FINAL

OVERSEAS ENVIRONMENTAL ASSESSMENT

For

Office of Naval Research Arctic Research Activities in the Beaufort Sea 2018-2021

August 2018

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Abstract

Designation:	**Overseas Environmental Assessment**
Title of Proposed Action:	Office of Naval Research Arctic Research Activities in the Beaufort Sea 2018-2021
Project Location:	Beaufort Sea
Lead Agency for the EA:	Department of the Navy
Affected Region:	Beaufort Sea, Arctic
Action Proponent:	Office of Naval Research
Point of Contact:	Raymond Soukup Office of Naval Research Program Officer Email address: Raymond.soukup@navy.mil
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The Office of Naval Research (ONR) prepared this Overseas Environmental Assessment (OEA) in compliance with the Executive Order (E.O.) 12114, Department of Defense regulations found at 32 Code of Federal Regulations Part 187, Department of Defense Directive 6050.7, and the Chief of Naval Operations Instruction 5090.1D and its accompanying manual (M-5090).

This OEA evaluates the potential harm to the environment from ONR Arctic Research Activities that will occur under multiple projects. The Proposed Action includes research activities by the Naval Research Laboratory, for which ONR is a parent command. The Naval need for this scientific research relates to environmental characterization in support of combat capable forces ready to deploy worldwide in accordance with Title 10 United States Code (U.S.C.) §§ 5062, and to support the aims of the Arctic Research and Policy Act (15 U.S.C. §§ 4101 et seq.). For the Arctic this consists of potential submarine and surface ship operations with active sonar for anti-submarine warfare and submarine/surface ship force protection. The characterization of the potential Arctic battlespace, given the changes in water properties and ice cover, is critical to performance predictions for active and passive acoustic systems. The year-round characterization of the arctic environment requires characterization of the environment by leave-behind sources and autonomous vehicles, and the research projects are geared toward building multiple sources transmitting intermittently to allow vehicles to transmit under the ice. The purpose of the Proposed Action is to conduct scientific research in the Arctic and to gather data on environmental conditions and acoustics in an Arctic environment. This OEA evaluates three alternatives: the No Action Alternative and two Action Alternatives. Alternative 1, would conduct all the scientific research described in the Proposed Action, including the use of permitted active acoustic sources in shallow and deep water. Under Alternative 2, the use of permitted active acoustic sources would be limited to the deep-water area to meet only the core scientific objectives described in Alternative 1. Under Alternative 2, "*De minimis*" acoustic sources (sources qualitatively analyzed to determine appropriate determinations under E.O. 12114 in the appropriate resource harm analysis, as well as under the Marine

Mammal Protection Act and Endangered Species Act) would be allowed throughout the whole Study Area.

In this OEA, the Navy analyzes potential harm to the environment that could result from the No Action Alternative and two Action Alternatives. The resources evaluated include marine habitats, marine invertebrates, marine birds, fish, Essential Fish Habitat, and marine mammals.

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EXECUTIVE SUMMARY

Proposed Action

ONR's Arctic Research Activities (ARA), the Proposed Action, would conduct scientific experiments in the Beaufort Sea from June 2018 to December 2021. The Proposed Action includes several scientific objectives which support the Arctic and Global Prediction Program as well as the Ocean Acoustics Program. Specifically, the Proposed Action would include the Stratified Ocean Dynamics of the Arctic (SODA) project, Arctic Mobile Observing System (AMOS) project, Ocean Acoustics field work, and Naval Research Laboratory (NRL) experiments. The Proposed Action would occur within the Study Area depicted in Figure 1-1. The Study Area consists of a "deep water area" (where the twelve red dots are located), and a "shallow water area" (where the two yellow dots are located). All activities, except for the transit of ships or aircraft, would take place outside U.S. territorial waters. The Proposed Action would occur in either the U.S. Exclusive Economic Zone or the global commons (waters greater than 200 nautical miles (370 kilometers) from shore; Figure 1-1). Additional details regarding the specific experiments, timeframes and research objectives are further detailed below.

The SODA project would begin field work in September 2018 to the summer/fall of 2020 consisting of research cruises and the deployment of autonomous measurement devices for year-round observation of water properties (temperature and salinity) and the associated stratification and circulation. The deployment of the navigational sources shown by the 12 red dots would occur in the "deep water area" of the Study Area depicted in Figure 1-1. Navigation sources transmit intermittently from multiple locations. Autonomous vehicles would be able to navigate by receiving acoustic signals from multiple locations and triangulating. This is needed for vehicles that are under ice and cannot communicate with satellites. These physical processes are related to the ice cover and as the properties of the ice cover change, the water properties will change as well. Warm water feeding into the Arctic Ocean also plays an important role changing the environment. Observations of these phenomena require geographical sampling of areas of varying ice cover and temperature profile, and year-round temporal sampling to understand what happens during different parts of the year. Autonomous systems (gliders, unmanned undersea vehicles, moored sources) are needed for this type of year-round observation of a representative sample of active waters. Geolocation of autonomous platforms requires the use of acoustic navigation signals, and therefore, year-long use of active acoustic signals.

AMOS is planning field work from the summer/fall of 2019 to the summer/fall of 2021. The purpose of AMOS is to advance the technology required to field and operate an autonomous network of mobile sensing platforms in the Arctic, providing the Navy with the potential for persistent, year-round maritime domain awareness capability in the Arctic for both ice-covered and ice-free conditions. AMOS would develop and test a mobile array of unmanned platforms in the surface, air and undersea domains. The first generation of acoustic navigation beacons, deployed as part of SODA, would be usable (due to battery lifetime) through the summer of 2021, and while Arctic research may continue after that date, the nature of the platforms and the locations of deployments is expected to substantially change and be covered under future environmental planning documentations in collaboration with other Navy entities.

The ONR Ocean Acoustics Program also supports Arctic field work. The emphasis of the Ocean Acoustics field efforts is to understand how the changing environment affects acoustic propagation and the noise environment. These experiments are also spatially and temporally dependent, so observations in different locations on a year-round basis would be required. The potential for understanding the large-scale (range and depth) temperature structure of the ocean requires the use of long-range acoustic transmissions. The use of specialized waveforms and acoustic arrays allows signals to be received over a hundred kilometers from a source, while only requiring moderate source levels. The Ocean Acoustics program may perform these experiments in conjunction with the Arctic and Global Prediction Program by operating in the same location and with the same research vessels.

NRL would also conduct Arctic research in the same time frame with the same general scientific purpose as the Arctic and Global Prediction and Ocean Acoustics programs. Up to ten ice-tethered acoustic buoys are expected to be deployed for real-time environmental sensing and mid-frequency sonar performance predictions in the deep water area. Real-time assimilation of acoustic data into an ocean model is also planned. The ice-tethered acoustic buoys are designed to be operational up to two years. In addition, the NRL Acoustics Division has sources designed for long-range transmissions in the Arctic, and can perform acoustic experiments in conjunction with other ongoing experiments. NRL also plans to perform ice-characterization experiments with autonomous unmanned vehicles and aircraft. As ONR is a parent organization to NRL, ONR serves as action proponent for both ONR and NRL activities in this document.

Purpose of and Need for the Proposed Action

The primary purpose of these activities is to conduct acoustic propagation experiments over an extended period of time to assess the effects of the changing Arctic environment on acoustic propagation and oceanography and test the feasibility of using a field of active acoustic sources as navigation aids to unmanned vehicles collecting oceanographic and ice data under ice-covered conditions.

The Naval need for this scientific research relates to environmental characterization in support of combat capable forces ready to deploy worldwide in accordance with Title 10 United States Code (U.S.C.) §§ 5062, and to support the aims of the Arctic Research and Policy Act (15 U.S.C. §§ 4101 et seq.). For the arctic this consists of potential submarine and surface ship operations with active sonar for anti-submarine warfare and submarine/surface ship force protection. The characterization of the potential Arctic battlespace, given the changes in water properties and ice cover, is critical to performance predictions for active and passive acoustic systems. The year-round characterization of the arctic environment requires characterization of the environment by leave-behind sources and autonomous vehicles, and the research projects are geared toward building multiple sources transmitting intermittently to allow vehicles to transmit under the ice.

Alternatives Considered

Alternatives were developed for analysis based upon the following reasonable alternative screening factors: geographic sampling over a large area within the Arctic basin to observe large-scale oceanographic phenomena influencing the entire region (primary science objective); geographic sampling in deep water areas where there will be a total ice coverage during a portion of the year (primary science objective); acoustic source transmissions in deep water to allow for navigation of unmanned vehicles in ice-covered areas; acoustic source transmissions in deep water to observe how changes in Arctic oceanography are affecting acoustic propagation and bottom interaction (primary science objective); acoustic source propagation and oceanography in areas with varied bottom types and proximity to continental shelf areas (secondary science objective, depending on results obtained from CANAPE 2016/17 experiment); waters of appropriate depths to meet the scientific objectives of the Proposed Action (e.g., deep water sources require specific depths in order to appropriately measure duct propagation), and; locations which will have total ice coverage during a portion of the year and specific bottom types needed in the Arctic environment for scientific measurement. The Navy is considering two action alternatives that meet the purpose and need for the Proposed Action and a No Action Alternative. Alternative 1 would be to conduct all the scientific research described in the Proposed Action, including the use of permitted active acoustic sources in shallow and deep water. This meets the core scientific objectives of the research projects described above (Purpose and Need), particularly the measurement of acoustic, oceanographic, and ice properties over a multi-year period and the use of acoustic sources as navigation aids to unmanned vehicles in the basin. It also meets secondary scientific objectives of performing acoustic testing in a complex three directional bathymetric environment by including the use of permitted active acoustic sources in the shelf areas. Alternative 2 (Preferred Alternative) would be to conduct only that scientific research that is directly related to the core scientific objectives laid out in Alternative 1. Under Alternative 2, only deep water area, permitted active acoustic sources and *de minimis* sources would be used. The No Action Alternative would not involve any ONR activity associated with the Proposed Action.

Summary of Environmental Resources Evaluated in the OEA

Executive Order (E.O.) 12114 and Navy instructions for implementing E.O. 12114, specify that an Overseas Environmental Assessment (OEA) should address those resource areas potentially subject to harm. In addition, the level of analysis should be commensurate with the anticipated level of environmental harm.

The following resource areas have been addressed in this OEA: physical resources (atmospheric temperature, bathymetry, currents, circulation, and water masses, water quality, and sea ice) and biological resources (invertebrates, marine birds, fish, Essential Fish Habitat, and marine mammals). Because potential impacts were considered to be negligible or nonexistent, the following resources were not evaluated in this OEA: air quality, cultural resources, land use, visual resources, airspace, water quality, deep sea corals and coral reefs, marine vegetation, and sea turtles.

Summary of Potential Environmental Consequences of the Action Alternatives and Major Mitigating Actions

The results of the analysis indicate that none of the alternatives considered would significantly harm physical or biological resources. The Navy will consult with the National Marine Fisheries Service (NMFS) and the United States Fish and Wildlife Service (USFWS) under Section 7 of the Endangered Species Act (ESA) regarding the Preferred Alternative.

Under both Alternatives 1 and 2, some of the species protected under the Marine Mammal Protection Act (MMPA) were predicted to be exposed to acoustic stressors (non-impulsive acoustic sources and icebreaking noise) that equated to Level B harassment levels. The Navy will consult annually with NMFS to request Incidental Harassment Authorizations (IHA), for the duration of the Proposed Action, for the predicted Level B exposures.

Table ES-1 provides a tabular summary of the potential impacts to the resources associated with each of the alternative actions analyzed.

Table ES-1. Summary of Potential Harm to Resource Areas

Resource Area	***No Action Alternative***	***Alternative 1***	***Alternative 2 (Preferred Alternative)***
Physical Resources	No change to baseline.	The potential harm would be temporary and localized due to the minimal number of devices and the infrequency of testing activities, and soft sediment is expected to shift back as it would following a disturbance of tidal energy. No long-term increases in turbidity (sediment suspended in water) would be anticipated. The localized disturbances would not alter the function or habitat provided by marine substrates or sea ice. No significant harm to ambient noise levels would occur as a result of the Proposed Action.	The potential harm would be temporary and localized due to the minimal number of devices and the infrequency of testing activities, and soft sediment is expected to shift back as it would following a disturbance of tidal energy. No long-term increases in turbidity (sediment suspended in water) would be anticipated. The localized disturbances would not alter the function or habitat provided by marine substrates or sea ice. No significant harm to ambient noise levels would occur as a result of the Proposed Action.
Invertebrates	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to invertebrates.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to invertebrates.
Marine Birds	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine birds.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine birds.
Fish	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to fish.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to fish.
Essential Fish Habitat	No change to baseline.	With standard operating procedures and mitigation measures, potential adverse effects from the Proposed Action would be considered minimal.	With standard operating procedures and mitigation measures, potential adverse effects from the Proposed Action would be considered minimal.

Resource Area	***No Action Alternative***	***Alternative 1***	***Alternative 2 (Preferred Alternative)***
Marine Mammals	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine mammals.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine mammals.

Overseas Environmental Assessment

ONR Arctic Research Activities 2018-2021

Beaufort Sea, Arctic

TABLE OF CONTENTS

List of Figures

List of Tables

Appendices

Appendix Tables

Appendix Figures

Abbreviations and Acronyms

Acronym	Definition
°C	Degrees Celsius
°E	Degrees East
°F	Degrees Fahrenheit
°N	Degrees North
°W	Degrees West
ACDP	Acoustic Doppler Current Profiler
AMOS	Arctic Mobile Observing System
ARA	Arctic Research Activities
BOEM	Bureau of Ocean Energy Management
BRF	Behavioral Response Function
CASS/GRAB	Comprehensive Acoustic System Simulation/Gaussian Ray Bundle
CFR	Code of Federal Regulations
CGC	Coast Guard Cutter
cm	centimeter(s)
cm/s	centimeters per second
cm^3	cubic centimeters
dB	decibel(s)
dB re 1 µPa	decibel(s) referenced to 1 micropascal
dB re 1 $µPa^2$-s	decibel(s) referenced to 1 square micropascal-second
dB re 20 µPa	decibel(s) referenced to 20 micrpascal
dBA	A-weighted sound level
DPS	Distinct Population Segment
EEZ	Exclusive Economic Zone
EMATT	Expendable Mobile Anti-Submarine Warfare Training Targets
E.O.	Executive Order
ESA	Endangered Species Act
ft	foot/feet
Hz	hertz
IHA	Incidental Harassment Authorization
in	inch(es)
in^3	cubic inches
in/s	inches per second
kg	kilogram(s)
kHz	kilohertz
km	kilometer(s)
km^2	square kilometer(s)
km/day	kilometers per day
lb	pound(s)
m	meter(s)
MBTA	Migratory Bird Treaty Act
mi	mile(s)
mi^2	square miles
m/s	meters per second
MSA	Magnuson Stevens Fishery Conservation and Management Act
MMPA	Marine Mammal Protection Act
NAEMO	Navy Acoustic Effects Model
NAAQS	National Ambient Air Quality Standards
Navy	United States Department of the Navy
nm	nautical miles
NMFS	National Marine Fisheries Service
NMSDD	Navy Marine Species Density Database
NRL	National Research Laboratory
OAML	Oceanographic and Atmospheric Master Library
OEA	Overseas Environmental Assessment
ONR	Office of Naval Research
PIES	Pressure Inverted Echosounders
psu	practical salinity units
PTS	Permanent Threshold Shift
R/V	Research Vessel

Acronym	Definition
SEL	sound exposure level
SODA	Stratified Ocean Dynamics in the Arctic
SPL	sound pressure level
SPL_{RMS}	Root mean square sound pressure level
SWIFT	Surface Wave Instrument Float with Tracking
TTS	temporary threshold shift
UAS	Unmanned Aerial System
U.S.	United States
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service

1 Purpose of and Need for the Proposed Action

1.1 Introduction

The Office of Naval Research's (ONR) Arctic Research Activities (ARA), the Proposed Action, would conduct scientific experiments in the Beaufort Sea from September 2018 to December 2021. The Proposed Action includes several scientific objectives which support the Arctic and Global Prediction Program as well as the Ocean Acoustics program. Specifically, the Proposed Action would include the Stratified Ocean Dynamics of the Arctic (SODA) project, Arctic Mobile Observing System (AMOS) project, Ocean Acoustics field work, and Naval Research Laboratory (NRL) experiments.

The United States (U.S.) Department of the Navy (Navy) has prepared this Overseas Environmental Assessment (OEA) in accordance with Executive Order (E.O.) 12114.

1.2 Location

The Proposed Action would occur within the Study Area depicted in Figure 1-1. The Study Area consists of a "deep water area" (where the twelve red dots are located), and a "shallow water area" (*de minimis* sources used near continental shelf). All activities, except for the transit of ships or aircraft, would take place outside U.S. territorial waters. The Proposed Action would occur in either the U.S. Exclusive Economic Zone (EEZ) or the global commons (waters greater than 200 nautical miles (370 kilometers) from shore; (Figure 1-1). Additional details regarding the specific experiments, timeframes and research are further detailed below in Section 2.1.

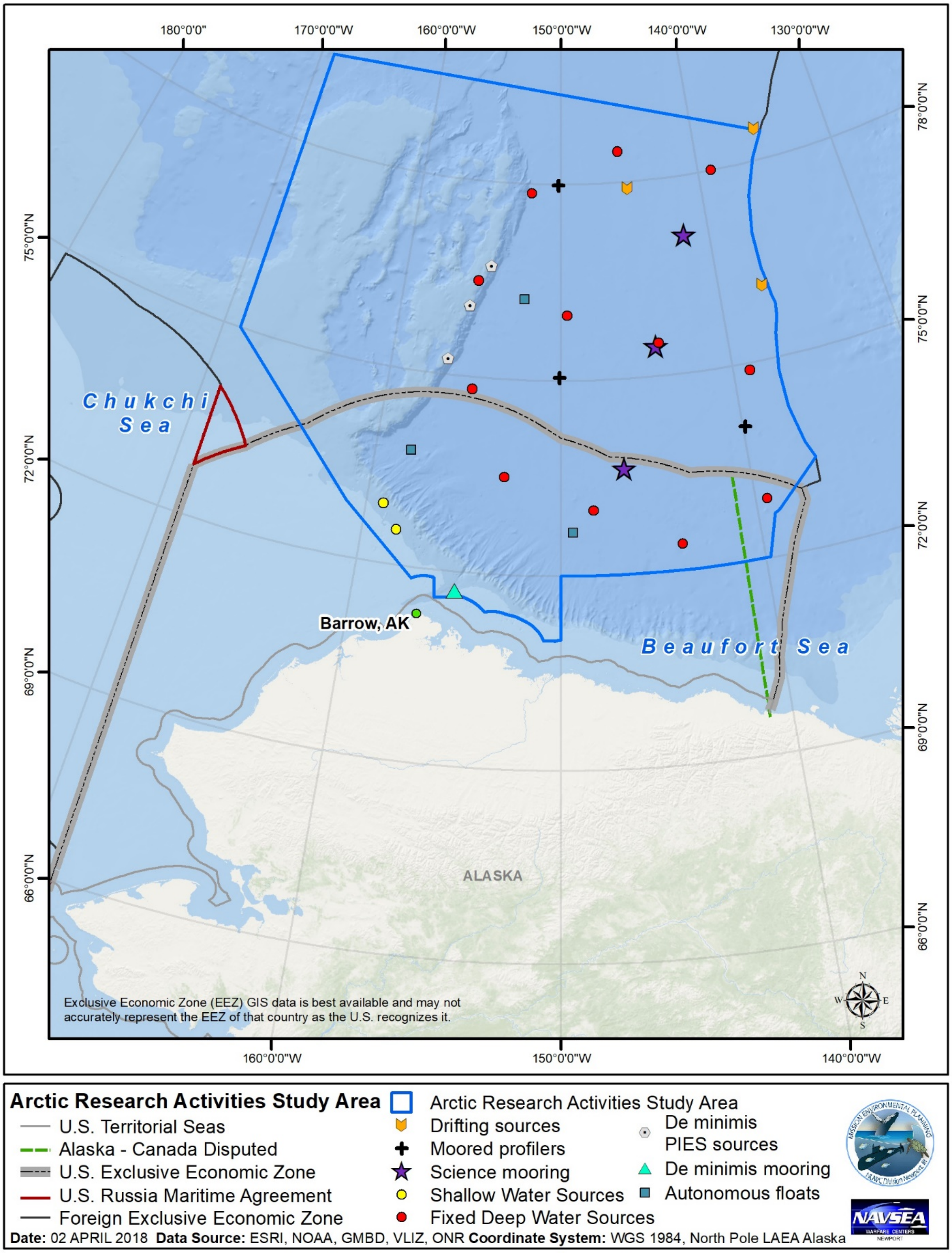

Figure 1-1. Arctic Study Area

1.3 Purpose of and Need for the Proposed Action

ARA encompass activities supported by the ONR Arctic and Global Prediction Program, the ONR Ocean Acoustics Program, and the NRL. The primary purpose of these activities is to conduct acoustic propagation experiments over an extended period of time to assess the effects of the changing Arctic environment on acoustic propagation and oceanography and test the feasibility of using a field of active acoustic sources as navigation aids to unmanned vehicles collecting oceanographic and ice data under ice-covered conditions.

The Naval need for this scientific research relates to environmental characterization in support of combat capable forces ready to deploy worldwide in accordance with Title 10 United States Code (U.S.C.) §§ 5062, and to support the aims of the Arctic Research and Policy Act (15 U.S.C. §§ 4101 et seq.). For the arctic this consists of potential submarine and surface ship operations with active sonar for anti-submarine warfare and submarine/surface ship force protection. The characterization of the potential Arctic battlespace, given the changes in water properties and ice cover, is critical to performance predictions for active and passive acoustic systems. The year-round characterization of the arctic environment requires characterization of the environment by leave-behind sources and autonomous vehicles, and the research projects are geared toward building multiple sources transmitting intermittently to allow vehicles to transmit under the ice. The Navy's strategic objectives for the Arctic Region, according to the U.S. Navy Arctic Roadmap 2014-2030 (Chief of Naval Operations 2014) are to (1) ensure U.S. Arctic sovereignty and provide homeland defense, (2) provide naval forces ready to respond to crises and contingencies, (3) preserve freedom of the seas, and (4) promote partnerships within the U.S. Government and International allies. The Department of Defense specifically tasks the Navy with providing "Increased certainty and accuracy of sea-ice forecasts and predictions, and by showing improved understanding of feedback processes driving sea ice variability". Predictive models of the arctic environment are needed to understand how military equipment, sensors, training and operation may be affected by changing conditions. The results also would also allow more accurate predictions of the physical and acoustic processes that would affect how sound transmissions (natural and human-made) could affect marine mammal populations. Therefore, the scientific research contains both military and non-military implications.

1.4 Scope of Environmental Analysis

This OEA includes an analysis of potential environmental harm associated with the action alternatives and the No Action Alternative. The environmental resource areas analyzed in this OEA include: physical environment (atmospheric temperature, bathymetry, currents, circulation, and water masses, water quality, and sea ice) and biological resources (invertebrates, marine birds, fish, Essential Fish Habitat, and marine mammals).

1.5 Relevant Laws and Regulations

The Navy has prepared this OEA based upon federal, statutes, regulations, and policies that are pertinent to the implementation of the Proposed Action, including the following:

- Arctic Research and Policy Act (15 U.S.C. section 4101-4111)
- Endangered Species Act (ESA) (16 U.S.C. section 1531 et seq.)
- Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (16 U.S.C. section 1801 et seq.)
- Marine Mammal Protection Act (MMPA) (16 U.S.C. section 1361 et seq.)

- Migratory Bird Treaty Act (MBTA) (16 U.S.C. sections 703-712)
- E.O. 12114, Environmental Effects Abroad of Major Federal Actions

A description of the Proposed Action's consistency with these laws, policies and regulations, as well as the names of regulatory agencies responsible for their implementation, is presented in Table 6-1.

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2 Proposed Action and Alternatives

2.1 Proposed Action

The Office of Naval Research's (ONR) Arctic Research Activities (ARA), the Proposed Action, would conduct scientific experiments in the Beaufort Sea from September 2018 to December 2021. The Proposed Action includes several scientific objectives which support the Arctic and Global Prediction Program as well as the Ocean Acoustics program. Specifically, the Proposed Action would include the Stratified Ocean Dynamics of the Arctic (SODA) project, Arctic Mobile Observing System (AMOS) project, Ocean Acoustics field work, and Naval Research Laboratory (NRL) experiments as described below. The Proposed Action would occur within the Study Area depicted in Figure 1-1. The Study Area consists of a "deep water area" (where the twelve red dots are located), and a "shallow water area" (where the two yellow dots are located). All activities, except for the transit of ships or aircraft, would take place outside U.S. territorial waters. The Proposed Action would occur in either the U.S. Exclusive Economic Zone (EEZ) or the global commons (Figure 1-1). Additional details regarding the specific experiments, timeframes and research are further detailed below.

The Arctic and Global Prediction Program would support two projects: SODA and AMOS. SODA would conduct observation of water properties (temperature and density) and the associated stratification and circulation over a period of up to three years. These physical processes are related to the ice cover and as the properties of the ice cover change, the water properties will change as well. Observations of these phenomena require geographical sampling of areas of varying ice cover and temperature profile, and year-round temporal sampling to understand what happens during different parts of the year. Autonomous systems are needed for this type of year-round observation of a representative sample of active waters. Geolocation of autonomous platforms requires the use of acoustic navigation signals, and therefore, year-long use of active acoustic signals. Warm water feeding into the Arctic Ocean is playing an important role changing the environment over a multi-year period, so observations over three years will be needed.

AMOS would conduct field work from the summer/fall of 2019 through summer/fall of 2021. The purpose of AMOS is to advance the technology required to field and operate an autonomous network of mobile sensing platforms in the Arctic, providing the Navy with the potential for persistent, year-round maritime domain awareness capability in the Arctic for both ice-covered and ice-free conditions. AMOS would develop and test a mobile array of unmanned platforms in the surface, air and undersea domains.

ONR's Ocean Acoustics program also supports Arctic field work. The Ocean Acoustics program may perform future experiments in conjunction with the Arctic and Global Prediction Program by operating in the same location and with the same research vessels. The emphasis of the Ocean Acoustics programs field efforts would be to understand how the changing environment affects acoustic propagation and the noise environment. These experiments are spatially and temporally dependent, so observations in different locations on a year-round basis would be required. The potential for understanding the large-scale (range and depth) temperature structure of the ocean requires the use of long-range acoustic transmissions. The use of specialized waveforms and acoustic arrays allows signals to be received over a hundred kilometers from a source, while only requiring moderate source levels. Ocean Acoustics program efforts also involve the characterization of acoustic propagation in canyon and continental shelf areas where three-dimensional bathymetry is relevant.

The NRL would also conduct Arctic research during the same time frame which would support the same general purposes. The NRL Acoustics division has sources designed for long-range transmissions in the Arctic and can perform acoustic experiments in conjunction with the Ocean Acoustics and Arctic and

Global Prediction Programs. The emphasis of the NRL's work has been on evaluating the potential performance of mid-frequency sonar systems in the Arctic environment. Future work would focus on the possibility of performing near real-time acoustic environmental assessment through the exfiltration of ice-tethered buoy data. NRL would also perform airborne measurements of ice properties using electromagnetic signals and acoustic measurement of ice properties using unmanned vehicles.

2.2 Research Equipment and Platforms

Below are the descriptions of the equipment and platforms which would be deployed at different times during the Proposed Action. The presentation of the information is provided starting with the experiments or data collection which would happen first.

2.2.1 Glider Surveys

The Proposed Action would begin in September 2018 with the deployment of gliders from a small vessel outside U.S. territorial waters. The gliders would transit to the Study Area. Glider deployments and surveys are also proposed for 2019, 2020 and 2021. All gliders would be recovered during the cruises of the U.S. Coast Guard Cutter (CGC) HEALY and/or Research/Vessel (R/V) Sikuliaq.

Long-endurance, autonomous seagliders (Figure 2-1) are intended for use in extended missions in ice-covered waters. Gliders are buoyancy-driven, equipped with satellite modems providing two-way communication, and are capable of transiting to depths of up to 3,280 feet (ft; 1,000 meters [m]). Gliders would collect data in the area of the shallow water sources and moored sources, moving at a speed of 0.25 meters per second (m/s; 23 kilometers per day [km/day]). A combination of recent advances in Seaglider technology would provide full-year endurance. When operating in ice-covered waters, gliders navigate by trilateration (the process of determining location by measurement of distances, using the geometry of circles, spheres or triangles) from moored acoustic sound sources (or dead reckoning should navigation signals be unavailable). Hibernating gliders would continue to track their position, waking to reposition should they drift too far from their target region. Gliders would measure temperature, salinity, dissolved oxygen, rates of dissipation of temperature variance (and vertical turbulent diffusivity), and multi-spectral downwelling irradiance.


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Figure 2-1. Example of Seagliders

2.2.2 Research Vessels: CGC HEALY and R/V Sikuliaq

CGC HEALY and/or the R/V Sikuliaq would be the two primary vessels to perform research cruises as part of the Proposed Action. Research cruises are proposed for 2018, 2019, 2020 and 2021. Therefore, there would be a maximum of eight cruises; one cruise per vessel that could occur each year in each of the four calendar years (2018-2021) of the Proposed Action. The research cruises would last up to 30 days and the research activities would occur within the Study Area (Figure 1-1).

The R/V Sikuliaq has a maximum speed of approximately 12 knots with a cruising speed of 11 knots (University of Alaska Fairbanks 2014). The R/V Sikuliaq is not an ice breaking ship, but an ice strengthened ship. It would not be ice breaking and therefore acoustic signatures of ice breaking for the R/V Sikuliaq are not relevant. The R/V Sikuliaq has a one-third octave signature band range of 10 Hertz (Hz) to 200 kilohertz (kHz) and a source level of 130 to 172 decibels (dB) referenced to 1 microPascal at 1 m (re 1 µPa at 1 m) when traveling the maximum transit speed of 11 knots, and an one-third octave signature band range of 10 Hz to 200 kHz with a source level of 127 to 154 dB r re 1 µPa at 1 m when traveling at a nominal tow speed of 4 knots (Naval Sea Systems Command 2015).

CGC HEALY travels at a maximum speed of 17 knots with a cruising speed of 12 knots (United States Coast Guard 2013), and a maximum speed of 3 knots when traveling through 3.5 ft (1.07 m) of sea ice (Murphy 2010). CGC HEALY may be required to perform icebreaking to deploy the moored and ice tethered acoustic sources in deep water. Icebreaking would only occur during the warm season, presumably in the August through October timeframe. CGC HEALY has proven capable of breaking ice up to 8 ft (2.4 m) thick while backing and ramming (Roth et al. 2013). A study in the western Arctic Ocean was conducted while CGC HEALY was mapping the seafloor north of the Chukchi Cap in August 2008. During this study, CGC HEALY icebreaker events generated signals with frequency bands centered near 10, 50, and 100 Hz with maximum source levels of 190 to 200 dB re 1 µPa at 1 m (full octave band) (Roth et al. 2013). Icebreaking would only occur in the deep water area of the Proposed Action (Figure 1-1) while deploying moored and ice-tethered sources. The duration of icebreaking would be dependent on sea ice extent and deployment location. Due to the continual decrease in the maximum extent and volume of both annual and multiyear ice in the Arctic, icebreaking may not be required during each year of the Proposed Action.

The R/V Sikuliaq and CGC HEALY may perform the following activities during their research cruises:

- Towing of active acoustic sources (See Section 2.2.2.1)
- Use of impulsive source non explosive sources (airguns, compact sound source; See Section 2.2.2.2)
- Deployment of moored and/or ice-tethered passive sensors (oceanographic measurement devices, acoustic receivers; See Section 2.2.2.6)
- Deployment of moored and/or ice-tethered active acoustic sources to transmit acoustic signals for up to three years after deployment. Transmissions could be terminated during ice-free periods (August-October) each year if needed
- Deployment of unmanned surface, underwater and air vehicles
- Recovery of equipment

Additional oceanographic measurements would be made using ship-based systems, including the following:

- Modular Microstructure Profiler, a tethered profiler that would measure oceanographic parameters within the top 984 ft (300 m) of the water column.

