to the west and southwest of Point Barrow. Migratory corridor BIAs have been described for the Bering Strait to the eastern Beaufort Sea during the spring migration, and along the northern Alaskan coast from Point Barrow eastward, during the fall migration (Clarke et al. 2015).

Citta et al. (2015, 2018b) reported concentration areas for bowhead whales off Point Barrow and in the eastern Beaufort Sea during summer. Similarly, based on the Aerial Survey of Arctic Marine Mammals (ASAMM), Schick et al. (2017) also reported high densities of bowheads off Point Barrow and the Beaufort Sea during summer and into October. Additionally, Kuletz et al. (2015) reported hot spots in the same areas during summer and fall. Several areas in the nearshore waters of the Beaufort Sea have been identified as reproduction BIAs from spring through fall, based on calf sightings in the region (Clarke et al. 2015). The location and size of the BIA changes depending on the season. During spring, the BIA is located off Point Barrow; during July and August, it is located in the eastern Beaufort Sea; during September, a BIA has been identified from Point Barrow eastward; and during October, the BIA spans from west of Point Barrow all the way eastward along the Alaska coast (Clarke et al. 2015). The feeding BIAs change during the seasons as well, with a BIA located near Barrow Canyon in spring, within the 20-m isobath from Point Barrow to Smith Bay (just to the east) during August through October, and within the 50-m isobath all along the northern Alaska coast spanning from Point Barrow eastward, during the westward fall migration in September and October (Clarke et al. 2015).

Densities just south of the proposed survey area are likely to be low (Schick et al. 2017); they are also expected to be low throughout the proposed survey area. However, bowhead whales have been tracked near the southern portion of the survey area and likely forage there (Quakenbush et al. 2018; Citta et al. 2018a). Bowhead whales were not reported by vessel-based observers during cruises in the Arctic Ocean north of Utqiaġvik in August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). No bowhead whales were seen during surveys north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). However, there are several records of bowhead whales in the OBIS database for 75°N, 154°W, as well as four records at 73.2°N (OBIS 2021). Sekiguchi et al. (2008) reported one sighting of an aggregation of ~30 bowheads during vessel-based operations ~130 km north of Cape Lisburne on 9 August 2007. One bowhead whale that was satellite-tagged in Utqiaġvik on 23 September 2008 traveled 330 km northwest of Utqiaġvik (~73°N; 163°W), south of the proposed survey area, in water ~200 m deep (Quakenbush et al. 2010a). Another whale tagged in late August 2007 traveled northwest (~75°N; 176°W), where water depth was 600 m (Quakenbush et al. 2010a). One whale tagged in the fall of 2009 traveled as far as ~76°N; 179°W, west of the proposed survey area (Quakenbush et al. 2010b). Given the telemetry data (Quakenbush et al. 2010a,b) and OBIS records (OBIS 2021), some bowheads could be encountered during the proposed survey in the Arctic Ocean.

Gray Whale (*Eschrichtius robustus*)

Two separate populations of gray whales are recognized in the North Pacific: the eastern North Pacific DPS and western North Pacific (or Korean-Okhotsk) DPS (LeDuc et al. 2002; Weller et al. 2013). However, the distinction between these two populations has been recently debated owing to evidence that whales from the western feeding area also travel to breeding areas in the eastern North Pacific (Weller et al. 2012, 2013; Mate et al. 2015). Thus, it is possible that whales from either the U.S. ESA-listed ***endangered*** Western North Pacific DPS or the delisted Eastern North Pacific DPS could occur near the proposed survey area. Based on communications with NMFS, it is assumed that 0.1% of gray whales could be from the endangered Western North Pacific DPS (NMSF pers. comm. based on Carretta et al. 2019, 2020).

The western population is known to feed in the Okhotsk Sea along the northeast coast of Sakhalin Island (Weller et al. 1999, 2002a, 2008), eastern Kamchatka, and the northern Okhotsk Sea in the summer and autumn (Vladimirov et al. 2008). Winter breeding grounds are not known; however, it has been postulated that wintering areas occur along the south coast of the Korean Peninsula, but it is more likely that they are located in the South China Sea, along the coast of Guangdong province and Hainan

(Wang 1984 and Zhu 1998 *in* Weller et al. 2002a; Rice 1998). If migration timing is similar to that of the better-known eastern gray whale, southbound migration probably occurs mainly in December–January and northbound migration mainly in February–April, with northbound migration of newborn calves and their mothers probably concentrated at the end of that period.

Eastern Pacific gray whales breed and calve in the protected waters along the west coast of Baja, California, and the east coast of the Gulf of California from January to April (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the breeding and calving season, most of these gray whales migrate ~8000 km, generally along the west coast, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957; Rice and Wolman 1971; Braham 1984; Nerini 1984; Moore et al. 2003; Bluhm et al. 2007). Most summering gray whales congregate in the northern Bering Sea, particularly off St. Lawrence Island and in the Chirikov Basin (Moore et al. 2000b) and in the southern Chukchi Sea. However, Moore et al. (2003) suggested a decrease in gray whale use of Chirikov Basin, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower quality food. The Chirikov Basin and St. Lawrence Island have been described to be feeding BIAs for gray whales from May through November (Ferguson et al. 2015a). The northeastern-most of the recurring gray whale feeding areas is in the northeastern Chukchi Sea southwest of Utqiaġvik (Clarke et al. 1989); this region as well as others in the northeastern Chukchi Sea have also been identified as summer feeding BIAs (Clarke et al. 2015). Areas in the northeastern Chukchi Sea have also been reported as reproduction BIAs during June through September (Clarke et al. 2015). The Chirikov Basin and Bering Strait are also considered a northbound migratory corridor BIA, in particular from June through December (Ferguson et al. 2015a).

Moore et al. (2000a) reported that during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. In autumn, gray whales were clustered near shore at Point Hope and between Icy Cape and Point Barrow, and in offshore waters northwest of Point Barrow at Hanna Shoal and southwest of Point Hope. Citta et al. (2018b) also reported concentration areas in the central Chukchi Sea and southwest of Point Barrow during May–November. Similarly, Schick et al. (2017) noted high densities southwest of Point Barrow during summer and early fall, but very low densities near the southern parts of the proposed survey area. Kuletz et al. (2015) also noted hot spots of gray whales in those areas. Based on aerial surveys of nearshore waters of the eastern Chukchi Sea, Thomas et al. (2010) reported that gray whale sighting rates and abundance were greater in the 0–5 km offshore band in 2006, and in the 25–30 km band in 2007 and 2008; they suggested that the difference in distribution may have been attributable to differences in food availability and perhaps ice conditions. Clarke et al. (2016) found that in the northeastern Chukchi Sea, gray whales primarily occur within 95 km from shore, whereas in the southern Chukchi Sea, they occur ~60–115 km

Only a small number of gray whales enter the Beaufort Sea east of Point Barrow. Over the years, ice conditions have become lighter near Utqiaġvik, and gray whales may have become more common. Several gray whale sightings were reported during both vessel-based and aerial surveys in the Beaufort Sea during 2006–2010 (Funk et al. 2011) and by Beland and Ireland (2010) in 2010. Several single gray whales have been seen farther east in the Canadian Beaufort Sea (e.g., Rugh and Fraker 1981), indicating that small numbers must travel through the Alaskan Beaufort during some summers. However, no gray whales were sighted during cruises north of Utqiaġvik in 2002, August–September 2005, July–August 2006, or August–September 2009 (Harwood et al. 2005; Haley 2006; Haley and Ireland 2006; Mosher et al. 2009). Similarly, no gray whales were seen during surveys north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). In the OBIS database, there are >1000 gray whale records for the Chukchi Sea and ~30 for the Beaufort Sea; no records were reported north of 73°N (OBIS 2021). Given that most gray

whales are typically seen nearshore, and the seismic survey is proposed to occur far offshore, few gray whales, if any, are expected to be in the region at the time of the proposed survey.

NOAA (2021b) declared an unusual mortality event (UME) for gray whales for 2019–2021, as an elevated number of strandings have occurred along the west coast of North America from Mexico to Alaska since January 2019. As of 31 December 2020, a total of 386 strandings have been reported in 2019 and 2020, including 201 in the U.S. (93 in Alaska); some of the whales were emaciated. UMEs for gray whales were also declared in 1999 and 2000 (NOAA 2021b).

Humpback Whale (*Megaptera novaeangliae*)

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

North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008; Bettridge et al. 2015). Humpbacks winter in four different breeding areas: (1) the coast of Mexico; (2) the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). There is potential for mixing of the western and eastern North Pacific humpback populations on their summer feeding grounds, but several sources suggest that this occurs to a limited extent (Muto et al. 2020). According to Muto et al. (2020), NMFS is currently reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (NMFS 2016b). Individuals that may be encountered in the Arctic Ocean would most likely be from the Hawaii, Mexico, or Western North Pacific DPSs (Calambokidis et al. 2008; Wade 2017). According to Wade (2017), 87% of humpbacks occurring in the Aleutian Islands and Bering Sea are likely from the Hawaii DPS, whereas 11% are from the Mexico DPS, and 2% are from the Western North Pacific DPS.

During summer, most eastern North Pacific humpback whales are on feeding grounds in Alaska, with smaller numbers summering off the U.S. west coast and B.C. (Calambokidis et al. 2001, 2008). Currently, two stocks of humpback whales are recognized as occurring in Alaskan waters. The Central North Pacific Stock occurs from Southeast Alaska to the Alaska Peninsula, and the Western North Pacific Stock occurs from the Aleutians to the Bering Sea and Russia. These two stocks overlap on feeding grounds in the eastern Bering Sea and the western Gulf of Alaska (Muto et al. 2020), where several feeding BIAs have been designated (Ferguson et al. 2015a,b). Critical habitat has also been proposed for the humpback whale in the Bering Sea, Gulf of Alaska, and southeast Alaska (NMFS 2019a).

In the Bering Sea, humpback whales have been sighted southwest of St. Lawrence Island, in the southeastern Bering Sea, and north of the central Aleutian Islands (Moore et al. 2002; Muto et al. 2020). There have also been sightings in the Chukchi Sea and a single sighting in the Beaufort Sea (Greene et al. 2007; Haley et al. 2010; Funk et al. 2011; Brower et al. 2018). Haley et al (2010) reported three humpback whales during vessel-based surveys in the Chukchi Sea in 2007 and one sighting in 2008. Funk et al. (2011) reported 7 sightings of 11 humpbacks during surveys in 2006–2010. A humpback whale sighting was also made during the 2009 Chukchi Offshore Monitoring in Drilling Area (COMIDA) aerial surveys (Clarke et al. 2011). Greene et al. (2007) reported and photographed a humpback whale cow/calf pair east of

Utqiaġvik near Smith Bay in 2007. No humpback whales were reported during cruises in the Arctic Ocean north of Utqiaġvik in August–September 2005, July–August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010) or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There are 56 humpback records in the OBIS database for the Chukchi Sea; no records occurred north of 71°N (OBIS 2021). Humpback whales could occur in the Chukchi Sea and possibly in the Beaufort Sea but would be unlikely to occur in the offshore waters of the proposed survey area in the Arctic Ocean.

Common Minke Whale (*Balaenoptera acutorostrata scammoni*)

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring and summer and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move south to within 2º of the Equator (Perrin et al. 2018).

The IWC recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). Minke whales are relatively common in the Bering Sea and Gulf of Alaska (Brueggeman et al. 1990). Sightings are also thought to be increasing in the Chukchi Sea (Brower et al. 2018). In the far north, minke whales are likely to be migratory, but they are believed to be year-round residents in nearshore waters off west coast of the U.S. (Dorsey et al. 1990).

During vessel-based surveys in the Chukchi Sea during 2006–2010, 48 sightings of 59 minke whales were made (Funk et al. 2011). Brueggeman (2009) and Aerts et al. (2013) reported sightings of single minke whales in the northeastern Chukchi Sea in 2008. Savarese et al. (2010) reported one minke whale in the Beaufort Sea during vessel-based operations in 2007. However, no minke whales were sighted during cruises in the Arctic Ocean north of Utqiaġvik in August–September 2005, July–August 2006, August–September 2009, August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010) or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There are 14 records of minke whales in the OBIS database for the Chukchi Sea; none were reported north of 71°N (OBIS 2021). Minke whales sometimes occur in areas with minimal ice cover, but it is unlikely that they would be encountered during the proposed survey in the Arctic Ocean.

Fin Whale (*Balaenoptera physalus physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). A review of fin whale distribution in the North Pacific noted the lack of sightings across pelagic waters between eastern and western winter areas (Mizroch et al. 2009). Fin whales most commonly occur offshore, but can also be found in coastal areas (Jefferson et al. 2015).

Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar and García-Vernet 2018). Some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The northern and southern fin whale populations likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales

tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015).

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985); they typically do not range into the Alaskan Beaufort Sea or waters of the northern Chukchi Sea. A feeding BIA has been identified in the Bering Sea, with highest densities from June through September (Ferguson et al. 2015a). Four fin whales were sighted in the Chukchi Sea in 2008 (Haley et al. 2010). Funk et al. (2011) reported three sightings of six fin whales during surveys in the Chukchi Sea during 2006–2010. Clarke et al. (2011) also reported a fin whale off Point Lay in 2008 during the COMIDA aerial surveys. Acoustic detections of fin whales in the Chukchi Sea have been made from July to November (Delarue et al. 2013; Tsujii et al. 2016). Fin whales were not recorded during vessel-based or aerial surveys in the Beaufort Sea in 2006–2008 (Funk et al. 2010) and were not sighted during surveys in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010), or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There are six records in the OBIS database for the Chukchi Sea (OBIS 2021). Fin whales likely would not be encountered in the proposed survey area in the Arctic Ocean.

Odontocetes

Beluga (*Delphinapterus leucas*)

The beluga whale is an arctic and subarctic species with a circumpolar distribution in the Northern Hemisphere, occurring between 50º and 80ºN (Reeves et al. 2002). It is distributed in seasonally ice-covered seas and migrates to warmer coastal estuaries, bays, and rivers in summer for molting (Finley 1982). Of five distinct beluga stocks recognized in Alaska (O'Corry-Crowe et al. 1997), only the Beaufort Sea and Eastern Chukchi Sea stocks could be encountered during the proposed survey. Both stocks of belugas may share common wintering grounds in the pack ice of the central Bering Sea (O'Corry-Crowe et al. 1997), and a migratory corridor has been described for the eastern Bering Strait with highest densities occurring there from October through May (Ferguson et al. 2015a). A feeding BIA has also been described for coastal waters of the eastern Bering Sea (Ferguson et al. 2015a).

In summer, whales from the Eastern Chukchi Sea stock are known to congregate in Kasegaluk Lagoon; this area has been identified as a feeding BIA (Clarke et al. 2015). However, evidence from a small number of satellite-tagged animals suggests that some of these whales may subsequently range into the Arctic Ocean north of the Beaufort Sea. Suydam et al. (2005) deployed satellite tags on 23 beluga whales captured in Kasegaluk Lagoon in late June and early July 1998–2002. Five of these whales moved far into the Arctic Ocean and into the pack ice to 79–80°N. These and other whales moved to areas as far as 1100 km offshore between Utqiaġvik and the Mackenzie River Delta, spending time in water with 90% ice coverage. A migratory corridor BIA has been identified for this stock from Point Barrow eastward to the U.S./Canada border for the fall migration (Clarke et al. 2015).