- Shallow Water Integrate Mapping System, a winched towed body with a Conductivity Temperature Depth sensor, upward and downward looking Acoustic Doppler Current Profilers (ADCPs), and a temperature sensor within the top 328 ft (100 m) of the water column.
- Three dimensional Sonic Anemometer, which would measure wind stress from the foremast of the ship
- Surface Wave Instrument Float with Tracking (SWIFTs) are freely drifting buoys measuring winds, waves, and other parameters with deployments spanning from hours to days.
- A single mooring (designated as *de minimis* mooring on Figure 1-1) would be deployed to perform measurements of currents with an ADCP.

2.2.2.1 Towed Active Acoustic Sources

CGC HEALY and/or R/V Sikuliaq may tow active acoustic sources, in transit to deploying moored or ice-tethered acoustic sources. Each vessel may tow sources for up to 15 days in the deep area and up to 15 days in the shallow water area during each cruise only in open water or marginal ice. Towing cannot be conducted while icebreaking. Navy acoustic sources are categorized into “bins” based on frequency, source level, and mode of usage, as previously established between the Navy and NMFS (Department of the Navy 2013a). The towed sources associated with the Proposed Action fall within bins LF4, LF5, and MF9 (parameters listed in the first four rows of Table 2-1).

2.2.2.2 Impulsive Acoustic Sources

In addition to towing active acoustic sources the R/V Sikuliaq and CGC HEALY may utilize a compact sound source or airguns. These would only be used in open waters or marginal ice areas. Neither of the impulsive acoustic sources would be operated in conjunction with the active towed sources.

The compact sound source is a non-explosive impulsive source with acoustic parameters given in Table 2-1. Each vessel may deploy these sources for up to 15 days in the shallow area and 15 days in the deep area during each cruise. Additionally, vessels may also employ two types of air gun sources described in Table 2-1 for up to 15 days in the shallow area and up to 15 days in the deep area during each cruise. The number of airgun and compact sound source emissions per day is given in Table 2-1.

At each location, the maximum would be 80 airguns per day and there would be a maximum of three days for airgun use. The airguns would be used every 10 minutes. These impulsive sound sources were modeled using third-octave processing to capture their broadband characteristics in quantifying their environmental effects.

Table 2-1. Source Characteristics of Modeled Acoustic (Impulsive and Non-Impulsive) Sources for the Proposed Action

Source Name	*Frequency Range (Hz)*	*Sound Pressure Level (dB re 1 µPa at 1 m)*	*Pulse Length (milliseconds)*	*Duty Cycle (Percent)*	*Source Type*	*Alt 1 Location*	*Alt 2 Location (Preferred Alt)*	*Usage*
LF4 towed source	100 to 1,000	200	10,000	50%	Towed	Deep water only	Deep water only	4 hours per day for 15 days
Low frequency towed source	100 to 1,000	185	10,000	50%	Towed	Shallow water only	N/A	4 hours per day for 15 days
LF5 towed source	100 to 1,000	180	10,000	50%	Towed	Both Areas	Deep water only	4 hours per day for 15 days
MF9 towed source	1,000 to 10,000	200	10,000	50%	Towed	Bloth Areas	Deep water only	8 hours per day for 15 days
Compact Sound Source	5 to 5,000	184 maximum	100	< 1% (10 minutes between shots)	Ship-deployed	Both Areas	Deep water only	60 counts per day for 15 days
Air Gun (10 cubic inch sleeve gun)	10-150	178 maximum	300	<1% (10 minutes between shots)	Ship-deployed	Both Areas	Deep water only	40 counts per day for 15 days
Air Gun (20 cubic inch bolt gun)	10-150	181 maximum	200	<1% (10 minutes between shots)	Ship-deployed	Both Areas	Deep water only	40 counts per day for 15 days
Spiral Wave Beacon	2,500	183	50	< 1%	Moored	Deep water only	Deep water only	24 hours per day for 7 days
Navigation and real-time sensing sources	700	185	60,000	< 1%	Moored or drifting	Deep water only	Deep water only	1 minute every 4 hours, up to 3 years
Tomography Sources	250	185	135,000	< 1%	Moored	Deep water only	Deep water only	2.25 minutes every 4 hours, up to 3 years
MF9	1,000 to 10,000	200	10,000	50%	Moored	Shallow water only	N/A	24 hours per day; up to 3 years
LF4	100 to 1,000	200	10,000	50%	Moored	Shallow water only	N/A	24 hours per day; up to 3 years

2.2.2.3 Moored/Drifting Acoustic Sources

Moored and drifting acoustic sources would be deployed from either CGC HEALY or the R/V Sikuliaq in either shallow or deep areas. These areas are further described herein.

Shallow moored and drifting sources would deployed by either CGC HEALY or R/V Sikuliaq along the continental shelf (Table 2-1). The parameters for these sources are given in Table 2-1. These sources would be moored to the seafloor and deployed for up to three years.

Each vessel may deploy up to three moored spiral wave beacon sources in the deep water area and these sources would operate for up to seven days per year. The acoustic characteristics of the spiral-wave beacon source are given in Table 2-1. The spiral wave beacon sources would be separated by distances similar to the deep water source locations in Figure 1-1.

The two vessels (combined) would deploy a maximum of 15 acoustic navigation sources in the deep water area during the period September 2018 to October 2020 at the deep water source locations shown in Figure 1-1. Navigation sources transmit intermittently from multiple locations. Autonomous vehicles would be able to navigate by receiving acoustic signals from multiple locations and triangulating. This is needed for vehicles that are under ice and cannot communicate with satellites. Acoustic transmissions from these non-impulsive acoustic sources could transmit until October 2021 at the latest, and the total transmission time for each individual source would be less than three years, but could be turned off yearly. The acoustic parameters of these sources are given in Table 2-1. Source transmits would be offset by 15 minutes from each other (i.e. sources would not be transmitting at the same time). During the initial cruise it is unlikely that all 15 sources would be deployed. Subsequent cruises would continue to deploy the navigation sources until the maximum number of 15 sources was reached. The navigation sources would also be used for rapid environmental characterization in addition to the SODA and AMOS projects.

CGC HEALY and R/V Sikuliaq (combined) would deploy a maximum of six moored tomography sources in the deep water area during the period September 2018 to September 2020 at the six SODA source locations closest to the coast shown in Figure 1-1. Acoustic transmissions from these non-impulsive acoustic sources would end in October 2021 at the latest, and the total transmission time for each individual source would be less than three years. The acoustic parameters of these sources are given in Table 2-1. Source transmits would be offset by six minutes from each other (i.e. sources would not be transmitting at the same time). When the acoustic navigation sources and tomography sources are both transmitting they would be offset from each other by at least three minutes.

All moorings would be anchored on the seabed and held in the water column with subsurface buoys. All sources would be deployed by shipboard winches which would lower sources and receivers in a controlled manner. Anchors would be steel “wagon wheels” typically used for this type of deployment. All moored and drifting sources would be recovered.

2.2.2.4 *De minimis* Sources

De minimis sources have the following parameters: low source levels, narrow beams, downward directed transmission, short pulse lengths, frequencies above (outside) known marine mammal hearing ranges, or some combination of these factors (Department of the Navy 2013b). Additionally, any sources 200 kHz or above in frequency and/or 160 dB or below in source level are automatically considered *de minimis*. Sources 200 kHz or above are considered outside of marine mammal hearing ranges. Assuming spherical spreading for a 160 dB re 1 µPa source, the sound will attenuate to less than 140 dB within 32 ft (10 m) and less than 120 dB within 328 ft (100 m) of the source. Ranges would be even shorter for a source less than 160 dB re 1 µPa source level. All of the sources described in this section are considered *de minimis.* Since they are not expected to have effects on marine mammals, *de minimis* sources are not quantitatively analyzed. Qualitative analysis is performed when special circumstances (i.e., unusual method of usage, enclosed environment) dictate.

The following are some of the planned *de minimis* sources which would be used during the Proposed Action: Pressure Inverted Echosounders (PIES) sources, ADCPs, ice profilers, upward looking chirp sonar, Expendable Mobile Anti-Submarine Warfare Training Targets (EMATTs), and additional sources below 160 dB re 1 µPa used during towing operations. The PIES sources used in the Proposed Action would be deployed in the deep basin and have a de minimis level of 160 dB within 32 ft-320 ft (10-100 m) of the ocean bottom. Observations of oceanographic phenomena (i.e., temperature, salinity, velocity, turbulence) flowing into the Beaufort Sea would be made using PIES, which would be deployed on the ocean bottom at the white circles with the center dot locations shown in Figure 1-1. PIES are similar in their acoustic parameters (pulse length, duty cycle, beamwidth), but transmit acoustic signals upwards rather than downwards. The PIES has an extremely low pulse length and very low duty cycle, as shown in Table 2-2. ADCPs may be used on moorings. The shallow water ADCP mooring location is depicted on Figure 1-1 by the bright green triangle. Ice-profilers measure ice properties and roughness. These sources would all be above 200 kHz and therefore out of marine mammal hearing ranges. They may be employed on moorings or unmanned undersea vehicles. An upward looking chirp-sonar would also be deployed for measuring ice and oceanographic properties.

Up to ten EMATTs would be deployed each year. Each EMATT would transmit two simultaneous Continuous Wave signals at frequencies selected from two different frequency bands (700-1,100 Hz and 1,100-4,000 Hz). The EMATTs, swimming at 164 to 459 ft (50 to 140 m) below the surface, would scuttle after completing missions that would last up to 8 hours.

The bottom loss measurement system would be used for bottom characterization. The bottom loss measurement system (parameters listed in Table 2-2) from Applied Physics Laboratory could be attached to a Conductivity Temperature Depth Sensor, which is typically found on research vessels. The source would move up and down in the water column, transmitting very short pulses (4 milliseconds) with a low duty cycle (2 percent) and is considered *de minimis* (Department of the Navy 2013a).

Table 2-2. Parameters for *de minimis* Acoustic Sources

Source Name	***Frequency Range (kHz)***	***Sound Pressure Level (dB re 1 µPa at 1 m)***	***Pulse Length (milli-seconds)***	***Duty Cycle (Percent)***	***Beamwidth***	***De minimis justification***
PIES	12	170-180	6	<0.01	45	Extremely low duty cycle, low source level, very short pulse length
ADCP	>200, 150, or 75	190	<1	<0.1	2.2	Very low pulse length, narrow beam, moderate source level
Chirp sonar	2-16	200	20	<1	narrow	Very short pulse length, low duty cycle, narrow beam width
EMATT	700-1,100 Hz and 1,100-4,000 Hz	<150	N/A	25-100	Omni	Very low source level
Coring system	25-200	158-162	< 1	16	Omni	Very low source level[2]
CTD[1] attached Echosounder	5-20	160	4	2	Omni	Very low source level

[1] CTD = Conductivity Temperature Depth
[2] within sediment, not within the water column

2.2.2.5 Drifting Oceanographic Sensors

Observations of ocean-ice interactions require the use of sensors which are moored and embedded in the ice. Sensors are deployed within a few dozen meters of each other on the same ice floe. Their initial locations are depicted as the yellow arrow symbols in Figure 1-1. Three types of sensors would be used: autonomous ocean flux buoys, Integrated Autonomous Drifters, and Ice Tethered Profilers. The autonomous ocean flux buoys measure oceanographic properties just below the ocean-ice interface. The autonomous ocean flux buoys would have ADCPs and temperature chains attached, to measure (temperature, salinity, and other ocean parameters) the top 20 ft (6 m) of the water column. Integrated Autonomous Drifter's would have a long temperate string extending down to 656 ft (200 m) depth and would incorporate meteorological sensors, and a temperature spring to estimate ice thickness. The Ice Tethered Profilers would collect information on ocean temperature, salinity and velocity down to 820 ft (250 m) depth.

Fifteen autonomous floats (Air-Launched Autonomous Micro Observer) would be deployed during the Proposed Action to measure seasonal evolution of the ocean temperature and salinity, as well as currents. They would be deployed on the eastern edge of the Chukchi Sea in water less than 3,280 ft (1,000 m) deep. Three autonomous floats would act as virtual moorings by originating on the seafloor, then moving up the water column to the surface and returning to the seafloor. The other 12 autonomous floats would sit on the seafloor and at intervals begin to move towards the surface. At programmed intervals, a subset of the floats would release anchors and begin their profiling mission. Up to 15 additional floats may be deployed by ships of opportunity in the Beaufort Gyre. The general locations for the autonomous floats are depicted by the blue squares in Figure 1-1.

2.2.2.6 Moored Oceanographic Sensors

Moored sensors would capture a range of ice, ocean, and atmospheric conditions on a year-round basis. The location of the bottom-anchored sub-surface moorings sensors are depicted by the purple stars in Figure 1-1. These would be bottom anchored, sub-surface moorings measuring velocity, temperature, and salinity in the upper 1,640 ft (500 m) of the water column. The moorings also collect high-resolution acoustic measurements of the ice using the ice profilers described above. Ice velocity and surface waves would be measured by 500 kHz multibeam sonars from Nortek Signatures.

Additionally, Beaufort Gyre Exploration Project moorings BGOS-A and BGOS-B (depicted by the black plus signs in Figure 1-1) would be augmented with McLane Moored Profilers. BGOS-A and BGOS-B would be placed on existing Woods Hole Oceanographic Institute moorings. The two BGOS moorings would provide measurements near the Northwind Ridge, with considerable latitudinal distribution. Existing deployments of Nortek Acoustic Wave and Current Profilers on BGOS-A and BGOS-B would also be continued as part of the Proposed Action.

2.2.2.7 Fixed and Towed Receiving Arrays

Horizontal and vertical arrays may be used to receive acoustic signals. The Distributed Vertical Line Array is a long line acoustic receiver that was used in a recent ONR action (i.e., the CANAPE experiment) and would be deployed within the SODA sensor locations. The Distributed Vertical Line Array would be moored to the seafloor by a 1,940 pound (lb; 880 kilogram [kg]) anchor. An array (horizontal and vertical) may also be placed on the seabed in the shallow water area. Other receiving arrays are the Single Hydrophone Recording Units and Autonomous Multichannel Acoustic Recorder. All these arrays would be moored to the seafloor and remain in place throughout the activity. CGC HEALY and R/V Sikuliaq may also tow arrays of acoustic receivers.

2.2.3 Activities Involving Aircraft and Unmanned Air Vehicles

The NRL would be conducting flights to characterize the ice structure and character, ice edge and wave heights across the open water and marginal ice zone to the ice. Up to four flights, lasting approximately three hours in duration, would be conducted each year over a 10-day period during February or March for ice structure and character measurements and during late summer/early fall for ice edge and wave height studies. Flights would be conducted with a Twin Otter aircraft over the seafloor mounted acoustic sources and receivers. Most flights would transit at 1,500 ft or 10,000 ft (457 or 3,048 m) above sea level. Twin Otters have flight speeds of 80 to 160 knots, a typical survey speed of 90 to 110 knots, 66 ft (20 m) wing span, and a total length of 26 ft (8 m) (U.S. Department of Commerce and National Oceanic and Atmospheric Administration 2015). At a distance of 2,152 ft (656 m) away, the received pressure levels of a Twin Otter range from 80 to 98.5 A-weighted decibels (dBA; expression of the relative loudness in the air as perceived by the human ear) and frequency levels ranging from 20 Hz to 10 kHz, though they are more typically in the 500 Hz range (Metzger 1995). The objective of the flights is to characterize thickness and physical properties of the ice mass overlying the experiment area.

Rotary wing aircraft may also be used during the activity. Helicopter transit would be no longer than two hours to and from the ice location. An infrared capable twin engine helicopter may be used to transit scientists from land to an offshore, floating ice location. Once on the floating ice, the team would drill holes with up to a 10 inch (in; 25.4 centimeter [cm]) diameter to deploy scientific equipment (e.g., source, hydrophone array, EMATT) into the water column (Figure 2-2). The science team would depart the area and return to land after three hours of data collection and leave the equipment behind for a later recovery.

Figure 2-2. Helicopter Assisted On-Ice Experiments

The Proposed Action includes the use of an Unmanned Aerial System (UAS). The UAS would be utilized for aid of navigation and to confirm and study ice cover. The UAS would be deployed ahead of the ship to ensure a clear passage for the vessel and would have a maximum flight time of 20 minutes. The UAS would not be used for marine mammal observations or hover close to the ice near marine mammals. There would be no videotaping or picture taking of marine mammals as part of the Proposed Action. The UAS that would be used during the Proposed Action is a small commercially available system that generates low sound levels and is smaller than military grade systems. The dimensions of the proposed UAS are: 11.4 in (29 cm) by 11.4 in (29 cm) by 7.1 in (18 cm) and weighs only 2.5 lbs (1.13 kg). The UAS can operate up to 984 ft (300 m) away, which would keep the device in close proximity to the ship. The planned operation of the UAS is to fly it vertically above the ship to examine the ice conditions in the path of the ship and around the area (i.e. not flown at low altitudes around the vessel). Currently acoustic parameters are not available for the proposed models of UASs to be utilized in the Proposed Action. As stated above these systems are very small and are similar to a remote control helicopter. It is likely marine mammals would not hear the device since the noise generated would likely not be audible from greater than 5 ft (1.5 m) away (Christiansen et al. 2016).

2.2.4 On-Ice Measurement Systems

On-ice measurement systems would be used to collect weather data. These would include an Autonomous Weather Station and an Ice Mass Balance Buoy. The Autonomous Weather Station would be deployed on a tripod; the tripod has insulated foot platforms that are frozen into the ice (Figure 2-3). The system would consist of an anemometer, humidity sensor, and pressure sensor. The Autonomous Weather Station also includes an altimeter that is *de minimis* due to its very high frequency (200 kHz). The Ice Mass Balance Buoy is a 20 ft (6 m) sensor string, which is deployed through a two-inch (5 cm) hole drilled into the ice (Figure 2-4). The string is weighted by a 2.2 lb (1 kg) lead weight, and is supported by a tripod. The buoy contains a *de minimis* 200 kHz altimeter and snow depth sensor. Autonomous Weather Stations and Ice Mass Balance Buoys will be deployed in fall 2018, and will drift with the ice, making measurements, until their host ice floes melt, thus destroying the instruments (likely in summer, roughly one year after deployment). After the on-ice instruments are deployed they cannot be recovered, and would sink to the seafloor as their host ice floes melted. Autonomous Weather Stations and Ice Mass Balance Buoys will likely be deployed again in 2019 and 2020, for similar one-year missions.

Figure 2-3. Autonomous Measurement System

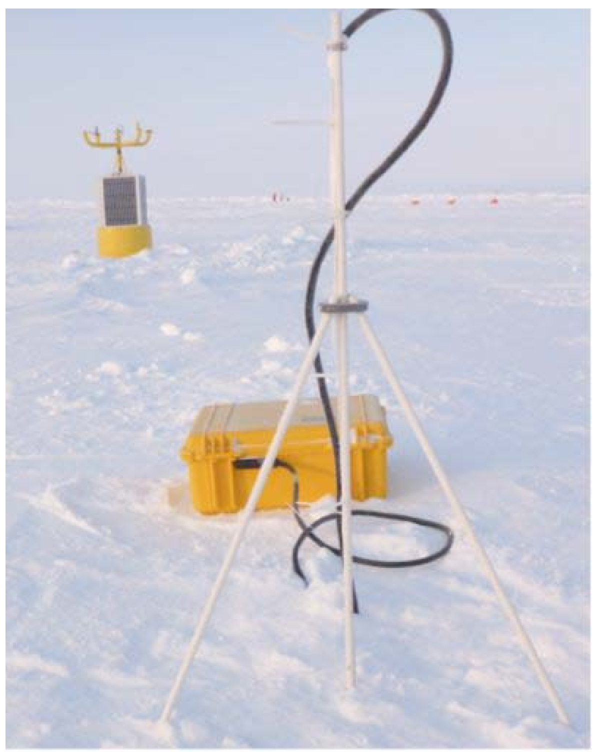

Figure 2-4. Ice Mass Balance Buoy (foreground)

2.2.5 Bottom Interaction Systems

Coring of bottom sediment could occur anywhere within the Study Area to obtain a more complete understanding of the Arctic environment. Coring equipment would take up to 50 samples of the ocean bottom in the Study Area annually. The samples would be roughly cylindrical, with a 3.1 in (8 cm) diameter cross-sectional area; the corings would be between 10 and 20 ft (3 and 6 m) long. Coring would only occur while the research vessel or CGC HEALY were deployed, during the summer or early fall. The coring equipment moves very slowly through the muddy bottom, at a speed of approximately 3.3 ft (1 m) per hour, and would not create any detectable acoustic signal within the water column, though very low levels of acoustic transmissions may be created in the mud (parameters listed in Table 2-2).

2.2.6 Weather Balloons

To support weather observations and research objectives, up to forty Kevlar or latex balloons would be launched per year for the duration of the Proposed Action. These balloons and associated radiosondes (a sensor package that is suspended below the balloon) are similar to those that have been deployed by the National Weather Service since the late 1930s. When released, the balloon is approximately 5-6 ft (1.5-1.8 m) in diameter and gradually expands as it rises owing to the decrease in air pressure. When the balloon reaches a diameter of 13-22 ft (4-7 m), it bursts and a parachute is deployed to slow the descent of the associated radiosonde. Weather balloons would not be recovered.

2.3 Screening Factors

Implementing regulations provide guidance on the consideration of alternatives to a federally proposed action and require rigorous exploration and objective evaluation of reasonable alternatives. Only those alternatives determined to be reasonable and meet the purpose and need require detailed analysis.

Potential alternatives that meet the purpose and need were evaluated against the following screening factors:

- Geographic sampling over a large area within the Arctic basin to observe large-scale oceanographic phenomena influencing the entire region (primary science objective)
- Geographic sampling in deep water areas where there will be a total ice coverage during a portion of the year (primary science objective)
- Acoustic source transmissions in deep water to allow for navigation of unmanned vehicles in ice-covered areas
- Acoustic source transmissions in deep water to observe how changes in Arctic oceanography are affecting acoustic propagation and bottom interaction (primary science objective)
- Acoustic source propagation and oceanography in areas with varied bottom types and proximity to continental shelf areas (secondary science objective, depending on results obtained from CANAPE 2016/17 experiment)
- Waters of appropriate depths to meet the scientific objectives of the Proposed Action (e.g., deep water sources require specific depths in order to appropriately measure duct propagation)

2.4 Alternatives Carried Forward for Analysis

Based on the reasonable alternative screening factors and meeting the purpose and need for the proposed action, two action alternatives were identified and will be analyzed within this OEA.

2.4.1 No Action Alternative

Under the No Action Alternative, ARA would not occur. This alternative requires no subsequent analysis of potential consequences to environmental resources, as no action would occur. The No Action Alternative would not meet the purpose and need for the Proposed Action; however, the No Action Alternative is carried forward for analysis in this OEA and provides a baseline for measuring the environmental consequences of the action alternatives.

2.4.2 Alternative 1

Alternative 1 would be to conduct all the scientific research described in the Proposed Action, including the use of permitted active acoustic sources in shallow and deep water. This meets the core scientific objectives of the research projects described in Section 1.3 (Purpose and Need), particularly the measurement of acoustic, oceanographic, and ice properties over a multi-year period and the use of acoustic sources as navigation aids to unmanned vehicles in the basin. It also meets secondary scientific objectives of performing acoustic testing in a complex three directional bathymetric environment by including the use of permitted active acoustic sources in the shelf areas.

2.4.3 Alternative 2 (Preferred Alternative)

Under Alternative 2 (the Preferred Alternative), all of the scientific research described in the Proposed Action would occur, though the use of permitted active acoustic sources would be limited to the deep-water area only. This alternative would meet the core scientific objectives of the research projects described in Section 1.3 (Purpose and Need), particularly in the measurement of acoustic, oceanographic, and ice properties over a multi-year period and the use of acoustic sources as navigation aids to unmanned vehicles in the basin. "*De minimis*" acoustic sources (qualitatively analyzed to determine appropriate determinations under E.O. 12114 in the appropriate resource harm analysis, as well as under the Marine Mammal Protection Act and Endangered Species Act) would be allowed throughout the whole Study Area.

2.5 Alternatives Considered but not Carried Forward for Detailed Analysis

Other locations were considered but specific water depths are required for proper operation of the acoustic sources and receiver arrays. Additionally, the shallow water equipment and deep water equipment need to be within the same general geographic area to try and accomplish the overlap of the shallow water source receiving the deep water source signals. The experiments must be left out long term to collect the data necessary for proper acoustic propagation analysis under open-water, marginal ice, and ice-covered conditions as well as achieve the other scientific objectives. The environment is complex and variable and models to successfully simulate acoustic conditions need to be developed – hence the need for at-sea observations. There are no reasonable surrogate environments that can be used to observe the various phenomena associated with unmanned vehicle navigation and acoustic propagation in the Arctic. Consideration was given to other locations further to the east, but the proposed location was selected due to the substantial distance from areas in which marine mammal hunting by Alaska Natives take place.

3 Affected Environment

This chapter presents a description of the environmental resources and baseline conditions that could be affected from implementing any of the alternatives.

All potentially relevant environmental resource areas were initially considered for analysis in this Overseas Environmental Assessment (OEA). In compliance with Executive Order (E.O.) 12114, the discussion of the affected environment (i.e., existing conditions) focuses only on those resource areas potentially subject to harm. Additionally, the level of detail used in describing a resource is commensurate with the anticipated level of potential environmental harm. This section includes physical resources and biological resources.

The potential harm to the following resource areas are considered to be negligible or non-existent so they were not analyzed in this OEA:

Air Quality: The Proposed Action is substantially outside of 12 nm, attainment status is not applicable and the Clean Air Act National Ambient Air Quality Standards (NAAQS) does not apply. Additionally, all coastal Alaska boroughs and counties are classified as attainment areas of the eight-hour standard for ozone (40 Code of Federal Regulations [CFR] 81.322). Attainment areas are areas that meet the NAAQS for specific pollutants. Under the Clean Air Act, only nonattainment areas are required to limit and act to decrease emissions below the NAAQS.

Cultural Resources: There are no known cultural resources within the Study Area.

Land Use: There would be no land use as part of the Proposed Action.

Visual Resources: The use of research vessels in the Arctic is common, and the limited use of the vessels would not harm visual resources. The general project area is outside of the view shed of anyone on land.

Airspace: Any use of airspace would be in coordination with the local airport and within Federal Aviation Administration regulations. The minor use of aircraft would not increase the overall use of airspace or limit any other air operations in the area. The majority of the Proposed Action would occur in the water or on the ice surface. Aircraft may be used for a portion of the Proposed Action but would not interfere with regular pubic airspace usage given that the offshore location is not a frequently used flight corridor.

Water Quality: The Proposed Action would not have any discharges or chemical interaction with the water.

Deep Sea Corals and Coral Reefs: No deep sea corals or coral reefs are present in the Study Area.

Marine Vegetation: The marine vegetation in the Study Area is made up of free-floating diatoms and plankton, which would not be harmed by objects deployed on the sea ice, in the water column, or by acoustic stressors.

Sea Turtles: No sea turtles would be present in the Study Area.

3.1 Physical Resources

This discussion of physical resources includes atmospheric temperature, bathymetry, currents, circulation, and water masses, water quality, and sea ice. This section discusses the physical characteristics of the Study Area; biological resources are addressed in Section 3.2.

3.1.1 Affected Environment

The following discussions provide a description of the existing conditions for the physical environment of the Arctic in the Study Area. There are no specific regulations which apply to these resources.

3.1.1.1 Atmospheric Temperature

The Earth's climate has warmed approximately 1.1 degrees Fahrenheit (°F; 0.6 degrees Celsius [°C]) over the past 100 years with two main periods of warming occurring between 1910 and 1945 and from 1976 to present day (Overland et al. 2014; Walther et al. 2002). Temperature trends in the Arctic exhibit regional and annual variability (Maxwell 1997; Symon et al. 2005); however, a general warming trend has been observed since the late 1970s. Warming air temperatures have played a major role in the observed increase in permafrost temperatures around the Arctic rim, earlier spring snowmelt, reduced sea ice, widespread glacial retreat, increases in river discharge into the Arctic Ocean, and an increase in greenness of Arctic vegetation (Overland et al. 2014). Arctic atmospheric circulation is a complicated system, though air moves west to east across the Study Area and into the Canadian Archipelago and mainland (Hudson et al. 2001). Based on approximately nine months of data (including those months during which the Proposed Action would occur) from a 2014 model, the wind speed measured at a point in the Beaufort Sea south of the Study Area averaged 14.6 feet per second (6.83 meters per second [m/s]) (Naval Oceanographic Office 2014). The climatologic, hydrologic, and biological subsystems of the Arctic are highly interconnected, and thus cannot be easily isolated for discussion (Hinzman et al. 2005).

3.1.1.2 Bathymetry

The Beaufort Sea has a narrow, shallow shelf along the north coast of Alaska, with a width of less than 80 nm (148 km) at any given point (Dome Petroleum Ltd. et al. 1982). Off the coast of Canada, the shelf is broader and depths of 33 feet (ft; 10 meters [m]) or less can be found up to 16 nm (30 km) from shore (Wilkinson et al. 2009). The average depth within the shelf of the Beaufort Sea is less than 213 ft (65 m) (Dome Petroleum Ltd. et al. 1982). The continental slope in this area drops steeply to the Canada Basin. In the Canada Basin, which extends north into the Arctic Ocean and is bordered to the west by the Mendeleev Ridge, averages a depth of about 11,811 ft (3,600 m) (Wilkinson et al. 2009). Seafloor sediments in this deep water basin are typically muddy (Bluhm et al. 2011). Based on visual evaluation by Bluhm et al. (2005), the seafloor within the Canada Basin is composed of very fine, silty sediment over a thick clay layer. Coastal erosion supplies an estimated 7 million tons of sediment each year near shoreline areas of the Beaufort Sea. While erosion is an important local source of sediments, the relative contribution of coastal erosion to sediment loading in the Beaufort Sea is minor compared to sediments originating from the Mackenzie River, which reaches approximately 130 million tons of sediment each year (Carmack and Macdonald 2002).

The Study Area also encompasses the majority of the Chukchi Plateau, which lies to the west of the Canada Basin in the Chukchi Sea. The eastern margin of the Chukchi Plateau, the Northwind Ridge, is also contained in the Study Area. It runs parallel to the northward trend of the plateau, and is separated from the rest of the plateau by the Northwind Basin, an abyssal plain, that reaches depths of 11,482 ft (3,500 m) (Nuttall 2005). The Northwind Ridge is bounded on the eastern side to the Canada Basin by a steep, downward slope. Due to the escarpment, the slope contains a large amount of rock substrate, but clayey mud forms the predominate sediments (Mayer and Armstrong 2012).

The benthic communities of the Beaufort Sea are comprised of benthic macroalgae, macrophytic algae, infaunal invertebrates (living within the sediment), and epifaunal fish and invertebrates (living on the seafloor) (Minerals Management Service 1991). The biomass and diversity of benthic communities generally increase with depth within the inshore or intermediate zone, except from 49 to 82 ft (15 to

25 m) depth, which is an area where the most intensive ice-gouging occurs (Minerals Management Service 1991). Soft sediments dominate the continental shelves of the Beaufort and Chukchi Seas. This sediment is largely a combination of muds, sands, and gravels—substrate that support high densities of invertebrates (Holland-Bartels et al. 2011). Benthic macroalgae requires rocky substrate for attachment, which is rare within the Study Area. Sediments in the Study Area of the Beaufort Sea consist mostly of gravel and sand and those in the deep Canada Basin, in particular, are mainly fine-grained clay and silt (Hong et al. 2012). Any areas with hard substrate suitable for attachment by kelps and macroalgae are located outside of the Study Area. Nautical charts of the North Coast of Alaska show primarily mud substrate near the shallow water deployment area (National Oceanic and Atmospheric Administration 2015).

3.1.1.3 Currents, Circulation, and Water Masses

The processes governing water currents and circulation into and out of the Beaufort and Chukchi Seas are complex. Water enters the Arctic from the Pacific via the Bering Strait, a narrow, shallow passageway at only 46 nm (85 km) wide and 164 ft (50 m) deep (Woodgate 2012). Due to the narrow width of this passage, it is only an inflow point. On the Atlantic side, both an inflow and outflow movement of water occurs (Woodgate 2012). Cold, less saline water (averaging about 32.5 practical salinity units [psu]) enters the Bering Strait from the Pacific Ocean (Woodgate et al. 2005). During winter, winds from interior Alaska blow over the shallow Chukchi Sea, freezing the water into ice and moving the ice away from land. This process is constantly creating and moving ice as well as leaving behind salt; this cold, salty water becomes denser and will sink into the western Arctic. The cold, salty water lies atop warmer, even saltier water (about 35 psu) from the Atlantic Ocean, creating the Arctic halocline (Woodgate 2012). This halocline prevents the warm, dense bottom water from melting the polar ice from below (Woods Hole Oceanographic Institution (WHOI) 2006). Meanwhile, the waters from both the Atlantic and Pacific inflows get swept into the Beaufort Gyre, an anticyclonic (clockwise) system north of Alaska where Canadian rivers deposit fresh water. When winds shift, the Beaufort Gyre weakens and fresh water is dispersed throughout the Arctic via the Transpolar Current (Woods Hole Oceanographic Institution (WHOI) 2006). The water exiting the Arctic for global circulation is colder and less saline than the incoming water (Woodgate 2012). Water exits the Arctic through several areas: the Canadian Archipelago via Hudson Strait, Baffin Bay via Davis Strait, or through the Fram Strait between Greenland and Svalbard into the Atlantic Ocean. The circulation patterns through the Arctic are shown in Figure 3-1, demonstrating the means by which water distributes from the Beaufort Gyre throughout the Arctic and beyond.

Currents within the Beaufort Gyre are variable, and depend on multiple factors including: wind speed, presence of eddies, and the value of the Arctic Oscillation. These factors come together to affect the overall velocity of the waters as they move throughout the Arctic Ocean, and can make predicting the velocity of the currents difficult. While subsurface velocities have been measured from ice camps historically, the most comprehensive studies are often of short duration (Plueddemann et al. 1998). Plueddemann et al. (1998) used an Ice-Ocean Environmental Buoy frozen into Arctic pack ice approximately 130 nm (241 km) north of Prudhoe Bay, Alaska, to take long-term measurements of meteorological and oceanographic variables in the Arctic. This buoy travelled within the vicinity of the Study Area for the first few months of its expenditure before travelling into the Chukchi Sea. This study concluded that the ice drift within the Beaufort Gyre ranged from approximately 0.4 to 2 inches per second (in/s; 1 to 5 centimeters per second [cm/s]) (Plueddemann et al. 1998). Ice Ocean Environmental Buoy deployment within the Beaufort Gyre has also been used to study various physical properties of Arctic eddies. A recent study by O'Brien et al (2013) used moorings with sequential sediment traps to study downward sediment flux in the Canada Basin. These sediment traps measured water current speed at multiple depths, finding that from the surface to 272 ft (83 m), velocities were typically between 0 and 4 in/s (0 and 10 cm/s), though could jump up to 16 in/s (40 cm/s) in the event of encounter with an eddy. The Beaufort Gyre expands and contracts based on the state of Arctic Oscillation; under high Arctic Oscillation conditions, the Beaufort Gyre will contract (Woodgate 2012).

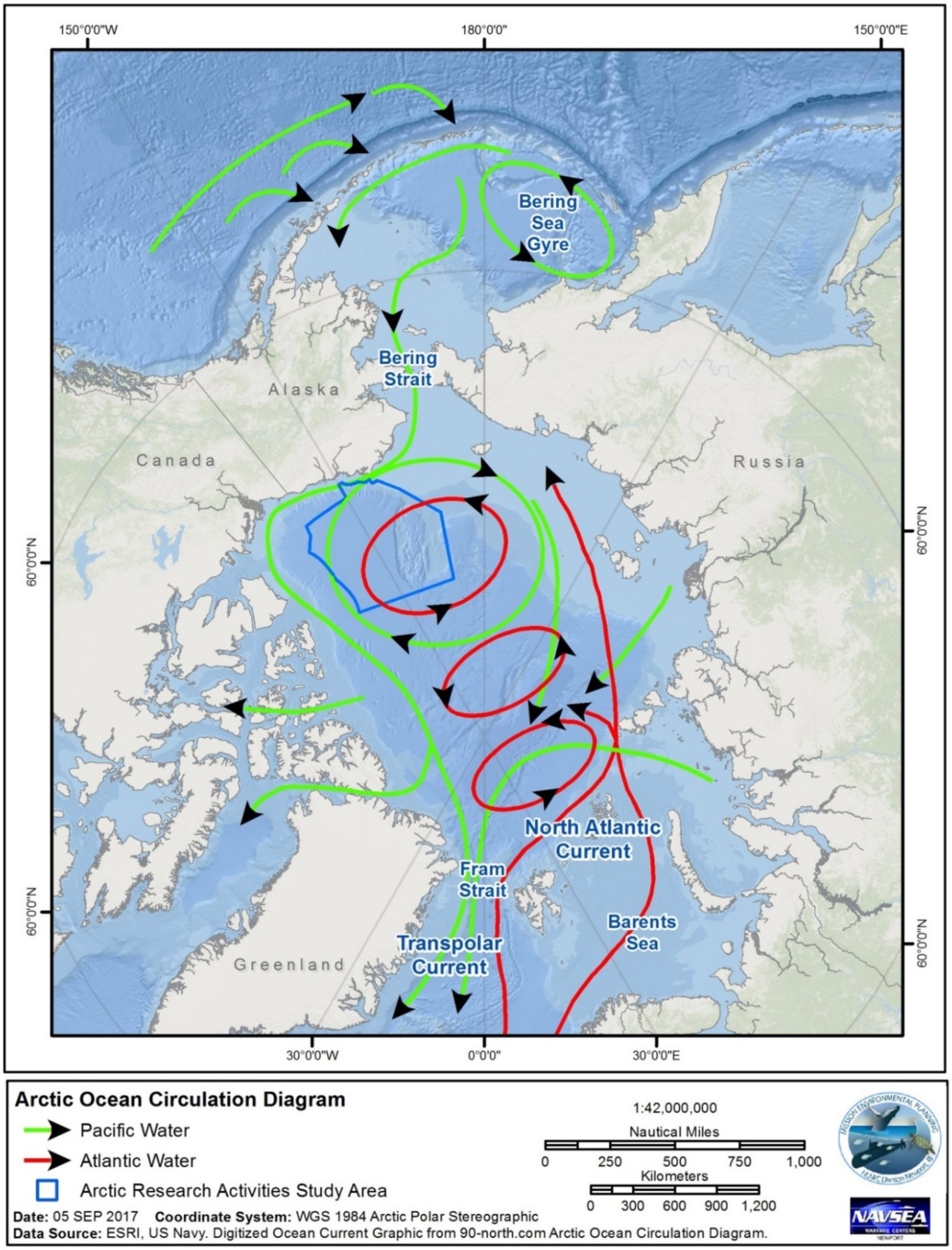

Figure 3-1. Arctic Ocean Circulation

In the Arctic, areas of ice-cover usually have a surface mixed layer 16 to 32 ft (5 to 10 m) deep. In ice-free regions, which have increased over time, this mixed layer, driven by winds, can be more than twice as deep (Rainville et al. 2011). In most of the western Arctic (also referred to as the Canada Basin), Pacific Waters are found below this mixed layer. Pacific Winter Waters are indicated by a deep minimum temperature around freezing at depths of about 320 to 492 ft (100 to 150 m) (Woodgate 2012). Shallower temperature maxima, probably formed locally by solar heating, are observed in some regions (Jackson et al. 2010; Shimada et al. 2001). Below the Pacific Water, Atlantic Water forms a temperature maximum (up to 33.8 °F [1 ºC]) at depths of around 640 to 1312 ft (200 to 400 m). These are called Fram Strait Branch Waters since they come mainly from the Fram Strait inflow (Rudels et al. 1994), although some influence is likely from the Barents Sea (Rudels et al. 2000; Woodgate et al. 2001). Below the Fram Strait Branch Waters, temperatures decrease and an inflexion point in temperature-salinity marks waters of mainly Barents Sea (Rudels et al. 1994; Smith et al. 1999). Throughout the Arctic, a cold halocline layer provides a density barrier, trapping Atlantic Water heat at depth away from the ice. Arctic Bottom Water occurs at depths greater than 2,953 ft (900 m), and ranges in temperature from 30.6 to 30.4 °F (-0.8 to -0.9 °C) and salinities of 34 to 35 psu (Woodgate 2012). Upwelling and eddies allow for increased mixing of water both by currents, and by mixing of water layers containing different temperatures and salinities (Weingartner et al. 2008).

In the Beaufort Sea, the Alaska Shelf-Slope Front stretches along the north coast of Alaska from Point Barrow to the Mackenzie Delta by the Canadian Border. This front is a “hot spot” of activity where marine life, including mammals and sea birds, gather. Additionally, this is the site of the Cape Bathurst Polynya (an area of open sea surrounded by pack ice) (Belkin et al. 2009). In the Arctic Ocean, the observation of fronts is hampered by perennial ice cover that prevents satellite remote sensing in the Arctic Basin. Data collected from drifting stations and submarines has revealed a major front separating Atlantic waters from Pacific waters. Until the mid-1990s this front was located over the Lomonosov Ridge, but is not along the Mendeleyev-Alpha Ridge (Belkin et al. 2009).

3.1.1.4 Water Quality

The high Arctic waters (a term used to describe barren polar areas) consist of water with relatively low nutrient loads. At the end of the winter, a burst of primary productivity occurs under the ice when light levels become sufficiently high and nutrients are released from the ice. This surge of nutrients includes nitrogen (as ammonium, nitrite, and nitrate), phosphorus (as phosphate), iron, and other elements, which would then be either grazed upon and move through the food chain, or sink to the bottom and incorporate into bottom sediments (Vancoppenolle et al. 2013). In polar waters, nutrient concentrations undergo seasonal depletion in surface waters due to photosynthesis during spring/summer and renewal during winter when photosynthesis stops (Whitledge et al. 2008).

3.1.1.5 Sea Ice

3.1.1.5.1 Arctic Sea Ice Regime

Sea ice is frozen seawater that floats on the surface of the ocean, covering millions of square miles. Sea ice that persists year after year, surviving at least one summer melt season, is known as multiyear ice. Sea ice forms and melts with polar seasons and affects both human activity and biological habitat (Jeffries et al. 2014). Arctic sea ice plays a crucial role in Northern Hemisphere climate and ocean circulation, and is thought to play an even more crucial role in regulating climate than Antarctic sea ice (National Snow and Ice Data Center 2007; Serreze et al. 2003).

Sea ice directly impacts coastal areas and broadly affects surface reflectivity, ocean currents, water cloudiness, humidity, and the exchange of heat and moisture at the ocean’s surface. Since sea ice reflects the sun's heat, when ice retreat is greater and there is more open ocean, more of the sun's heat is absorbed, increasing the warming of the water (Timmermans and Proshutinsky 2014).

3.1.1.5.2 Sea Ice Extent

Though the record of sea ice extent dates as far back as 1900 in the Northern Hemisphere, the most complete record of sea ice is provided by microwave satellites, which have routinely and accurately monitored sea ice extent since 1979 (Jeffries et al. 2014; Timmermans and Proshutinsky 2014). Annually, sea ice extent is at its maximum in March, representing the end of winter, and is at its minimum in September (Jeffries et al. 2014). Figure 3-2 demonstrates minimum and maximum 2016 ice extent in comparison to the median minimum and maximum extents from 1981 to 2010.

Data from 2016 reveals a minimum extent of 1.6 million square miles (mi^2; 4.14 million square kilometers [km^2]). This extent is tied with September of 2007 for the second lowest minimum ice extent on record. September 2012 remains the record low minimum ice extent of 1.3 million mi^2 (3.4 million km^2) (National Snow and Ice Data Center 2017). In September of 2007, the sea ice recession was so vast that the Northwest Passage completely opened up for the first time in human memory (National Snow and Ice Data Center 2007).

The age of the sea ice is another key descriptor of the state of the sea ice cover, as it is an indicator for its physical properties including surface roughness, melt pond coverage, and ice thickness. Older ice tends to be thicker and thus more resilient to changes in atmospheric and oceanic forcing than younger ice. The age of the ice can be determined using satellite observations and drifting buoy records to track ice parcels over several years (Tschudi et al. 2010). The distribution of ice of different ages illustrates the extensive loss in recent years of the older ice types (Maslanik et al. 2011). In 2014, the distribution of ice age favored first-year ice, or ice that has not survived a melt season. This is the thinnest type of ice. The month of March has shown a decreasing trend in the oldest ice, which is 4 years old or older. In 1988, 26 percent of ice cover was the oldest ice. The oldest ice cover decreased to 19 percent in 2005 and to 10.1 percent in 2014, which has increased slightly from 2013 (Perovich et al. 2013). Sea ice has also been experiencing later freeze-up than usual and earlier ice melt over the past few years, leading to a decline in multiyear ice, although there was an increase in multi-year ice seen from 2013 to 2014 (Overland and Wang 2013). In March of 2014, the coverage of multi-year ice increased to 31 percent of ice cover. In March of 2013, the coverage was only 22 percent. The mean thickness of this ice, measured northwest of Greenland, also increased: 7.7 ft (2.35 m) in March of 2014 compared to 6.46 ft (1.97 m) in March of 2013.

Sea ice extent fluctuates annually and is influenced by natural variations in atmospheric pressure and wind patterns, but clear linkages have also been made to decreased Arctic sea ice extent and rising greenhouse gas concentrations dating back to the early 1990s (Timmermans and Proshutinsky 2014). A general downward trend in Arctic sea ice has occurred during the last few decades (Serreze et al. 2003). The maximum ice extent from March 2016 tied with March 2014 for the lowest maximum ice extent in the 37 year satellite record (5.7 million mi^2 [14.76 million km^2]). This maximum extent is 5 percent below the 1981 through 2010 average, though fairly typical of measurements taken in the last decade (Perovich et al. 2013). The March 2015 maximum extent measured 1.75 million mi^2 (4.52 million km^2) (National Snow and Ice Data Center 2017). The ice is declining faster than computer models had projected, and this downward trend is predicted to continue (National Snow and Ice Data Center 2007; Timmermans and Proshutinsky 2014). The decrease in sea ice extent can be seen in Figure 3-3 below, illustrating yearly sea ice extent over various years (National Snow and Ice Data Center 2017).

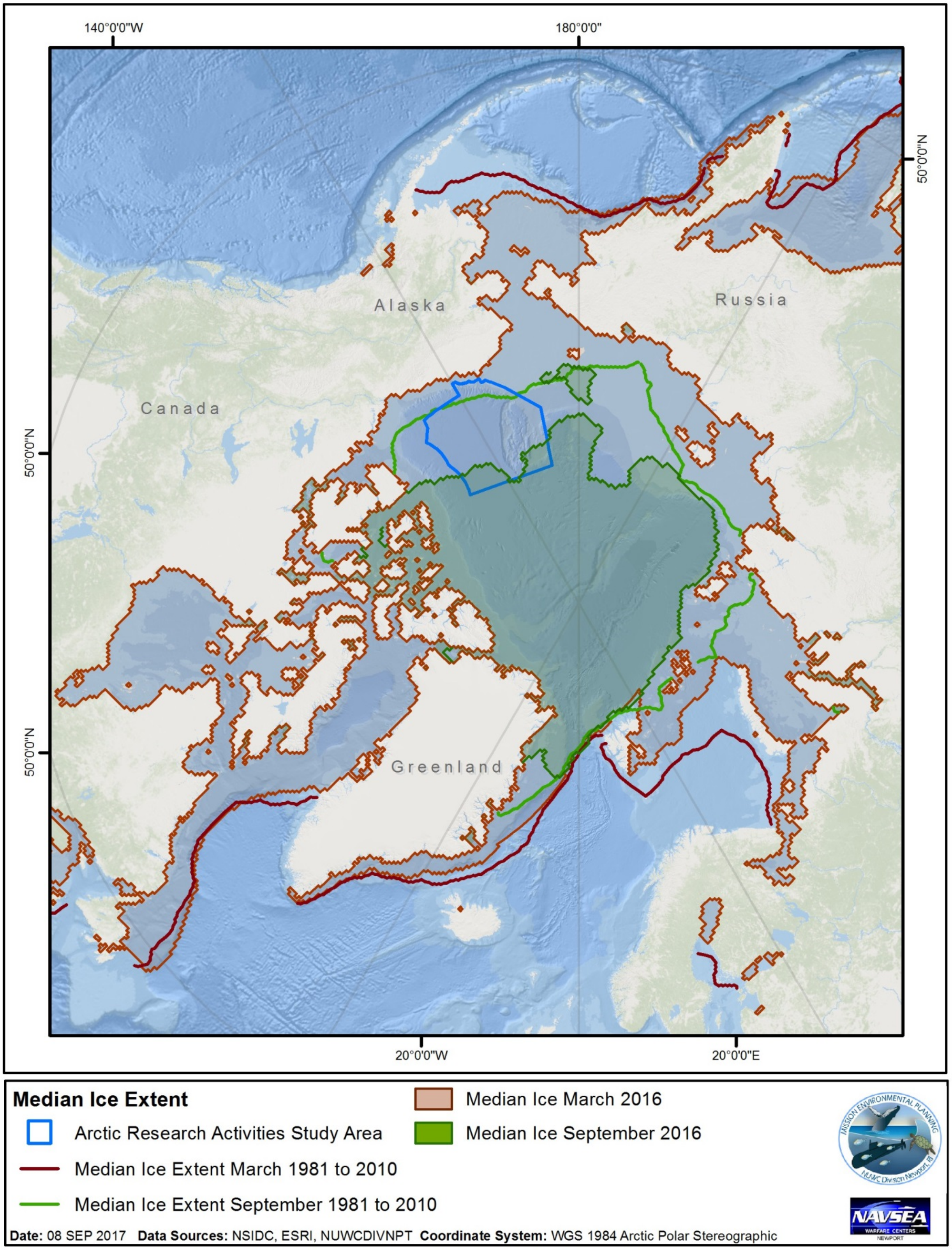

Figure 3-2. Average Arctic Sea Ice Extent in March and September

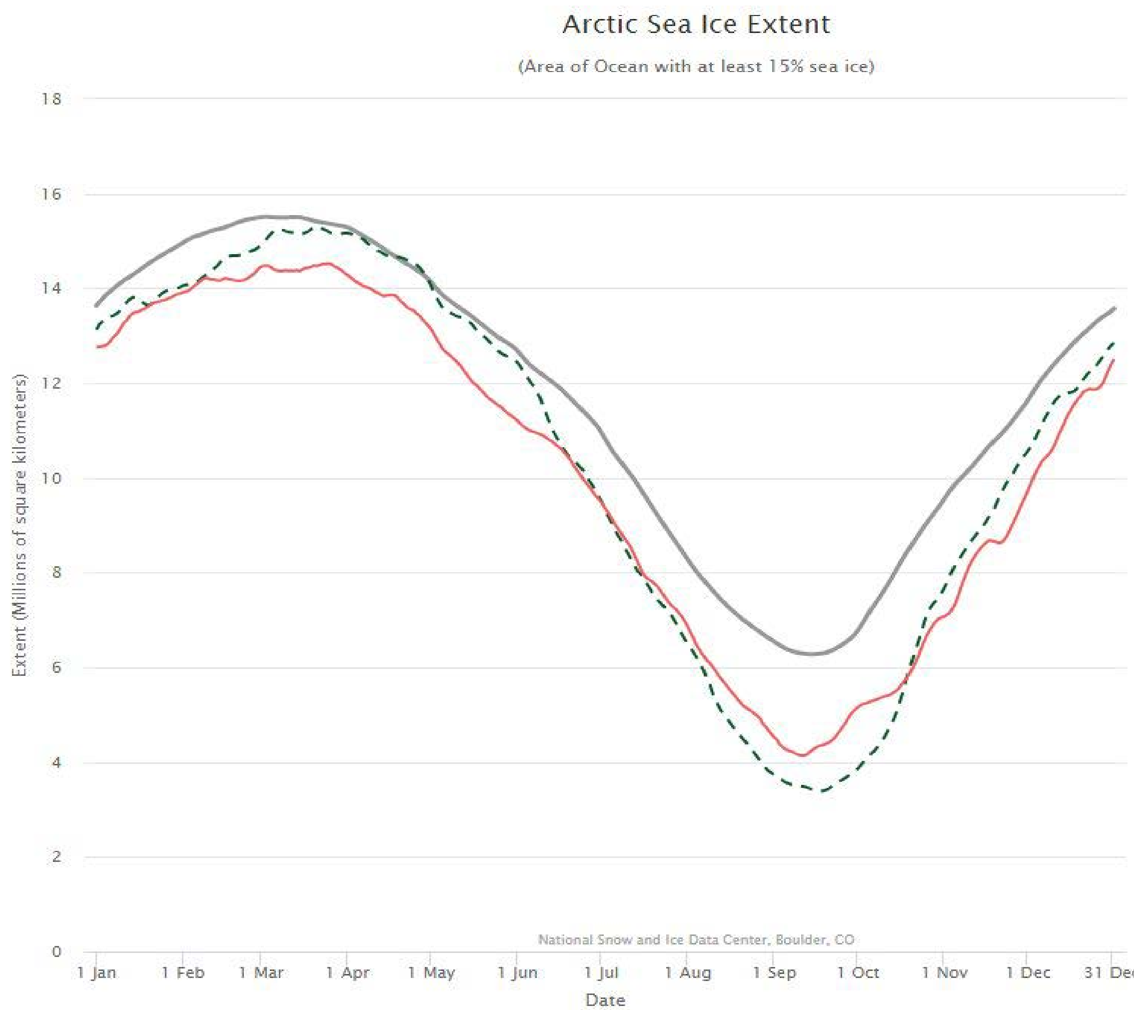

Figure 3-3. Yearly Sea Ice Extent Trends. The grey line represents the 1981-2010 average sea ice extent, the dashed green line represents 2012 (record low extent), and the red line represents 2016

3.2 Biological Resources

Biological resources include living, native, or naturalized plant and animal species and the habitats within which they occur. Plant associations are referred to generally as vegetation, and animal species are referred to generally as wildlife. Habitat can be defined as the resources and conditions present in an area that support a plant or animal.

Within this OEA, biological resources are divided into five major categories: (1) invertebrates, (2) marine birds, (3) fish, (4) Essential Fish Habitat, and (5) marine mammals. Threatened, endangered, and other special status species are discussed in their respective categories.

3.2.1 Regulatory Setting

Special-status species, which for the purposes of this OEA are those species listed as threatened or endangered under the Endangered Species Act (ESA), and species afforded federal protection under the Marine Mammal Protection Act (MMPA) or the Migratory Bird Treaty Act (MBTA).

3.2.1.1 Endangered Species Act

The purpose of the ESA (16 United States Code [U.S.C.] §§ 1531-1544) is to conserve the ecosystems upon which threatened and endangered species depend and to conserve and recover listed species. Section 7 of the ESA requires Federal agencies to consult with the responsible wildlife agency (i.e., U.S. Fish and Wildlife Service [USFWS] and/or National Marine Fisheries Service [NMFS]) to ensure that their actions are not likely to jeopardize the continued existence of federally listed threatened and endangered species, or result in the destruction or adverse modification of designated critical habitat (16 U.S.C. § 1536 (a)(2)). Regulations implementing the ESA include a requirement for consultation on those actions that "may affect" a listed species or adversely modify critical habitat.

If an agency's proposed action would "take" a listed species, then the agency must obtain an incidental take authorization from the responsible wildlife agency. The ESA defines the term "take" to mean "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt any such conduct" (16 U.S.C. §1532(19)). The regulatory definitions of "harm" and "harass" are relevant to the Navy's determination as to whether the Proposed Action would result in adverse effects on listed species.

- Harm is defined by regulation as "an act which actually kills or injures" fish or wildlife (50 CFR § 222.102, 50 CFR § 17.3; 64 FR 60727, Nov 8 1999).
- Harass is defined by USFWS regulation to mean an "intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering" (50 CFR § 17.3). NMFS has not defined the term in its regulations.

3.2.1.2 Marine Mammal Protection Act

All marine mammals are protected under the provisions of the MMPA (16 U.S.C. §§ 1361-1407). The MMPA prohibits any person or vessel from "taking" marine mammals in the United States or the high seas without authorization. The act further regulates "takes" of marine mammals in U.S. waters and by U.S. citizens on the high seas. The term "take," as defined in Section 3 (16 U.S.C. § 1362) of the MMPA, means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal."

The Proposed Action constitutes a military readiness activity as defined in Public Law 107-314 (Migratory Bird Treaty Act (as amended) at 16 U.S.C. § 703 note) because these proposed scientific research activities directly support the "adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability for combat use" by providing critical data on the changing natural and physical environment in which such materiel will be assessed and deployed. This proposed scientific research also directly supports fleet training and operations by providing up to date information and data on the natural and physical environment essential to training and operations. For military readiness activities, such as the Proposed Action, the relevant definition of harassment is any act that:

- Injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild ("Level A harassment"); or
- Disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered ("Level B harassment") [16 U.S.C. § 1362(18)(B)(i) and (ii)].

In addition to incidental taking of marine mammals, section 101(a)(4)(B) provides an exception to otherwise prohibited acts, allowing the use of measures that may deter a marine mammal from, among other things, damaging private property or endangering personal safety (16 U.S.C. 1371(a)(4)(A)(ii) and (iii), respectively. These measures may not result in the death or serious injury of a marine mammal. Section 101(a)(4)(A) of the MMPA specifically identifies the circumstances when the deterrence of a marine mammal may be undertaken and by whom. For polar bears, the USFWS has provided deterrence guidelines in 50 CFR § 18.34. These guidelines, if followed by a person otherwise subject to the provisions of the MMPA, provide an exception to the take prohibition under the MMPA; therefore, a permit under the MMPA is not required. Additionally, section 101(c) of the MMPA specifically states that “it shall not be a violation of this chapter to take a marine mammal if such taking is imminently necessary in self-defense or to save the life of a person in immediate danger, and such taking is reported to the Secretary within 48 hours.”

3.2.1.3 Migratory Bird Treaty Act and Other Regulations Associated with Birds

The MBTA (16 U.S.C. §§ 703-712) and the Migratory Bird Conservation Act (16 U.S.C. §§ 715-715d, 715e, 715f-715r) of February 18, 1929, are the primary laws in the U.S. established to conserve migratory birds. The MBTA prohibits the taking, killing, or possessing of any migratory bird or their parts, nests, or eggs of such birds, unless permitted by regulation.

The 2003 National Defense Authorization Act provided interim authority to members of the Armed Forces to incidentally take migratory birds during approved military readiness activities without violating the MBTA. The National Defense Authorization Act provided this interim authority to give the Secretary of the Interior time to exercise his/her authority under section 704(a) of the MBTA to prescribe regulations authorizing such incidental take. The Secretary of the Interior delegated this task to the USFWS. On February 28, 2007, the USFWS issued a final military readiness rule authorizing members of the Armed Forces to incidentally take migratory birds during military readiness activities.

The definition of military readiness activities applies to the MBTA in the same way that it applies to the MMPA, and the Proposed Action is considered a military readiness activity for the purposes of this act. Under this regulation, the Navy must consider the potential environmental effects of its actions and assess the adverse effects of military readiness activities on migratory birds. If a Proposed Action may result in a significant adverse effect on a population of migratory bird species, the Navy shall consult with the USFWS to develop and implement appropriate conservation measures to minimize or mitigate these effects. A significant adverse effect on a population is defined as an effect that could, within a reasonable period of time, diminish the capacity of a population of a migratory bird species to sustain itself at a biologically viable level (50 CFR § 21.3). Conservation measures, as defined in 50 CFR § 21.3, include project designs or mitigation activities that are reasonable from a scientific, technological, and economic standpoint and are necessary to avoid, minimize, or mitigate the take of migratory birds or other potentially adverse impacts.

Bald and golden eagles are protected by the Bald and Golden Eagle Protection Act. This act prohibits anyone, without a permit issued by the Secretary of the Interior, from taking bald eagles, including their parts, nests, or eggs. The Act defines "take" as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb.

3.2.1.4 Magnuson-Stevens Fishery Conservation and Management Act

The MSA (16 U.S.C. §§ 1801-1822), enacted to conserve and restore the nation’s fisheries, includes a requirement for NMFS and regional fishery councils to describe and identify Essential Fish Habitat for all species that are federally managed. Essential Fish Habitat is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Under the MSA, federal agencies must consult with the Secretary of Commerce regarding any activity or proposed activity that is authorized, funded, or undertaken by the agency that may adversely affect Essential Fish Habitat. An adverse effect is any effect that may reduce the quantity or quality of Essential Fish Habitat. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of Essential Fish Habitat.

3.2.2 Affected Environment

The following discussions provide a description of the existing conditions for each of the categories of biological resources in the Study Area.

3.2.2.1 Invertebrates

Marine invertebrates are a large, diverse group containing tens of thousands of species distributed from warm shallow waters to cold deep waters throughout the global marine environment (Kohlbach et al. 2016). Invertebrates are the dominant animals in all habitats of the Study Area. Excluding microbes, approximately 5,000 known marine invertebrates have been documented in the Arctic; the number of species is likely higher, though, since this area is not well studied (Josefson et al. 2013). Although most species are found within the benthic zone, marine invertebrates can be found in all zones (sympagic [within the sea ice], pelagic [open ocean], or benthic [bottom dwelling]) of the Beaufort Sea (Josefson et al. 2013). Sea ice provides a habitat for algae and a nursery ground for invertebrates during times when the water column does not support phytoplankton growth (Winfree 2005). Sympagic zone invertebrates live within the pores and brine channels of the ice (small spaces within the sea ice which are filled with a salty solution called brine) or at the ice-water interface. Biodiversity of species is low within the sympagic zone due to the extreme conditions of the sea ice (Leet et al. 2001). Within the Study Area, many sympagic species also exist in and along the edges of ice coverage, feeding on blooms of phytoplankton and other algae which grow in, on, or adjacent to the ice (Wyllie-Echeverria and Ackerman 2003). Marine invertebrate distribution in the Beaufort Sea is influenced by habitat and oceanographic conditions (e.g., depth, temperature, salinity, nutrient concentrations, and ocean currents) (Levinton 2009). The cold water of the Arctic generally results in slow growth and high longevity among invertebrates and food sources which are only seasonally abundant. Major taxonomic groups found within the Beaufort Sea are listed and described in Table 3-1, since there are no specific studies that have been completed in the Beaufort Sea. The distribution ranges of pelagic zooplankton species in the Chukchi Sea have been shifting in recent years, especially with copepods (e.g. *Calanus glacialis*) due to warming in the regional waters (Ershova et al. 2015). Additional information on an invertebrate sampling cruise completed in the Canadian Basin is provided in Section 3.2.2.1.1 below. No endangered, threatened, candidate, species of concern, or proposed species for listing under the ESA exist within the Study Area. Additionally, Essential Fish Habitat has not been designated for any federally managed invertebrate species within the Study Area.

3.2.2.1.1 Canada Basin Species

MacDonald et al. (2010) conducted an invertebrate sampling cruise in the summer of 2005 within the Canada Basin and Chukchi Borderland areas. MacDonald et al. (2010) observed that abundance and biomass of invertebrates decreased with increasing depth and were lowest in the Canada Basin compared to the Chukchi Sea. However, biodiversity increased with increasing depth. Taxon inhabiting the Canada Basin ranged from 8 to 10 for macrofauna assemblages and 11 to 15 for megafauna assemblages, depending on where the sample was collected. Macrofauna assemblages were mainly composed of polychaetes, crustaceans (copepods, tanaids, isopods, cumaceans, amphipods, and ostracods), and mollusks, but also included nematodes, sipunculids, nemerteans, pogonophorans, turbellarians, sponges, bryozoans, cnidarians, ascideans, holothurians, and ophiuroids. Megafauna assemblages within the Canada Basin were dominated by lebensspuren, Actiniaria, and holothuroid.