Belugas from the Beaufort Sea stock migrate from the Bering Sea through offshore waters of western and northern Alaska and summer in the eastern Beaufort Sea. These regions have been identified as migratory corridor BIAs for this stock; the BIA occurs from the Bering Strait to the Beaufort Sea during the spring migration, and from Point Barrow eastward to the U.S./Canada border for the fall migration (Clarke et al. 2015). Most whales migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July (Braham et al. 1984; Ljungblad et al. 1984). Much of the population enters the Mackenzie River estuary for a short period during July–August

to molt their epidermis, but they spend most of the summer in offshore waters of the eastern Beaufort Sea, Amundsen Gulf, and more northerly areas (Davis and Evans 1982; Harwood et al. 1996; Richard et al. 2001). Belugas are rarely seen in the central Alaskan Beaufort Sea during the early summer. During late summer and autumn (September–October), most belugas migrate westward far offshore near the pack ice (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1999).

Irregular ice conditions during spring and summer can influence the migratory paths to summer areas (O'Corry-Crowe et al. 2016) as well as the fall migration (Hauser et al. 2017). Moore (2000) and Moore et al. (2000a) suggested that beluga whales select deeper slope water independent of ice cover. However, during the westward migration in late summer and autumn, small numbers of belugas are sometimes seen near the north coast of Alaska (e.g., Johnson 1979). The main fall migration corridor of beluga whales is ~100+ km north of the coast. Satellite-linked telemetry data showed that some belugas of this population migrate west considerably farther offshore, as far north as 76–78ºN (Richard et al. 1997, 2001).

Hauser et al. (2014) and Citta et al. (2018b) reported concentration areas of the Eastern Beaufort Sea stock in some regions of the Chukchi Sea and the eastern Beaufort Sea from May–November, and core concentration areas for the Eastern Chukchi Sea stock off the northern coast of Alaska, in particular Barrow Canyon; however, no concentration areas were reported near the proposed survey area, although beluga occurrence was also noted there. Kuletz et al. (2015) also reported hot spots for belugas along the northern coast of Alaska, especially during summer, as well as along the northwest coast of Alaska in the Chukchi Sea. Schick et al. (2017) also showed high summer and early fall density areas off Point Barrow, as well as within the western portion of the proposed survey area, between ~73.5–78°N and 162–168°W. Tagged beluga whales from both stocks have also been reported to occur within the southern portion of the survey area from July to November (Hauser et al. 2014). There are several thousand records of belugas in the OBIS database for the Pacific sector of the Arctic Ocean; 32 occurred between 73 and 74.5ºN, and there are numerous records just to the south of the proposed survey area (OBIS 2021). Belugas were not recorded, however, during arctic cruises in August–September 2005, July–August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010), or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). The beluga whale is the most likely cetacean species to occur in the proposed project area.

Narwhal (*Monodon monoceros*)

The narwhal has a discontinuous arctic distribution (Hay and Mansfield 1989; Reeves et al. 2002). A large population inhabits Baffin Bay, West Greenland, and the eastern part of the Canadian Arctic archipelago, and much smaller numbers inhabit the Northeast Atlantic/East Greenland area. Narwhals are associated with sea ice. In the spring, as the ice breaks up, they follow the receding ice edge and enter deep sounds and fjords, where they remain during the summer and early fall (Reeves et al. 2002). As the ice reforms, narwhals move to offshore areas in the pack ice (Reeves et al. 2002), living in leads in the heavy pack ice throughout the winter.

There are scattered records of narwhal in Alaskan waters, where the species is considered extralimital (Reeves et al. 2002). George and Suydam (unpubl. ms *in* Muto et al. 2020) reported eight sightings of narwhals in the Chukchi and Beaufort seas from 1989 to 2008 as observed by Alaska Native hunters. Narwhals were not recorded during cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010), or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There is one narwhal record in the OBIS database for the Bering Strait (OBIS 2021). Narwhals are unlikely to be encountered during the proposed survey.

Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales are segregated socially, genetically, and ecologically into three distinct ecotypes: residents, transients, and offshore animals. Killer whales are known to inhabit almost all coastal waters of Alaska, extending from southeast Alaska through the Aleutian Islands and to the Bering Sea (Muto et al. 2020). Killer whales that occur in the Arctic Ocean could be from two stocks: the Alaska Residents, that occur from Southeast Alaska to the Bering Sea; or Gulf of Alaska, Aleutians, and Bering Sea Transients, that occur from Prince William Sound through to the Aleutians and Bering Sea (Carretta et al. 2020; Muto et al. 2020). In the past, Alaska residents were considered to be the same stock as Northern Residents (Muto et al. 2020), but acoustic and genetic data confirmed that these are separate stocks (e.g., Hoelzel et al. 2002; Yurk et al. 2002).

Killer whales have also been sighted in the Chukchi and Beaufort seas, but they are unlikely to occur there regularly (Leatherwood et al. 1986; Lowry et al. 1987). George et al. (1994) reported that a few killer whales are seen at Point Barrow each year. Although little is known about the whales that occur in the Beaufort Sea, they appear to be transient-type whales (Muto et al. 2020). Killer whales were observed predating on belugas in Kotzebue Sound in the southern Chukchi Sea during 2007 (O'Corry-Crowe et al. 2016). Observers onboard industry vessels in the Chukchi Sea recorded two killer whales in 2006 and one killer whale in 2008 (Haley et al. 2010). Another two groups totaling nine killer whales were seen in the eastern Chukchi Sea during surveys in 2008 by Aerts et al. (2013). No killer whales were seen during aerial or vessel surveys in the Beaufort Sea during 2006–2008 (Funk et al. 2010). The killer whale was not sighted during cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010), or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There are 10 killer whale records in the OBIS database for the Bering Strait (OBIS 2021). Killer whales are unlikely to be encountered during the proposed seismic survey.

Harbor Porpoise (*Phocoena phocoena vomerina*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore but is occasionally sighted in deeper offshore water (Jefferson et al. 2015); abundance declines linearly as depth increases (Barlow 1988). In the eastern North Pacific, its range extends from Point Barrow, Alaska, to Point Conception, California. In Alaska, three stocks of harbor porpoise are currently recognized: Southeast Alaska, Gulf of Alaska, and Bering Sea. Only the Bering Sea stock could occur near the proposed survey area. The seasonal movements of harbor porpoise appear to be inshore-offshore, rather than north-south, as a response to the abundance and distribution of food resources (Dohl et al. 1983; Barlow 1988). Genetic testing has also shown that harbor porpoises along the west coast of North America are not migratory and occupy restricted home ranges (Rosel et al. 1995).

During vessel-based surveys in the Chukchi Sea, the harbor porpoise was one of the most abundant cetaceans sighted during summer and fall 2006–2008 (Haley et al. 2010); they were also seen during surveys in the open water seasons of 2008–2010 (Aerts et al. 2013). Point Barrow is the approximate northeastern extent of its regular range (Suydam and George 1992), though there are extralimital records east to the mouth of the Mackenzie River in Canada and sightings in the Beaufort Sea near Prudhoe Bay during aerial surveys in 2006–2008 (Christie et al. 2010; LGL Limited, unpubl. data). Observers onboard industry vessels reported one sighting in the Beaufort Sea in 2006, but none in 2007 or 2008 (Savarese et al. 2010). Harbor porpoises were not recorded during aerial surveys in the Beaufort Sea in 2002–2004 (Monnett and Treacy 2005), nor during cruises in the Arctic Ocean during August–September 2005, July–

August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010), or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There are ~10 records for the Chukchi Sea, but none north of 72°N (OBIS 2021). Given that the harbor porpoise is mainly a shallow-water species, no encounters with this species are expected in the far offshore waters where the seismic survey is to occur.

Pinnipeds

Pacific Walrus (*Odobenus rosmarus divergens*)

The walrus occurs in moving pack ice over shallow water of the circumpolar arctic coast (King 1983). Walruses are most commonly found near the southern margins of the pack ice as opposed to deep in the pack where few open leads (polynyas) exist to afford access to the sea for foraging (Estes and Gilbert 1978; Fay 1982; Gilbert 1989). Walruses are not typically found in areas of >80% ice cover (Fay 1982). Ice serves as an important mobile platform providing walruses with a place to rest and nurse their young that is safe from predators and near feeding grounds. Walruses typically feed in depths of 10–80 m (Vibe 1950; Fay 1982; Reeves et al. 2002).

The Pacific walrus ranges from the Bering Sea to the Chukchi Sea, occasionally moving into the East Siberian and Beaufort seas. Walruses are migratory, moving south with the advancing ice in autumn and north as the ice recedes in spring (Fay 1981). Jay et al. (2011) reported that walrus have been arriving in the Chukchi Sea earlier and have stayed later into the fall, due to early ice-breakup in the summer and delayed freeze-up during fall. In the summer, most Pacific walruses move to the Chukchi Sea, but several thousand aggregate in the Gulf of Anadyr and in Bristol Bay (Garlich-Miller et al. 2011). Citta et al. (2018b) reported a concentration area for walrus occurrence in the Chukchi Sea off Point Barrow. Similarly, Schick et al. (2017) noted high densities northwest of Point Barrow during summer and early fall, as did Kuletz et al. (2015).

Limited numbers of walruses inhabit the Beaufort Sea during the open water season, and they are considered extralimital east of Point Barrow (Sease and Chapman 1988). The northeast Chukchi Sea west of Utqiaġvik is the northeastern extent of the main summer range of the walrus, and only a few individuals are seen farther east in the Beaufort Sea (e.g., Harwood et al. 2005; Funk et al. 2010). During a survey through the northern Chukchi Sea/Arctic Ocean in August–September 2005, two sightings of a total of seven walruses were made between 71.5 and 73°N, 164ºW, just south of the proposed survey area in water depths <70 m (Haley and Ireland 2006). No walruses were sighted during surveys in the Arctic Ocean during July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Mosher et al. 2009; Beland and Ireland 2010); however, several sightings were made during surveys between 72 and 76°N during September–October 2002 (Harwood et al. 2005) and September–October 2012 (RPS 2012). Eighty-four walrus were seen just south of the proposed survey area between 72.5 and 73.5°N during September 2018 Navy research activities (U.S. Navy 2019). There are 384 records in the OBIS database for the central Chukchi Sea (OBIS 2021). Few, if any, walrus are expected to be encountered in the survey area because they occur in pack ice, and R/V *Sikuliaq* would avoid ice during the cruise.

Bearded Seal (*Erignathus barbatus*)

The bearded seal is associated with sea ice and has a circumpolar distribution, generally south of 80ºN (Jefferson et al. 2015). In waters around Alaska, it occurs over the continental shelves of the Bering, Chukchi, and Beaufort seas and Arctic Ocean. During the open-water period, bearded seals occur mainly in relatively shallow areas, because they are predominantly benthic feeders (Burns 1981). They prefer areas of water no deeper than 200 m (e.g., Harwood et al. 2005). Bearded seals have occasionally been reported to maintain breathing holes in sea ice and broken areas within the pack ice, particularly if the water depth

is <200 m. Bearded seals apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas considerably deeper than 200 m.

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988; Boveng and Cameron 2013). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi and Beaufort seas, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter. Nonetheless, bearded seal vocalizations have been recorded nearly year-round in the Beaufort and Chukchi seas, with peak activity during March–June (MacIntyre et al. 2015). From mid-April to June, as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer, they are found near the widely fragmented margin of multi-year ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea. In the Beaufort Sea, bearded seals rarely use coastal haulouts.

In some areas, bearded seals are associated with the ice year-round; however, they usually move shoreward into open water areas when the pack ice retreats to areas with water depths greater than 200 m. During the summer, when the Bering Sea is ice-free, the most favorable bearded seal habitat is found in the central or northern Chukchi Sea/Arctic Ocean along the margin of the pack ice. Citta et al. (2018b) reported concentration areas in the Chukchi Sea along the coast of Alaska. Suitable habitat is more limited in the Beaufort Sea where the continental shelf is narrower and the pack ice edge frequently occurs seaward of the shelf and over water too deep for benthic feeding. The preferred habitat in the western and central Beaufort Sea during the open water period is the continental shelf seaward of the scour zone. Nonetheless, Schick et al. (2017) reported high densities off northwestern Alaska in the Chukchi Sea as well as in the nearshore waters of the Beaufort Sea.

Vessel surveys in the Arctic Ocean have reported much lower percentages of bearded compared to ringed seals during cruises in the Arctic Ocean in 2005, 2006, and 2010 (Haley 2006; Haley and Ireland 2006; Beland and Ireland 2010). During surveys north of the Chukchi Sea during September–October 2011, bearded seals were only recorded between 72 and 73°N (RPS 2012). However, a sighting of two bearded seals was made in deep water as far north as 78.5°N, 149.8°W during August 2010 (Beland and Ireland 2010). Two bearded seals were sighted in the Arctic Ocean during August–September 2009; one seal was seen at 80.8°N, 151.9°W and the other at 80.9°N, 147°W (Mosher et al. 2009). Boveng and Cameron (2013) also reported sightings of tagged bearded seals near the southern portion of the proposed survey area, north of 70°N. In the OBIS database, there are 28 records between 73 and 79°N for the Pacific sector of the Arctic Ocean; in addition, there are several thousand records for the Beaufort Sea and several hundred records for the Chukchi Sea (OBIS 2021). Thus, bearded seals could be encountered in the proposed survey area, but they are more likely to occur in the shallower southern portion.

Critical habitat for the Beringia DPS of Pacific bearded seal was proposed in January 2021 (NMFS 2021a). Critical habitat has been proposed to include waters of the U.S. EEZ within the 200-m depth contour, including portions of the Chukchi and Beaufort seas, as well as parts of the Bering Sea (Fig. 1). Essential physical features of the habitat include areas with 25% ice cover where the sea ice suitable for nursing and whelping, and habitat with 15% ice cover with sea ice suitable for molting (NMFS 2021a). Although the proposed seismic survey area does not occur within the proposed critical habitat (the survey area is located 63 km to the north), the transit through the Bering Strait and Chukchi Sea would transect the proposed critical habitat (Fig. 1).

NOAA (2021c) declared a UME for Alaska Ice Seals in 2019 for the Chukchi and Beaufort seas, which is still active; since June 2018, 94 bearded seals have been found stranded, as well as 96 unidentified ice seals.

Spotted Seal (*Phoca largha*)

The spotted seal (also known as largha seal) occurs in the Beaufort, Chukchi, Bering, and Okhotsk seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). During summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998). At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. The seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 71ºN (Boveng et al. 2009). In summer, they are rarely seen on the pack ice, except when the ice is very near to shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

Spotted seals have been sighted during open-water seismic programs and barge operations in the Alaskan Beaufort Sea (Moulton and Lawson 2002; Greene et al. 2007; Savarese et al. 2010) and during vessel-based seismic surveys and aerial surveys in the Chukchi Sea during 2006–2008 (Brueggeman 2009; Funk et al. 2010). Citta et al. (2018b) reported concentration areas for spotted seals in the Chukchi Sea along the coast of Alaska. One spotted seal was seen just south of the proposed survey area during September 2018 Navy research activities (U.S. Navy 2019). Spotted seals were also sighted around 72°N during surveys in September–October 2011 (RPS 2012). Boveng et al. (2017) noted their likely occurrence near the southern portion of the proposed survey area. However, no spotted seals were recorded on arctic cruises during August–September 2005, July–August 2006, August–September 2009, or August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010). There are 12 records between 72 and 73°N in the OBIS database for the Pacific sector of the Arctic Ocean, in addition to ~100 records for the Chukchi Sea and ~20 records for the Beaufort Sea. Spotted seals are unlikely to occur in the proposed survey area although some spotted seals could be encountered during transit periods. Since June 2018, 51 spotted seals have been found stranded (NOAA 2021c).