Table 3-1. Taxonomic Groups of Marine Invertebrates in the Study Area

Invertebrate Group		***Presence in Study Area***		
Common Name (Taxonomic Group)	***Description***	***Sympagic***	***Pelagic***	***Benthic***
Flatworms (Phylum Platyhelminthes)[1]	Simplest form of marine worm with a flattened body.	✓		✓
Ribbon worms (Phylum Nemertea)[1]	Worms with a long extension from the mouth (proboscis) that helps capture food.		✓	✓
Roundworms (Phylum Nematoda)[1]	Small worms; many live in close association with other animals (typically as parasites).	✓	✓	✓
Sponges (Phylum Porifera)[2]	Large species have calcium carbonate or silica structures embedded in cells to provide structural support.			✓
Segmented worms (Phylum Annelida)[2]	Highly mobile marine worms; many tube-dwelling species.	✓	✓	✓
Bryozoans (Phylum Bryozoa)[3]	Lace-like animals that exist as filter feeding colonies. Form either encrusting or bushy-tuftlike lacy colonies.			✓
Hydroids and jellyfish (Phylum Cnidaria)[2]	Animals with stinging cells.	✓	✓	✓
Cephalopods, bivalves, sea snails, chitons (Phylum Mollusca)[2]	Mollusks are a diverse group of soft-bodied invertebrates with a specialized layer of tissue called a mantle. Mollusks such as squid are active swimmers and predators, while others such as sea snails are predators or grazers and clams are filter feeders.		✓	✓
Shrimp, crab, barnacles, copepods (Phylum Arthropoda – Crustacea)[2]	Diverse group of animals, some of which are immobile. Most have an external skeleton. All feeding modes from predator to filter feeder.	✓	✓	✓
Sea stars, sea urchins, sea cucumbers (Phylum Echinodermata)[2]	Predators and filter feeders with tube feet.			✓

[1]Based on Arctic Ocean biodiversity (Bluhm 2008), and due to lack of information on phyla species added for analysis (presence within the Study Area is unknown).
[2]Invertebrate phyla are based on the World Register of Marine Species (Appeltans et al. 2010) and Catalogue of Life (Bisby et al. 2014).
[3]Phyla not extracted when searched the distribution of the Beaufort Sea on the World Register of Marine Species. Individual species found on Arctic Ocean biodiversity, and verified via the distribution maps on the World Register of Marine Species (Appeltans et al. 2010)

Another survey of zooplankton by Kosobokova and Hopcroft (2010) was conducted in the summer of 2005 in the Canada Basin. This study identified 14 taxonomic groups of zooplankton including 111 species in the area. These taxonomic groups included Copepoda, Amphipoda, Euphausiacea, Decapoda, ostracoda, Cnidaria, Ctenophora, Polychaeta, Pteropoda, Chaetognatha, Larvacea, Forminifera, Radiolario, and Tintinnina. Of the 111 species identified, 74 were crustaceans (copepods, euphausiids, amphipods, decapods, and ostracods), 17 were cnidarians (hydromedusae, scyphomedusae, siphonophora), 1 was foraminifera, 4 were ctenophores, 2 were pteropods, 4 were larvaceans, 4 were chaetognaths, and 5 were polychaetes. Copepods were the most dominate invertebrate species in the area, making up approximately 91 percent of the species abundance. Similar to MacDonald et al. (2010), Kosobokova and Hopcroft (2010) observed abundance and biomass of invertebrates decreasing with an increased depth whereas biodiversity increased with an increase in depth. Specifically, they noted a progressive decrease in zooplankton abundance and biomass below 164 ft (50 m), followed by a slight increase in the 656 ft to 984 ft (200 to 300 m) layer, and a slow decrease below 984 ft (300 m). The increase at 656 ft (200 m) is thought to be attributed to the transition between the Pacific halocline and Atlantic waters (Kosobokova and Hopcroft 2010). Based on previous studies (Harding 1966; Virketis 1957), the overall species assemblages in the Canada Basin have not changed significantly in the past 50 to 60 years (Kosobokova and Hopcroft 2010).

It is important to note that both of these studies only surveyed species in the water column, at a limited number of locations, and during the summer months (Kosobokova and Hopcroft 2010; MacDonald et al. 2010). Therefore, not all species (such as benthic invertebrates) are represented in these surveys. Because of the large number of species, a general discussion of each ecologic zone (sympagic, pelagic, and benthic) is provided below.

3.2.2.1.2 Sympagic Zone

Sea ice provides a habitat for algae and a nursery ground for invertebrates during times when the water column does not support phytoplankton growth (Michel et al. 2002). Sympagic zone invertebrates live within the pores and brine channels of the ice (small spaces within the sea ice which are filled with a salty solution called brine) or at the ice-water interface. Biodiversity of species is low within the sympagic zone due to the extreme conditions of the sea ice (Nuttall 2005). Species abundance within the ice has been found to be highly variable with most species occurring within the bottom 4 inches (in; 10 centimeters [cm]) of ice core samples. Species are also found in greater densities in coastal fast ice compared to offshore pack ice. Additionally, abundance is 1 to 4 orders of magnitude greater in spring and early summer (compared to winter) in coastal fast ice (Bluhm et al. 2010). The most dominant sympagic species are nematodes, harpacticoid copepods, and rotifers (Josefson et al. 2013). At the ice-water interface, *Apherusa glacialis, Onisimus glacialis, O. nanseni,* and *Gammarus wilkitzkii* are common amphipods (Gradinger et al. 2010). Although the sympagic environment is spatially limited, recent research indicates that large pelagic copepod species such as *Calanus glacialis* and *C. hyperboreus*, which are a primary food source for higher trophic levels, are substantially dependent on sea ice synthesized carbon, illustrating the importance of this unique environment to the broader Arctic food web (Sheffield-Guy et al. 2014).

3.2.2.1.3 Pelagic Zone

Pelagic habitats include downwelling and upwelling areas and frontal zones. Dominant species groups within the pelagic zone are highly stratified by depth. In a zooplankton survey from the Arctic Canadian Basin (east of the Study Area) within the pelagic zone, 50 percent of the biomass was concentrated in the upper layer from 0 to 328 ft (0 to 100 m) in depth (Hopcroft et al. 2005). The pelagic zone invertebrate fauna is dominated by large copepods such as *Calanus glacialis* and *C. hyperboreus*. Copepods in the pelagic zone of the Beaufort Sea have longer life cycles (2–4 years) and are larger than copepod species living in warmer water (Hopcroft et al. 2008). Sirenko (2001) and Sirenko et al (2010) found that cnidarians are second to copepods in diversity and numbers. Jellyfish are likely important invertebrate predators within this zone (Josefson et al. 2013).

3.2.2.1.4 Benthic Zone

The benthic zone is the most diverse and species-rich habitat, where the majority of the species within the Study Area can be found. Benthic marine invertebrates play an important role in the food web as scavengers, recyclers of nutrients, and habitat-forming organisms, or as prey to predators such as fish and whales.

Within the Arctic region, major species groups within the benthic zone that have the highest diversity and abundance are Arthropoda (e.g., crabs and barnacles), Bryozoa (moss animals), Mollusca (e.g., snails and clams), and Nematoda (Josefson et al. 2013). In a recent Beaufort Sea trawl, the invertebrates with the highest densities in descending order of abundance were the notched brittle star (*Ophiura sarsi*), snow crab (*Chionoecetes opilio*), mussels (*Musculus* spp.), and the mud star (*Ctenodiscus crispatus*) (Rand and Logerwell 2010). Within the sediment, roundworms are one of the most widespread marine invertebrates with population densities of one million organisms per 10.8 square feet (1 square meter) of mud (Levinton 2009). The principal habitat-forming invertebrates of the benthos are Porifera (e.g., sponges), Annelida (e.g., tube worms), and Mollusca (e.g., spiral margarite).

3.2.2.1.5 Invertebrate Hearing

Hearing capabilities of invertebrates are largely unknown (Lovell et al. 2005; Popper and Schilt 2008). Outside of studies conducted to test the sensitivity of invertebrates to vibrations, very little is known on the effects of anthropogenic underwater noise on invertebrates (Edmonds et al. 2016). While data are limited, research suggests that some of the major cephalopods and decapods may have limited hearing capabilities (Hanlon 1987; Offutt 1970), and may hear only low-frequency (less than 1 kiloHertz [kHz]) sources, with best sensitivities at lower frequencies (Budelmann 2010; Mooney et al. 2010; Offutt 1970; Packard et al. 1990), which is most likely within the frequency band of biological signals (Hill 2009). A few cephalopods may sense higher frequencies up to 1,500 Hertz [Hz] (Hu et al. 2009).Both behavioral and auditory brainstem response studies suggest that crustaceans may sense frequencies up to 3 kHz, but best sensitivity is likely below 200 Hz (Goodall et al. 1990; Lovell et al. 2005; Lovell et al. 2006). In a review of crustacean sensitivity of high amplitude underwater noise by Edmonds et al (2016) crustaceans may be able to hear the frequencies at which they produce sound, but it remains unclear which noises are incidentally produced and if there are any negative effects from masking them. Acoustic signals produced by crustaceans range from low frequency rumbles (20-60 Hz) to high frequency signals (20-55 kHz) (Celi et al. 2014; Henninger and Watson 2005; Patek and Caldwell 2006; Staaterman et al. 2011).

Aquatic invertebrates that can sense local water movements with ciliated cells include cnidarians, flatworms, segmented worms, urochordates (tunicates), mollusks, and arthropods (Budelmann 1992a, 1992b; Popper et al. 2001). Some aquatic invertebrates have specialized organs called statocysts for determination of equilibrium and, in some cases, linear or angular acceleration. Statocysts allow an animal to sense movement and may enable some species, such as cephalopods and crustaceans, to be sensitive to water particle movements associated with sound (Hu et al. 2009; Kaifu et al. 2008; Montgomery et al. 2006; Popper et al. 2001). Because any acoustic sensory capabilities, if present at all, are limited to detecting water motion, and water particle motion near a sound source falls off rapidly with distance, aquatic invertebrates are probably limited to detecting nearby sound sources rather than sound caused by pressure waves from distant sources.

3.2.2.2 Marine Birds

For the purpose of this document, "marine birds" refers to shoreline, coastal, and pelagic bird species. A description is provided below for species of marine birds that would likely occur in the Study Area and include species protected under the MBTA. No ESA-listed bird species exist within the Study Area.

A combination of short-distance migrants, long-distance migrants, and year-round resident marine bird species occur within the Study Area. Typical behaviors that would be encountered within the Study Area predominantly include foraging and migrating, among others. Black-legged kittiwakes (*Rissa tridactyla*) and ivory gulls (*Pagophila aburnea*) are associated with sea ice and inhabit waters along the continental shelf about 90 nm (167 km) from the shore. Other species found near or over the Canada Basin include glaucous gull (*Larus hyperboreus*), herring gull (*Larus argentatus*), ross's gull (*Rhodostethia rosea*), northern fulmar (*Fulmarus glacialis*), and thick-billed murre (*Uria lomvia*) (Harwood et al. 2005). Of all the marine birds that occur in the vicinity of the Study Area, only the thick-billed murre exhibits foraging diving behaviors at distances greater than 90 nm (167 km) from the shoreline during the timeframe of the Proposed Action. Therefore, only the thick-billed murre may be foraging at the shallow water Study Area. No birds are expected to be foraging or migrating through the deep water Study Area. All other marine bird species in the area would either not travel over 90 nm (167 km) offshore or are not expected to forage underwater within the Study Area.

Other bird species may be migrating through the Study Area. These species include black guillemot (*Cepphus grylle*), ivory gull, ross's gull, short-tailed shearwater (*Puffinus tenuirostris*), king eider (*Somateria spectabilis*), and long-tailed duck (*Clangula hyemalis*) (National Audubon Society 2015). None of these species are listed under the ESA, but all are protected under the MBTA. Species in the orders Charadriiformes (i.e., ivory gull, Ross's gull, thick-billed murre, black guillemot) and Procellariiformes (i.e., northern fulmar, short-tailed shearwater) are expected.

Within the Study Area, two species from the family Laridae (ivory gull [*Pagophila eburnean*] and Ross's gull [Rhodostethia rosea]) may be present during the timeframe of the Proposed Action. These species winter in the Arctic Ocean, and will spend time at edges of pack ice. Outside of the breeding season, ivory gulls occur singly or in flocks of up to 20 individuals (BirdLife International 2016; International Union for the Conservation of Nature 2016). These species consume fish, surface-dwelling marine invertebrates, and algae, though ivory gulls also will scavenge on marine mammal remains on the sea ice (International Union for the Conservation of Nature 2016; Kaufman 1996). Ross's gull will forage solitarily or in small, loose flocks.

Black guillemots (Cepphus grille) may also be present in the Study Area during the Proposed Action. This species of marine foragers dives for benthic species of fish and crustaceans in shallow waters near their cliffside nesting sites, though they can also be found farther offshore. They are a non-migratory species that can winter as far north as the edges of pack ice (International Union for the Conservation of Nature 2016). In areas of the Arctic with higher concentrations of prey, colonies of black guillemots can reach sizes upwards of 2,000 nesting pairs (Cornell Lab of Ornithology 2016).

Thick-billed murres may be encountered in the shallow water portion of the Study Area year-round, but more commonly in the summer. They have a circumpolar distribution in the arctic region (BirdLife International 2012). Known breeding sites occur in coastal areas and islands of the Beaufort Sea (Gaston and Hipfner 2000). The thick-billed murre is one of the most numerous marine birds in the Northern Hemisphere. In the summer months, it inhabits continental-shelf waters of the Arctic Ocean and adjacent seas, including the Beaufort Sea. Their range shifts a bit more to the south in the winter, occurring in greater number in the Bering Sea and coastal areas of southern Alaska (Gaston and Hipfner 2000). Thick-billed murres diet consists of mid-water school fish (cod, smelt, sandlance), pelagic amphipods and euphausiids, benthic fish (sculpins, blennies, lumpsuckers), deepwater fish (lanternfish), shimp, squid, and annelids (Gaston and Hipfner 2000). Thick-billed murres may travel up to 92 nm (170 km) from their breed colonies to forage (Gaston and Hipfner 2000). They travel in V-formation flocks to foraging sites, but are mainly solitary feeders. However, they can aggregate in large groups where prey is concentrated (Cairns and Schneider 1990; Schneider et al. 1990). They capture prey underwater with maximum diving depths of 690 ft (210 m) and more typical depths around 33 ft (10 m) (Croll et al. 1992).

Procellariiformes is a large order of pelagic marine birds. Fulmars are medium to large birds, and are typically scavengers. Shearwaters obtain their food at or close to the water's surface (Brooke 2001). Typically only non-breeding short-tailed shearwaters will stay within the Study Area during the winter, though most of this species migrates south and will return to the Arctic in May (U.S. Fish and Wildlife Service 2006). This order includes species that are generally long lived, breed once per year, and lay only one egg; thus, they have a low reproductive output.

3.2.2.2.1 Marine Bird Hearing

Although hearing range and sensitivity has been measured for many terrestrial birds, little research has been conducted on the hearing capabilities of marine birds. The majority of published literature on bird hearing focuses on terrestrial birds, particularly songbirds, and their ability to hear in the air. A review of 32 terrestrial and marine species reveals that birds generally have greatest hearing sensitivity between 1 and 4 kHz (Beason 2004; Dooling 2002). Research shows that very few birds can hear below 20 Hz, most have an upper frequency hearing limit of 10 kHz, and none exhibit the ability to hear frequencies higher than 15 kHz (Dooling 2002; Dooling et al. 2000). Hearing capabilities have been studied for only a few marine birds (Beason 2004; Beuter et al. 1986; Thiessen 1958; Wever et al. 1969); these studies show that marine birds have hearing ranges and sensitivities that are consistent with what is currently known about general bird hearing capabilities.

Auditory abilities have been measured in ten diving bird species in-air using electrophysiological techniques (Crowell et al. 2015). All species tested had the best hearing sensitivity from 1 to 3 kHz. The red-throated loon (*Gavia stellata*) and northern gannet (*Morus bassanus*) (both non-duck species) had the highest thresholds of the duck species while the lesser scaup (*Aythya affinis*) and ruddy duck (*Oxyura jamaicensis*) (both duck species) had the lowest thresholds (Crowell et al. 2015). Auditory sensitivity varied amongst the species tested, spanning over 30 decibels (dB) in the frequency range of best hearing. While electrophysiological techniques provide insight into hearing abilities, audiotry sensitivity is more accurately obtained using behavioral techniques. Crowell (2016) used behavioral methods to obtain an in-air audiogram of the lesser scaup. Best hearing frequency range in-air was similar to other birds, with best sensitivity of 14 dB referenced to 20 micropascals (re 20 µPa) at 2.68 kHz.

Crowell et al. (2015) also compared the vocalizations of the same ten diving bird species to the region of highest sensitivity of in-air hearing. Of the birds studied, vocalizations of only eight species were obtained due to the relatively silent nature of two of the species. The peak frequency of vocalizations of seven of the eight species fell within the range of highest sensitivity of in-air hearing. Crowell et al. (2015) suggested that the colonial nesters tested had relatively reduced hearing sensitivity because they relied on individually distinctive vocalizations over short ranges. Additionally, Crowell et al. (2015) observed that the species with more sensitive hearing were those associated with freshwater habitats, which are relatively quieter compared to marine habitats with wind and wave noise.

Although important to seabirds in air, it is unknown if seabirds use hearing or vocalizations underwater for foraging, communication, predator avoidance, or navigation (Crowell 2016; Dooling and Therrien

2012). Some scientists suggest that birds must rely on vision rather than hearing while underwater (Hetherington 2008), which others suggest birds must rely on an alternative sense in order to coordinate cooperative foraging and foraging in low light conditions (e.g., night, at depth) (Dooling and Therrien 2012).

There is little known about the hearing ability of birds underwater (Dooling and Therrien 2012). In air, the size of the bird is usually correlated with the sensitivity to sound (Johansen et al. 2016); for example, songbirds tend to be more sensitive to higher frequencies and larger non-songbirds tend to be more sensitive to lower frequencies (Dooling et al. 2000). Two studies have tested the ability of a single diving bird, a great cormorant (*Phalacrocorax carbo sinensis*), to respond to underwater sounds (Hansen et al. 2017; Johansen et al. 2016). These studies suggest that the cormorant's hearing in air is less sensitive than birds of similar size; however, the hearing capabilities in water are better than what would be expected for a purely in-air adapted ear (Johansen et al. 2016). The frequency range of best hearing underwater was observed to be narrower than the frequency range of best hearing in air, with greatest sensitivity underwater observed around 2 kHz (about 71 dB referenced to 1 micropascal [re 1 μPa] based on behavioral responses).

Diving birds may not hear as well underwater, compared to other (non-avian) terrestrial species, based on adaptations to protect their ears from pressure changes (Dooling and Therrien 2012). Because reproduction and communication with conspecifics occurs in air, adaptations for diving may have evolved to protect in-air hearing ability and may contribute to reduced sensitivity underwater (Hetherington 2008). There are many anatomical adaptations in diving birds that may reduce sensitivity bot in air and underwater. Common murres (*Uria aalge*) were deterred from gillnets by acoustic transmitters emitting 1.5 kHz pings at 120 dB re 1 μPa; however, no significant reaction was observed in rhinoceros auklet (*Cerorhinca monocerata*) bycatch in the same nets (Melvin et al. 1999).

3.2.2.3 Fish

Fish are vital components of the marine ecosystem. They have great ecological and economic aspects. To protect this resource, NMFS works with the regional fishery management councils to identify the essential habitat for every life stage of each federally managed species using the best available scientific information. Essential Fish Habitat has been described for approximately 1,000 managed species to date. Essential Fish Habitat includes all types of aquatic habitat including wetlands, coral reefs, seagrasses, and rivers; all locations where fish spawn, breed, feed, or grow to maturity (Section 3.2.2.4).

The fish species located in the Study Area include those that are closely associated with the deep ocean habitat of the Beaufort Sea. Nearly 250 marine fish species have been described in the Arctic, excluding the larger parts of the sub-Arctic Bering, Barents, and Norwegian Seas (Mecklenburg et al. 2011). However, only about 30 are known to occur in the Arctic waters of the Beaufort Sea (Christiansen and Reist 2013). Largely because of the difficulty of sampling in remote, ice-covered seas, many high-Arctic fish species are known only from rare or geographically patchy records (Mecklenburg et al. 2013). Aquatic systems of the Arctic undergo extended seasonal periods of ice cover and other harsh environmental conditions. Fish inhabiting such systems must be biologically and ecologically adapted to surviving such conditions. Important environmental factors that Arctic fish must contend with include reduced light, seasonal darkness, ice cover, low biodiversity, and low seasonal productivity. No ESA-listed fish species occur within the Study Area. Fish present on the continental shelf were not studied further, as they would not be impacted by aircraft flyovers.

3.2.2.3.1 Major Fish Groups

Marine fish can be broadly categorized into horizontal and vertical distributions within the water column. The primary distributions of fish that occur in the marine environment of the Study Area are within the water column near the surface. While there are multiple major fish groups inhabiting the deep waters of the Beaufort Sea (Table 3-2), the only federally managed species within the Study Area is the Arctic cod (*Boreogadus saida*).

Table 3-2. Major Groups of Marine Fish in the Study Area during the Proposed Action*

Common Name		***Vertical Distribution Within the***
Cod	Order Gadiformes	Water column
Scorpionfish	Order Scorpaeniformes	Seafloor, water column
Eelpouts, Eelblennys, and Wolffishes	Order Perciformes	Seafloor

* All distribution information was obtained from Food and Agriculture Organization of the United Nations (Cohen et al. 1990), Kaschner et al. (2013), and Arctic Ocean Diversity (Mecklenburg and Mecklenburg 2009).

Cods (Order Gadiformes)

The two major species of cod within the Study Area are Arctic cod (*Boreogadus saida*) and polar cod (*Arctogadus glacialis*). Cod are an important component in the food web of the Beaufort Sea environment, preying on primary producers such as plankton, and being preyed upon by ringed seal (*Phoca hispida*), bearded seal (*Erignathus barbatus*), beluga whale (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), and many marine birds (including gulls and guillemots) (Bluhm and Gradinger 2008; Cohen et al. 1990; Welch et al. 1993). Fish inhabiting the water column of oceanic waters seaward of the 200-m isobath comprise this assemblage; most species exhibit some preference of bathymetric stratification.

Arctic cod are the only federally managed species within the Study Area (for more information, see Section 3.2.2.4). Arctic cod is the northernmost-occurring fish species and is widespread throughout Arctic seas (Mecklenburg et al. 2013). Arctic cod are both cryopelagic (live in cold, deep water) and epontic (live on the underside of ice). They use sea ice for shelter, to capture prey, and to avoid predators. Arctic cod often occur in ice holes, cracks, hollows, and cavities in the lower surface of the ice and are most common near the ice edge or among broken ice. As the ice thaws at these margins, plankton grow and provide a food source. They occur in the open-ocean waters of the Study Area from the surface to depths of 1,312 ft (400 m). Onshore-offshore movements are associated with spawning and movements of ice. Cod are generally found near the bottom in the continental shelf areas, feeding on benthic organisms (Paxton and Eshmeyer 1998). The primary offshore food source of Arctic cod is plankton (Mecklenburg et al. 2011). Specifically, they feed predominantly on epibenthic mysids, amphipods, copepods, and fish (Cohen et al. 1990). It is possible that they also feed on the amphipod-diatom ice community inhabiting the lower ice layer. This species moves and feeds in different groupings, dispersed in small and very large schools throughout the water column (Welch et al. 1993). Cod in the arctic are preyed upon by marine mammals, including ringed and bearded seals.

Scorpionfish (Order Scorpaeniformes)

Scorpionfish, of the order Scorpaeniformes, are distinguishable by the well-developed spines on their cheeks, and the distinct ridges or spines on top of the head. Adults of most Arctic species live on the seafloor, but some are both benthic and pelagic. These fish typically consume small crustaceans, worms, clams, and fish eggs. One example of a scorpionfish that inhabits the Study Area is the gelatinous seasnail (*Liparis fabricii*), which is both benthic and pelagic, living at depths up 8,202 ft (2,500 m) (Mecklenburg et al. 2011). Scorpionfish are prey species for other fishes and marine birds.

Eelpouts, Eelblennys, and Wolffishes (Order Perciformes)

Though most species of the order Perciformes are found in the benthic habitats of shallower shelf waters, some species are associated with deep-water marine environments. One such species is the glacial eelpout (*Lycodes frigidus*), which is endemic to the Arctic basins. This species is benthic in water depths up to 9,843 ft (3,000 m) (Mecklenburg et al. 2011). To feed themselves, these species move along the seafloor and use the cartilaginous keels on their lower jaws to stir up prey, such as crustaceans, worms, and fishes (Mecklenburg et al. 2011).

3.2.2.3.2 Hearing

All fish have two sensory systems to detect sound in the water: the inner ear, which functions very much like the inner ear in other vertebrates, and the lateral line, which consists of a series of receptors along the fish's body (Popper and Schilt 2008). The lateral line system is sensitive to external particle motion arising from sources within a few body lengths of the animal. The lateral line detects particle motion at low frequencies from 1 Hz up to at least 400 Hz (Coombs and Montgomery 1999; Hastings and Popper 2005; Higgs and Radford 2013; Webb et al. 2008). The inner ears of fish contain three dense otoliths (i.e., small calcareous bodies) that sit atop many delicate mechanoelectric hair cells, similar to the hair cells found in mammalian ears. Sound waves in water tend to pass through fish's bodies, which have a composition similar to water, and vibrate the otoliths. This causes a relative motion between the dense otoliths and the surrounding tissues causing a deflection of the hair cells, which are sensed by the nervous system.

Although a propagating sound wave contains pressure and particle motion components, particle motion is most significant at low frequencies (less than a few hundred Hz) and closer to the sound source (Popper and Fay 2010). The inner ears of fishes are directly sensitive to acoustic particle motion rather than acoustic pressure. Historically, studies that have investigated hearing in, and effects to, fishes have been carried out with sound pressure metrics. Although particle motion may be the more relevant exposure metric for many fish species, there is little data available that actually measures it due to a lack in standard measurement methodology and experience with particle motion detectors (Hawkins et al. 2015; Martin et al. 2016). In these instances, particle motion can be estimated from pressure measurements (Nedelec et al. 2016).

Some fishes possess additional morphological adaptations or specializations that can enhance their sensitivity to sound pressure, such as a gas-filled swim bladder (Astrup 1999; Popper and Hastings 2009). A fish's gas-filled swim bladder can enhance sound detection by converting acoustic pressure into localized particle motion, which may then be detected by the inner ear (Radford et al. 2012). Fish with swim bladders generally have better sensitivity and better high-frequency hearing than fish without swim bladders (Popper 2014; Popper and Hastings 2009).In addition, structures such as gas-filled bubbles near the ear or swim bladder, or even connections between the swim bladder and the inner ear, also increase sensitivity and allow for high-frequency hearing capabilities and better sound pressure detection.

Although many researchers have investigated hearing and vocalizations in fish species (Ladich and Fay 2013; Popper 2014), hearing capability data only exist for fewer than 100 of the over 35,000 fish species (Eschmeyer and Fong 2017). Data suggest that most species of marine fish either lack a swim bladder (e.g., sharks and flatfishes) or have a swim bladder not involved in hearing and can only detect sounds below 1 kHz. Some marine fishes (clupeiforms) with a swim bladder involved in hearing are able to detect sounds to about 4 kHz (Colleye et al. 2016; Mann et al. 2001; Mann et al. 1997). One subfamily of clupeids (i.e., Alosinae) can detect high- and very high-frequency sounds (i.e., frequencies from 10 to 100 kHz, and frequencies above 100 kHz, respectively), although auditory thresholds at these higher frequencies are elevated and the range of best hearing is still in the low-frequency range (below 1 kHz) similar to other fishes. Mann et al. (Mann et al. 1998; Mann et al. 1997) theorize that this subfamily may have evolved the ability to hear relatively high sound levels at these higher frequencies in order to detect echolocations of nearby foraging dolphins. For fishes that have not had their hearing tested, such as deep sea fishes, the suspected hearing capabilities are based on the structure of the ear, the relationship between the ear and the swim bladder, and other potential adaptations such as the presence of highly developed areas of the brain related to inner ear and lateral line functions (Buran et al. 2005; Deng et al. 2011; Deng et al. 2013). It is believed that most fishes have their best hearing sensitivity from 100 to 400 Hz (Popper 2003).

Permanent hearing loss has not been documented in fish. A study by Halvorsen et al. (2012) found that for temporary hearing loss or similar negative impacts to occur, the noise needed to be within the fish's individual hearing frequency range; external factors, such as developmental history of the fish or environmental factors, may result in differing impacts to sound exposure in fish of the same species. The sensory hair cells of the inner ear in fish can regenerate after they are damaged, unlike in mammals where sensory hair cells loss is permanent (Lombarte et al. 1993; Smith et al. 2006). As a consequence, any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Smith et al. 2006), and no permanent loss of hearing in fish would result from exposure to sound.

While no auditory studies have been completed on Arctic cod specifically, and anatomical differences may result in different hearing abilities, other Gadidae have the potential to be surrogate species for Arctic cod. Gadidae have been shown to detect sounds up to about 500 Hz (Popper 2008; Sand and Karlsen 1986). Atlantic cod (*Gadus morhua*) may also detect high-frequency sounds (Astrup and Mohl 1993). Astrup and Møhl (1993) indicated that conditioned Atlantic cod have high frequency thresholds of up to 38 kHz at 185 to 200 dB re 1 µPa, which likely only allows for detection of predators at distances no greater than 33–98 ft (10–30 m) (Astrup 1999). A more recent study by Schack et al. (2008) revisited the conclusions from Astrup and Mohl's study, arguing that hearing and behavioral responses in Atlantic cod would be different with unconditioned fish. They found that ultrasound exposures mimicking those of echosounders and odontocetes would not induce acute stress responses in Atlantic cod, and that frequent encounters with ultrasound sources would therefore most likely not induce a chronic state of stress (Schack et al. 2008). The discrepancies between the two studies remain unresolved, but it has been suggested the cod in Astrup and Mohl's (1993) study were conditioned to artifacts rather than to the ultrasonic component of the exposure (Astrup 1999; Ladich and Popper 2004; Schack et al. 2008). Additionally, Jørgensen et al (2005) found that juvenile Atlantic cod did not show any clear behavioral response when exposed to either 1.5 or 4 kHz simulated sonar sound. Therefore, accepted research on cod hearing indicates sensitivities limited to low-frequency sounds.

3.2.2.4 Essential Fish Habitat

The fisheries of the United States are managed within a framework of overlapping international, federal, state, interstate, and tribal authorities. Individual states and territories generally have jurisdiction over fisheries in marine waters within 3 nm (5.6 km) of their coast. Federal jurisdiction includes fisheries in marine waters inside the U.S. Exclusive Economic Zone (EEZ), which encompasses the area from the outer boundary of state waters out to 200 nm (370 km) offshore of any U.S. coastline, except where intersected closer than 200 nm (370 km) by bordering countries (61 Federal Register [FR] 19390-19429, May 1, 1996). The Study Area resides within the U.S. EEZ, but outside of state jurisdiction.

The Study Area is within the jurisdiction of the North Pacific Fishery Management Council, which is responsible for designating Essential Fish Habitat and habitat areas of particular concern for all federally managed species occurring off the coast of Alaska. This council has prepared and implemented a Fishery Management Plan for the Arctic Management Area, which encompasses all marine waters in the U.S. EEZ from 3 nm (5.6 km) offshore of the Alaskan coast to 200 nm (370 km) offshore north of the Bering Strait. This Fishery Management Plan identifies Essential Fish Habitat for Arctic cod, saffron cod (*Eleginus gracilis*), and snow crab (*Chionoecetes opilio*). Only Essential Fish Habitat for Arctic cod overlaps the Study Area (Figure 3-4). No habitat areas of particular concern have been designated for any species within the Arctic Management Area Fisheries Management Plan (North Pacific Fishery Management Council 2009).

Insufficient information is available to determine Essential Fish Habitat for eggs, larvae, and early juveniles of Arctic cod. Essential Fish Habitat for late juvenile and adult Arctic cod within the Arctic Management Area occurs in waters from the nearshore to offshore areas along the continental shelf (0-656 ft [0-200 m]) and upper slope (656-1,640 ft [200-500 m]) throughout Arctic waters and often associated with ice floes which may occur in deeper waters (North Pacific Fishery Management Council 2009).

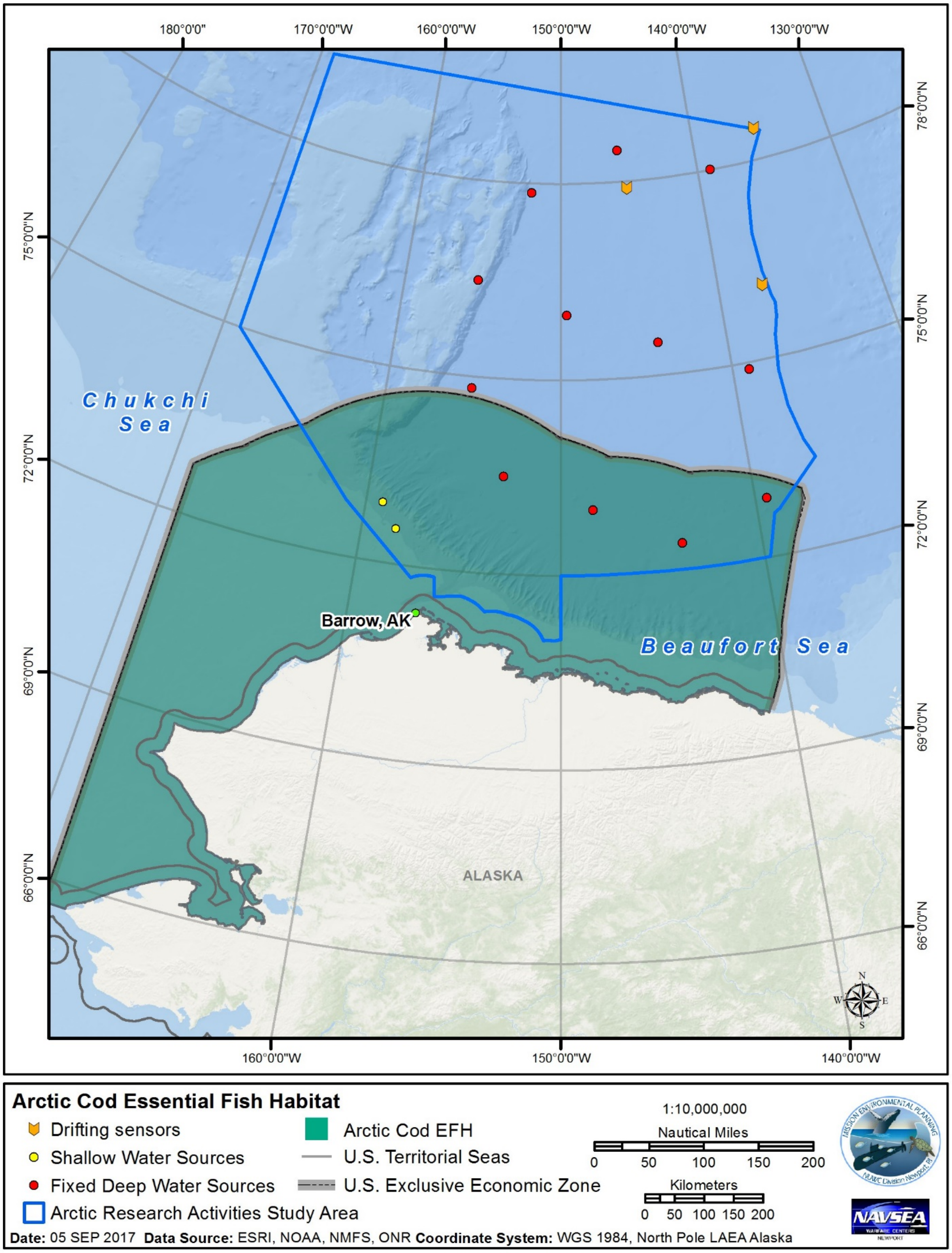

Figure 3-4. Essential Fish Habitat for Arctic Cod

3.2.2.5 Marine Mammals

Nine marine mammal species, which include three cetaceans, five pinnipeds, and the polar bear, are likely to occur in the Study Area during the Proposed Action. Marine mammals are found throughout the Study Area, including on the sea ice and within the water column. All marine mammals are protected under the MMPA, and some are additionally protected under the ESA. Table 3-3 lists the potential marine mammals within the Study Area, their stock, and ESA status. Details about the geographic range, habitat and distribution, and predator/prey interactions of each these species are provided below.

Table 3-3. Mammals Found in the Study Area during the Proposed Action

Common Name	*Scientific Name*	*Stock(s) within the Study Area*	*ESA-Listing*
ESA-Listed Species			
Bearded seal	*Erignathus barbatus nauticus*[1]	Alaska[2]	Threatened
Bowhead whale	*Balaena mysticetus*	Bering-Chukchi-Beaufort Seas	Endangered
Pacific walrus	*Odobenus rosmarus*	n/a	De-listed (previous candidate for listing)
Polar bear	*Ursus maritimus*	Southern Beaufort Sea, Chukchi/Bering Sea	Threatened
Ringed seal	*Phoca hispida*	Alaska[2]	De-listed but subject to relisting[3]
Non-ESA Listed Species			
Beluga whale	*Delphinapterus leucas*	Beaufort Sea	n/a
Gray whale	*Eschrichtius robustus*	Eastern North Pacific	n/a
Ribbon seal	*Histriophoca fasciata*	Alaska	n/a
Spotted seal	*Phoca largha*	Alaska	n/a

[1] Scientific name of subspecies within the Study Area
[2] Stock is designated by the MMPA.
[3] District Court is currently waiting for a mandate from the U.S. court of appeals for the ninth circuit to re-instate the ringed seal as threatened. Once the mandate is received the District Court will enter a final judgement on the case.

3.2.2.5.1 ESA-listed Marine Mammals

The ESA-listed marine mammals that may occur in the Study Area are described below.

Bearded Seal

The bearded seal (*Erignathus barbatus*) is listed as threatened under the ESA, and listed as depleted under the MMPA. The bearded seal has been separated into two subspecies: *E. b. barbatus* and *E. b. nauticus*. Only the *E. b. nauticus* subspecies is located within the Study Area. Based on evidence, the *E. b. nauticus* subspecies was further divided into an Okhotsk Distinct Population Segment (DPS) and a Beringia DPS. The Beringia DPS is the only DPS of bearded seal that is located within the Study Area, along the Beaufort Sea continental shelf (Muto et al. 2017). The Beringia DPS is considered the Alaska Stock of the bearded seal. NMFS published a final rule (on December 28, 2012) listing the Beringia and Okhotsk DPS as threatened. There is currently no critical habitat designated for the bearded seal.

Figure 3-5 shows the extent of bearded seals in the Northern Hemisphere. Bearded seal have a circumpolar distribution that does not extend farther north than 85 degrees North (°N) (Muto et al. 2017; Reeves et al. 2002). Beringia bearded seals are widely distributed throughout the northern Bering, Chukchi, and Beaufort Seas and are most abundant north of the ice edge zone (MacIntyre et al. 2013). Telemetry data from Boveng and Cameron (2013) showed that large numbers of bearded seals move south in fall/winter as sea ice forms and move north as the seasonal sea ice melts in the spring. The highest densities of bearded seals are found in the central and northern Bering Sea shelf during winter (Braham et al. 1981; Burns 1981a; Burns and Frost 1979; Fay 1974; Heptner et al. 1976; Nelson et al. 1984). In late winter and early spring bearded seals are widely (not uniformly) ranging from the Chukchi Sea south to the ice front in the Bering Sea usually on drifting pack ice (Muto et al. 2016). In a shallow water study by MacIntyre et al. (2013), bearded seal calls were recorded throughout the year (11 to 12 months) in the Beaufort Sea, with the peak of calls detected from January to July. Bearded seals inhabit the seasonally ice-covered seas of the Northern Hemisphere, where they whelp and rear their pups, and molt their coats on the ice in the spring and early summer (Muto et al. 2017).

Bearded seals along the Alaskan coast tend to prefer areas where sea ice covers 70 to 90 percent of the surface, and are most abundant 20 to 100 nm (37 to 185 km) offshore during the spring season (Bengston et al. 2000; Bengtson et al. 2005; Simpkins et al. 2003). In spring, bearded seals may also concentrate in nearshore pack ice habitats, where females give birth on the most stable areas of ice (Reeves et al. 2002). Bearded seals haul out on spring pack ice (Simpkins et al. 2003) and generally prefer to be near polynyas (areas of open water surrounded by sea ice) and other natural openings in the sea ice for breathing, hauling out, and prey access (Nelson et al. 1984; Stirling 1997). While molting between April and August, bearded seals spend substantially more time hauled out then at other times of the year (Reeves et al. 2002).

In their explorations of the Canada Basin, Harwood et al. (2005) observed bearded seals in waters of less than 656 ft (200 m) during the months from August to September. These sightings were east of 140 degrees West (°W). The Bureau of Ocean Energy Management (BOEM) conducted an aerial survey from June through October that covered the shallow Beaufort and Chukchi Sea shelf waters, and observed bearded seals from Point Barrow to the border of Canada (Clarke et al. 2014). The farthest from shore that bearded seals were observed was the waters of the continental slope.

Bearded seals feed on the seafloor, commonly occupying shallow waters (Fedoseev 2000; Kovacs 2002). The preferred depth range is often described as less than 656 ft (200 m) (Allen and Angliss 2014; Fedoseev 2000; Jefferson et al. 2008; Kovacs 2002), although adults have been known to dive to around 984 ft (300 m) (Cameron and Boveng 2009; Kovacs 2002). At these depths, they feed on demersal fish (e.g., Arctic and saffron cod, flatfish, and sculpins) and a variety of small invertebrates that live in the substrate or on its surface (Fedoseev 2000; Kovacs 2002). They may also opportunistically supplement their diet with crab, shrimp, mollusks, and octopus (Reeves et al. 2002).

Bearded seals may be present close to the continental shelf and therefore, may be present near the deep water area within the Study Area year-round.

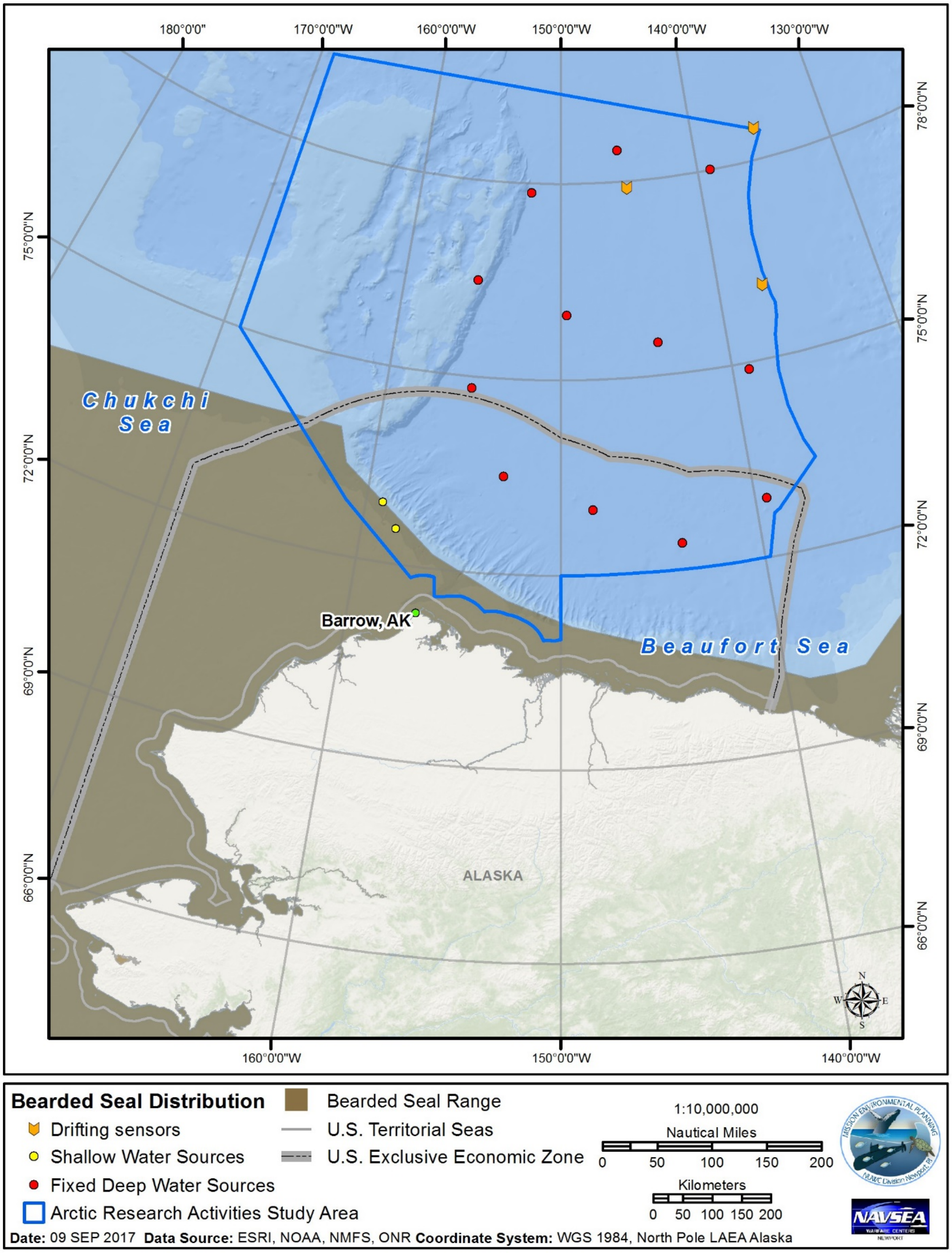

Figure 3-5. Bearded Seal Distribution in Study Area

Bowhead Whale

The bowhead whale (*Balaena mysticetus*) is listed as endangered under the ESA, and listed as depleted under the MMPA. Bowhead whales that may be present within the Study Area are part of the Bering–Chukchi–Beaufort Seas stock (i.e., Western Arctic stock), which ranges from Siberia east to Amundsen Gulf in Canada to 74 °N, north to the Bering Sea and south to the Pribilof Islands (Figure 3-6). No critical habitat is currently designated for this species.

The bowhead whale is the northernmost of all whales, inhabiting only regions close to the ice edge. Bowhead whales are found in arctic and subarctic regions (55 °N to 85 °N) of the North Atlantic and North Pacific oceans (Rice 1998). Their range can expand and contract depending on ice cover and access to Arctic straits (Rugh et al. 2003). These whales are also found in the Bering, Beaufort, and Chukchi Seas, Russia, and the northern parts of Hudson Bay, Canada (Wiig et al. 2007). In Alaska, bowhead whales are closely associated with sea ice most of the year (Moore and Reeves 1993; Quakenbush et al. 2010). The majority of the Western Arctic stock migrates annually from wintering areas, which they inhabit from December to March, in the northern Bering Sea (which are typically areas with 90 to 100 percent sea ice cover (Citta et al. 2015; Quakenbush et al. 2010)), through the Chukchi Sea in the spring (April through May) following fractures in the sea ice around Alaskan coast, generally in the shear zone between the shore-fast and mobile pack ice (Muto et al. 2017). Bowhead whales spend most of the summer (June to September) in the Beaufort Sea before returning again to the Bering Sea in the fall (October through December) to overwinter in select shelf waters in all but heavy ice conditions (Braham et al. 1980; Citta et al. 2015; Moore 2000; Moore and Reeves 1993; Quakenbush et al. 2010). Mating occurs from late winter to spring and calving occurs from April to June, both in the Bering Sea (Quakenbush 2008).

Several areas within the Chukchi and Beaufort Seas along the northern coast of Alaska are important to bowhead whales. In the Alaskan Beaufort Sea and northeastern Chukchi Sea, there is a reproductive area that is in use during the month of October. Near Barrow Canyon, there is another area used from April to June for reproduction. In the eastern Chukchi and Alaskan Beaufort Sea, there is a migration area used from April to May. Finally, in the Alaskan Beaufort Sea, there is feeding ground used from September to October, a migration area used from September to October, and a reproduction area used in September (Calambokidis et al. 2015). The feeding grounds used from September to October are focused in the coastal waters of the eastern, central, and western Beaufort Sea (Lowry et al. 2004). Large groups of bowhead whales have been documented feeding in the western Alaskan Beaufort Sea as early as July and continuing into October (Clarke et al. 2014).

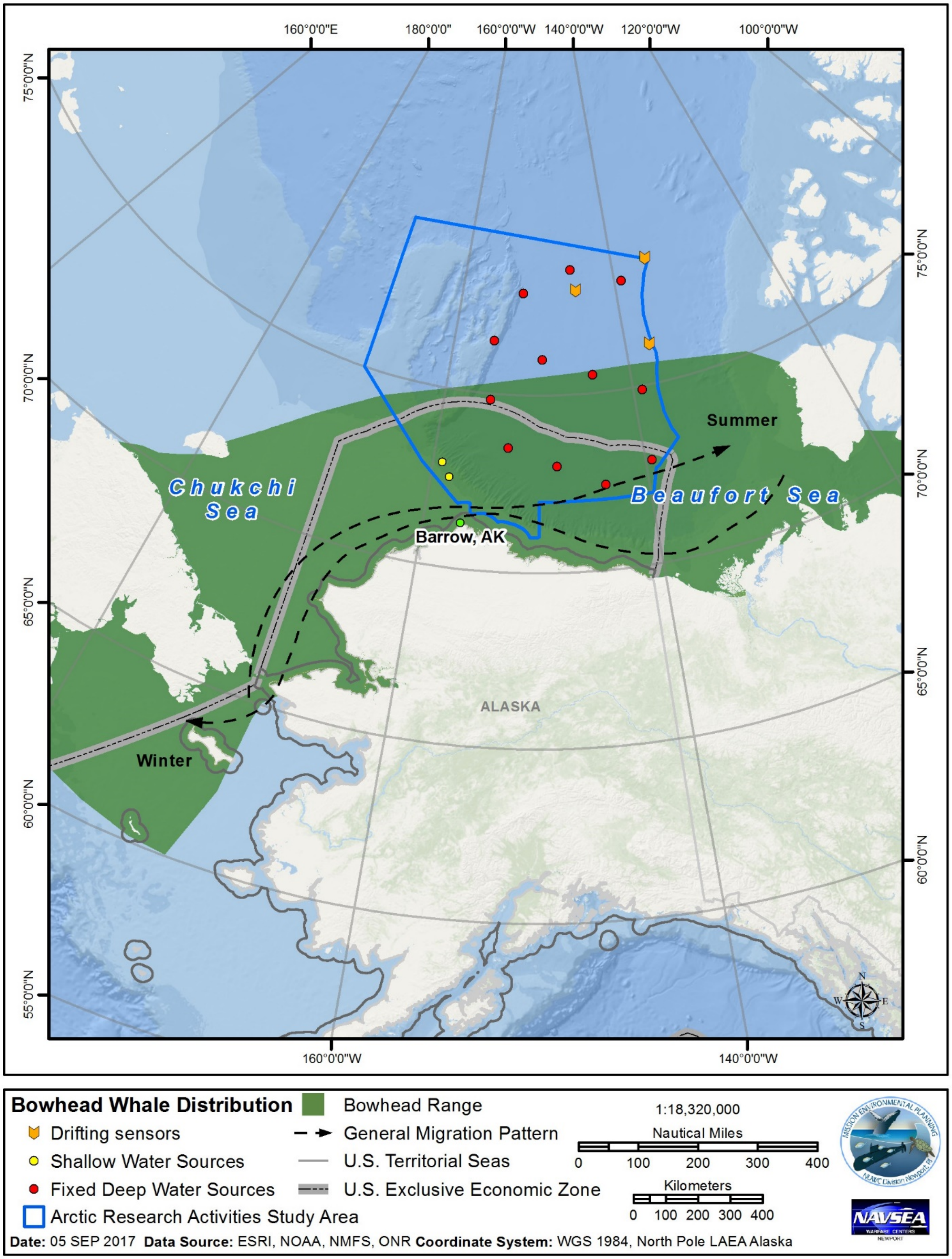

Figure 3-6. Bowhead Whale Distribution in the Study Area

Bowheads are one of the most commonly sighted cetaceans in the Chukchi Sea when the ice has receded during warm seasons (Aerts et al. 2013). During summer, most of the population is in relatively ice-free waters in the southeastern Beaufort Sea. Some bowhead whales are found in the western Beaufort, Chukchi, and Bering seas in summer, and these are thought to be a part of the expanding Western Arctic stock (Citta et al. 2015; Clarke et al. 2013; Clarke et al. 2014; Clarke et al. 2015; Rugh et al. 2003). Summer aerial surveys conducted in the western Beaufort Sea during July and August of 2012-2014 have had relatively high sighting rates of bowhead whales, including cows with calves and feeding animals (Alaska Fisheries Science Center Marine Mammal Laboratory 2014; Clarke et al. 2013; Clarke et al. 2014; Muto et al. 2016). According to the annual arctic aerial surveys conducted along the north shore of Alaska, the distribution of bowhead whales was primarily on the outer continental shelf (at depths of 167 to 656 ft [51 to 200 m]) in July, on the outer and inner continental shelf (at depths of 0 to 656 ft [0 to 200 m]) in August, and on the inner continental shelf (at depths of less than 164 ft [50 m]) in September. Sighting rate (whales per transect km) by depth zone between 140°W and 154°W in the western Beaufort Sea was highest in the 167 to 656 ft (51 to 200 m) zone in July, then less than or equal to 66 ft (20 m) zone in August, and the 69 to 164 ft (21 to 50 m) zone in September (Clarke et al. 2014). Compared to previous years that also had light sea ice cover, bowhead whale sightings (not normalized by survey effort) in the western Beaufort Sea in fall 2013 were significantly farther from shore and in deeper water in the west. Krutizikowski and Mate (2000) determined the average dive depth of bowhead whales in the Chukchi and Beaufort Sea to be less than 328 ft (100 m) with a maximum recorded dive of 1,155 ft (352 m).

Bowhead whales feed by skimming the surface or sometimes near the seafloor (Rugh and Shelden 2009). Preferred prey include various species of copepods and euphausiids (Budge et al. 2008; Rugh and Shelden 2009; Wiig et al. 2007). Likely or confirmed feeding areas include Amundsen Gulf and the eastern Canadian Beaufort Sea; the central and western U.S. Beaufort Sea; Wrangel Island; and the coast of Chukotka, between Wrangel Island and the Bering Strait (Alaska Fisheries Science Center Marine Mammal Laboratory 2014; Ashjian et al. 2010; Clarke et al. 2013; Clarke et al. 2014; Clarke et al. 2015; Lowry et al. 2004; Muto et al. 2016; Okkonen et al. 2011; Quakenbush et al. 2010).

Bowhead whales are most likely to be present in the Beaufort and Chukchi Seas from March to April and August through October.

Pacific Walrus

The Pacific walrus (*Odobenus rosmarus*) is the only subspecies occurring in U.S. waters, and is considered a single stock. On October 4, 2017, the Pacific walrus was removed as a candidate species by the USFWS, and determined that the population did not warrant listing at this time. Due to the likelihood for the petition for re-listing during the timeframe of the Proposed Action, the Pacific walrus was included as a candidate species. Additionally, the Pacific walrus within the U.S. EEZ is not designated as depleted under the MMPA, but is classified as strategic because the level of human-caused mortality exceeds the rate of reproduction and survival required for a stable population. The walrus is managed by the USFWS under the Department of the Interior.

Walruses have a circumpolar distribution in the Arctic Ocean and are associated with pack ice everywhere they are found, at least during winter. Pacific walruses range throughout the continental shelf waters of the Bering and Chukchi Seas, occasionally moving into the East Siberian Sea and the Beaufort Sea (Figure 3-7) (Muto et al. 2017). A significant proportion of the Pacific walrus population migrates into the Chukchi Sea region each summer. Walruses are known to stay fairly close to land for most of their lives and make shallow dives inshore (depths of roughly 262 ft [80 m]) (Kastelein 2002) from the continental shelf and slope, so they do not regularly occur in deep oceanic waters. Walruses haul out on ice floes and sandy beaches or rocky shores, along remote stretches of mainland coastlines or islands (Jefferson et al. 2008; Kastelein 2009). Walruses haul out on land to a greater extent during years with reduced pack ice. The movements of walruses generally follow the movements of pack ice. However, some individuals do travel farther from the ice during summer months.

The shallow, productive, ice covered waters of the eastern Chukchi Sea are considered particularly important habitat for female walrus and their dependent young. Several thousand animals (primarily adult males) aggregate near coastal haulouts in the Bering Strait region and Bristol Bay, as well as several areas near Russia and Japan. During the late winter breeding season, most walruses are found in two major Bering Sea concentration areas where open leads, polynyas, or thin ice allows open water access (Fay et al. 1984; Garlich-Miller et al. 2011). While the specific location of these groupings can vary annually and seasonally depending upon the extent of the sea ice, one group will generally range from the Gulf of Anadyr in Russia into a region southwest of St. Lawrence Island (northern Bering Sea), and the second group will aggregate somewhere in the southeastern Bering Sea from south of Nunivak Island to northwestern portions of Bristol Bay.

In the annual BOEM survey, only a few walruses were observed east of Barrow, and then, only in shallow waters in August (Clarke et al. 2014). In their explorations of the Canada Basin, Harwood et al. (2005) only saw walruses in the Chukchi Sea at the Chukchi shelf break and at the Northwind Ridge, located just east of 160° W.

Walrus feed on bottom-dwelling invertebrates and slow-moving fish to depths of roughly 262 ft (80 m) (Kastelein 2002). Preferred prey include clams, snails, shrimp and slow-moving fish (Jefferson et al. 1993). Walruses have been observed preying on seabirds, seals, and Northern sea lions (Reeves et al. 2002). Walruses are known to consume between 88 and 176 pounds (lbs; 40 and 80 kilograms [kg]) of food per day (Jefferson et al. 2008; Kastelein and Wiepkema 1989). Common predators to the walrus are killer whales and polar bears.

Pacific walrus may be encountered during the transit out to the Study Area, but would most likely not be encountered in the Study Area.

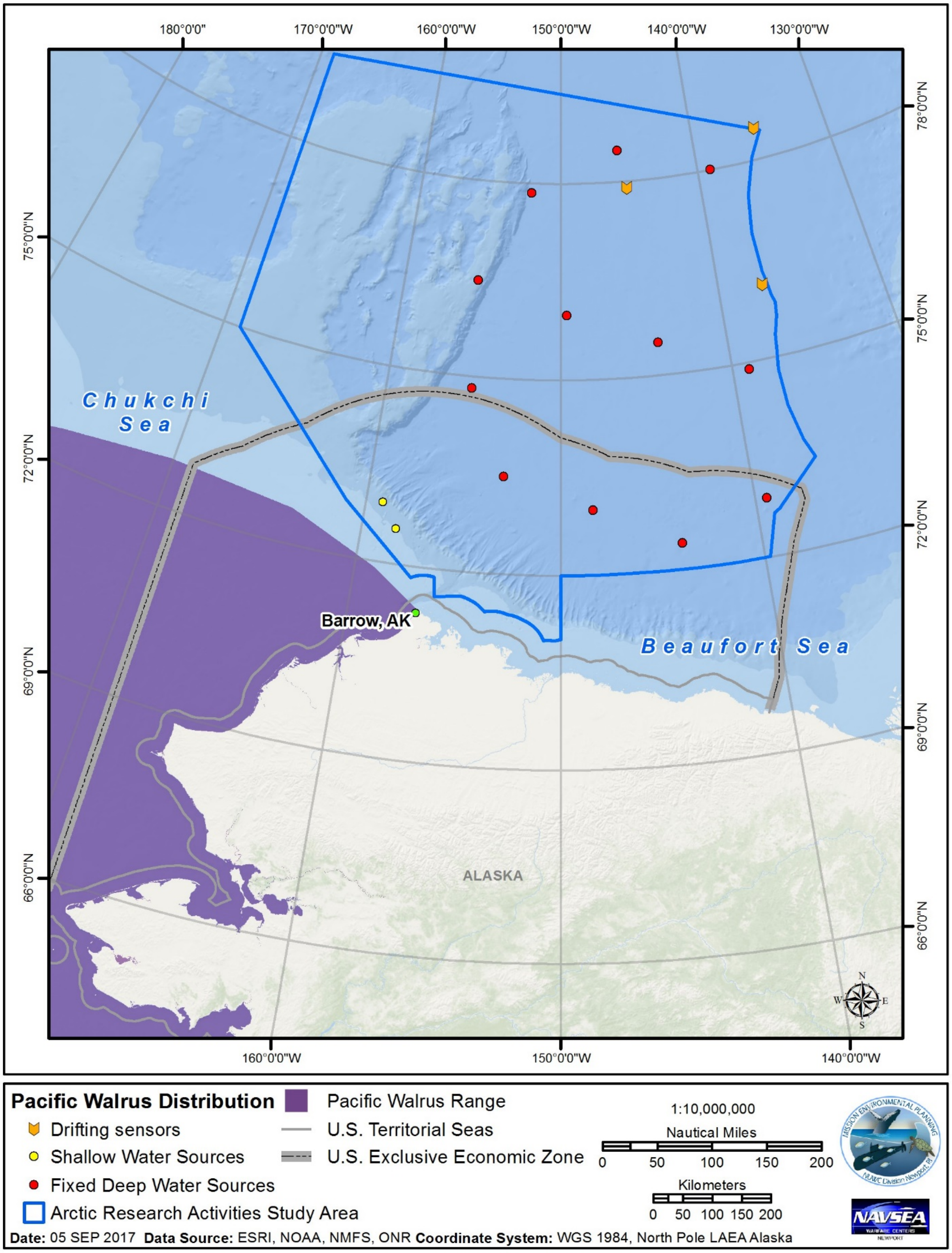

Figure 3-7. Pacific Walrus Distribution Near the Study Area

Polar Bear

Two polar bear stocks occur within the Study Area: (1) the Southern Beaufort Sea stock and (2) the Chukchi/Bering Seas stock. Both of these stocks are listed as threatened under the ESA (73 FR 28212, May 15, 2009). The determination of polar bears as threatened under the ESA was made based on an extinction risk assessment. This assessment found that the main concern regarding the conservation of polar bears stems from the loss of habitat, particularly sea ice. Polar bears were determined to likely become endangered within the foreseeable future (defined as 45 years) throughout its range, based on expected continued decline of sea ice. Additionally, both stocks are currently listed as depleted and classified as strategic under the MMPA. Designated critical habitat for the polar bear (75 FR 76085; December 7, 2010) encompasses three areas or units: barrier islands, sea ice, and terrestrial denning habitat. The total area designated covers 187,157 mi^2 (484,734 km^2) (Figure 3-8). About 96 percent of the proposed critical habitat area is sea ice.

The USFWS identified physical and biological features essential to the conservation of the polar bear. These include:

- Sea ice habitat located over the continental shelf at depths of 984 ft (300 m) or less. In spring and summer, this habitat follows the northward progression of the ice edge as it retreats northward. In fall, this sea ice habitat follows the southward progression of the ice edge as it advances southward.
- Sea ice within 1 mile (mi; 1.6 km) of the mean high tide line of barrier island habitat. Barrier islands are used as migration corridors. Polar bears can move freely between barrier islands by swimming or walking on ice or sand bars, thereby avoiding human disturbance.