Ribbon Seal (*Histriophoca fasciata)*

The ribbon seal is found along the pack-ice margin in the southern Bering Sea during late winter and early spring, and it moves north as the pack ice recedes during late spring to early summer (Burns 1970; Burns et al. 1981). Little is known about ribbon seal summer and fall distribution, but a review of sightings during the summer suggested that they move into the southern Chukchi Sea (Kelly 1988). Boveng et al. (2013) reported that the known distribution extends into the Arctic Ocean to ~79°N. During a satellite telemetry program, a number of ribbon seals tagged in the Bering Sea in May had moved to the Chukchi Sea by July (Cameron et al. 2009), and Boveng et al. (2017) noted their likely occurrence near the southern portion of the proposed survey area. However, ribbon seals appeared to be relatively rare in the northern Chukchi Sea during vessel and aerial surveys in summer and fall of 2006–2008 (Brueggeman 2009; Funk et al. 2010). Nonetheless, Aerts et al. (2013) reported six ribbon seals during open-water surveys in the northwestern Chukchi Sea. Ribbon seals do not normally occur in the Beaufort Sea, although three ribbon seal sightings were reported during vessel-based surveys in the Beaufort Sea in 2008 (Savarese et al 2010). No ribbon seals were recorded on cruises in the Arctic Ocean during August–September 2005, July–August 2006, August–September 2009, and August–September 2010 (Haley 2006; Haley and Ireland 2006; Mosher et al. 2009; Beland and Ireland 2010), or north of the Chukchi Sea between ~72 and ~77°N in September–October 2011 (RPS 2012). There is one record in the OBIS database for the Chukchi Sea, three for the Bering Strait, and two for the Canadian Beaufort Sea (OBIS 2021). It is possible but unlikely that ribbon seals would be encountered in the proposed survey area.

Ringed Seal (*Phoca hispida hispida*)

The ringed seal has a circumpolar distribution and occurs in all seas of the Arctic Ocean (King 1983). Ringed seals are closely associated with ice, and in summer they often occur along the receding ice edges or farther north in the pack ice. During winter, ringed seals occupy landfast ice and offshore pack ice, maintaining breathing holes in the ice and occupying lairs in accumulated snow where they give birth and nurse their pups (Smith and Stirling 1975). In winter and spring, the highest densities of ringed seals are found on stable shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi Sea, and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970; Stirling et al. 1982; Finley et al. 1983). During the summer, ringed seals are known to undertake long-distance movements when sea ice extent is minimal (Kelly et al. 2010b; Martinez-Bakker et al. 2013).

Ringed seals are year-round residents in the northern Chukchi and Beaufort seas and are the most frequently encountered seal species in the area. Some ringed seals are known to migrate from the Beaufort Sea to the Chukchi Sea during fall (Harwood et al. 2012). There are core concentration areas in the Chukchi and Beaufort seas, but none were reported for the southern portion of the proposed survey area, although occurrence was reported there (Citta et al. 2018b).

In the Chukchi Sea, the ringed seal was the most abundant seal species sighted during vessel-based surveys in 2006–2008, with densities up to 0.129/km^2 in the fall (Haley et al 2010). In the Beaufort Sea, the ringed seal was also the most abundant seal species during similar fall vessel-based surveys, with densities up to 0.103/km^2 (Savarese et al. 2010). Many unidentified seals during these surveys may have also been ringed seals, thus actual densities may have been higher. In the Arctic Ocean, the ringed seal was also the most frequently sighted marine mammal species during cruises in August–September 2005 (Haley and Ireland 2006), July–August 2006 (Haley 2006), August–September 2009 (Mosher et al. 2009), or August–September 2010 (Beland and Ireland 2010). Ringed seals were also seen during surveys north of the Chukchi Sea between ~75 and ~77°N in September–October 2011 (RPS 2012). Von Duyke et al. (2020) reported movements of ringed seals through the southern survey area during summer/fall. In the OBIS database, there are nearly 200 records between 72 and 82°N for the Pacific sector of the Arctic Ocean, including 99 sightings made during the aforementioned surveys, and an additional ~260 records for the Chukchi Sea, and nearly 4000 records for the Beaufort Sea (OBIS 2021). The ringed seal is the marine mammal most likely to be encountered during the proposed survey.

Critical habitat for the Arctic subspecies of ringed seal was first proposed in December 2014 (NMFS 2014). Revisions to the proposed critical habitat were made in January 2021 (NMFS 2021b). Critical habitat was proposed to include nearly all waters of the U.S. EEZ in the Chukchi and Beaufort seas, as well as a portion of the Bering Sea (Fig. 1). Essential physical features of the habitat include snow-covered ice suitable for subnivean birth lairs and sea ice habitat of 15% concentration or greater suitable for basking and molting (NMFS 2021b). The southern portion of the proposed seismic survey area, as well as the proposed transit through the Bering Strait and Chukchi seas, occur within proposed critical habitat (Fig. 1). Since June 2018, 74 ringed seals have been found stranded (NOAA 2021c).

Marine Fissiped

Polar Bear (*Ursus maritimus*)

The polar bear has a circumpolar distribution throughout the Northern Hemisphere (Amstrup et al. 1986); it occurs in relatively low densities throughout most ice-covered areas (DeMaster and Stirling 1981). In addition to the U.S. MMPA, the polar bear is protected by the International Agreement on the Conservation of Polar Bears, ratified in 1976 by Canada, Denmark, Norway, Russia (former USSR), and the U.S. Article II

of the agreement states, "Each contracting party…shall manage polar bear populations in accordance with sound conservation practices based on the best scientific data."

Polar bears are divided into 19 relatively distinct populations or management units although there may be overlap of some individuals among populations (Aars et al. 2006; USFWS 2008; IUCN/SSC PBSG 2019). Individuals from four populations could occur in the proposed survey area: Arctic Basin (unknown population size); Chukchi Sea population (~2937 bears), from most of the Chukchi Sea and the northern Bering Sea; Southern Beaufort Sea population (~907 individuals), ranging from the Baillie Islands, Canada, to near Point Lay, Alaska; and the Northern Beaufort Sea population (~980 polar bears), located in Canadian waters primarily north of the Southern Beaufort Sea and extending into Amundsen Gulf (IUCN/SSC PBSG 2019). IUCN/SSC PBSG (2019) reported the Northern and Southern Beaufort Sea populations as likely decreasing, the Chukchi Sea population as likely stable over one generation, and the Arctic Basin population as data deficient. Data from tracking studies indicate wide-ranging movements of individual bears and overlap among polar bear populations (Garner et al. 1990; Amstrup 1995; Durner and Amstrup 1995).

Polar bears usually forage in areas where there are high concentrations of ringed seals which is their primary prey, and bearded seals (Larsen 1985; Stirling and McEwan 1975). This includes areas of landfast ice, as well as moving pack ice. They typically range as far north as 88°N (Ray 1971; Durner and Amstrup 1995) where the population thins dramatically. However, polar bears have been observed across the Arctic, including close to the North Pole (van Meurs and Splettstoesser 2003). During a cruise in the Arctic Ocean in August–September 2005, there were 21 sightings of 27 polar bears, most between ~80 and 82ºN with one at ~87ºN (Haley and Ireland 2006). During a cruise in the Arctic Ocean in July–August 2006, there were three sightings of nine polar bears at ~73 and 78ºN, all on ice (Haley 2006). During a cruise in the Arctic Ocean in August–September 2009, there were nine sightings of 11 polar bears between ~79 and 82ºN (Mosher et al. 2009). Sixteen polar bears were seen on the ice during a seismic survey in the Arctic Ocean in August–September 2010, including five sightings of seven polar bears between 74 and 78ºN (Beland and Ireland 2010). Several sightings were made between 73 and 75°N during surveys in the Pacific sector of the Arctic Ocean during August–October 2002 (Harwood et al. 2005). In addition, three polar bears were seen within the proposed survey area, four polar bears were spotted just south of the proposed survey area at ~73°N, and another three polar bears were sighted swimming in open water adjacent to the proposed survey area at 74.6°N, 146.2°W during September–October Navy research activities in 2018–2019 (U.S. Navy 2019). In the OBIS database, there are 224 records in the Pacific sector of the Arctic Ocean between 72 and 79°N, as well as an additional ~160 for the Chukchi Sea and ~800 for the Beaufort Sea (OBIS 2021).

On 7 December 2010, critical habitat for polar bear was listed (50 CFR Part 17). The critical habitat is designated in three units: sea-ice critical habitat, terrestrial denning critical habitat, and barrier island critical habitat (USFWS 2010). Only the sea-ice critical habitat is relevant here; it occurs within the U.S. EEZ in the Beaufort and Chukchi seas (Fig. 1). The sea-ice critical habitat includes all contiguous waters from mainland Alaska out to the 300-m isobath, and extends from the U.S.-Canada border to the U.S.-Russian boundary, and southwards to 61.5°N in the east and 62.6°N in the west. Although the proposed vessel transit transects the critical habitat in the Bering Strait and Chukchi seas, the critical habitat is located ~44 km south of the proposed survey area (Fig. 1). The cruise would only overlap sea-ice critical habitat if sea ice was actually present in the area where R/V *Sikuliaq* would be transiting. As R/V *Sikuliaq* would be avoiding ice, neither polar bears nor their critical habitat are likely to occur within the seismic survey area.

V. Type of Incidental Take Authorization Requested

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

The University of Alaska requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned seismic surveys in the Arctic Ocean during summer 2021. The operations outlined in § I have the potential to take marine mammals by harassment. Sounds would be generated by the airguns used during the survey, by echosounders, and by general vessel operations. “Takes” by harassment would potentially result when marine mammals near the activity are exposed to the pulsed sounds, such as those generated by the airguns. The effects would depend on the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals near the tracklines of the source vessel.

At most, effects on marine mammals would be anticipated as falling within the MMPA definition of “Level B Harassment” for those species managed by NMFS. No take by serious injury is expected, given the nature of the planned operations and the mitigation measures that are planned (see § XI, Mitigation Measures), and no lethal takes are expected. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes would be unlikely.

VI. Numbers of Marine Mammals That Could be Taken

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

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

VII. Anticipated Impact on Species or Stocks

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

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

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

for the estimates of the potential numbers of harassment "takes" during the planned surveys, as well Level A "takes".

Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017; Halliday et al. 2020). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

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

Tolerance

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

Masking

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

Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales.

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

Disturbance Reactions

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

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

seasonal variation in distribution when considering the effects of exposure of airgun sounds on marine mammals (e.g., Hückstädt et al. 2020; Gallagher et al. 2021).

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

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

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

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

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in^3) within 3 km and received levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000). However, some individuals did not show avoidance behaviors even at levels as high as 160 to 170 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2018). Dunlop et al. (2020) found that humpback whales were significantly less likely to interact socially (e.g., joining a group) in the

presence of a vessel, whether it was towing an active airgun array or not, at greater ranges and received sound levels lower than the recommended thresholds.

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015). On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 µPa on an approximate rms basis (Malme et al. 1985). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007).

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

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

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

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

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~170 dB re 1 μPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994 to 2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, fin whales were seen at significantly farther distances during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst

2010). Minke whales were seen significantly farther from the vessel during periods with than without seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010). However, Matos (2015) reported no change in sighting rates of minke whales in Vestfjorden, Norway, during ongoing seismic surveys outside of the fjord. Vilela et al. (2016) cautioned that environmental conditions should be taken into account when comparing sighting rates during seismic surveys, as spatial modeling showed that differences in sighting rates of rorquals (fin and minke whales) during seismic periods and non-seismic periods during a survey in the Gulf of Cadiz could be explained by environmental variables.

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

Toothed Whales.— Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994 to 2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther (>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015).

During seismic surveys in the northwest Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was

significantly farther (by ~200 m) during seismic operations compared with periods when the seismic source was not active; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment.

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

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

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel. Observations from seismic vessels off the U.K. from 1994 to 2010 indicated that detection rates of beaked whales were significantly higher (p<0.05) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013b) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth,

Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 μPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

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

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

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for grey seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in^3 airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Hearing Impairment and Other Physical Effects

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

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

levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019b,c, 2020a,b,c,d,e; Supin et al. 2016).

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

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL_{cum} of 188 and 191 $\mu Pa^2 \cdot s$, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

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

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

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Based on studies that exposed harbor porpoises to one-sixth-octave noise bands ranging from 1 to 88.4 kHz, Kastelein et al. (2019c,d, 2020d,e) noted that susceptibility to TTS increases with an increase in sound less than 6.5 kHz but declines with an increase in frequency above 6.5 kHz. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 µPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). In addition, according to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. Mulsow et al. (2015) suggested that basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals. Simulation modeling to assess the risk of sound exposure to marine mammals (gray seal and harbor porpoise) showed that SEL is most strongly influenced by the weighting function (Donovan et al. 2017). Houser et al. (2017) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Harbor seals appear to be equally susceptible to incurring TTS when exposed to sounds from 2.5 to 40 kHz (Kastelein et al. 2020a,b), but at frequencies of 2 kHz or lower, a higher SEL was required to elicit the same TTS (Kastelein et al. 2020c). A maximum TTS of 44 dB was reported for a harbor seal exposed to an octave-band white noise centered at 4 kHz with a mean received SPL of 163 dB for 1 h; for a harbor seal exposed to 4 kHz for 1 h with mean SPLs of 124–148 dB, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). A maximum TTS >45 dB was elicited from a harbor seal exposed to 32 kHz at 191 dB SEL (Kastelein et al. 2020a). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Similarly, no TTS was measured when a bearded seal was exposed to a single airgun pulse with an unweighted SEL of 185 dB and an SPL of 207 dB; however, TTS was elicited at 400 Hz when exposed to four to ten consecutive pulses with a cumulative unweighted SEL of 191–195 dB, and a weighted SEL of 167–171 dB (Sills et al. 2020). However, free-swimming harbor and other seals, may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018).

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

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

The noise exposure criteria for marine mammals that were recently released by NMFS (2016a, 2018) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids as well and other non-phocid carnivores underwater (OW). When Matthews et al. (2021) modeled the potential of serious injury/mortality using the above PTS thresholds, they found that few marine mammals would be exposed to airgun sounds that could be injurious, although porpoise appeared to be more susceptible to being exposed to injurious sounds.

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

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2106). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater

noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding. Morell et al. (2020) described new methodology that visualizes scars in the cochlea to detect hearing loss in stranded marine mammals.

Since 1991, there have been 70 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2021d). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (https://www.energy.senate.gov/public/index.cfm/2016/5/hearing-is-examine-the-bureau-of-ocean-energy-management-s-2017-2022-ocs-oil-and-gas-leasing-program), it was Dr. Knapp's (a geologist from the University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico. Similarly, the large whale UME Core Team found that seismic testing did not contribute to the 2015 UME involving humpbacks and fin whales from Alaska to B.C. (Savage 2017).

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

Possible Effects of Other Acoustic Sources

The Kongsberg EM 302 MBES, Kongberg TOPAS PS-18 SBP, ADCP, and pingers would be operated from the source vessel during the proposed surveys. Information about these types of sound sources was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs, SBPs, ADCP, and pingers on marine mammals appears in § 3.6.4.3, § 3.7.4.3, and § 3.8.4.3, and Appendix E of the PEIS.

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

Reference has also been made that two beaked whales stranded in the Gulf of California in 2002 were observed during a seismic survey in the region by the R/V *Ewing* (Malakoff 2002, Cox et al. 2006 *in* PEIS:3-136), which used a similar MBES system. As noted in the PEIS, however, "The link between the

stranding and the seismic surveys was inconclusive and not based on any physical evidence" (Hogarth 2002, Yoder 2002 *in* PEIS:3-190).

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2016:209).

There is nearly no available information on marine mammal behavioral responses to MBES sounds (Southall et al. 2013). Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior of Cuvier's beaked whales during multibeam mapping in southern California (Varghese et al. 2020). The study found that the number of GVP per hour increased during as well as after multibeam mapping compared with before MBES exposure, and that the animals neither left the area nor stopped foraging during the MBES surveys. During an analogous study assessing Naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded for Blainville's beaked whales during sonar transmission (McCarthy et al. 2011; Varghese et al. 2020).

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

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

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

Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear. Vessel noise from R/V *Sikuliaq* could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20 to 300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise have been shown to affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018); Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2018; Williams et al. 2020). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017; Popov et al. 2020). In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018; Halliday et al. 2019). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews 2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016; Oakley et al. 2017). Based on modeling, Halliday et al. (2017) suggested that shipping noise can be audible more than 100 km away and could affect the behavior of a marine mammal at a distance of 52 km in the case of tankers.

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

(Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or have had little or no recent exposure to ships (Richardson et al. 1995). Dolphins of many species tolerate and sometimes approach vessels (e.g., Anderwald et al. 2013). Some dolphin species approach moving vessels to ride the bow or stern waves (Williams et al. 1992). Noise and/or physical presence of vessels has been shown to disturb the foraging activity of bottlenose dolphins (Pirotta et al. 2015), blue whales (Lesage et al. 2017) and killer whales (Holt et al. 2020). Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015).

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

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

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

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

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

The estimates are based on consideration of the number of marine mammals that could be harassed (Level B takes) by received sound levels ≥160 dB re 1 μPa_{rms} produced by the seismic surveys in the Arctic Ocean. It should be noted that available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2016c). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (NMFS 2016c).

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

Basis for Estimating "Takes"

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the survey area in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

Habitat-based estimates of cetacean density in the U.S. Arctic were published by Schick et al. (2017). This study used line-transect aerial survey data from ASAMM collected in the U.S. Chukchi and Beaufort seas from 2000–2016 and associated habitat covariates to estimate abundance monthly (from July through October) within 10 km x 10 km grid cells (equivalent to a density in units of individuals/100 km^2) which are provided in GIS raster files. Estimates were produced for bowhead, gray, and beluga whales, as well as a guild of other "baleen whales" that included fin, humpback, and minke whales. However, the spatial extent of the density estimates differed by species and therefore proximity to the survey area. For all species except beluga whales, the methods described below that were used to extend the Schick et al. (2017) predictions to areas farther north likely produced conservative density estimates since those species are rarely sighted in the survey area.

The spatial coverage of density estimates for bowhead whales extends northward to ~74°N, which overlaps the southern-most survey lines by ~25 km. However, the majority of the survey lines do not overlap with the spatial coverage of the Schick et al. (2017) density estimates, so the following method was used to produce a conservative estimate of average bowhead density farther north. The two northern-most rows of 10 km x 10 km grid cells (i.e., northern 20 km of estimates) and the two additional cells overlapped by the southern-most survey lines, were selected from the bowhead whale GIS raster files for August and September between 140°W and 165°W, the approximate east-west extend of the survey lines. Density estimates within those cells were then evaluated and cells east of ~157°W were excluded as they contained densities that were effectively zero which would reduce the calculated average. The mean of the remaining

cells (west of 157°W) was then calculated resulting in an overall density estimate of 0.01237 whales/km^2 (Table 5).

The same process was used to calculate densities for gray whales and the baleen whale guild, except that the northern extent of the spatial coverage from Schick et al. (2017) for those species is ~73°N. This meant there was no overlap with any of the survey lines and no additional cells beyond the two northern-most rows (20 km) were used in the calculations. The resulting density estimates were extremely small, 0.0000001 and 0.00002 individuals/1000 km^2 for gray whales and other baleen whales, respectively. These are shown as zero in Table 5.

For beluga whales, the spatial coverage of the Schick et al. (2017) density estimates overlapped the full extent of survey lines and associated ensonified areas. To calculate an average beluga whale density in areas that may be exposed above threshold levels, we selected all grid cells from the August and September estimates that overlapped (wholly or partially) with the 160-dB ensonifed area and calculated the mean, resulting in an estimate of 0.0255 whales/km^2 (Table 5).

During ASAMM, sightings of pinnipeds were recorded when possible and the resulting data were used by Schick et al. (2017) to produce habitat-based density estimates in the same manner as for cetaceans. However, given ASAMM was designed for large whales, including typically being flown at altitudes above 1,000 ft ASL, and small pinniped sightings may not have been recorded as consistently, the Schick et al. (2017) pinniped densities were not used in this analysis. As an alternative, NMFS recommended using bearded and ringed seal densities from their Biological Opinion for the Navy's Arctic Research Activities 2018–2021 (NMFS 2019b), which were based on habitat-based modeling by Kaschner et al. (2006) and Kaschner (2004) (see Table 5).

Spotted and ribbon seals were not included in NMFS (2019b). Thus, spotted seal densities were estimated by multiplying ringed seal density by 0.18. This was based on the ratio of the estimated Chukchi Sea populations of the two species (Table 4). The Alaskan population of spotted seals is 461,625 (Muto et al. 2020), and ~8% of the population (~37,000) is estimated to be present in the Chukchi Sea during the summer and fall (Rugh et al. 1997). As the population of ringed seals in the Alaskan Chukchi Sea is ~208,000 animals (Bengtson et al. 2005), this resulted in a ratio of 0.18. Based on Hartin et al. (2013), four ribbon seal sightings were reported during industry vessel operations in the Chukchi Sea from 2006 through 2010, resulting in a density estimate of 0.0007/km^2 (Table 5).

Highly variable oceanographic and atmospheric conditions determine the amount and distribution of sea ice in the Arctic, which heavily influences the species and number of marine mammals potentially present at these high latitudes. Thus, there is considerable year-to-year variation in the distribution and abundance of the marine mammal species in the survey area. Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data.

The number of individual marine mammals potentially exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) was calculated by multiplying the estimated densities by the total area expected to be ensonified above the Level B threshold; these are shown as *Requested Take Authorization*. The 160-dB re 1 μPa_{rms} criterion assumes that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". The area expected to be ensonified was determined by entering the planned survey lines into a GIS and then "buffering" the lines by the applicable 160-dB distance (see Appendix B). The resulting ensonified areas were then increased by 25% to allow for any necessary additional operations, such as re-surveying segments where data quality was insufficient. This approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the threshold as R/V *Sikuliaq* approaches.

TABLE 5. Densities, calculated exposures, and requested number of takes of marine mammals that could be exposed to airgun sounds during the proposed survey in the Arctic Ocean during summer 2021. Species in italics are listed under the ESA as threatened or endangered.

	Density	Ensonified Area (km^2)		Calculated Takes		Requested	Regional	
Species	**(Individuals /km^2)**	**Level B**	**Level A**	**Level B**	**Level A**	**Take Authorization[1]**	**Population Size**	**Take by % of Pop.**
LF Cetaceans								
Bowhead whale	*0.0124*	*27,309*	*279*	*334*	*3*	*337*	*16,820*	*2.00*
Gray whale^	0	27,309	279	0	0	**2**	26,960	0.01
Humpback whale^	0	27,309	279	0	0	**2**	11,210	0.02
Fin whale	*0*	*27,309*	*279*	*0*	*0*	***2***	*13,620*	*0.01*
Minke whale	0	27,309	279	0	0	**2**	20,000	0.01
MF Cetaceans								
Beluga whale	0.0255	27,309	45	696	1	697	60,010	1.16
Killer whale	-	27,309	45	-	-	**6**	2,934	0.20
Narwhal	-	27,309	45	-	-	2*	-	-
HF Cetaceans								
Harbor porpoise	-	27,309	1175	-	-	**2**	48,215	<0.01
Phocid Seals								
Bearded seal	*0.0332*	*27,309*	*187*	*900*	*6*	*907*	*125,000*	*0.73*
Ribbon seal	0.0677	27,309	187	1,836	13	1,849	184,697	1.00
Ringed seal	*0.3760*	*27,309*	*187*	*10,198*	*70*	*10,269*	*171,418*	*5.99*
Spotted seal	0.0007	27,309	187	19	0	19	461,625	<0.01

[1] Numbers in bold based on group sizes from ASAMM. * Arbitrary estimate based on extralimital sightings. ^ No takes for ESA-listed DPS expected.

For most species for which no densities were available or the calculations resulted in zero estimated exposures, we included a *Requested Take Authorization* based on average group size from ASAMM; average group size was determined from sightings made during surveys in 2016–2019 (Clarke e al. 2017, 2018, 2019, 2020).

Table 5 shows the calculated number of marine mammals that could potentially be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic surveys if no animals moved away from the survey vessel. Since the estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} include several conservative assumptions, they likely overestimate the actual numbers of marine mammals that could be affected.

Estimates of the numbers of marine mammals that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Tables 2 and 3), if there were no mitigation measures (shut downs when PSOs observe animals approaching or inside the EZs), are also given in Table 5. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

Conclusions

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

In § 3.6.7, § 3.7.7, and § 3.8.7 of the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, and pinniped species, and that Level A effects were highly unlikely. Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for the Proposed Action, however, following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys. For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g., NMFS 2019c,d).

Estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes. However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on marine mammals would be anticipated from the proposed activities.

In decades of seismic surveys carried out by NSF-owned vessels, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Similar surveys conducted in the region in the past had no observed significant impacts. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5500-km, 2-D seismic survey conducted by R/V *Langseth* in the Arctic Ocean in September–October 2011, only 11 pinnipeds were observed within the predicted 160-dB zone and potentially taken, representing ~0.1% of the 9323 takes authorized by NMFS (RPS 2012). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The Level B estimates are thought to be conservative; thus, not all animals detected within this threshold distance would be expected to have been exposed to actual sound levels >160 dB.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

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

The coast and nearshore waters of Alaska are of cultural importance to indigenous peoples for fishing, hunting, gathering, and ceremonial purposes. Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives. There are seven communities in the North Slope Borough region of Alaska (northwestern and northern Alaska) that harvest seals, including from west to east Point Hope, Point Lay, Wainwright, Utqiaġvik, Atqusak, Nuiqsut, and Kaktovik (Ice Seal Committee 2019). Bearded seals are the preferred species to harvest as food and for skin boat coverings, but ringed seals are also commonly taken for food and their blubber (Ice Seal Committee 2019). Ringed seals are typically harvested during the summer and can extend up to 64 km from shore (Stephen R. Braund & Associates 2010).

No ribbon seals have been harvested in any of the North Slope Borough communities since the 1960s (Ice Seal Committee 2019). Table 6 shows number of ice seals harvested in North Slope Borough during the most recent year that data were available. However, number of seals harvested each year varies considerably. The five-year mean annual harvest of Pacific walrus for 2006–2010 was 4852 individuals, with 1782 of those harvested in the U.S. (Muto et al. 2020). The average annual Alaska polar bear harvest for the Southern Beaufort Sea was 33 bears for 2003–2007; the combined annual harvest for Alaska and Canada was 53.6 animals (USFWS 2020a). For the same years, the annual harvest for the Chukchi/Bering Sea stock in Alaska was 37 (USFWS 2020b).

A subsistence harvest of bowheads and belugas is also practiced by Alaskan Natives, providing nutritional and cultural needs. In 2019, 36 bowhead whales were taken during the Alaskan subsistence hunt (Suydam et al. 2020). Whaling near Utqiaġvik occurs during spring (April and May) and autumn, and can continue into November, depending on the quota and conditions. Communities that harvested bowheads during 2019 include Utqiaġvik, Gamgell, Kaktovik, Nuiqsut, Point Hope, Point Lay, and Wainwright. Bowhead whales and gray whales are also taken in the aboriginal subsistence hunt in the Russian Federation (Zharikov et al. 2020). During 2019, 135 gray whales and one bowhead whale were harvested at Chukotka.

Beluga whales from the eastern Chukchi Sea stock are an important subsistence resource for residents of the village of Point Lay, adjacent to Kasegaluk Lagoon, and other villages in northwest Alaska. Each year, hunters from Point Lay drive belugas into the lagoon to a traditional hunting location. The belugas have been predictably sighted near the lagoon from late June through mid to late July (Suydam et al. 2001). The mean annual number of Beaufort Sea belugas landed by Alaska Native subsistence hunters in 2011–2015 was 47, and an average of 92 were taken in Canadian waters; the mean annual number of Eastern Chukchi Sea belugas landed by Alaska Native subsistence hunters in 2011–2015 was 67 (Muto et al. 2020).

Interactions between the proposed surveys and fishing/hunting operations in the study area are expected to be limited. Although fishing/hunting would not be precluded in the survey area, a safe distance would need to be kept from R/V *Sikuliaq* and the towed seismic equipment. Dr. Coakley has presented the Proposed Action to the Alaska Eskimo Whaling Commission (AEWC) at the July 2020, October 2020, and February 202 Triannual Meetings. As specifically noted, during the meetings, daily email communications with interested community members would be made from the vessel. Communication may include notice of any unusual marine mammal observations during the Proposed Action. Any potential space use conflicts would be further avoided through direct communication with subsistence fishers/hunters during the surveys. Considering the limited time that the planned seismic surveys would take place and the far offshore location of the surveys, no direct interaction with subsistence fishers/hunters would be anticipated.

Table 6. Seal harvests in the North Slope Borough (Ice Seal Committee 2019).

Community	Year	# of Bearded Seals	# of Ringed Seals	# of Spotted Seals
Kaktovik	2014	3	1	0
Nuiqsut	2014	26	58	7
Utqiaġvik	2014	1070	428	98
Atqasuk	1998	3	0	0
Wainwright	2003	79	27	3
Point Lay	2012	55	51	8
Point Hope	2014	183	246	5

IX. Anticipated Impact on Habitat

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

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

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

X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

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

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

XI. Mitigation Measures

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

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

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

Planning Phase

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

1. *Energy Source*—Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. The sources proposed already are relatively small energy sources (most of the acquisition would use a 2-airgun, 1040 in^3 array), and the scientific objectives for the proposed surveys could not be met using smaller sources. The 2-airgun array would be needed to penetrate substantial thicknesses of sediment expected to be encountered in the Canada Basin. Recognizing the structures associated with the extinct mid-ocean ridge and adjacent possible hyper-extended continental crust in the Canada Basin is also an important objective. On the Chukchi Borderland, there appear to be substantial basement structures beneath the sediment cover. Imaging these structures is critical to understanding the pre-extension history of the Borderland. The 2-airgun array was considered the minimum that would provide sufficient energy to image the stratigraphy and underlying structure.
2. *Survey Location and Timing*—The PI worked with NSF to consider potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., ice cover, seasonal presence of marine mammals and seabirds), subsistence activities weather conditions, equipment, and optimal timing for other proposed research cruises using R/V *Sikuliaq*, as well as coordination with the Geological Survey of Denmark and Greenland. The schedule is mainly constrained by the ice-minimum (~15 September) and consideration of subsistence activities in the region (i.e., seismic surveys would occur ≥300 km north of Utqiaġvik). Working north of the Chukchi Borderland around the time of the ice-minimum enables the longer lines to be acquired. R/V *Sikuliaq* is expected to encounter only limited ice in the marginal ice zone during this cruise. Arriving earlier risks heavier residual ice from the previous season, whereas arriving later risks encountering fresh annual ice that could impair operations. The plan is to have all the gear on board and be southbound to Nome prior to the beginning of fall whaling in Utqiaġvik. Therefore, summer is the most practical season for the proposed surveys.
3. *Mitigation Zones*—The proposed surveys would acquire MCS data with 2 G-airguns and OBS refraction data with a 6 G-airgun array, at a maximum tow depth of 9 m. L-DEO model results are used to determine the 160-dB_{rms} radius for the airgun arrays at a 9-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor of 1.5. Table 1 shows the distances at which the 160-dB re 1µPa_{rms} sound levels are expected to be received for the 2- and 6-airgun arrays. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals.

   The thresholds for PTS onset or Level A Harassment (injury) for marine mammals for impulsive sounds use dual metrics of SEL_{cum} over 24 hours and peak SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans, MF cetaceans, HF cetaceans, PW, and OW and other marine carnivores underwater (NMFS 2016a, 2018). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018), the largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances for marine mammals. Enforcement of mitigation zones for marine mammals via shut downs would be implemented during operations, as noted below.