The Chukchi/Bering Seas stock is widely distributed on the pack ice in the Chukchi Sea and northern Bering Sea and adjacent coastal areas in Alaska and Russia (Muto et al. 2017). An extensive area of overlap between the Southern Beaufort Sea stock and the Chukchi/Bering Seas stock occurs between Point Barrow and Point Hope, centered near Point Lay (Amstrup 2000; Garner et al. 1994; Garner et al. 1990).

The Southern Beaufort Sea population spends the summer on pack ice and moves toward the coast during fall, winter, and spring (Durner et al. 2004). Polar bears in the Southern Beaufort Sea concentrate in waters less than 984 ft (300 m) deep over the continental shelf and in areas with greater than 50 percent ice cover in all seasons except summer to access prey such as ringed and bearded seals (Durner et al. 2004; Durner et al. 2006b; Durner et al. 2009; Stirling et al. 1999). The eastern boundary of the Southern Beaufort Sea stock occurs south of Banks Island and east of the Baillie Islands, Canada (Amstrup et al. 2000). The western boundary of the Southern Beaufort Sea stock is near Point Hope, Alaska. Polar bears from this population have historically denned on both the sea ice and land. Therefore, the southern boundary of the Southern Beaufort Sea stock is defined by the limits of terrestrial denning sites inland of the coast, which follows the shoreline along the North Slope in Alaska and Canadian Arctic (Bethke et al. 1996). Polar bears could be within the Study Area at any time during the Proposed Action. General year-round distribution of polar bears within the Study Area is depicted in Figure 3-8. The size of a polar bear's range depends on a number of factors, including habitat quality and the amount of available food (Polar Bears International 2015). In the Beaufort Sea, annual polar bear activity areas for individually monitored female bears averaged 57,529 mi^2 (149,000 km^2), ranging from 5,020 to 230,500 mi^2 (13,000 km^2 to 597,000 km^2) (Amstrup et al. 2000).

Mating occurs in late March through early May. In November and December, females dig maternity dens in pressure ridges in fast ice, drifting pack ice, or on land (up to 100 mi [161 km] inland). Females give birth to their cubs from December to January and stay within their dens until spring (Reeves et al. 2002).

Each year, only 25 percent of reproductively active females produce a litter. Studies conducted between 1981 and 1994 of radio-collared bears found over half of the dens on sea ice (53 percent on pack ice and 4 percent on land fast ice) with the remainder of dens on land. Polar bears do not show fidelity to specific den sites but certain bears do show fidelity to denning on either land or sea ice. The U.S. Geological Survey mapped polar bear dens between 1910 and 2010 using satellite telemetry, very high frequency telemetry, forward-looking infrared, polar bear captures, and reports from coastal Alaskans, hunters, and industry personnel (Durner et al. 2010). The main terrestrial denning areas for the Southern Beaufort Sea population in Alaska occur on the barrier islands from Utqiagvik (Barrow) to Kaktovik and along coastal areas up to 25 mi (40 km) inland, including the Arctic National Wildlife Refuge to Peard Bay, west of Utqiagvik (Barrow) (Amstrup et al. 2000; Amstrup and Gardner 1994; Durner et al. 2001, 2006a). Denning sites in the Beaufort Sea and neighboring regions of Alaska are depicted in Figure 3-8.

Little comprehensive information exists that allows for reliable population estimates of the Chukchi/Bering Seas and Southern Beaufort Sea stocks. The Chukchi Sea population is estimated to comprise 2,000 animals, based on extrapolation of aerial den surveys (Lunn et al. 2002). Research on the Southern Beaufort Sea population began in 1967 and is one of only four polar bear populations with long term (greater than 20 years) data. The population estimate of 1,526 bears (Regehr et al. 2006), which is based on open population capture-recapture data collected from 2001 to 2006, is considered the most current and valid population estimate (Regehr et al. 2006). The most recent stock assessment for polar bears indicates that the Southern Beaufort Sea stock is declining (Allen and Angliss 2011).

Polar bears' main prey are ringed and bearded seals (Durner et al. 2004; Durner et al. 2006b; Durner et al. 2009; Stirling et al. 1999). Occasionally, polar bears are known to prey upon walruses or beluga whales trapped by ice, and may also consume carrion when prey is scarce (U.S. Fish and Wildlife Service 2014).

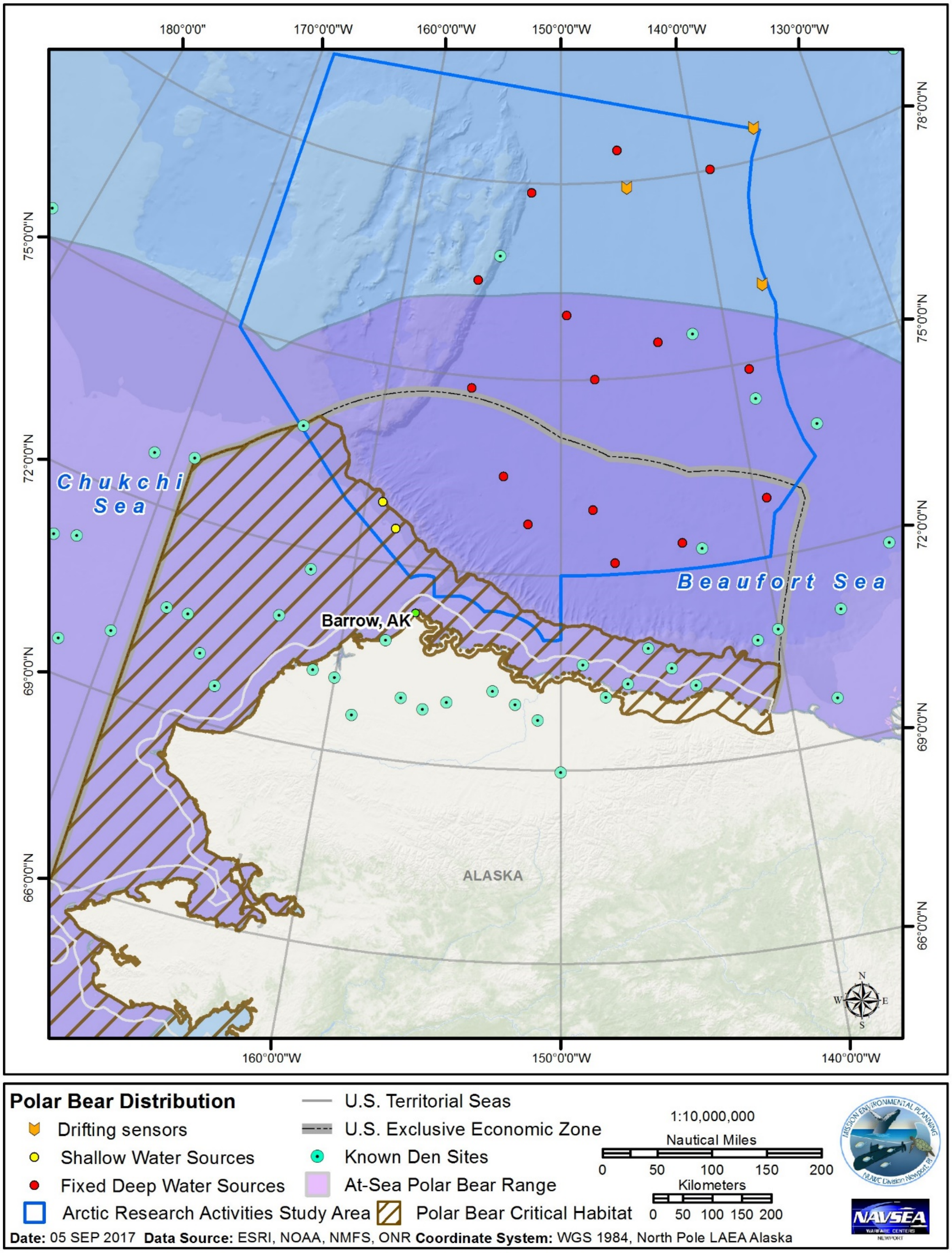

Figure 3-8. Polar Bear At-Sea Distribution in Study Area

Ringed Seal

The ringed seal, specifically the Arctic/Bering Sea subspecies *Phoca hispida hispida*, occurs within the U.S. EEZ of the Beaufort, Chukchi, and Bering Seas and overlaps with the Study Area (Kelly et al. 2009; Palo 2003; Palo et al. 2001). Currently, the ringed seal is not listed under the ESA. In March 2016, the U.S. District Court for the District of Alaska in the case of *Alaska Oil & Gas Association v. National Marine Fisheries Service, et al.,* (Case no:14-cv-00029-RRB) vacated the NMFS' ESA listing of the Arctic/Bering Sea subspecies of ringed seals (*P. h. hispida*) as threatened under the ESA. On February 12, 2018 the U.S. Court of Appeals for the Ninth Circuit reversed the District Court's decision upholding NMFS's decision to list the arctic ringed seals as threatened. The listing will be reinstated after the ninth circuit issues a mandate to the District Court and the District Court then enters a final judgement on the case. Although not currently listed, because the Ninth Circuit reversed the District Court's decision to de-list the ringed seal, and the ringed seal will most likely be re-listed prior to the commencement or during the period of the Proposed Action, the ringed seal is treated as a threatened species within this document. No critical habitat is currently designated. Critical habitat for the ringed seal that was proposed by NMFS in 2014 (79 FR 71714; December 3, 2014) would fall within the Study Area and includes all the contiguous marine waters from the coast line of Alaska to an offshore limit of the U.S. EEZ north of Alaska (Figure 3-9). Since the Proposed Action spans over three years, and due to ongoing litigation and the fact that a decision could be rendered to re-list the ringed seal and designate proposed critical habitat before or during the Proposed Action, this document addresses proposed critical habitat. The Arctic/Bering Sea subspecies is listed as depleted and strategic under the MMPA. For the purposes of this analysis, the Alaska stock of ringed seals, as designated under the MMPA, is considered to be the portion of the subspecies *P. h. hispida* that occurs within the U.S. EEZ of the Beaufort, Chukchi, and Bering Seas.

NMFS regulations (50 CFR § 424.12(b)) state that, in determining what areas qualify as critical habitat, the agencies "shall consider those physical and biological features that are essential to the conservation of a given species and that may require special management considerations or protection." These principal biological or physical constituent elements are referred to as "essential features" and "may include, but are not limited to, the following: spawning sites, feeding sites, seasonal wetland or dryland, water quality or quantity, geological formation, vegetation type, tide, and specific soil types." In a proposed rule on December 3, 2014, NMFS identified areas used by ringed seals along with a description of those features essential to conservation. These three features are as follows:

- Sea ice habitat suitable for the formation and maintenance of subnivean birth lairs used for sheltering pups during whelping and nursing.
- Sea ice habitat suitable as a platform for basking and molting, which is defined as sea ice of 15 percent or more concentration, except for bottom-fast ice extending seaward from the coastline in waters less than 6.6 ft (2 m) deep.
- Primary prey resources to support Arctic ringed seals, which are defined to be Arctic cod, saffron cod, shrimps, and amphipods.

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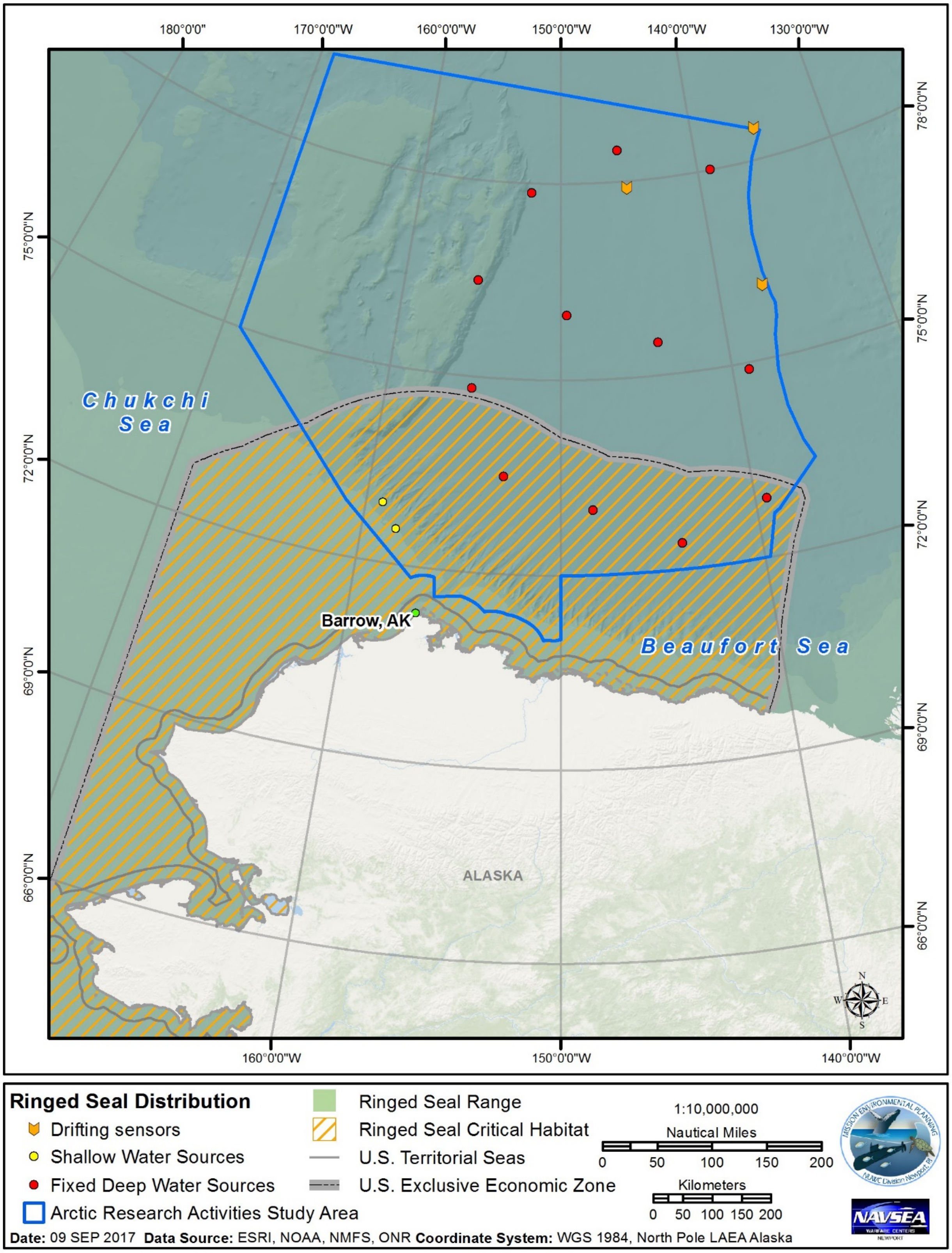

2

3 **Figure 3-9. Ringed Seal Distribution in Study Area**

The area proposed for critical habitat was deemed to have one or more of these essential features that may require special management or protection. Areas focused on were those with physical or biological features that support functions of whelping and nursing, where birth lairs are constructed and maintained, and molting. The specific geographic locations of essential sea ice habitat vary annually, or even daily, depending on many factors, including time of year, local weather, and oceanographic conditions. In addition, the duration that any given location has sea ice habitat essential for birth lairs or for molting can vary annually depending on the rate of ice melt and other factors. The southern boundary suggests that sea ice essential for Arctic ringed seal birth lairs extends to some point south of St. Matthew Island and Nunivak Island. Given the inherent variability in the spatial distribution of sea ice and the widespread distribution of Arctic ringed seals, including in offshore pack ice, the northern and eastern boundaries of the area were identified as the outer extent of the U.S. exclusive economic zone (Figure 3-9). NMFS determined that the essential features of the habitat of the Arctic ringed seal may require special management considerations or protection in the future to minimize the risks posed to these features by potential shipping and transportation activities, because: (1) both the physical disturbance and noise associated with these activities could displace seals from favored habitat that contains the essential features, thus altering the quantity and/or quality of these features; and (2) in the event of an oil spill, sea ice essential for birth lairs and for molting could become oiled, and the quantity and/or quality of the primary prey resources could be adversely affected.

Ringed seals are the most common pinniped in the Study Area and have wide distribution in seasonally and permanently ice-covered waters of the Northern Hemisphere (North Atlantic Marine Mammal Commission 2004). Throughout their range, ringed seals have an affinity for ice-covered waters and are well adapted to occupying both shore-fast and pack ice (Kelly 1988c). Ringed seals can be found further offshore than other pinnipeds since they can maintain breathing holes in ice thickness greater than 6.6 ft (2 m) (Smith and Stirling 1975). Breathing holes are maintained by ringed seals' sharp teeth and claws on their fore flippers. They remain in contact with ice most of the year and use it as a platform for molting in late spring to early summer, for pupping and nursing in late winter to early spring, and for resting at other times of the year (Muto et al. 2017).

Ringed seals have at least two distinct types of subnivean lairs: haulout lairs and birthing lairs (Smith and Stirling 1975). Haulout lairs are typically single-chambered and offer protection from predators and cold weather. Birthing lairs are larger, multi-chambered areas that are used for pupping in addition to protection from predators. Ringed seals pup on both land-fast ice as well as stable pack ice. Lentfer (1972) found that ringed seals north of Barrow, Alaska (Figure 3-9), build their subnivean lairs on the pack ice near pressure ridges. Since subnivean lairs were found north of Barrow, Alaska, in pack ice, they are also assumed to be found within the sea ice in the Study Area. Ringed seals excavate subnivean lairs in drifts over their breathing holes in the ice, in which they rest, give birth, and nurse their pups for 5–9 weeks during late winter and spring (Chapskii 1940; McLaren 1958; Smith and Stirling 1975). Snow depths of at least 20–26 in (50–65 cm) are required for functional birth lairs (Kelly 1988a; Lydersen 1998; Lydersen and Gjertz 1986; Smith and Stirling 1975), and such depths typically are found only where 8–12 in (20–30 cm) or more of snow has accumulated on flat ice and then drifted along pressure ridges or ice hummocks (Hammill 2008; Lydersen et al. 1990; Lydersen and Ryg 1991; Smith and Lydersen 1991). Ringed seals are born beginning in March, but the majority of births occur in early April. About a month after parturition, mating begins in late April and early May.

In Alaskan waters, during winter and early spring when sea ice is at its maximal extent, ringed seals are abundant in the northern Bering Sea, Norton and Kotzebue Sounds, and throughout the Chukchi and Beaufort seas (Frost 1985; Kelly 1988c), and therefore are in the Study Area (Figure 3-9). Passive acoustic monitoring of ringed seals from a high frequency recording package deployed at a depth of

787 ft (240 m) in the Chukchi Sea, 65 nm (120 km) north-northwest of Barrow, Alaska detected ringed seals in the area between mid- December and late May over the four year study (Jones et al. 2014). With the onset of the fall freeze, ringed seal movements become increasingly restricted and seals will either move west and south with the advancing ice pack with many seals dispersing throughout the Chukchi and Bering Seas, or remain in the Beaufort Sea (Crawford et al. 2012; Frost and Lowry 1984; Harwood et al. 2012). Kelly et al., (2010a) tracked home ranges for ringed seals in the subnivean period (using shorefast ice); the size of the home ranges varied from less than 0.39 up to 10.8 mi^2 (1 up to 27.9 km^2); (median is 0.24 mi^2 [0.62 km^2] for adult males and 0.25 mi^2 [0.65 km^2] for adult females). Most (94 percent) of the home ranges were less than 1.15 mi^2 (3 km^2) during the subnivean period (Kelly et al. 2010a). Near large polynyas, ringed seals maintain ranges, up to 2,703 mi^2 (7,000 km^2) during winter and 811 mi^2 (2,100 km^2) during spring (Born et al. 2004). Some adult ringed seals return to the same small home ranges they occupied during the previous winter (Kelly et al. 2010a). The size of winter home ranges can, however, vary by up to a factor of 10 depending on the amount of fast ice; seal movements were more restricted during winters with extensive fast ice, and were much less restricted where fast ice did not form at high levels (Harwood et al. 2015). Ringed seals may occur within the Study Area throughout the year and during the Proposed Action.

Ringed seal population surveys in Alaska have used various methods and assumptions, had incomplete coverage of their habitats and range, and were conducted more than a decade ago; therefore, current, comprehensive, and reliable abundance estimates or trends for the Alaska stock are not available (Muto et al. 2017). Frost et al. (2004) conducted surveys within 21.6 nm (40 km) of shore in the Alaska Beaufort Sea during May-June 1996-1999, and observed ringed seal densities ranging from 0.81 seal per km^2 in 1996 to 1.17 seals per km^2 in 1999. Moulton et al. (2002) conducted similar, concurrent surveys in the Alaska Beaufort Sea during 1997-1999 but reported substantially lower ringed seal densities (0.43, 0.39, and 0.63 seals per km^2 in 1997-1999, respectively) than Frost et al. (2004). Using the most recent estimates from surveys by Bengtson et al. (2005) and Frost et al. (2004) in the late 1990s and 2000, Kelly et al. (2010b) estimated the total population in the Alaska Chukchi and Beaufort seas to be at least 300,000 ringed seals, which Kelly et al. (2010b) states is likely an underestimate since the Beaufort surveys were limited to within 21.6 nm (40 km) of shore.

In general, ringed seals prey upon fish and crustaceans. Ringed seals are known to consume up to 72 different species in their diet; their preferred prey species is the polar cod (Jefferson et al. 2008). Ringed seals also prey upon a variety of other members of the cod family, including Arctic cod (Holst et al. 2001), and saffron cod, with the latter being particularly important during the summer months in Alaskan waters (Lowry et al. 1980). Invertebrate prey seems to become prevalent in the ringed seals diet during the open-water season and often dominates the diet of young animals (Holst et al. 2001; Lowry et al. 1980). Large amphipods (e.g., *Themisto libellula*), krill (e.g., *Thysanoessa inermis*), mysids (e.g., *Mysis oculata*), shrimps (e.g., *Pandalus* spp., *Eualus* spp., *Lebbeus polaris*, and *Crangon septemspinosa*), and cephalopods (e.g., *Gonatus* spp.) are also consumed by ringed seals.

3.2.2.5.2 Non ESA-listed Marine Mammals

Marine mammals that may occur in the Study Area, and are not listed under the ESA, are described below.

Beluga Whale

In the United States and Canada, individual populations have been assessed for status under the applicable conservation statutes. Five stocks of beluga whales are recognized within U.S. waters: (1) Cook Inlet, (2) Bristol Bay, (3) Eastern Bering Sea, (4) Eastern Chukchi Sea, and (5) Beaufort Sea. Only the Cook Inlet population of the beluga whale is listed as endangered under the ESA. The Beaufort Sea, Eastern Chukchi Sea, Eastern Bering Sea, and Bristol Bay stocks of beluga whales are not listed as threatened or endangered under the ESA. Additionally, those stocks not listed as threatened or endangered under the ESA are not listed as depleted or classified as strategic under the MMPA. Only the Beaufort Sea and Eastern Chukchi Sea stocks of beluga whales are expected to occur in the Study Area.

The majority of belugas are distributed discontinuously around the Arctic Ocean and adjacent seas, primarily on the continental shelf and near coasts around North America, Russia, and Greenland (Rice 1998). Beluga whales are found primarily in shallow coastal waters (in depths as shallow as 3 to 10 ft [1 to 3 m]), but can be found in waters deeper than 2,624 ft (800 m) (Jefferson et al. 2012; Richard et al. 2001). Beluga whales are distributed throughout the seasonally ice-covered arctic and subarctic waters of the Northern Hemisphere (Gurevich 1980). Their range includes Greenland, the Arctic coast of Eurasia and central Asia, the Arctic coast of Siberia to the Bering Sea, the Arctic coast of Alaska and northwestern Canada, and from the Chukchi Sea east to the Beaufort Sea. Disjoined populations are located in the St. Lawrence estuary, Sea of Okhotsk, Cook Inlet, and northern Gulf of Alaska.

Belugas are both migratory and residential (non-migratory), depending on the population. Migratory populations move between seasonal ranges. During winter, migratory belugas can be found foraging around the pack ice. When the sea ice melts in summer, they move to warmer river estuaries and coastal areas for molting and calving (Muto et al. 2017). These annual migrations can span over thousands of kilometers (Frost et al. 1985). It has also been observed in a 2016 study that irregular sea ice conditions during the spring and summer months can influence beluga whales to adjust their migratory tracks to summering areas (O'Corry-Crowe et al. 2016). There are two migration areas used by belugas that overlap the Study Area. One, located in the Eastern Chukchi and Alaskan Beaufort Sea, is a migration area in use from April to May. The second, located in the Alaskan Beaufort Sea, is used by migrating belugas from September to October (Calambokidis et al. 2015). The residential populations participate in short distance movements within their range throughout the year. Seasonal distribution is affected by ice cover, tidal conditions, prey availability, temperature, and human interaction (Frost et al. 1985). Belugas are closely associated with open leads and polynyas in ice-covered regions (Hazard 1988).

Near the Study Area, beluga whales may spend summer in both offshore and coastal waters, with concentrations in Kasegaluk Lagoon (on the north slope of Alaska) and the Mackenzie Delta (in the Beaufort Sea) (Hazard 1988). Most beluga whales from these summering areas overwinter in the Bering Sea, excluding those found in the northern Gulf of Alaska (Shelden 1994). The Eastern Chukchi Sea belugas move into coastal areas along Kasegaluk Lagoon in late June and remain in the area until mid-July (Frost and Lowry 1990; Frost et al. 1993). Telemetry tags attached to belugas within Kaseguluk Lagoon in June and July of 1998 showed that whales traveled 594 nm (1,100 km) north of the Alaska coastline and to the Canadian Beaufort Sea within three months (Suydam et al. 2001), which indicated an overlap in distribution with the Beaufort Sea stock of beluga whales. Adult males appear to use deep waters rather than shallow shelf areas and remain in these deep waters for the duration of the summer. All belugas that moved into the Arctic Ocean (north of 75° N) were males that can travel through 90 percent pack ice cover to reach deeper waters of the Beaufort Sea and Arctic Ocean (approximately 79 to 80° N) by late July/early August, while the adult and immature females remain at or near the shelf break of the Chukchi Sea. After October, the remaining females in the Chukchi Sea migrate south, through the Bering Strait into the Bering Sea north of Saint Lawrence Island, which suggests that some belugas that summer in the eastern Chukchi Sea overwinter in the waters north of Saint Lawrence Island (Suydam 2009).

The Beaufort Sea beluga whale stock range includes the Alaska north coast and the Canadian Arctic Archipelago northward to the pack-ice (Department of Fisheries and Oceans 2000). Beaufort Sea belugas congregate in the Mackenzie Estuary in early summer. Later in summer, belugas move eastward toward Canada. By mid-August and early September, belugas begin their migration westward along the Alaska coast and far offshore to the pack-ice of the Chukchi Sea. The winter range is thought to include the offshore areas of the Chukchi and Bering Seas.

Belugas are opportunistic feeders that vary their diets according to their location and the season. Fish (eulachon, salmon, capelin, cod, herring, smelt, flounder, sole, lamprey and lingcod), crustaceans (crab, clams, mussels and shrimp) and other deep-sea invertebrates (octopus and squid) are their main prey (Reeves et al. 2002). Belugas are shallow divers with typical dives of about 66 ft (20 m) or less (Goetz et al. 2012). Goetz et al. (2012) recorded belugas in the Cook Inlet of Alaska diving to mean depths ranging from (5.2 to 22 ft (1.6 to 6.7 m) with mean durations ranging from 1.1 to 6.9 minutes.

According to the annual BOEM aerial surveys along the north coast of Alaska, beluga distribution in the western Beaufort Sea was centered over the continental slope and Barrow Canyon, with few sightings nearshore. There were more beluga whales in the Chukchi Sea than the Beaufort Sea (Clarke et al. 2014).

Beluga whales may be present within the Beaufort Sea during the summer.

Gray Whale

Two genetically distinct populations of Pacific gray whales (*Eschrichtius robustus*) are currently recognized (Reilly et al. 2008): (1) the Eastern North Pacific stock and (2) the Western North Pacific stock (Bonner 1986; LeDuc et al. 2002; Weller et al. 2013). Although the Western North Pacific stock is listed as endangered under the ESA and depleted under the MMPA, only the Eastern North Pacific stock is expected to be in the Study Area. The Eastern North Pacific stock is not listed under the ESA.

The Eastern North Pacific stock lives along the West Coast of North America (Rice 1981; Rice et al. 1984; Swartz et al. 2006). Gray whale occurrence is primarily in shallow waters over the continental shelf. Breeding and calving are seasonal and closely synchronized with migratory timing. An important area for reproduction stretches from Point Lay to Point Barrow, west of the Study Area, and is in use from June to September. Gray whale migration typically follows the coastline (within 1.1 nm [2 km] of the coast), except when crossing major bays, straits and inlets from southeastern Alaska to the eastern Bering Sea. The northbound migration from low latitude winter calving grounds in Mexico begins about mid-February (Rice and Wolman 1971). Gray whales are among the most commonly observed cetaceans in the Chukchi Sea during summer (Aerts et al. 2013). Then, by late November, the southbound migration is underway as whales begin to travel from summer feeding areas to winter calving areas off the West Coast of Baja California, Mexico, and the southeastern Gulf of California (Rugh et al. 2001; Swartz et al. 2006). Migrating whales move southward through the Unimak Pass and follow a shoreline route to the winter grounds (Rice 1998). Gray whales typically migrate to nearly landlocked lagoons and bays in Baja California, Mexico and give birth to calves between January and mid-February (Rice et al. 1981). Gray whale feeding grounds are generally in waters less than 223 ft (68 m) in depth. An important feeding ground for gray whales stretches from Point Lay to Point Barrow, west of the Study Area, and is in use from June to October. During summer and fall, most whales in the Eastern North Pacific stock feed in the Chukchi and Beaufort Seas, between 174 degrees East (°E) and 130 °W, and northwestern Bering Sea south to Russia (Rice 1998).

Prey of gray whales consists primarily of swarming mysids, and polychaete tube worms, and amphipods in the northern parts of their range (Jefferson et al. 2008). They will also take crabs, baitfish, and other food opportunistically. Killer whales (*Orcinus orca*) are the only known non-human predator to the gray whale. Gray whales feed by swimming slowly over the seafloor at depths up to 197 ft (60 m) (Golda 2015).

During the annual BOEM arctic survey, gray whales were observed east of Point Barrow in August and October. However, primarily they were seen nearshore and west of the Study Area.

Gray whales may be present in the Beaufort Sea in the late summer and early fall, but are unlikely to occur within the deeper waters of the Study Area.

Ribbon Seal

The ribbon seal (*Histriophoca fasciata*) does not have any subspecies, and is therefore considered a single species throughout its range. Ribbon seals are not listed under the ESA, although the species is a Species of Concern. Ribbon seals are protected under the MMPA.

The ribbon seal's range includes the Sea of Okhotsk, Bering Sea, and southern Chukchi Sea (Reeves et al. 2002). Their range stretches throughout the Bering Sea, including the Aleutian Islands, the western Pacific around the Kamchatka Peninsula and Kuril Islands (Russia), as well as the Sea of Okhotsk. The southern distribution within their effective range is strongly associated with the extent of ice formation in the Bering Sea and Sea of Okhotsk, which can drive large numbers of these seals further south in years with heavy ice. The inverse is also true; years of light ice formation causes greater numbers of seals to remain further north. The northernmost record of a ribbon seal was in the western Beaufort Sea, which is considered outside of the typical range of the ribbon seal, in August of 1983.