Mitigation During Operations

Mitigation measures that would be adopted during the proposed surveys include (1) shut-down procedures and (2) ramp-up procedures. Although these measures are proposed based on past experience and for consistency with the PEIS, the University of Alaska would ultimately follow monitoring and mitigation measures required by the IHA and ITS.

Shut-down Procedures

The operating airgun(s) would be shut down if a marine mammal is seen within or approaching the EZ. Special shut downs at any distance would be implemented for large whales with a calf and aggregations (6 or more individuals) of large whales. Following a shut down, airgun activity would not resume until the animal has cleared the EZ. The animal would be considered to have cleared the EZ if it is visually observed to have left the EZ; if it has not been seen within the zone for 15 min in the case of small odontocetes; or if it has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes. The airgun array would be ramped up gradually after a shut down. Ramp-up procedures are described below.

Ramp-up Procedures

A ramp-up procedure would be followed when the airgun array begins operating after a specified period without airgun operations. It is proposed that, for the present survey, this period would be 30 min, as long as PSOs have maintained constant visual and acoustic observations and no detections within the EZ have occurred. Ramp up would not occur if a marine mammal has not cleared the EZ as described earlier.

Ramp-up would begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Airguns would be added in a sequence such that the source level of the array would increase in steps not exceeding 6 dB per 5-min period. During ramp up, the PSOs would monitor the EZ, and if marine mammals are sighted, a shut down would be implemented, as though the full array were operational. Ramp up would only commence at night or during poor visibility if the EZ has been monitored acoustically monitoried with PAM for 30 min prior to the start of operations without any marine mammal detections during that period.

XII. Plan of Cooperation

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

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

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

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

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

The proposed activity would take place in the Arctic Ocean, but activities are not expected to occur in traditional Arctic subsistence hunting areas. The proposed activities would not preclude or hinder subsistence activities from occurring within the survey area or elsewhere. While subsistence activities may occur in nearshore waters of the region, no impacts would be anticipated on subsistence harvests due to the brief and temporary nature of the proposed activities, as well as the far offshore location of the surveys (≥300 km north of Utqiaġvik). Further, the survey timing was selected to avoid interference with any local subsistence hunting activities and whale migrations.

Dr. Coakley presented the Proposed Action to the Alaska Eskimo Whaling Commission (AEWC) at the July 2020, October 2020, and February 202 Triannual Meetings. As specifically noted, during the meetings, daily email communications with interested community members would be made from the vessel. Communication may include notice of any unusual marine mammal observations during the Proposed Action. Any potential space use conflicts would be further avoided through direct radio communication with subsistence fishers/hunters during the surveys and Notice to Mariners. NSF plans to conduct outreach to local stakeholders, including subsistence communities, as part of the National Environmental Policy Act (NEPA) process associated with the proposed action. Due to COVID, researchers have not proposed conducting additional in-person outreach in the region to discuss the proposed project in advance of research activities.

XIII. Monitoring and Reporting Plan

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

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

Vessel-based Visual Monitoring

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

During seismic operations, five PSOs would be based aboard R/V *Sikuliaq*. All PSOs would be appointed by University of Alaska with NMFS concurrence. During the majority of seismic operations, two PSOs would monitor for marine mammals around the seismic vessel; these observers may be referred

to as the visual PSOs or "PSVOs". Use of two simultaneous observers would increase the effectiveness of detecting animals around the source vessel. PSVO(s) would be on duty in shifts of duration no longer than 4 h, or per the IHA. Other crew would also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic survey, the crew would be given additional instruction regarding how to do so. During daytime, the PSVO(s) would scan the area around the vessel systematically with reticle binoculars (e.g., 7×50 Fujinon), and with the naked eye. During darkness, night vision devices (NVDs) would be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), when required.

Passive Acoustic Monitoring

Passive acoustic monitoring (PAM) would take place to complement the visual monitoring program. Visual monitoring typically is not effective during periods of poor visibility or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Acoustical monitoring can be used in addition to visual observations to improve detection, identification, and localization of cetaceans. The acoustic monitoring would serve to alert PSVOs (if on duty) when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or by night, and does not depend on good visibility. It would be monitored in real time so that the visual observers can be advised when cetaceans are detected.

The towed hydrophones would ideally be monitored 24 h per day while at the seismic survey areas during airgun operations, and during most periods when R/V *Sikuliaq* is underway while the airguns are not operating. PAM may not be possible if damage occurs to the array or back-up systems during operations; in that event, the PAM system would be repaired and re-deployed as quickly as possible. One PSO would monitor the acoustic detection system at any one time, by listening to the signals from two channels via headphones and/or speakers and watching the real-time spectrographic display for frequency ranges produced by cetaceans. The PSO monitoring the acoustical data referred to as the PSAO, would be on shift for no longer than 6 h at a time, or per the IHA. All observers would be expected to rotate through the PAM position, although the most experienced with acoustics would be on PAM duty more frequently.

When a vocalization is detected while visual observations are in progress, the PSAO would contact the PSVO immediately, to alert him/her to the presence of marine mammals (if they have not already been seen), and to allow a shut down to be initiated, if required. The information regarding the call would be entered into a database. The data to be entered include an acoustic encounter identification number, whether it was linked with a visual sighting, date, time when first and last heard and whenever any additional information was recorded, position and water depth when first detected, bearing if determinable, species or species group (e.g., unidentified whale), types and nature of sounds heard (e.g., clicks, continuous, sporadic, whistles, creaks, burst pulses, strength of signal, etc.), and any other notable information. The acoustic detection could also be recorded for further analysis.

PSO Data and Documentation

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

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

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

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

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

Results from the vessel-based observations would provide

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

A report would be submitted to NMFS and NSF within 90 days after the end of the cruise. The report would describe the operations that were conducted and sightings of marine mammals near the operations, and any other reporting requirements of the IHA. 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, all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities), and any observations of fish potentially affected by the sound sources. The report would also include estimates of the number and nature of exposures that could result in "takes" of marine mammals by harassment or in other ways.

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

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

The University of Alaska and NSF would coordinate with applicable U.S. agencies (e.g., NMFS, USFWS) and would comply with their requirements.

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List of Appendices

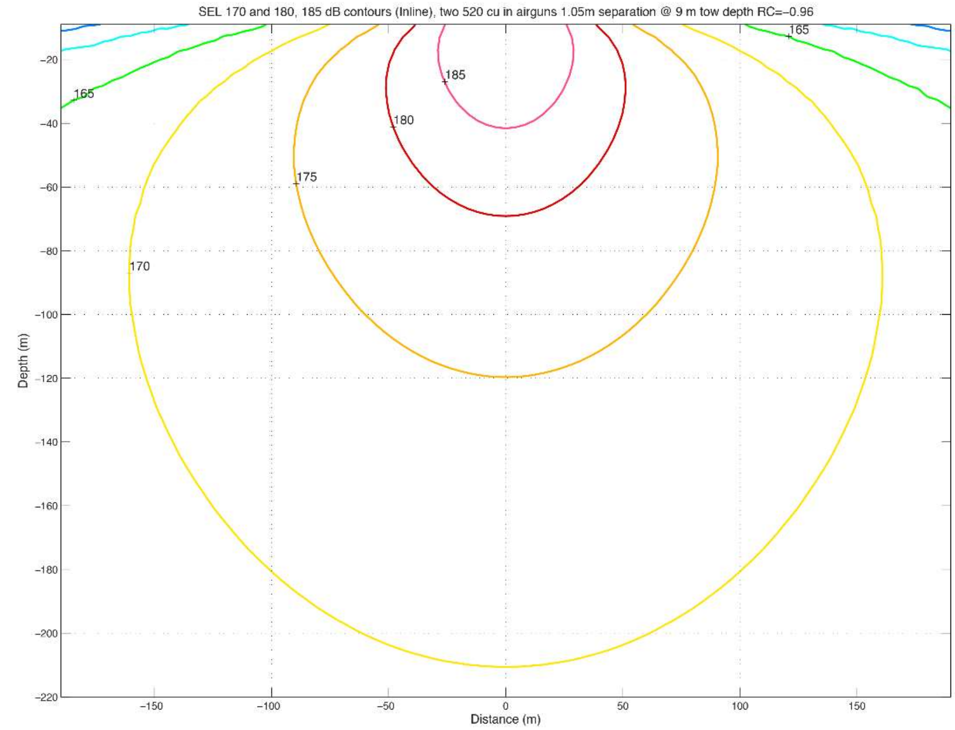
APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for the Level A exclusion zones (EZ) and the Level B (160 dB re 1µPa_{rms}) threshold. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the airgun arrays; all models used a 9-m tow depth. The L-DEO modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor).

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

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

The proposed surveys would acquire data with a 2 G-airgun and 6 G-airgun array at a maximum tow depth of 9 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m for the 2 G-airgun (Fig. A-1) and 6 G-airgun (Fig. A-2) array (Table A-1). The radii for intermediate water depths (100–1000 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 (Fig. 16 in Appendix H of the PEIS).



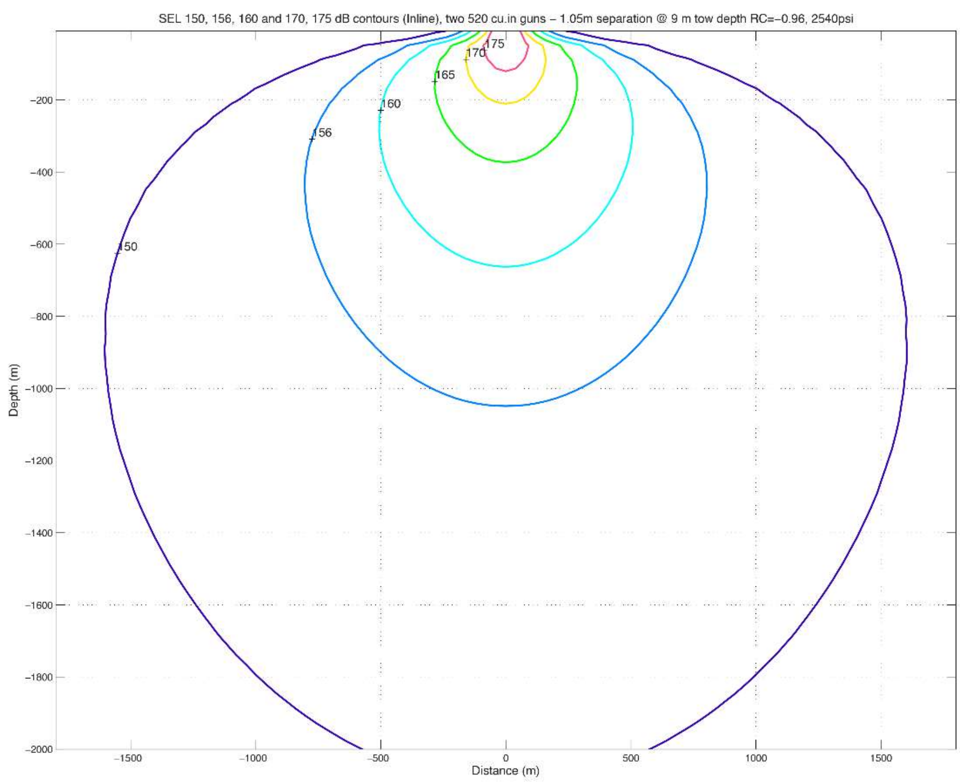
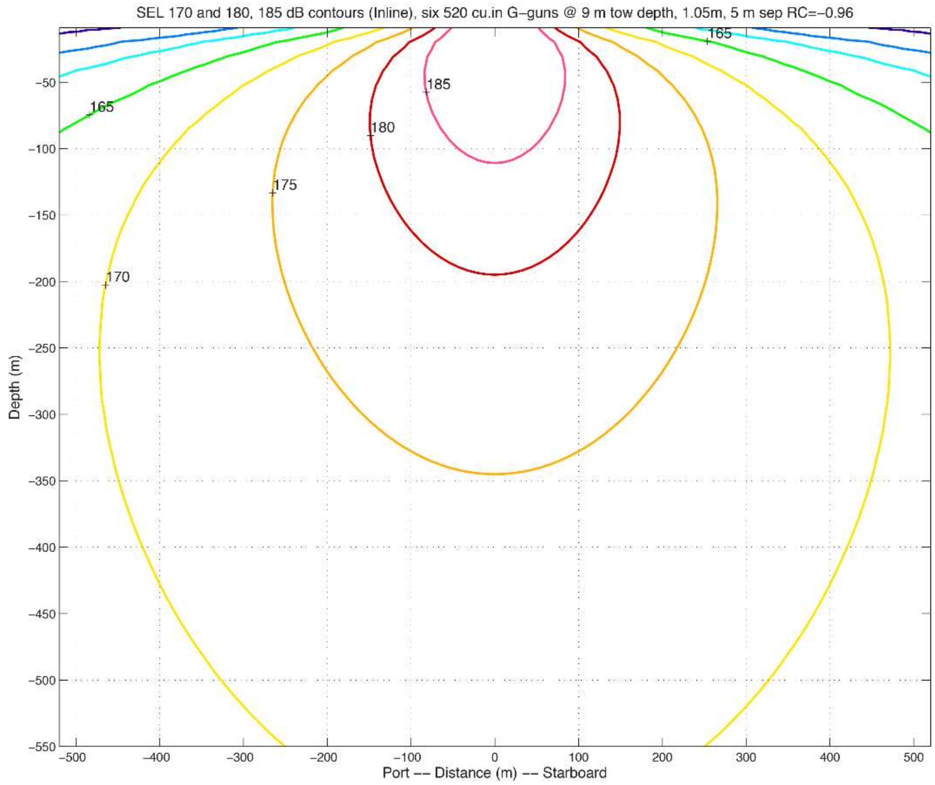


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 2 G-airgun array at a 9-m tow depth planned for use during the proposed surveys in the Arctic Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.



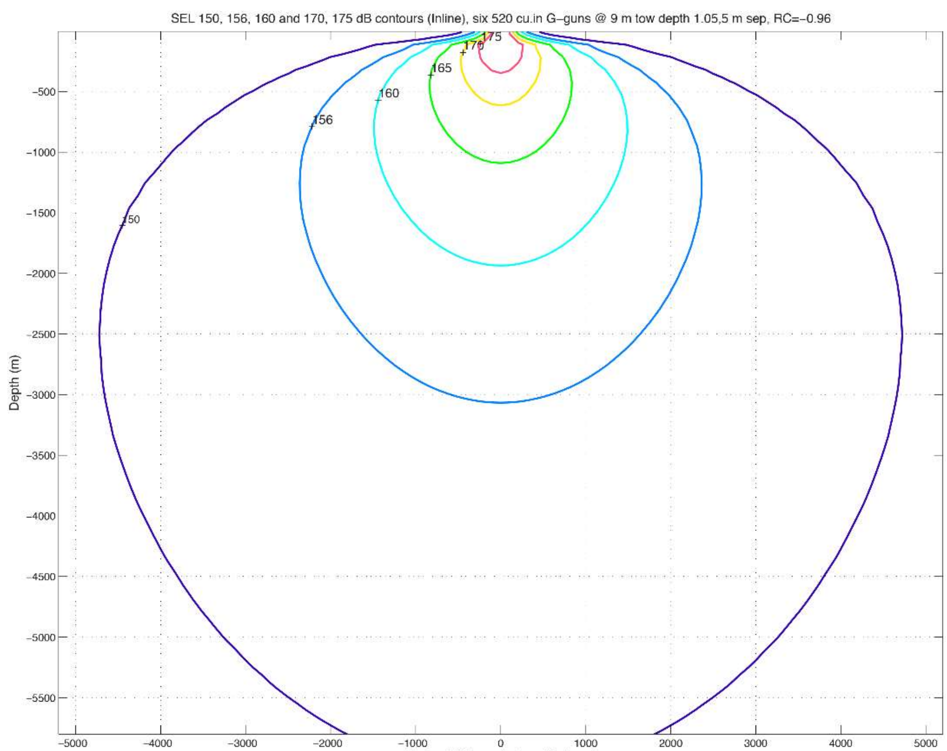


FIGURE A-2. Modeled deep-water received sound exposure levels (SELs) from the 6 G-airgun array at a 9-m tow depth planned for use during the proposed surveys in the Arctic Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

TABLE A-1. Level B. Predicted distances to which sound levels ≥160-dB could be received during the proposed surveys in the Arctic Ocean. The 160-dB criterion applies to all marine mammal hearing groups.

Source and Volume[1]	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level
Two 520 in^3 G-airguns, 1040 in^3	9	>1000 m	1604[2]
		100–1000 m	2406[3]
Six 520 in^3 G-airguns, 3120 in^3	9	>1000 m	4640[2]
		100–1000 m	6960[3]

[1] Modeled at 2540 psi.
[2] Distance is based on L-DEO model results.
[3] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.

Of note is that five separate comparisons conducted of the L-DEO model with *in situ* received levels[1] have confirmed that the L-DEO model generated conservative mitigation radii, resulting in significantly larger radii than required by NMFS.

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The noise exposure criteria for marine mammals account for newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL_{cum} and SPL_{flat}, respectively. The guidance incorporates marine mammal auditory weighting functions (Fig. A-3) and dual metrics of cumulative sound exposure level (SEL_{cum} over 24 hours) and peak sound pressure levels (SPL_{flat}). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids/other non-phocid carnivores underwater (OW). The largest distance of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate takes and Level A threshold distances. The NMFS guidance did not alter the current threshold, 160 dB re $1\mu Pa_{rms}$, for Level B harassment (behavior). Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups. It should be recognized that there are a number of limitations and uncertainties associated with these injury criteria (Southall et al. 2007). Lucke et al. (2020) caution that some current thresholds may not be able to accurately predict hearing impairment and other injury to marine mammals due to noise.

[1] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

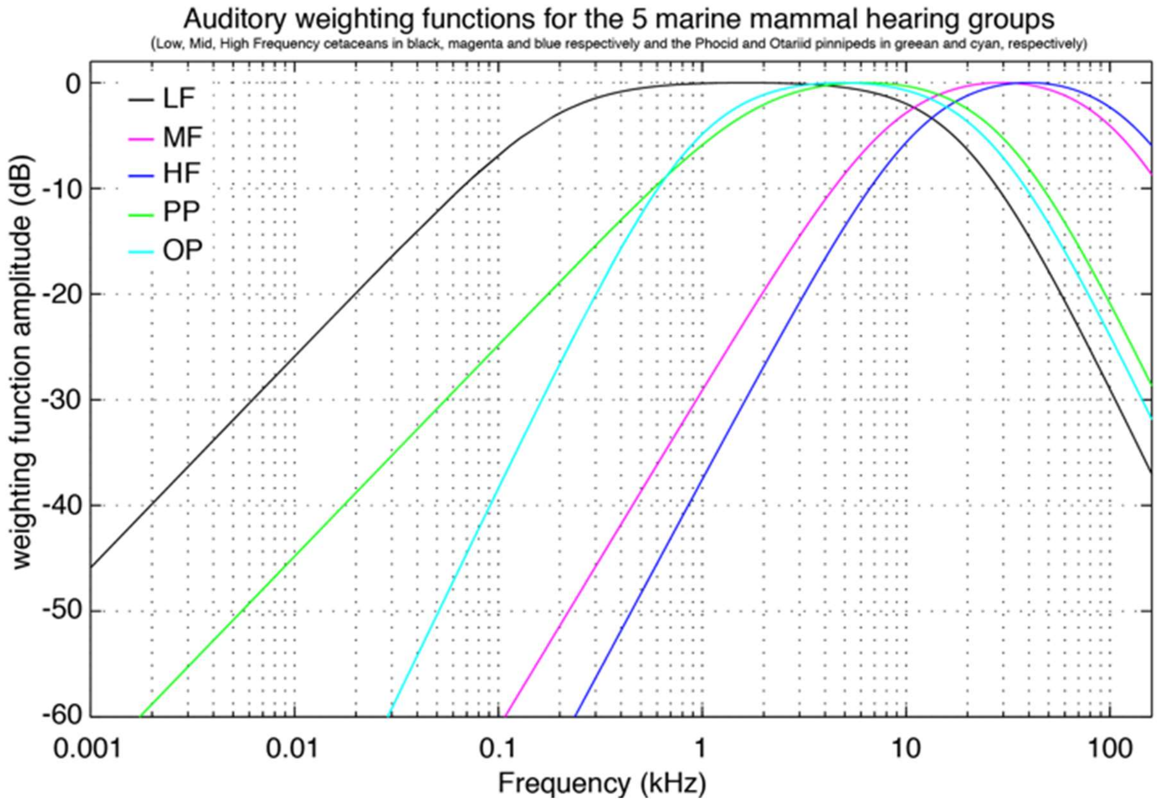


FIGURE A-3. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance.

The SEL_{cum} for the arrays are derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space (Tolstoy et al. 2009).

Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

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

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). Repetition rates of 15 s and 60 s were used for the 2 G-airgun and 6 G-airgun arrays, respectively, along with a source velocity of 2.315 m/s, as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the airgun arrays.

For the LF cetaceans, we estimated an adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function (e.g., the maximum isopleth was 39.87 m from the 2 G-airgun array; Table A-2). We then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum (e.g., the maximum isopleth was 13.79 m from the 2 G-airgun source). The difference between these values provides an adjustment factor and assumes a propagation of $20\log_{10}$(Radial distance), in this case 9.22 dB for the 2 G-airgun array. The radial distances are used to calculate the modified farfield values, whereas the radius is the vertical projection to the sea surface and distance from the source laterally, which is used for mitigation purposes.

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

For the 2 G-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 2 G-airgun array are shown in Table A-3. Figure A-4 shows the impact of weighting functions by hearing group. Figures A-5–A-7 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-8 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 2 G-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-9–A-10 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

For the 6 G-airgun array, the results for single shot SEL source level modeling are shown in Table A-5. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 6 G-airgun array are shown in Table A-6. Figure A-11 shows the impact of weighting functions by hearing group. Figures A-12–A-14 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-15 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 6 G-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-7. Figures A-16–A-17 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

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

SEL_{cum} Threshold	183	185	155	185	203
Radial Distance (m) (no weighting	39.8732	31.5298	1054.7	31.5298	4.2518
Modified Farfield SEL	215.0136	214.9744	215.4626	214.9744	215.5715
Radial Distance (m) (with weighting function)	13.7936	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-9.22	N.A.	N.A.	N.A.	N.A.

N.A. means not applicable or not available.

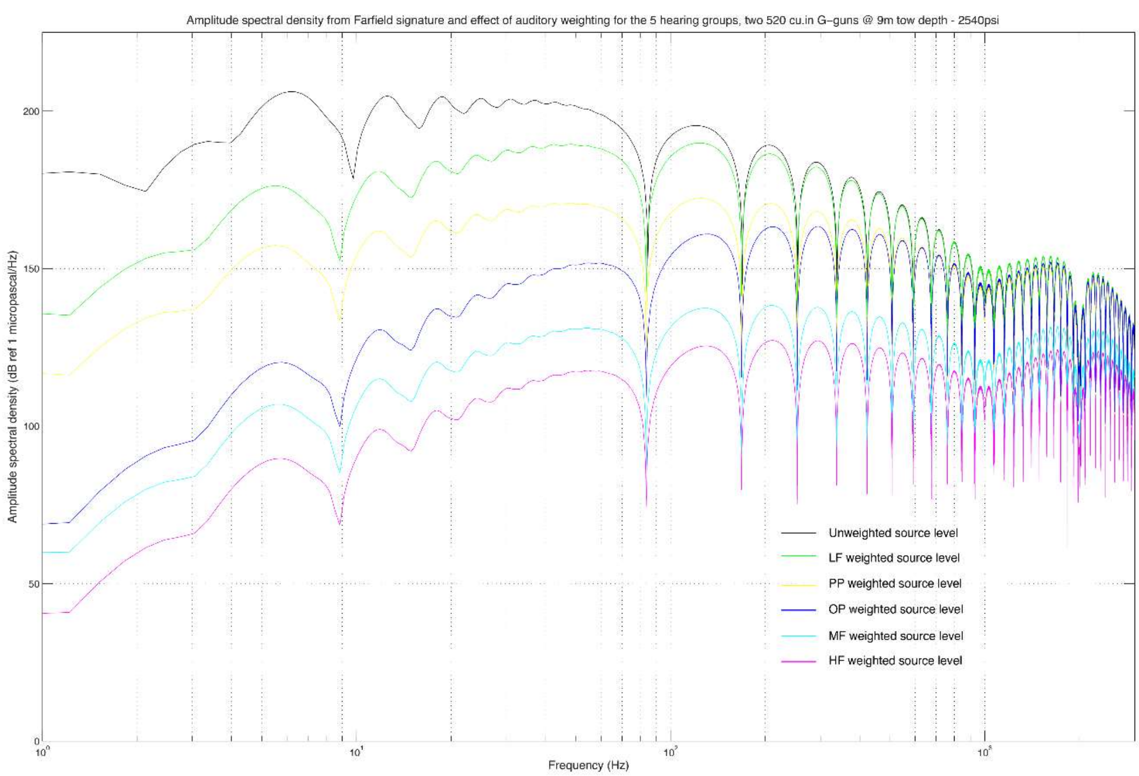


FIGURE A-4. Modeled amplitude spectral density of the 2 G-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-3. Results for modified farfield SEL source level modeling for the 2 G-airgun array with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for hearing groups.

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

VERSION 1.1: Aug-16

KEY	
(green)	**Action Proponent Provided Information**
(pink)	**NMFS Provided Information (Acoustic Guidance)**
(blue)	**Resultant Isopleth**

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Bernie Coakley
PROJECT/SOURCE INFORMATION Please include any assumptions	source : 2 x 520 cu.in G-guns at a 9m towed depth - (1.05 m separation) - 4.5 knots, shot interval is 15s. RMS SPL, Peak SPL and SELcum derived from the farfield signature
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	15

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

^Time between onset of successive pulses.

Modified farfield SEL	**215.0136**	**214.9744**	**215.4626**	**214.9744**	**215.5715**
Source Factor	**2.1148E+20**	**2.09579E+20**	**2.34514E+20**	**2.09579E+20**	**2.40469E+20**

RESULTANT ISOPLETHS*

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	**17.2**	**0.0**	**0.0**	**0.2**	**0.0**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-9.22	-57.71	-66.94	-26.96	-33.60	**OVERIDE Using LDEO Model**

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*$\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-4).

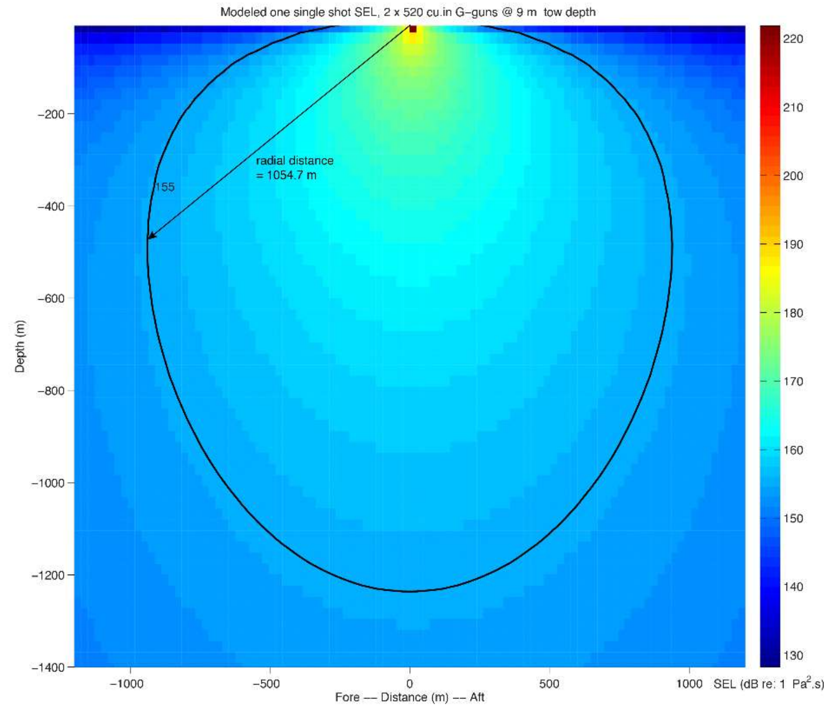


FIGURE A-5. Modeled received sound levels (SELs) in deep water from the 2 G-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth.

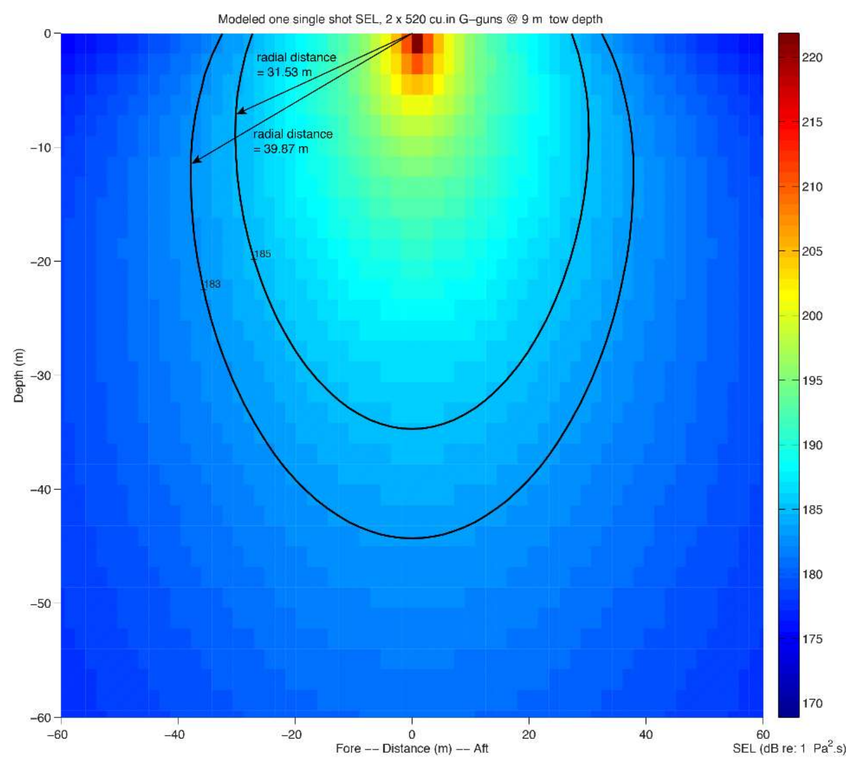


FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 2 G-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths.