Ribbon seals are found in the open sea and on the free-floating pack ice rather than shore-fast ice (Kelly 1988b). From late March to early May, ribbon seals inhabit the Bering Sea ice front (Braham et al. 1984; Burns 1970, 1981b) and are most abundant in the central and western parts of the Bering Sea along the southern edge of the ice front (Burns 1970, 1981b). As the ice front recedes, most seals move further north in the Bering Sea between May and mid-July, using the ice edge or ice remnants to haul out (Burns 1970, 1981b; Burns et al. 1981). The Bering Sea and Sea of Okhotsk are the principal breeding grounds for this species (Reeves et al. 2002). During summer, from July through October, these seals do not occur near shore, nor do they migrate northward to the fringe of polar ice as do bearded and ringed seals. Although their distribution is not completely understood, the most likely explanation is that they spend the summer at sea. A recent study using satellite telemetry has shown that animals tagged near the eastern coast of the Kamchatka Peninsula (Russia) spent the summer and fall in the Bering Sea and Aleutian Islands, while others moved from the central Bering Sea to the Bering Strait, Chukchi Sea, or Arctic Basin in a 2010 study as the seasonal ice receded (Boveng et al. 2008; Muto et al. 2017). In Alaskan waters, ribbon seals range northward from Bristol Bay in the Bering Sea into the Chukchi and western Beaufort Seas (Muto et al. 2017). Little is known about the range of ribbon seals during the rest of the year. In their explorations of the Canada Basin, Harwood et al. (2005) observed ribbon seals east of 140° W from the coast to waters as deep as 9,843 ft (3,000 m).

Ribbon seals in the Bering Sea and Sea of Okhotsk consume 35 different species of fish and invertebrates (Jefferson et al. 2008). Pollock and Arctic cod are among the prey species known for the ribbon seal (Reeves et al. 2002). Juvenile ribbon seals feed on euphausiids after weaning until they reach one year of age when they feed predominantly on shrimp for one year (Jefferson et al. 2008). In the Bering Sea, 65 percent of the ribbon seal's diet consists of squid and octopus. Potential predators include polar bears, killer whales, sharks, and walruses. Ribbon seals often dive to depths of 656 ft (200 m) while foraging, and have been recorded diving to depths greater than 1,969 ft (600 m) (London et al. 2015).

Ribbon seals are typically closer to shore, but may be rarely encountered in the Beaufort Sea in the summer and fall.

Spotted Seal

Within the Study Area, spotted seals (*Phoca largha*) are not listed as threatened or endangered under the ESA. The Bering Sea DPS is located off the coast of Alaska within the Study Area. Spotted seals are protected under the MMPA.

Spotted seals are widespread in the Sea of Okhotsk, Yellow, Japan, and Bering Seas. Spotted seals are closely related to and are often mistaken for Pacific harbor seals. The two species are often seen together and are partially sympatric with range overlap in the southern part of the Bering Sea (Quakenbush 1988). The key difference between the two species is spotted seals breed earlier than harbor seals and they are noticeably less social during the breeding season. Additionally, spotted seals are strongly associated with pack ice whereas harbor seals are not (Quakenbush 1988; Shaughnessy and Fay 1977).

Spotted seals inhabit the southern edges of the pack ice in the Chukchi Sea from winter to early summer. Spotted seals also overwinter in the Bering Sea, tending to remain associated with the ice edge and moving in an east to west direction (Lowry et al. 1998). To the south, and along the West Coast of Alaska, spotted seals can be found at the Pribilof Islands (in the Bering Sea), in Bristol Bay, and along the eastern Aleutian Islands. As mentioned above, a large percent of haulouts are associated with pack ice and their movements tend to remain associated with ice.

Breeding takes place on pack ice from January to mid-April, with the peak of pups born in mid to late March. Eight offshore breeding areas have been described, three of which are in the Bering Sea (Shaughnessy and Fay 1977). The seals remain at the breeding sites until the end of the breeding season which coincides with the break-up of ice in spring.

As ice begins to break up in the Bering Sea, seals follow the retreating ice edge and disperse northward along the shores of Alaska and Siberia (Bigg 1981). During spring, spotted seals tend to prefer the small, broken up floes (i.e., less than 66 ft [20 m] in diameter) and remain at the southern margin of the ice in areas where the water depth does not exceed 656 ft [200 m]. Once the sea ice retreats in early summer, seals move to coastal habitats, including the mouths of rivers, where they remain until the fall (Fay 1974; Lowry et al. 2000; Shaughnessy and Fay 1977; Simpkins et al. 2003). In the summer and fall, spotted seals occupy coastal haulouts regularly using sand bars and beaches as resting places between longer foraging periods at sea (Frost et al. 1993; Lowry et al. 1998), and can be found as far north as 69 to 72 °N in the Chukchi and Beaufort Seas (Porsild 1945; Shaughnessy and Fay 1977). When the cold season begins, some seals in the northeastern Chukchi Sea moved south in October and passed through the Bering Strait during November (Porsild 1945; Shaughnessy and Fay 1977).

Spotted seals feed opportunistically on a variety of fish, cephalopods, and crustaceans (Bigg 1981). While juveniles and adults eat a variety of schooling fish (pollock, capelin, Arctic cod and herring), epibenthic fish (especially flounder, halibut and sculpin), crabs, and octopus at depths up to 984 ft (300 m) (Reeves et al. 2002), pups feed on small amphipods found around ice floes. Predators of spotted seals include Pacific sleeper sharks, killer whales, polar and brown bears, walruses and Steller sea lions; predators to pups include golden eagles (*Aquila chrysaetos*), Steller's sea eagles (*Haliaeetus pelagicus*), ravens, gulls, and Arctic foxes (*Vulpes lagopus*) (Quakenbush 1988).

Spotted seals typically remain close to shorelines, but may be encountered in the Beaufort Sea during the summer and fall.

3.2.2.5.3 Marine Mammal Hearing

All marine mammals studied can use sound to forage, orient, socially interact with others, and detect and respond to predators. Measurements of marine mammal sound production and hearing capabilities provide some basis for assessment of whether exposure to a particular sound source may affect a marine mammal behaviorally or physiologically.

The hearing mechanism for marine mammals is similar to that of terrestrial mammals. It is comprised of an outer ear, a fluid-filled inner ear with a frequency-tuned membrane interacting with sensory cells, and an air-filled middle ear, which provides a connection between the outer ear and inner ear (Nedwell et al. 2004). The discussion on hearing below is broken down into the hearing groups of each species within the Study Area. Hearing groups for each species is shown in Table 3-4 below.

The typical terrestrial mammalian ear (which is ancestral to that of marine mammals) consists of an outer ear that collects and transfers sound to the tympanic membrane and then to the middle ear (Popper and Fay 1994; Rosowski 1994). The middle ear contains ossicles that amplify and transfer acoustic energy to the sensory cells (called hair cells) in the cochlea, which transforms acoustic energy into electrical neural impulses that are transferred by the auditory nerve to high levels in the brain (Møller 2012). All marine mammals display some degree of modification to the terrestrial ear; however, there are differences in the hearing mechanisms of marine mammals with an amphibious ear versus those with a fully aquatic ear (Wartzok and Ketten 1999). Marine mammals with an amphibious ear include the marine carnivores: pinnipeds, sea otters, and polar bears (Ghoul and Reichmuth 2014; Owen and Bowles 2011; Reichmuth et al. 2013). Outer ear adaptations in this group include external pinnae (ears) that are reduced or absent, and in the pinnipeds, cavernous tissue, muscle, and cartilaginous valves seal off water from entering the auditory canal when submerged (Wartzok and Ketten 1999). Marine mammals with the fully aquatic ear (cetaceans and sirenians) use bone and fat channels in the head to conduct sound to the ear; while the auditory canal still exists in pinnipeds, it is narrow and sealed with wax and debris, and external pinnae are absent (Ketten 1998).

For this analysis, marine mammals are arranged into the following functional hearing groups based on their generalized hearing sensitivities: mid-frequency cetaceans (odontocetes), low-frequency cetaceans (mysticetes), otariids and other non-phocid marine carnivores in water and air (walruses, and, polar bears), and phocids in water and air (true seals). Note that the designations of mid-, and low-frequency cetaceans are based on relative differences of hearing sensitivity between groups, as opposed to conventions used to describe active sonar systems. For discussion of all marine mammal functional hearing groups and their derivation see technical report Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects (U.S. Department of the Navy 2017a).

Table 3-4. Species in Marine Mammal Hearing Groups Potentially Within the Study Area

Functional Hearing Group	*Species in the Study Area*
Low-frequency cetaceans (mysticetes)	Bowhead whale
	Gray whale
Mid-frequency cetaceans (odontocetes)	Beluga whale
Phocids	Bearded seal
	Ribbon seal
	Spotted seal
	Ringed seal
Polar bear	Polar bear
Odobenids	Pacific walrus

Mysticete/Low-Frequency Cetacean Hearing

Anatomical and paleontological evidence suggests that the inner ears of mysticetes (baleen whales) are well adapted for hearing at lower frequencies (Ketten 1998; Richardson et al. 1995b). Functional hearing in low-frequency cetaceans is conservatively estimated to be between about 7 Hz and 22 kHz (Southall et al. 2007).

Non-biosonar communication signals span a wide frequency range, primarily having energy up into the tens of kilohertz range. Of particular note are the very low-frequency calls of mysticete whales that range from tens of hertz to several kilohertz, and have source levels of 150 to 200 dB re 1 µPa (Cummings and Thompson 1971; Edds-Walton 1997; Širović et al. 2007; Stimpert et al. 2007; Wartzok and Ketten 1999). These calls most likely serve social functions such as mate attraction, but may serve an orientation function as well (Green 1994; Green et al. 1994; Richardson et al. 1995b).

Odontocete/Mid-Frequency Cetacean Hearing

In general, odotocete hearing is very broad, including low-frequency, mid-frequency, and high-frequency cetaceans. Beluga whales are members of the mid-frequency cetacean functional hearing group, which also includes 32 species of dolphins and sperm whales. Functional hearing in mid-frequency cetaceans is conservatively estimated to be between 150 Hz and 160 kHz (Southall et al. 2007). Mid-frequency cetaceans also generate short-duration (50-200 microseconds) specialized clicks used in echolocation with peak frequencies between 10 and 200 kHz (Au 1993; Wartzok and Ketten 1999). Echolocation is used to detect, localize, and characterize underwater objects, including prey items (Au 1993). These clicks are often more intense than other communicative signals, with reported source levels as high as 229 dB re 1 µPa at 1 m peak-to-peak (Au et al. 1974). Castellote et al. (2014) found that wild beluga whales can hear in the range of 4 to 150 kHz. Klishin et al. (2000) tested a single beluga whale and found its hearing to be most sensitive from 32 kHz to 108 kHz.

Phocid Hearing

Phocids can make calls between 90 Hz and 16 kHz (Richardson et al. 1995b). The generalized hearing for phocids (underwater) (National Marine Fisheries Service 2016) ranges from 50 Hz to 86 kHz, which includes the suggested auditory bandwidth for pinnipeds in water proposed by Southall et al. (2007), ranging between 75Hz to 75 kHz. Phocid functional hearing in air is estimated to be 75 Hz to 30 kHz (Carretta et al. 2008; Kastak et al. 1999; Kastelein et al. 2009a; Kastelein et al. 2009b; Møhl 1968a, 1968b; Reichmuth 2008; Terhune and Ronald 1971, 1972).

Polar Bear Hearing

Airborne hearing threshold measurements of polar bears have shown best hearing sensitivity between 8 and 14 kHz, with a rapid decline in sensitivity below 125 Hz and above 20 kHz (Bowles et al. 2008; Nachtigall et al. 2007; Owen and Bowles 2011). Like the pinnipeds, polar bears are amphibious mammals in the order Carnivora. However, unlike pinnipeds polar bears spend only a few minutes submerged and spend the majority of their time above water, thus limiting any potential for acoustic exposure. Additionally, the polar bear ear is very similar to the otariid ear and therefore the polar bear is placed within the same hearing group as otariids (Nummela 2008a; Nummela 2008b). Hearing limits are 50 Hz to 35 kHz in air and 50 Hz to 50 kHz in water (Southall et al. 2007).

Odobenid Hearing

The walrus is the only extant Odobenid pinniped and may be found within the proposed action area. Walruses react to airborne sounds at 0.25 to 8 kHz, but absolute thresholds were not determined (Kastelein et al. 1993).The walrus is adapted to low-frequency sound with a range of best hearing in water from 1 to 12 kHz; its hearing ability falls off sharply at frequencies above 14 kHz (Kastelein 2002; Kastelein et al. 1996). Walrus hearing sensitivity is most similar to otariids, and therefore the walrus is assigned the same functional hearing range as for otariids for this analysis. Functional hearing limits are conservatively estimated to be 50 Hz to 35 kHz in air and 50 Hz to 50 kHz in water (Southall et al. 2007). Walrus produce low frequency (100-1,200 Hz) sounds including barks (females) and, bell sounds and whistles (males), as well as some grunts, guttural sounds, and roars (Charrier et al. 2010; Richardson et al. 1995b). Hearing in odobenids is very similar to that of Otariids (sea lions and fur seals).

4 Environmental Consequences

This chapter discusses the potential environmental consequences of the Proposed Action to the natural and physical environments described in Chapter 3. Stressors resulting from the Proposed Action that may potentially harm the biological environment include:

- Acoustic: non-impulsive acoustic sources, aircraft noise, impulsive sources, icebreaking noise, and vessel noise
- Physical: aircraft strike, vessel and in-water device strike, icebreaking (physical impacts), and bottom disturbance
- Expended Material: entanglement and ingestion

Under the No Action Alternative, the Proposed Action would not occur; therefore, there would be no harm to the natural and physical environments. No further analysis of the No Action Alternative will be presented. Appendix A provides a description of each stressor, as well as matrices showing which activities generate each stressor and what resources are impacted by each stressor. Throughout the analysis presented in this chapter, the ringed seal and Pacific walrus are considered ESA-listed species due to the duration of this project and the potential of relisting during the Proposed Action.

4.1 Stressors Associated with the Proposed Action

4.1.1 Acoustic Stressors

The acoustic stressors from the Proposed Action include non-impulsive acoustic sources, aircraft noise, impulsive sources, icebreaking noise, and vessel noise.

4.1.1.1 Non-Impulsive Acoustic Sources

The Office of Naval Research's (ONR) Arctic Research Activities (ARA) have non-impulsive acoustic sources that require quantitative analysis. Some of the acoustic sources are either above the known hearing range of marine species or have narrow beam widths and short pulse lengths that would not result in effects to marine species. Potential effects from these "*de minimis*" sources are analyzed qualitatively in accordance with current Navy policy. Navy acoustic sources are categorized into "bins" based on frequency, source level, and mode of usage, as previously established between the Navy and the National Marine Fisheries Service (NMFS) (Department of the Navy 2013a).

The Proposed Action involves the use of low-(less than 1 kiloHertz [kHz]), mid-(1-10 kHz), and high-(10-100 kHz) frequency sources; most of the high-frequency sources are above the hearing range of marine organisms. The acoustic (non-impulsive) sources associated with the Proposed Action are defined in Table 2-1, and fall within bins LF4 (low-frequency sources equal to 180 decibels [dB] and up to 200 dB), LF5 (low-frequency sources less than 180 dB), and MF9 (active sources [equal to 180 dB and up to 200 dB] not otherwise binned). The low frequency towed sources were modeled using 185 dB because the sources which would be used are not capable of transmitting above this level. The spiral wave beacon, navigation sources, and tomography sources were also modeled and included in the Proposed Action. These transmissions are associated with discrete events that may last up to 24 hours. The LF4, LF5, and MF9 would be towed for up to seven consecutive days for no more than 15 days total in the deep and/or shallow areas in open water or marginal ice. Three spiral wave beacons would be moored in the deep water area (separation similar to navigation sources) and would be active up to seven days. Up to 15 acoustic navigation sources would be deployed in the deep water area (September 2018 to October 2020). A maximum of six tomography sources would be deployed at the six navigation mooring locations closest to shore and would be active for less than three years. When the acoustic navigation sources and tomography sources are both transmitting they will be offset from each other by at least three minutes. Additionally, each of the acoustic source sets could be turned off during the following years cruise, but once sources are enabled they would be active for at least one year. Though 15 sources are proposed for placement in the deep water, it is unlikely due to weather conditions and limited ship schedule that all would be deployed the first year. In subsequent cruises the remainder of the sources would be deployed until the total of 15 navigation sources were deployed.

In assessing the potential for environmental harm to biological resources from non-impulsive acoustic sources, a variety of factors must be considered, including source characteristics, animal presence and associated density, duration of exposure, and thresholds for harm and harassment for the species that may occur in the Study Area. The severity of the potential consequences such as physiological stress and behavioral response depends on the received sound level at the animal, the details of the sound-producing activity, and the animal's life history stage (e.g., juvenile or adult, breeding or feeding season), and past experience with the stimuli. An animal's life history stage is an important factor to consider when predicting whether a stress response is likely. An animal's life history stage includes its level of physical maturity (i.e., larva, infant, juvenile, sexually mature adult) and the primary activity in which it is engaged such as mating, feeding, or rearing/caring for young. Prior experience with a stressor may be of particular importance because repeated experience with a stressor may dull the stress response via acclimation (St Aubin and Dierauf 2001) or increase the response via sensitization. The types of potential consequences to marine species from acoustic sources can be described by the following categories:

Non-auditory injury: Non-auditory injury can occur to lungs and organs and can cause tissue damage. Resonance occurs when the frequency of the sound waves matches the frequency of vibration of the air filled organ or cavity, causing it to resonate. This can, in certain circumstances, lead to damage to the tissue making up the organ or air filled cavity. Tissue damage can also be inflicted directly by sound waves in cases of sound waves with high amplitude and rapid rise time.

Hearing Loss: Also called a noise-induced threshold shift. Hearing loss manifests itself as loss in hearing sensitivity across part of an animal's hearing range, which is dependent upon the specifics of the noise exposure. Hearing loss may be either a Permanent Threshold Shift (PTS) or a Temporary Threshold Shift (TTS). If the threshold shift does not return to zero but leaves some finite amount of threshold shift, then that remaining threshold shift is a PTS. The intensity and duration of a sound that will cause PTS varies across species and even between individual animals. PTS is a consequence of the death of sensory hair cells of the auditory epithelia of the ear and a resultant loss of hearing ability in the general vicinity of the frequencies of stimulation (Myrberg 1990; Richardson et al. 1995b).

Physiological stress: Marine animals naturally experience physiological stress as part of their normal life histories. The physiological response to a stressor, often termed the stress response, is an adaptive process that helps an animal cope with changing external and internal environmental conditions. Sound-producing activities have the potential to cause additional stress. However, too much of a stress response can be harmful to an animal, resulting in physiological dysfunction.

If a sound is detected (i.e., heard or sensed) by an animal, a stress response can occur. Additionally, if an animal suffers injury or hearing loss, a physiological stress response will occur. The generalized stress response is characterized by a release of hormones (Reeder and Kramer 2005) and other chemicals (e.g., stress markers) such as reactive oxidative compounds associated with noise-induced hearing loss (Henderson et al. 2006). An acute stress response is traditionally considered part of the startle response and is hormonally characterized by the release of the catecholamines. Annoyance type reactions may be characterized by the release of either or both catecholamines and glucocorticoid hormones. Regardless of the physiological changes that make up the stress response, the stress response may contribute to an animal's decision to alter its behavior.

Behavioral response: Marine animals may exhibit short-term behavioral reactions such as cessation of feeding, resting, or social interaction, and may also exhibit alertness or avoidance behavior (Richardson et al. 1995b).

Masking: The presence of intense sounds or sounds within a mammals hearing range in the environment potentially can interfere with an animal's ability to hear relevant sounds. This effect, known as "auditory masking," could interfere with the animal's ability to detect biologically relevant sounds such as those produced by predators or prey, thus increasing the likelihood of the animal not finding food or being preyed upon (Myrberg 1981; Popper et al. 2004). Masking only occurs in the frequency band of the sound that causes the masking condition. Other relevant sounds with frequencies outside of this band would not be masked.

Non-impulsive acoustic sources are analyzed for their potential effects on invertebrates (Section 4.3.2.1.1), marine birds (Section 4.3.2.2.1), fish (Section 4.3.2.3.1), Essential Fish Habitat (Section 4.3.2.4.1), and marine mammals (Section 4.3.2.5.1).

4.1.1.1.1 Alternative 1

Under Alternative 1 all acoustic sources would be deployed at the shallow water and deep water portions of the Study Area.

4.1.1.1.2 Alternative 2 (Preferred Alternative)

Under Alternative 2 the use of permitted active acoustic sources would be limited to the deep-water area. "*De minimis*" acoustic sources would be allowed in both the deep and shallow water portions of the Study Area.

4.1.1.2 Aircraft Noise

Aircraft noise includes noise generated by any of the multiple types of aircraft used during the Proposed Action, including commercial small twin-engine fixed-wing aircraft, commercial rotary-wing aircraft (helicopters), and unmanned aerial systems (UASs). Though some of these aircraft (i.e., UASs) are small, most would create enough noise to potentially affect biological resources. Aircraft would be used exclusively for human transit from land to offshore sites, and ice reconnaissance missions. Fixed wing aircraft (e.g., Twin Otter aircraft) would be used for ice reconnaissance missions approximately 4 times annually, for a total of approximately 12 hours per year.

The noise associated with aircraft needs to be considered in multiple ways. Aircraft make noise in flight, which propagates through the air. This sound can also interact with the ice surface and potentially propagate through the ice into the water. Lastly, helicopters spend time on the ice warming up, taking off and landing, all of which produce noise and are considered herein.

Sound generated by aircraft is analyzed for both in-air and in-water effects. Airborne sound levels are normally expressed in dB. The decibel value is given with reference to the value and unit of the reference pressure; the standard reference pressures are 1 micropascal for water and 20 micropascals for air. It is important to note that, because of the difference in reference units between air and water, the same absolute pressure would result in different dB values for each medium. Because animals are not equally sensitive to sounds across their hearing range, weighting functions are used to emphasize ranges of best hearing and de-emphasize ranges of less or no sensitivity. In air, sound levels are frequently "A-weighted" and seen in units of A-weighted decibels (dBA), to account for sensitivity of the human ear to barely audible sounds. Many in-air sound measurements are A-weighted because the sounds levels are most frequently used to determine the potential noise impacts to humans.

Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors and has been addressed by Urick (1983), Young (1973), Richardson et al (1995b), Eller and Cavanagh (2000), Laney and Cavanagh (2000), and others. Sound is transmitted from an airborne source to a receptor underwater by four principal means: (1) a direct path, refracted upon passing through the air-water interface; (2) direct-refracted paths reflected from the bottom in shallow water (not applicable here given the depth of the water in the Study Area); (3) evanescent transmission in which sound travels laterally close to the water surface; and (4) scattering from interface roughness due to wave motion.

Airborne sound is refracted upon transmission into water because sound waves move faster through water than through air (a ratio of about 0.23:1). Based on this difference, the direct sound path is reflected if the sound reaches the surface at an angle more than 13 degrees from vertical. As a result, most of the acoustic energy transmitted into the water from an aircraft arrives through a relatively narrow cone extending vertically downward from the aircraft (Figure 4-1). The intersection of this cone with the surface traces a “footprint” directly beneath the flight path, with the width of the footprint being a function of aircraft altitude. Sound may enter the water outside of this cone due to surface scattering and as evanescent waves, which travel laterally near the water surface.

The inhomogeneous nature of sea ice does not necessarily allow for attenuation of noise from the air through the ice layer and into the water. When aircraft noise passes from air to water, there is a limiting ray of 13 degrees, where the noise would be reflected off the surface of the water instead of passing through (Richardson et al. 1995b). At frequencies less than 500 Hertz (Hz), which is the acoustic energy range of most aircraft, the ice layer is acoustically thin and causes little attenuation of sound (Richardson et al. 1991). This implies that noise travelling through the sea ice would only be slightly lower than that same noise travelling directly from the air to the water. It is expected that transmission of low-frequency sound through ice would be only slightly lower than that of low-transmission sound travelling directly from the air into the water (Richardson et al. 1995b). Use of the air-water transmission model would provide slight overestimates of underwater sound levels from aircraft overflights, but this is the best model available to analyze airborne sound transmission through ice (Richardson et al. 1995b).

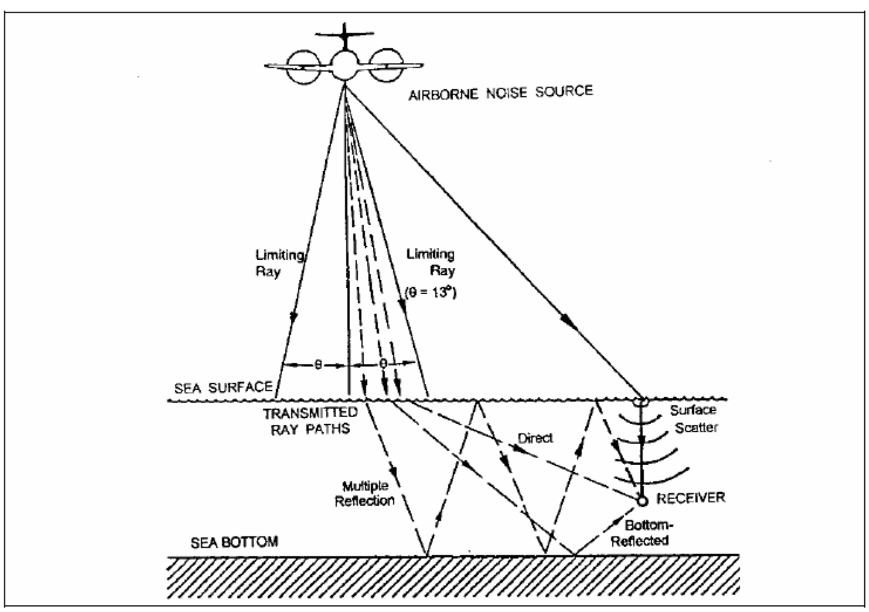

Figure 4-1. Characteristics of Sound Transmission through the Air-Water Interface (Richardson et al. 1995b)

Table 4-1 provides a list of manned aircraft similar to those used during the Proposed Action and their associated in-air and in-water source levels. In addition to the manned aircraft, two UASs would be utilized during the Proposed Action. The fixed-wing UAS is similar to, but smaller than, small fixed-wing aircraft (Piper PA-46-500TP, Cessna 180, and Cessna 185) included in the table below. The rotary-wing UAS operates in a similar manner as helicopters, but on a smaller scale. Acoustic data for the unmanned fixed-wing aerial systems are not currently available, but based on the small size of the systems and their engines, it is not anticipated that they would not create enough sound to cause a disturbance for the resources within the Study Area. Based on a study by Christiansen et al.(2016), an initial analysis of underwater recordings of noise produced by a rotary-wing UAS at 3 feet (ft; 1 meter [m]) below the water surface was only detectable above ambient noise when the system was flown at altitudes lower than 33 ft (10 m). Though the study found that in-air recordings showed that the noise levels produced by the unmanned aerial systems were within noise-level ranges known to cause disturbance in some marine mammals, the in-water received noise levels at 1 m depth were orders of magnitude below those shown to cause any direct damage on auditory systems or compromise physiology in marine mammals (Christiansen et al. 2016; Southall et al. 2007). The UAS used during the Proposed Action would be ship-deployed, and would not operate more than 984 ft (300 m) from the ship. Noise generated by the unmanned aerial system is not expected to be audible further than 5 ft (1.5 m) from the device (Christiansen et al. 2016).

Table 4-1. Source Levels of Representative Aircraft[1]

Aircraft Description	*Aircraft Altitude[2] (ft)*	*Frequency (Hz)*	*In-air Source Level (dB re 20 µPa)*	*In-water Source Level (dB re 1 µPa)[4]*
Fixed-wing takeoff	300	125		106
Fixed-wing (Piper PA-46-500TP)	25,000[2]	1700	73.7	
Fixed-wing (Cessna 180)	17,700[2]	1700	63-69	
Fixed-wing (Cessna 185)	17,900[2]	1700	64-66	
Rotary-wing (H-60)	50			125
Rotary-wing warmup	-	160		131[4]
Rotary-wing (Bell 250)	300	200		155
Rotary-wing (Sikorsky S61)	300	40		156

[1] All source level information was obtained from Malme et al (1989) and Federal Aviation Administration (2012).
[2] Where no altitude was given for flyovers, maximum aircraft cruising altitude was assumed, based on cruise ceiling values from Aircraft Owners and Pilots Association (2015).
[3] Depth of measurement is 3.3 ft (1 m), unless otherwise noted.
[4] Measurement taken at a depth of 65.6 ft (20 m) under ice.

Fixed-wing aircraft noise propagates through air at rates dependent on frequency (Richardson et al. 1995b). The absorption coefficient for in-air attenuation decreases rapidly with frequency to approximately 130 dB per kilometer (km) at 10 kHz, to the point that transmission loss is up to -100 dB at approximately 0.22 miles (mi; 0.35 km). It has been noted that the takeoff noise levels 3 ft (1 m) under the ice for small fixed wing aircraft is 106 dB referenced to 1 micropascal (re 1 µPa) at 125 Hz (Malme et al. 1989).

During the Proposed Action, small, fixed-wing aircraft would generally operate at altitudes of either 1,500 or 10,000 ft (457 or 3,048 m) above sea level. At this altitude, the footprint of airborne noise at the ice surface would be an approximate 0.77 square miles (mi^2; 2 square kilometers [km^2]) swath along the flight path of the aircraft. Due to the relatively small area over which aircraft noise would radiate outward, the noise would be transient. As noise levels would be reduced by the time they reach the ice from an overhead flight and would still have to attenuate through the ice, underwater noise would be generally brief in nature. At a distance of 2,152 ft (656 m) away, the received pressure levels of a Twin Otter range from 80 to 98.5 dBA and frequency levels ranging from 20 Hz to 10 kHz, though they are more typically in the 500 Hz range (Metzger 1995).

Helicopter flights associated with the Proposed Action are used for logistical purposes (transport of personnel and equipment) and are not conducting training or testing and therefore would not be hovering or flying a route pattern for an extended period; use would be limited to two hour flights to and from an ice location. Helicopters produce low-frequency sound and vibration (Pepper et al. 2003; Richardson et al. 1995b). Helicopter sounds contain dominant tones from the rotors that are generally below 500 Hz. Noise generated from helicopters is transient in nature and variable in intensity. Helicopters often radiate more sound forward than aft. The underwater noise produced is generally brief when compared with the duration of audibility in the air.

It is not anticipated that aircraft noise would harm marine habitats, invertebrates, fish, or Essential Fish Habitat, as the transmission of airborne noise through the ice or the air/water interface would be limited, and outside of the hearing sensitivity of most biological resources. Therefore, they are not discussed further. The only potential effects from aircraft noise would be on marine birds (Section 4.3.2.2.2) and marine mammals (Section 4.3.2.5.2).

4.1.1.2.1 Alternative 1

Aircraft noise associated with Alternatives 1 and 2 would be the same.

4.1.1.2.2 Alternative 2 (Preferred Alternative)

Aircraft noise associated with Alternatives 1 and 2 would be the same.

4.1.1.3 Icebreaking Noise

Of the two vessels involved in the Proposed Action (Research Vessel [R/V] Sikuliaq and Coast Guard Cutter [CGC] HEALY) only CGC HEALY would be involved in icebreaking. This is because the R/V Sikuliaq is not an ice breaking ship, but an ice strengthened ship. CGC HEALY travels at a maximum speed of 3 knots when traveling through 3.5 ft (1.07 m) of sea ice (Murphy 2010). CGC HEALY may be required to perform icebreaking to deploy the moored acoustic (navigation and tomography) sources in deep water. CGC HEALY has proven capable of breaking ice up to 8 ft (2.4 m) thick while backing and ramming (Roth et al. 2013). A study in the western Arctic Ocean was conducted while CGC HEALY was mapping the seafloor north of the Chukchi Cap in August 2008. During this study, CGC HEALY icebreaker events generated frequency bands centered near 10, 50, and 100 Hz with maximum source levels of 190 to 200 dB re 1 μPa at 1 m (full octave band) (Roth et al. 2013). Icebreaking would only occur in the deep water area of the Proposed Action (Figure 1-1) while deploying those associated sources.