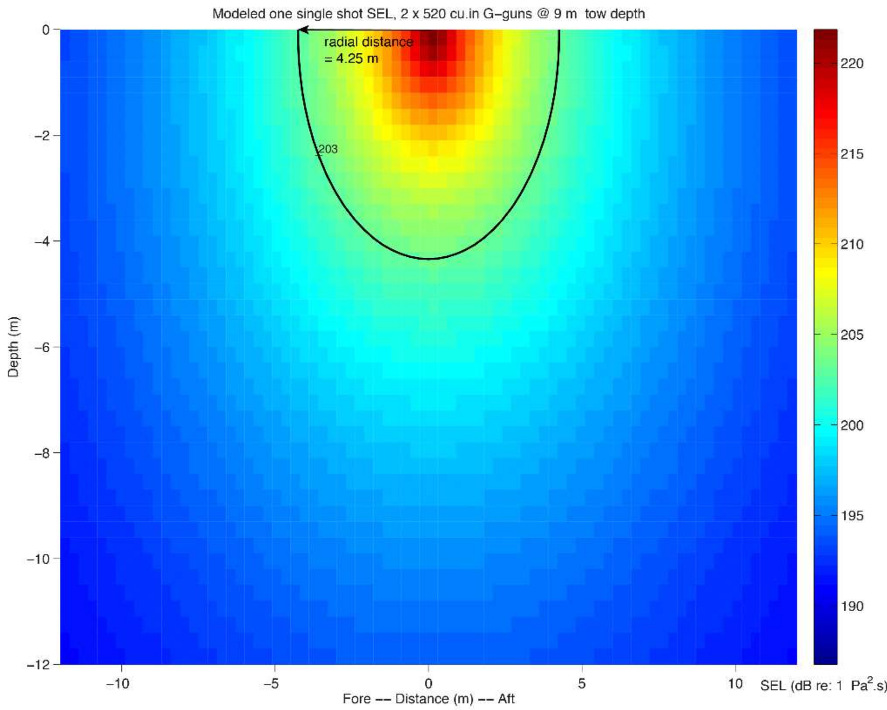


FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 2 G-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth.

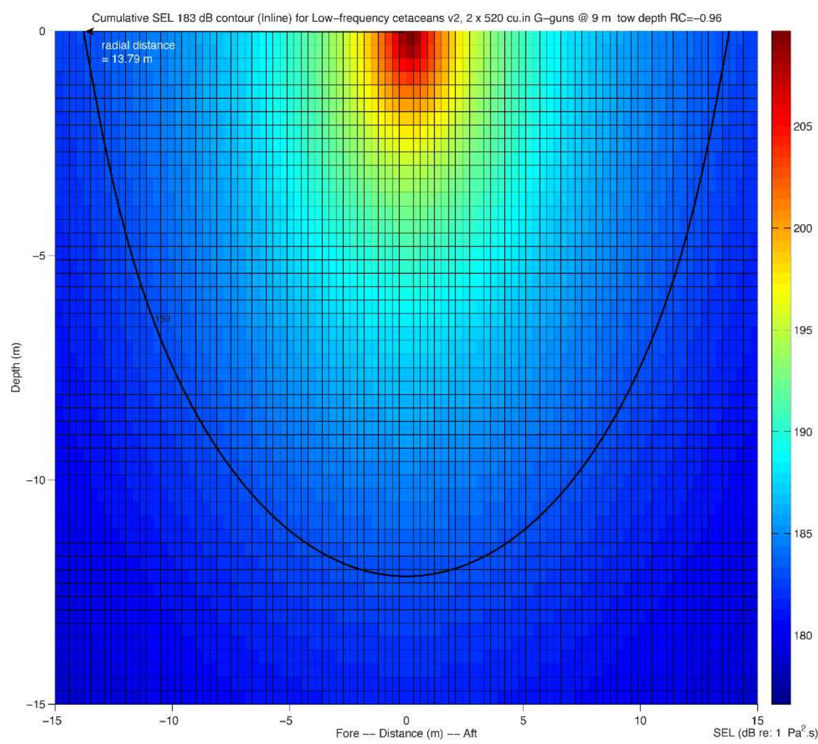


FIGURE A-8. Modeled received sound exposure levels (SELs) from the 2 G-airgun array at a 9-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-4 and this figure allows us to estimate the adjustment in dB.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 2 G-airgun array during the proposed surveys in the Arctic Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	10.29	2.86	72.92	11.55	2.26
PTS Peak Isopleth (Radius) to Threshold (m)	10.29	2.86	72.83	11.55	2.26

N.A. means not applicable or not available.

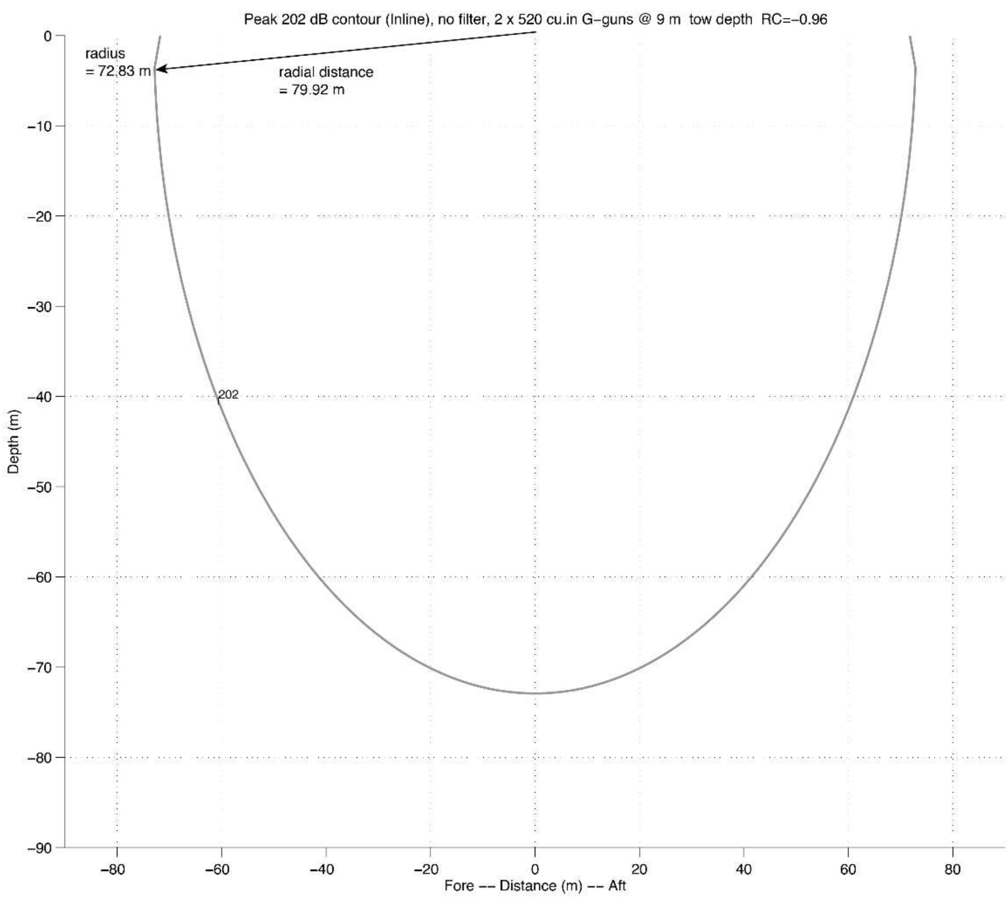


FIGURE A-9. Modeled deep-water received Peak SPL from the 2 G-airgun array at a 9-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

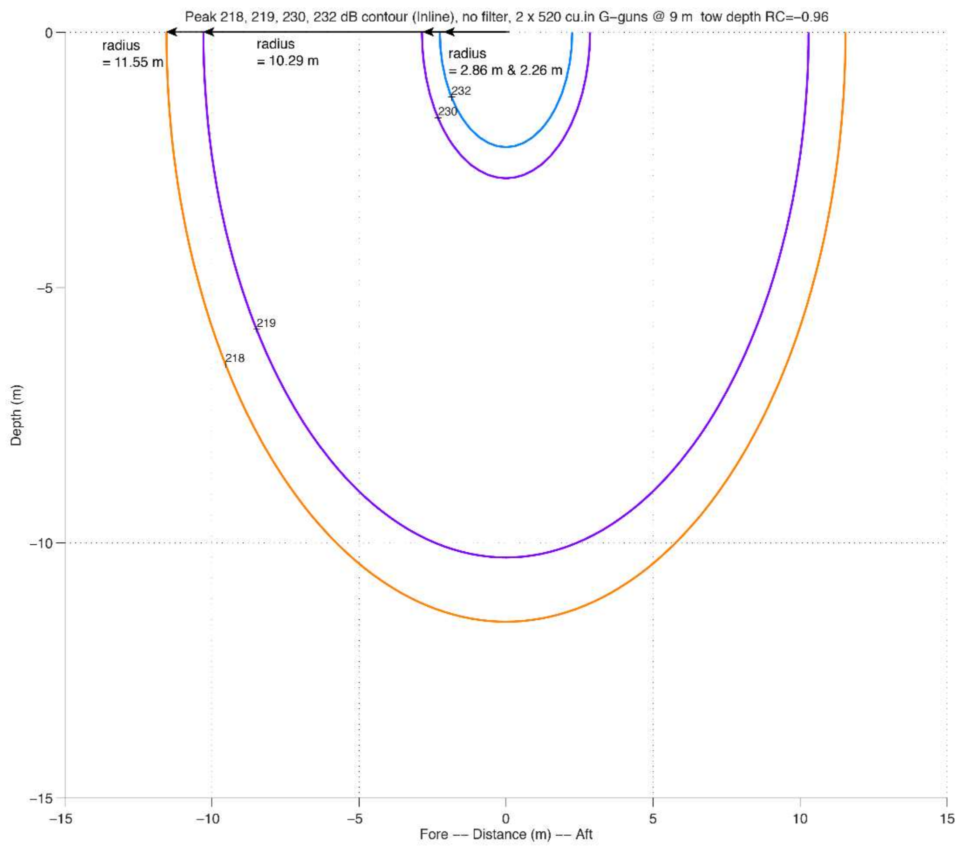


FIGURE A-10. Modeled deep-water received Peak SPL from the 2 G-airgun array at a 9-m tow depth. The plot provides the distances to the 218-, 219-, 230-, and 232-dB Peak isopleths.

TABLE A-5. Results for modified farfield SEL source level modeling for the 6 G-airgun array with and without applying weighting functions to the five marine mammal hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 log_{10} (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	183	185	155	185	203
Radial Distance (m) (no weighting	120.9616	95.4383	3127.6	95.4383	10.8078
Modified Farfield SEL	224.6530	224.5945	224.9042	224.5945	223.6747
Radial Distance (m) (with weighting function)	47.2888	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-8.1578	N.A.	N.A.	N.A.	N.A.

N.A. means not applicable or not available.

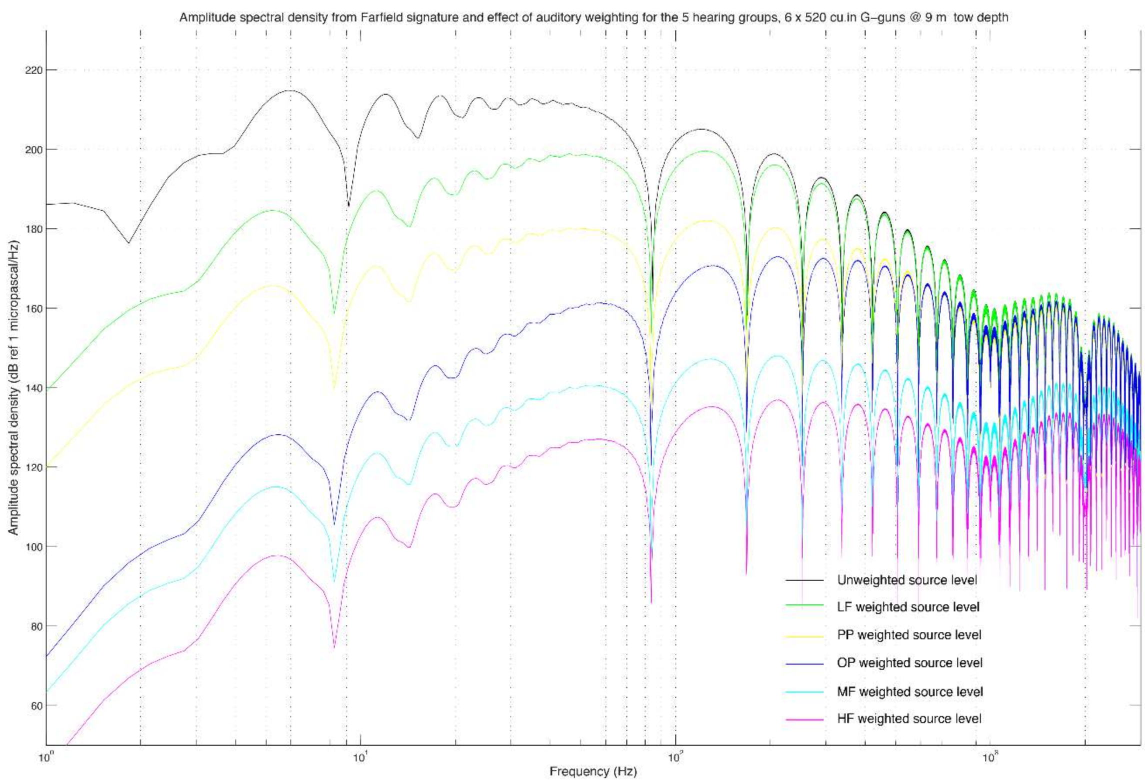


FIGURE A-11. Modeled amplitude spectral density of the 6 G-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-6. Results for modified farfield SEL source level modeling for the 6 G-airgun array with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	Bernie Coakley
PROJECT/SOURCE INFORMATION Please include any assumptions	source : 6 x 520 cu.in G-guns at a 9 m towed depth. Shot inteval is 60s. Source velocity of 4.5 knots
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT

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

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

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

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

STEP 3: SOURCE-SPECIFIC INFORMATION

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

NOTE: LDEO modeling relies on Method F2

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

SEL_{cum}

Source Velocity (meters/second)	2.315
1/Repetition rate^ (seconds)	60

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

^Time between onset of successive pulses.

Modified farfield SEL	224.653	224.5945	224.9042	224.5945	223.6747
Source Factor	4.86574E+20	4.80064E+20	5.15548E+20	4.80064E+20	3.88435E+20

RESULTANT ISOPLETHS*

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

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
SEL_{cum} Threshold	183	185	155	185	203
PTS SEL_{cum} Isopleth to threshold (meters)	**50.6**	**0.0**	**0.0**	**0.4**	**0.0**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-8.16	-57.42	-66.65	-26.67	-33.34	OVERIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*log10 (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-11).

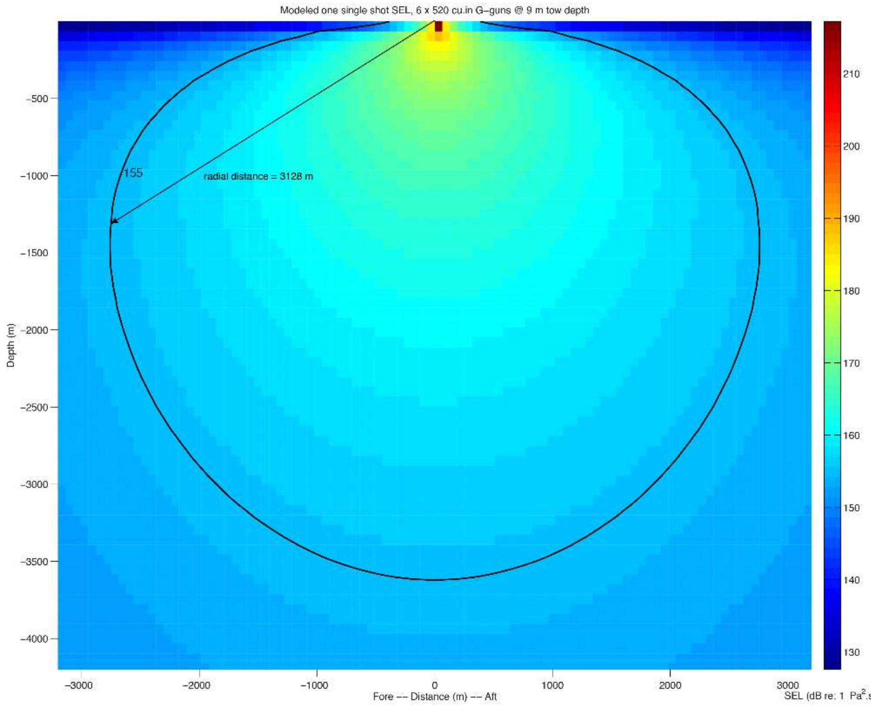


FIGURE A-12. Modeled received sound levels (SELs) in deep water from the 6 G-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth.

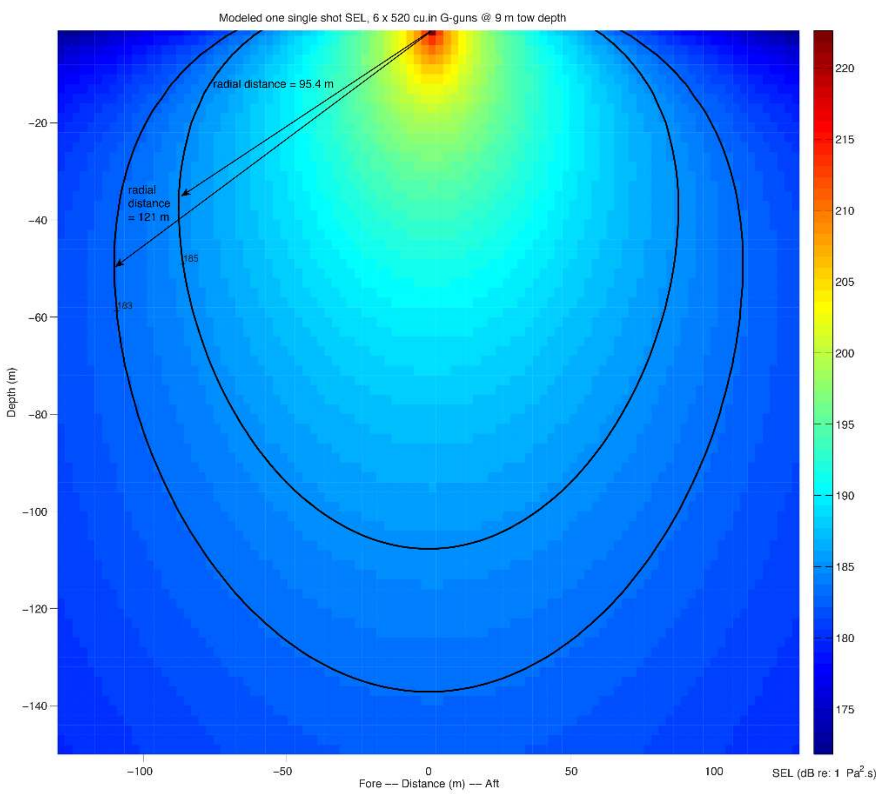


FIGURE A-13. Modeled received sound levels (SELs) in deep water from the 6 G-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths.

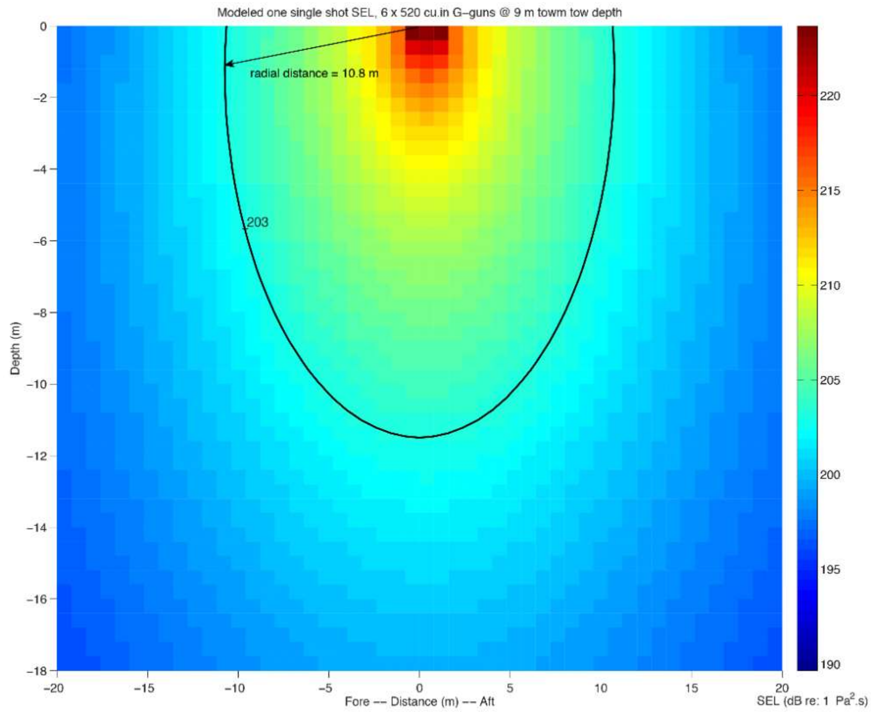


FIGURE A-14. Modeled received sound levels (SELs) in deep water from the 6 G-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB SEL isopleth.

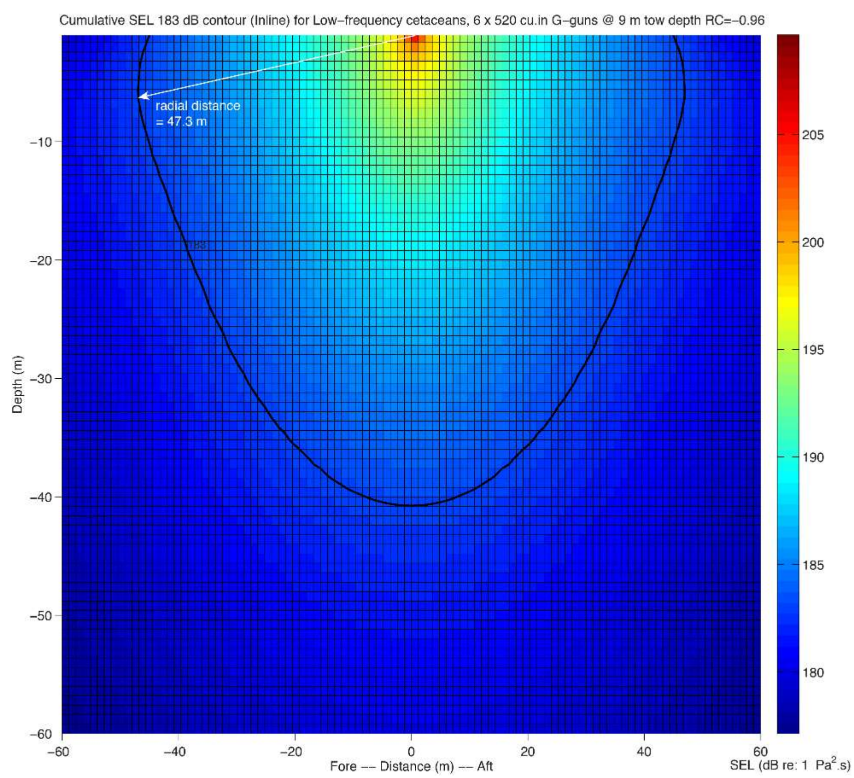


FIGURE A-15. Modeled received sound exposure levels (SELs) from the 6 G-airgun array at a 9-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot.

TABLE A-7. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 6 G-airgun array during the proposed surveys in the Arctic Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	29.8	7.2424	214.0959	33.603	5.1478
Modified Farfield Peak SPL	248.4971	247.1977	248.6122	248.5276	246.2324
PTS Peak Isopleth (Radius) to Threshold (m)	29.8	7.2	211.5	33.6	5.1

N.A. means not applicable or not available.

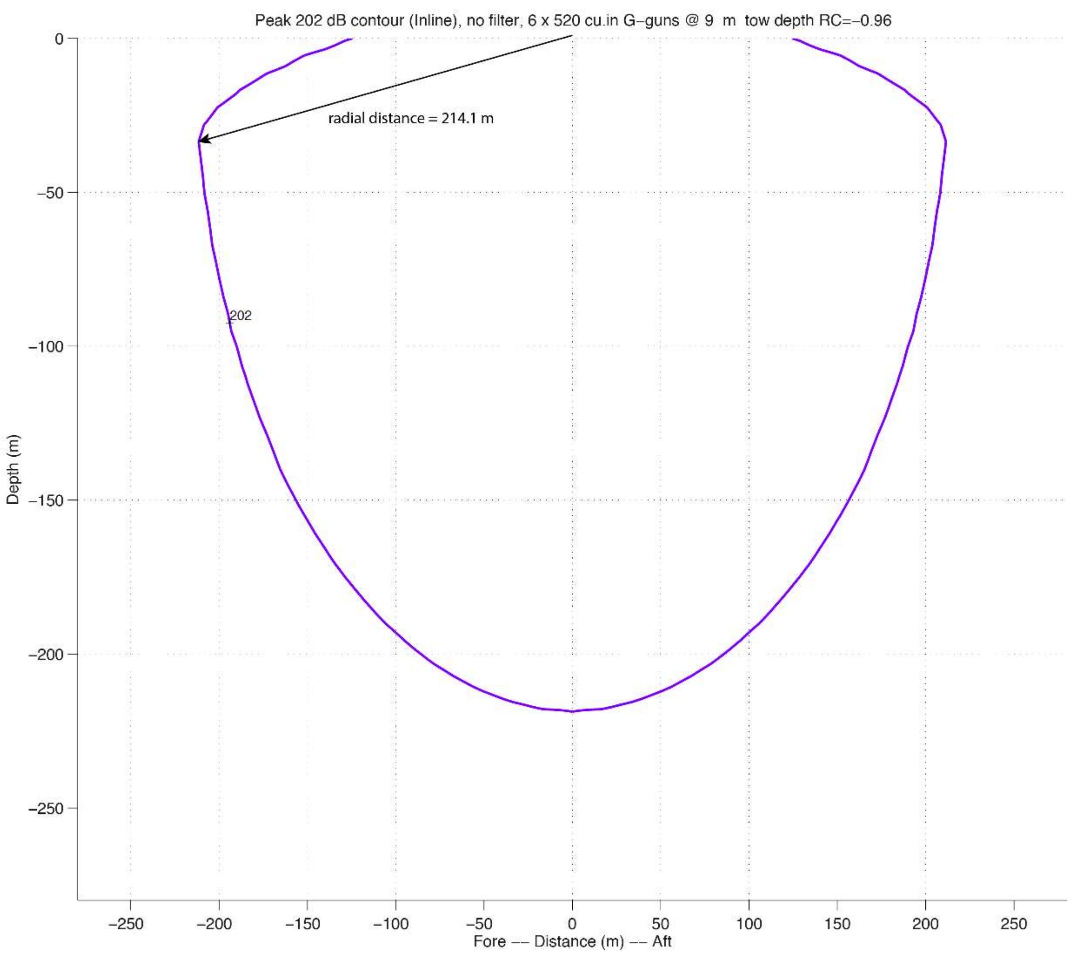


FIGURE A-16. Modeled deep-water received Peak SPL from the 6 G-airgun array at a 9-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

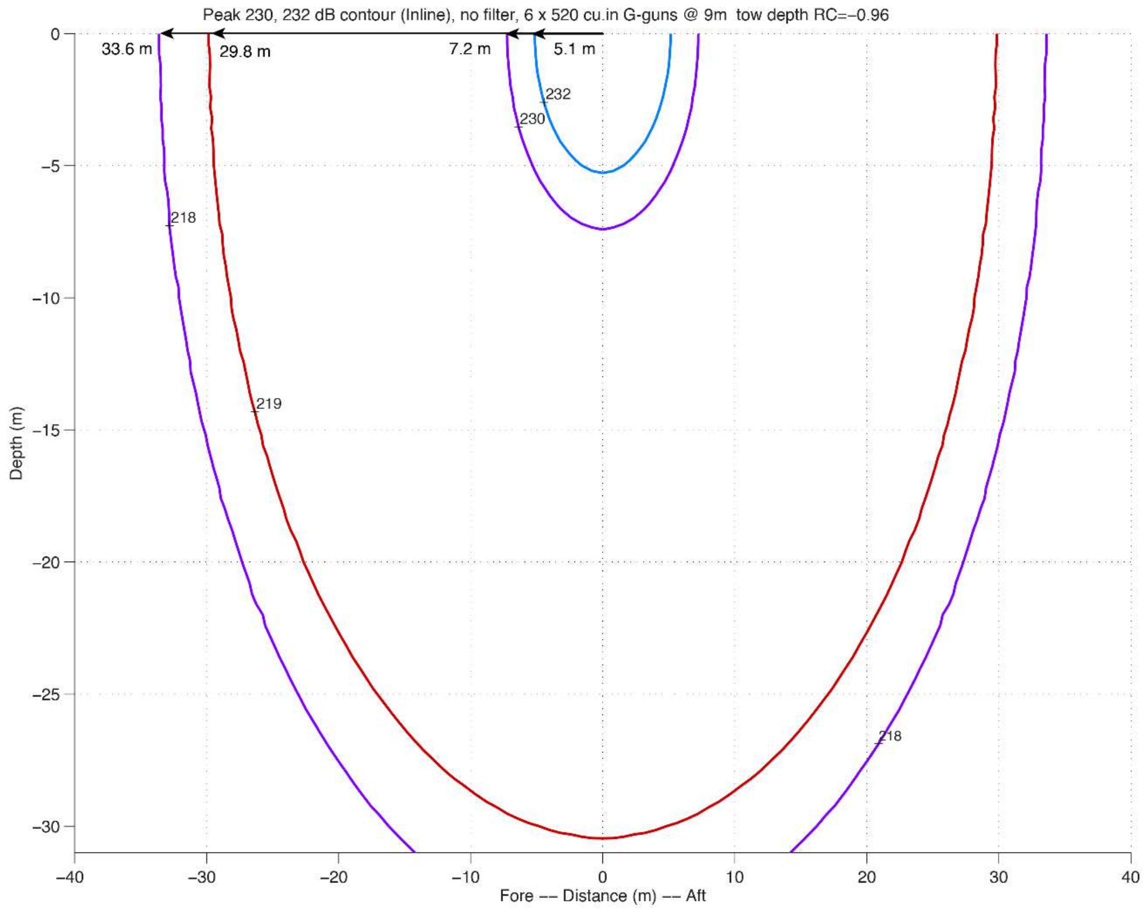


FIGURE A-17 Modeled deep-water received Peak SPL from the 6 G-airgun array at a 9-m tow depth. The plot provides the distances to the 218-, 219-, 230-, and 232-dB Peak isopleths.

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APPENDIX B: ENSONIFIED AREAS FOR MARINE MAMMAL TAKE CALCULATIONS

Survey Type	Depth Class	Criteria	Ensonified Area (km^2)	Ensonified Area + 25% Increase	Relevant Isopleth (m)
OBS	Deep >1000 m	160 dB	6,172	7,715	4,640
MCS	Deep >1000 m	160 dB	10,256	12,821	1,604
MCS	Intermediate 100-1000 m	160 dB	5,419	6,774	2,406
			21,847	27,309	
OBS	All	LF Cetacean	68.8	86.1	50.6
OBS	All	MF Cetacean	9.8	12.2	7.2
OBS	All	HF Cetacean	287.5	359.4	211.5
OBS	All	Phocid	45.7	57.1	33.6
OBS	All	Otariid	6.9	8.7	5.1
MCS	All	LF Cetacean	154.3	192.9	17.2
MCS	All	MF Cetacean	26.0	32.5	2.9
MCS	All	HF Cetacean	652.1	815.2	72.8
MCS	All	Phocid	104.1	130.1	11.6
MCS	All	Otariid	20.6	25.8	2.3
Total (OBS+MCS)	All	LF Cetacean	223.2	279.0	
Total (OBS+MCS)	All	MF Cetacean	35.8	44.8	
Total (OBS+MCS)	All	HF Cetacean	939.7	1174.6	
Total (OBS+MCS)	All	Phocid	149.8	187.3	
Total (OBS+MCS)	All	Otariid	27.6	34.5	