The type of ice in the Study Area during the icebreaking would influence the type of organisms present and their reaction to icebreaking. Icebreaking would occur in the warm season between August and October 2018 and each subsequent year in the same timeframe through 2021, when ice thickness is expected to be at or near its lowest levels, which would minimize the timeframe in which icebreaking would occur. Icebreaking was modeled for one day in 2018 and for three days per each subsequent year for the remainder of the Proposed Action (2019, 2020, 2021). In loose pack ice, the speed and noise of CGC HEALY is expected to be similar to those produced in the open ocean. In heavier pack ice or thick landfast ice, CGC HEALY would operate at a maximum speed of 3 knots, but power levels would be higher, which would increase the sound produced by CGC HEALY (Richardson et al. 1995b).

Marine species within the Study Area may be exposed to icebreaking noise associated with CGC HEALY during the Proposed Action. The potential harm from icebreaking noise is from masking other biologically important sounds or behavioral reactions such as alerting, avoidance, or other behavioral reactions.

The potential effects of icebreaking noise are analyzed for invertebrates (Section 4.3.2.1.3), marine birds (Section 4.3.2.2.3), fish (Section 4.3.2.3.2), Essential Fish Habitat (Section 4.3.2.4.2), and marine mammals (Section 4.3.2.5.3).

4.1.1.3.1 Alternative 1

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to biological resources, in that the same vessel would be utilized for both alternatives.

4.1.1.3.2 Alternative 2 (Preferred Alternative)

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to biological resources, in that the same vessel would be utilized for both alternatives.

4.1.1.4 Impulsive Sources

Impulsive sounds feature a very rapid increase to high pressures, followed by a rapid return to the static pressure. Impulsive sounds are often produced by processes involving a rapid release of energy or mechanical impacts (Hamernik and Hsueh 1991). Airgun detonations are examples of impulsive sound sources analyzed in this document. Impulse is a metric used to describe the pressure and time component of an intense shock wave from an explosive source. The impulse calculation takes into account the magnitude and duration of the initial peak positive pressure, which is the portion of an impulsive sound most likely to be associated with damage. Specifically, impulse is the time integral of the initial peak positive pressure with units Pascal-seconds.

Airguns function by suddenly venting high-pressure air into the water. This produced an air-filled cavity that expands violently, then contracts, and re-expands; sound is created with each oscillation. Airgun arrays are designed to direct a high proportion of the sound energy downward; the effective source level for horizontal propagation is generally less than that for vertical propagation (Richardson et al. 1995b). Airguns do produce broadband sounds; however, the duration of an individual impulse is about one-tenth of a second. The impulsive sources associated with the Proposed Action would operate at low to medium frequencies; the compact sound source would operate from 5 Hz to5 kHz, and the airguns would operate at frequencies ranging from 10 to 150 Hz. Airguns and compact sound source use within the Proposed Action would be used to bottom characterization and are not the typical airgun arrays. The proposed airguns and compact sound source are single shots only that could be fired in succession, not all at once. For 100 shots, the cumulative sound exposure level would be approximately 215 to 225 dB referenced to 1 square micropascal-second (re 1 μPa^2-s) at 1 m.

Use of airguns and compact sound sources during the Proposed Action would not have an effect on marine birds because of the noise loss due the air-water interface the potential for overlap of marine birds and underwater airguns is not expected. Analysis of impulsive sources associated with the Proposed Action has been completed for invertebrates (Section 4.3.2.1.3), fish (Section 4.3.2.3.3), Essential Fish Habitat (Section 4.3.2.4.3), and marine mammals (Section 4.3.2.5.4).

4.1.1.4.1 Alternative 1

Airguns would be used under Alternative 1 in both shallow and deep water areas.

4.1.1.4.2 Alternative 2 (Preferred Alternative)

Impulsive sources would not be used under Alternative 2.

4.1.1.5 Vessel Noise

During the Proposed Action vessel noise would be generated from either the R/V Sikuliaq or CGC HEALY. The R/V Sikuliaq has a maximum speed of approximately 12 knots with a cruising speed of 11 knots (University of Alaska Fairbanks 2014). The R/V Sikuliaq is not an ice breaking ship, but an ice strengthened ship, it would not be ice breaking and therefore acoustic signatures of ice breaking for the R/V Sikuliaq are not available. The R/V Sikuliaq has a one-third octave signature band range of 10 Hz to 200 kHz and a source level of 130 to 172 dB re 1 µPa at 1 m when traveling at 11 knots, and an one-third octave signature band range of 10 Hz to 200 kHz with a source level of 127 to 154 dB re 1 µPa at 1 m when traveling at 4 knots (Naval Sea Systems Command 2015). CGC HEALY travels at a maximum speed of 17 knots with a cruising speed of 12 knots (United States Coast Guard 2013), and a maximum speed of 3 knots when traveling through 1.07 m of sea ice (Murphy 2010). Icebreaking noise associated with CGC HEALY is discussed in Section 4.1.1.3.

Marine species within the Study Area may be exposed to vessel noise associated with the R/V Sikuliaq or CGC HEALY during the Proposed Action. Vessel noise would result from open-ocean movement. The potential harm from vessel noise is from masking (sound that interferes with the audibility of another sound) of other biologically relevant sounds as well as behavioral reactions such as elicit an alerting, avoidance, or other behavioral reaction. Although unlikely due to the low-level shipping lanes of the Arctic, some marine species may have habituated to vessel noise, and may be more likely to respond to the sight of a vessel rather than the sound of a vessel, although both could play a role in prompting reactions (Hazel et al. 2007).

Auditory masking can occur due to vessel noise, potentially masking vocalizations and other biologically important sounds (e.g., sounds of prey or predators) that marine organisms may rely on. Potential masking can vary depending on the ambient noise level within the environment, the received level and frequency of the vessel noise, and the received level and frequency of the sound of biological interest. In the open ocean, ambient noise levels are between about 60 and 80 dB re 1 µPa, especially at lower frequencies (below 100 Hz) (National Research Council 2003). When the noise level is above the sound of interest, and in a similar frequency band, auditory masking could occur. Any sound that is above ambient noise levels and within an animal’s hearing range needs to be considered in the analysis, however noise that is just detectable over ambient levels is unlikely to actually cause any substantial masking.

Analysis of vessel noise associated with the Proposed Action has been completed for invertebrates (Section 4.3.2.1.4), marine birds (Section 4.3.2.2.4), fish (Section 4.3.2.3.4), and marine mammals (Section 4.3.2.5.5).

4.1.1.5.1 Alternative 1

Vessel noise would be the same in both Alternatives 1 and 2.

4.1.1.5.2 Alternative 2 (Preferred Alternative)

Vessel noise would be the same in both Alternatives 1 and 2.

4.1.2 Physical Stressors

Physical stressors resulting from the Proposed Action include aircraft strike, icebreaking (physical impacts), vessel and in-water device strike, and bottom disturbance.

4.1.2.1 Aircraft Strike

The potential for aircraft strike is dependent upon the type of aircraft, altitude of flight, and speed of travel. Small, fixed-wing aircraft typically operate at altitudes up to 11,483 ft (3,500 m), during the Proposed Action fixed-wing aircraft would operate at either 4,921 or 32,808 ft (1,500 or 10,000 m). Small, fixed-wing aircraft typically travel at speeds of 80 to 160 knots. Helicopters, by nature, would either be hovering or traveling at speeds up to 150 knots. UASs travel at a significantly slower speed than manned aircraft.

Aircraft strike would have the potential to harm marine birds. Other natural and physical resources (such as marine mammals) would not have the potential to be impacted by aircraft strike. Therefore, an analysis of the potential effects of aircraft strike was only completed for marine birds (Section 4.3.2.2.5).

4.1.2.1.1 Alternative 1

Aircraft use would be the same for both Alternatives 1 and 2.

4.1.2.1.2 Alternative 2 (Preferred Alternative)

Aircraft use would be the same for both Alternatives 1 and 2.

4.1.2.2 Icebreaking (Physical Impacts)

Icebreaking would occur in the Study Area when transiting out to the deep water area to deploy and recover sources, at speeds of 3 to 6 knots. CGC HEALY would be icebreaking during the summer season while the ice is at its lowest extent of the year.

Icebreaking has the potential to harm sea ice (Section 4.2.2.1), invertebrates (Section 4.3.2.1.5), fish (Section 4.3.2.3.5), Essential Fish Habitat (Section 4.3.2.4.4), and marine mammals (Section 4.3.2.5.6) by causing behavior reactions, mortality upon impact, and/or altering habitats.

4.1.2.2.1 Alternative 1

Icebreaking would occur in equal measure under both Alternatives 1 and 2.

4.1.2.2.2 Alternative 2 (Preferred Alternative)

Icebreaking would occur in equal measure under both Alternatives 1 and 2.

4.1.2.3 Vessel and In-Water Device Strike

The vessels that would be utilized during the Proposed Action are the R/V Sikuliaq (maximum speed of 12.3 knots), and CGC HEALY (maximum speed of 17 knots). These vessels would not be operating at their maximum speed due to travel through the marginal ice zone. Gliders and associated towed arrays also have the potential to result in strike to marine resources. Gliders are slow moving, travelling at a speed of 14.3 mi per day (23 km per day). Physical disturbance from the use of in-water devices are not expected to result in more than a momentary behavioral response. Any change to an individual animal's behavior from in-water devices is not expected to result in long-term or population-level effects. Research on marine animal's responses to gliders has not been conducted; the discussion below is based on potential reactions to vessels, which is used as a surrogate for this analysis.

Vessels have the potential to affect invertebrates, fish, or marine mammals by eliciting a behavioral response or causing mortality or serious injury from collisions. It is difficult to differentiate between behavioral responses to vessel sound and visual cues associated with the presence of a vessel; thus, it is assumed that both play a role in prompting reactions from animals. Reactions to vessels often include changes in general activity (e.g., from resting or feeding to active avoidance), changes in surfacing-respiration-dive cycles, and changes in speed and direction of movement. Past experiences of the animals with vessels are important in determining the degree and type of response elicited from an animal-vessel encounter. Some species have been noted to tolerate slow-moving vessels within several hundred meters, especially when the vessel is not directed toward the animal and when there are no sudden changes in direction or engine speed (Heide-Jørgensen et al. 2003; Richardson et al. 1995b).

Vessel and in-water device strike would not affect bottom substrates, as none of the vehicles would be at bottom depth, nor would they affect Essential Fish Habitat, or marine birds. The potential effects on invertebrates (Section 4.3.2.1.6), fish (Section 4.3.2.3.6), and marine mammals (Section 4.3.2.5.7) have been analyzed.

4.1.2.3.1 Alternative 1

Vessel and in-water device use would be the same under both Alternatives 1 and 2,

4.1.2.3.2 Alternative 2 (Preferred Alternative)

Vessel and in-water device use would be the same under both Alternatives 1 and 2.

4.1.2.4 Bottom Disturbance

Various components of the Proposed Action would have the potential to alter the bottom substrate. These would include expenditure of anchors, radiosondes deployed by weather balloons, and other materials that would sink to the bottom, as well as bottom coring for research purposes.

During activities in the Study Area, various items would be introduced and expended into the marine environment, which, in the Study Area, has been determined to be soft bottom (Section 3.1.1.2). These expended materials have the potential to strike a resource once they sink to the seafloor and settle in the bottom substrate. Expended materials that are expected to sink to the seafloor include expended buoys, Expendable Mobile Anti-Submarine Warfare Training Targets (EMATTs), and other anchors or tethers. The Proposed Action would utilize various anchored and tethered equipment. These anchors would be bottom placed, and could weigh up to 800 pounds (lbs; 363 kilograms [kg]).

A relatively large number of weather balloons, made of latex or Kevlar would be used during the Proposed Action, with up to forty balloons released annually. These weather balloons would have radiosondes suspended 82-115 ft (25-35 m) below them, and would be used for weather and atmospheric data collection purposes. These balloons would eventually burst, and the radiosondes and balloon fragments would fall to the ocean surface and eventually sink, or, if they land on the ice, would sink once the ice melts and the materials are released into the water. Weather balloons can travel up to 186 mi (300 km) from the area of deployment depending on meteorological conditions, and would have a diameter of 19-26 ft (6-8 m) at full inflation before bursting (National Oceanographic and Atmospheric Administration 2009).

Coring equipment would take up to 50 samples of the ocean bottom annually. These samples would be cylindrical, and approximately 3.14 inches (in; 8 centimeters [cm]) in diameter; they could be between 10 and 20 ft (3 and 6 m) long. Coring equipment would move at a speed of approximately 3.3 ft (1 m) per hour.

Bottom disturbance is not expected to affect marine birds, Essential Fish Habitat, or marine mammals as they do not inhabit the seafloor within the Study Area. Therefore, they are not further analyzed. The potential effects on the physical environment (Section 4.2.2.2), invertebrates (Section 4.3.2.1.7), and fish (Section 4.3.2.3.7) have been analyzed.

4.1.2.4.1 Alternative 1

Under Alternative 1, bottom disturbance would occur from the deployment of arrays, anchors, moorings, weather balloons, and coring samples at the deep water and shallow water portions of the Study Area.

4.1.2.4.2 Alternative 2 (Preferred Alternative)

Under Alternative 2, there could be a decreased amount of moorings and expended anchors due to the elimination of shallow water permitted sources, though array and weather balloon deployment and coring samples would be taken in both deep water and shallow water portions of the Study Area.

4.1.3 Expended Materials

4.1.3.1 Entanglement

Devices that pose an entanglement risk are those with lines or tethers; devices with a potential for entanglement include moored or ice-tethered sensors, towed devices from the R/V Sikuliaq and CGC HEALY, and other fixed or towed receiving arrays. All lines hanging from buoys or ice tethered equipment would be weighted, and therefore would not have any loops or slack.

The final line that could be a threat for entanglement is the use of a device tethered to an unmanned underwater vehicle (depth of 295 ft [91 m]). The tether for this research initiative has a diameter of 8.9 millimeters, and is made of Kevlar. This tether has a very high breaking strength (1,543 lb force [700 kg force]), but environmental resources should not be at risk due to the small likelihood of any loops or slack developing in this line, since it would be under positive pressure. No mooring lines would be expended during the proposed action, so this further limits the chance for entanglement.

The weather balloons being released could introduce the potential for entanglement upon their descent; these balloons would consist of shredded plastic from bursting balloons, a parachute used to slow the descent of the radiosonde, and all of the ropes and twine used to keep all of the components together (the radiosonde would be suspended 82-115 ft [25-35 m] below the balloon). The components from the weather balloons present the highest risk of entanglement. Balloon fragments would temporarily be deposited on the ice, until the ice melts and the materials sink to the seafloor.

It is not anticipated that entanglement would affect marine habitats, marine birds or Essential Fish Habitat, as they are not within an area to be adversely affected or cannot become entangled in expended material. Therefore, they will not be further analyzed. The potential effects on invertebrates (Section 4.3.2.1.8), fish (Section 4.3.2.3.8), and marine mammals (Section 4.3.2.5.8) have been analyzed.

4.1.3.1.1 Alternative 1

Under Alternative 1, the potential for entanglement would be from mooring lines and arrays. Lines extending from the moorings would be retrieved at the completion of the Proposed Action. In the upper portion of the water column object deployment would be controlled.

4.1.3.1.2 Alternative 2 (Preferred Alternative)

Under Alternative 2, the potential for entanglement would be from mooring lines and arrays. Alternative 2 has less mooring lines associated with the Proposed Action. In the upper portion of the water column object deployment would be controlled.

4.1.3.2 Ingestion

During the Proposed Action, the only expended materials available for ingestion include the on-ice measurement systems and weather balloon fragments. On ice measurement systems include the autonomous weather station and the ice mass balance buoy. The autonomous weather station would be deployed on a tripod with insulated foot platforms frozen into the ice. While the ice mass balance buoy would be lowered into the water column through a two-inch hole in the ice, there would be a tripod located on the ice. All other expended objects would be expended into the water column and would sink to the seafloor. Balloon fragments and radiosondes could be found on the ice, in the water column, or on the seafloor. Ingestion of these materials does not require the entire object to be ingested; pieces of objects that either break off or are bitten off are included in this analysis.

Ingestion stressors are not anticipated to affect any resources other than marine mammals specifically polar bears, due to the large size of the material that is expended in the water column or stationed on the sea ice. These objects (e.g., EMATTs, anchors, buoys) would be too large for any marine resource to eat. Additionally, within the Study Area marine mammals would not be feeding near the seafloor further eliminating any overlap of expended materials and marine mammals. Therefore, harm to marine resources (other than polar bears) is not discussed further. The objects deployed and expended within the water column would be too deep to overlap with a swimming polar bear. The potential effects from ingestion of expended materials have been analyzed for polar bears (Section 4.3.2.5.9).

4.1.3.2.1 Alternative 1

Potential risk for ingestion would be the same under both Alternatives 1 and 2.

4.1.3.2.2 Alternative 2 (Preferred Alternative)

Potential risk for ingestion would be the same under both Alternatives 1 and 2.

4.2 Physical Resources

4.2.1 No Action Alternative

Under the No Action Alternative, the Proposed Action would not occur and there would be no change to the baseline physical environment. Therefore, no significant harm to the physical environment would occur with implementation of the No Action Alternative.

4.2.2 Action Alternatives

The Study Area for the Proposed Action is located within the Beaufort and Chukchi Seas, including the shelf, slope, and basin habitats north of Alaska. The Study Area itself encompasses the deep Canada Basin in the Beaufort Sea, the Chukchi Plateau in the Chukchi Sea, and the shelves and slopes of both the Beaufort and Chukchi Seas (Figure 1-1).

The Beaufort Sea has a narrow, shallow shelf along the north coast of Alaska, with a width of less than 80 nautical miles (nm; 148 kilometers [km]) at any given point (Dome Petroleum Ltd. et al. 1982). Off the coast of Canada, the shelf is broader and depths of 33 ft (10 m) or less can be found up to 16 nm (30 km) from shore (Wilkinson et al. 2009). The average depth within the shelf of the Beaufort Sea is less than 213 ft (65 m) (Dome Petroleum Ltd. et al. 1982). The continental slope in this area drops steeply to the Canada Basin. In the Canada Basin, which extends north into the Arctic Ocean and is bordered to the west by the Mendeleev Ridge, averages a depth of about 11,811 ft (3,600 m) (Wilkinson et al. 2009). Seafloor sediments in this deep water basin are typically muddy (Bluhm et al. 2011).

Though the record of sea ice extent dates as far back as 1900 in the Northern Hemisphere, the most complete record of sea ice is provided by microwave satellites, which have routinely and accurately monitored sea ice extent since 1979 (Jeffries et al. 2014; Timmermans and Proshutinsky 2014). Annually, sea ice extent is at its maximum in March, representing the end of winter, and is at its minimum in September (Jeffries et al. 2014). Sea ice extent fluctuates annually and is influenced by natural variations in atmospheric pressure and wind patterns, but clear linkages have also been made to decreased Arctic sea ice extent and rising greenhouse gas concentrations dating back to the early 1990s (Timmermans and Proshutinsky 2014). A general downward trend in Arctic sea ice has occurred during the last few decades (Serreze et al. 2003). The maximum ice extent from March 2016 tied with March 2014 for the lowest maximum ice extent in the 37 year satellite record (5.7 million mi^2 [14.76 million km^2]). This maximum extent is 5 percent below the 1981 through 2010 average, though fairly typical of measurements taken in the last decade (Perovich et al. 2013). The March 2015 maximum extent measured 1.75 million mi^2 (4.52 million km^2) (National Snow and Ice Data Center 2017).

4.2.2.1 Icebreaking (Physical Impacts)

Potential Harm

Sea ice is considered important habitat for many polar species including diatoms, Arctic cod, ringed seals, and polar bears, amongst others. Many species feed along the ice edge, while others use it for resting, pupping, or traveling.

Ice, however thin, doesn't facture by itself, but is rather wind, pressure systems, and ocean gyres that transport ice and often cause fractures to form. Cracks are a regular feature of ice. During winter when fractures appear, leads form but quickly freeze over again. From May onwards, with the sun shining down on the Arctic, the thin ice will disappear, leaving behind stretches of open water, sometimes well within the ice pack. The total sea ice extent was 4.27 million mi^2 (11.06 million km^2) in the Arctic, in June of 2017; the month when the sun's energy is strongest. An icebreaker cruising through the ice for 620 mi (1,000 km) and leaving an ice-free wake of 33 ft (10 m) would open an area of water 3.9 mi^2 (10 km^2) over the entire cruise. In contrast, the Arctic sea ice cover decreases by an average of over 3.5 million mi^2 (9 million km^2) each year during the melt season. This area is an area larger than the contiguous United States. In total, researchers estimate that the number of icebreakers traversing the Arctic at any given time is usually less than three. Thus, the actual contribution of icebreaking to sea ice reduction is miniscule—only one part in a million of the total ice cover. As the ice pack has started to break up in ever smaller parts earlier in the year, it has also become easier for vessels to move the ice around.

Alternative 1

Because CGC HEALY does not diminish or destroy ice habitat, and the amount of ice that is broken up relative to the overall total amount of ice is small, in accordance with Executive Order (E.O.) 12114 physical impacts from icebreaking associated with Alternative 1 would not significantly harm the physical environment (sea ice habitat).

Alternative 2 (Preferred Alternative)

Because CGC HEALY does not diminish or destroy ice habitat, and the amount of ice that is broken up relative to the overall total amount of ice is small, in accordance with E.O. 12114 physical impacts from icebreaking associated with Alternative 2 would not significantly harm the physical environment (sea ice habitat).

4.2.2.2 Bottom Disturbance

Potential Harm

In general, three things happen to expended materials that come to rest on the ocean floor: (1) they lodge in sediment where there is little or no oxygen, usually below 4 in (10 cm), (2) they remain on the ocean floor and begin to react with seawater, or (3) they remain on the ocean floor and become encrusted by marine organisms. As a result, rates of deterioration depend on the material and the conditions in the immediate marine and benthic environment. If buried deep in ocean sediments, materials tend to decompose at much lower rates than when exposed to seawater (Ankley et al. 1996). In those situations where metals are exposed to seawater, they begin to slowly corrode, a process that creates a layer of corroded material between the seawater and uncorroded metal. This layer of corrosion removes the metal from direct exposure to the corrosiveness of seawater, a process that further slows movement of the metals into the adjacent sediment and water column. Any elevated levels of metals in sediment would be restricted to a small zone around the metal, and any release to the overlying water column would be diluted. In a similar fashion, as materials become covered by marine life, the direct exposure of the material to seawater decreases and the rate of corrosion decreases (Little and Ray 2002). Dispersal of these materials in the water column is controlled by physical mixing and diffusion, both of which tend to vary with time and location. The disturbance of bottom sediments by objects settling onto the seafloor could result in temporary and localized increases in turbidity that would quickly dissipate.

As the radiosondes and parachutes pull the balloon fragments to the seafloor, they too would be degraded over time. Marine microbes and fungi are known to degrade biologically produced polyesters, such as polyhydroxyalkanoates, a bacterial carbon and energy source (Doi et al. 1992). Marine microbes also degrade other synthetic polymers, although at slower rates (Shah et al. 2008).

Sediment coring during the Proposed Action would employ equipment that moves very slowly through the muddy bottom (approximately 1 m per hour); therefore, it would be unlikely to lead to significant turbidity in the area around the corer during use. The removal of the sediment core could cause a small and temporary disruption to the sediment and localized turbidity. Overall, some displacement of soft sediments may occur due to use of coring equipment (Blomqvist 1991; Mudroch and MacKnight 1994). Because of the ocean currents turbidity would rapidly dissipate and water quality would return to normal.

Large-scale processes control sediment composition in the deep sea, so it tends to be uniform over hundreds of square miles; similarly, at the spatial scale at which most individual organisms experience their environment (millimeters to meters), the seafloor is typically heterogeneous (Thistle 2003). The instances of bottom disturbance during the Proposed Action would be minimal, due to the few items expended over the large region of the Study Area.

Alternative 1

The harm to bottom habitats from bottom disturbance under Alternative 1 would be slightly higher than that under Alternative 2, based on the increased number of expended anchors. Based on the geographically expansive size of the Study Area in comparison to the small area of the individual coring samples and anchors, the marine environment would not be altered in any meaningful way. In accordance with E.O. 12114, bottom disturbance associated with Alternative 1 would not result in significant harm to the physical environment (bottom substrate).

Alterative 2 (Preferred Alternative)

The harm to bottom habitats from bottom disturbance under Alternative 2 would be slightly lower than that under Alternative 1, based on the decreased number of expended anchors. Based on the distance expansive size of the Study Area in comparison to the small area of the individual coring samples and anchors, the marine environment would not be altered in any meaningful way. In accordance with E.O. 12114, bottom disturbance associated with Alternative 2 would not result in significant harm to the physical environment (bottom substrate).

4.3 Biological Resources

4.3.1 No Action Alternative

Under the No Action Alternative, the Proposed Action would not occur and there would be no change to biological resources. Therefore, no significant harm to biological resources would occur with implementation of the No Action Alternative.

4.3.2 Action Alternatives

4.3.2.1 Invertebrates

Excluding microbes, approximately 5,000 known marine invertebrates have been documented in the Arctic; the number of species is likely higher, though, since this area is not well studied (Josefson et al. 2013). Although most species are found within the benthic zone, marine invertebrates can be found in all zones (sympagic [within the sea ice], pelagic [open ocean], or benthic [bottom dwelling]) of the Beaufort Sea (Josefson et al. 2013). Sea ice provides a habitat for algae and a nursery ground for invertebrates during times when the water column does not support phytoplankton growth (Winfree 2005). Sympagic zone invertebrates live within the pores and brine channels of the ice (small spaces within the sea ice which are filled with a salty solution called brine) or at the ice-water interface. Biodiversity of species is low within the sympagic zone due to the extreme conditions of the sea ice (Leet et al. 2001). Within the Study Area, many sympagic species also exist in and along the edges of ice coverage, feeding on blooms of phytoplankton and other algae which grow in, on, or adjacent to the ice (Wyllie-Echeverria and Ackerman 2003). Marine invertebrate distribution in the Beaufort Sea is influenced by habitat and oceanographic conditions (e.g., depth, temperature, salinity, nutrient concentrations, and ocean currents) (Levinton 2009). No Endangered Species Act (ESA) listed invertebrate species are present in the Study Area.

Acoustic stressors that may have potential impacts on invertebrates include non-impulsive acoustic sources, icebreaking noise, impulsive sources, and vessel noise. Physical stressors that may have potential impacts on invertebrates include icebreaking (physical impacts), vessel and in-water device strike, and bottom disturbance. The only stressor associated with expended materials that may have potential impacts on invertebrates is entanglement.

4.3.2.1.1 Non-Impulsive Acoustic Sources

Potential Harm

Hearing capabilities of invertebrates are largely unknown, although they are not expected to hear sources above 3 kHz (see Section 3.2.2.1.5 for invertebrate hearing information). Invertebrates are only expected to potentially perceive the signals of a few sources used during the Proposed Action. In addition, most marine invertebrates in water are known to detect only particle motion associated with sound waves, which drop off rapidly with distance (Graduate School of Oceanography 2015).

Outside of studies conducted to test the sensitivity of invertebrates to vibrations, very little is known on the effects of anthropogenic underwater noise on invertebrates (Edmonds et al. 2016). While data are limited, research suggests that some of the major cephalopods and decapods may have limited hearing capabilities (Hanlon 1987; Offutt 1970), and may hear only low-frequency (less than 1 kHz) sources (Offutt 1970), which is most likely within the frequency band of biological signals (Hill 2009). In a review of crustacean sensitivity of high amplitude underwater noise by Edmonds et al. (2016), crustaceans may be able to hear the frequencies at which they produce sound, but it remains unclear which noises are incidentally produced and if there are any negative effects from masking them. Acoustic signals produced by crustaceans range from low frequency rumbles (20-60 Hz) to high frequency signals (20-55 kHz) (Henninger and Watson 2005; Patek and Caldwell 2006; Staaterman et al. 2016). Aquatic invertebrates that can sense local water movements with ciliated cells include cnidarians, flatworms, segmented worms, urochordates (tunicates), mollusks, and arthropods (Budelmann 1992a, 1992b; Popper et al. 2001). Some aquatic invertebrates have specialized organs called statocysts for determination of equilibrium and, in some cases, linear or angular acceleration. Statocysts allow an animal to sense movement and may enable some species, such as cephalopods and crustaceans, to be sensitive to water particle movements associated with sound (Goodall et al. 1990; Hu et al. 2009; Kaifu et al. 2008; Montgomery et al. 2006; Popper et al. 2001; Roberts and Breithaupt 2016; Salmon 1971). Because any acoustic sensory capabilities, if present at all, are limited to detecting water motion, and water particle motion near a sound source falls off rapidly with distance, aquatic invertebrates are probably limited to detecting nearby sound sources rather than sound caused by pressure waves from distant sources.

Studies of sound energy effects on invertebrates are few, and identify only behavioral responses. Non-auditory injury, permanent threshold shift, temporary threshold shift, and masking studies have not been conducted for invertebrates. Both behavioral and auditory brainstem response studies suggest that crustaceans may sense frequencies up to 3 kHz, but best sensitivity is likely below 200 Hz (Goodall et al. 1990; Lovell et al. 2005; Lovell et al. 2006). Most cephalopods likely sense low-frequency sound below 1 kHz, with best sensitivities at lower frequencies (Budelmann 2010; Mooney et al. 2010; Offutt 1970). A few cephalopods may sense higher frequencies up to 1,500 Hz (Hu et al. 2009).

Within the Study Area, marine invertebrate abundance is low within the sea ice and in the water column. The highest densities are on the seafloor, further reducing the likelihood of invertebrates hearing the frequencies of the active acoustic sources due to the dissipation of the non-impulsive acoustic sources in the water column. In studies by Christian et al. (2003) and Payne et al. (2007), neither found damage to lobster or crab statocysts from high intensity air gun firings (which is of greater intensity than the non-impulsive acoustic sources in the Proposed Action). Furthermore, in the study by Christian et al., (2003), no changes were found in biochemical stress markers in snow crabs.

Alternative 1

Under Alternative 1 all non-impulsive acoustic sources would be deployed at the shallow water and deep water portions of the Study Area (Figure 1-1). There is a low likelihood that invertebrates would be able to perceive the non-impulsive acoustic sources, and if perceived, that an individual animal would react. Therefore, in accordance with E.O. 12114, non-impulsive acoustic sources associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Under Alternative 2 only the deep water permitted sources and *de minimis* sources would be deployed (Figure 1-1). Although there would be more non-impulsive acoustic sources associated with Alternative 1, it is expected that non-impulsive acoustic sources under both alternatives would result in the same potential for effects to invertebrates. There is a low likelihood that invertebrates would be able to perceive the non-impulsive acoustic sources, and if perceived, that an individual animal would react. Therefore, in accordance with E.O. 12114, non-impulsive acoustic sources associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.1.2 Icebreaking Noise

Potential Harm

Icebreaking noise is generally low frequency impulsive sound similar in frequency to vessel noise, with the impulsive nature being the primary difference. As such, the species expected to respond and the levels of response to icebreaking noise would be expected to be similar for icebreaking and vessel noise. As addressed in Section 3.2.2.1.5, hearing capabilities of invertebrates are largely unknown, although they are not expected to hear sources above 3 kHz (Lovell et al. 2005; Popper 2008). Impacts to invertebrates from icebreaking noise is relatively unknown, but it is likely that some species including crustaceans and cephalopods would be able to perceive the low frequency sources generated from icebreaking that occurs during the Proposed Action, which could result in masking acoustic communication in invertebrates such as crustaceans (Staaterman et al. 2011). Avoidance behavior, short term temporary responses (such as feeding cessation, increased stress, or other minor physiological harm) may occur if invertebrates were close enough to the icebreaking (Edmonds et al. 2016; Roberts and Breithaupt 2016). Masking of important acoustic cues used by invertebrates during larval orientation and settlement may lead to maladaptive behavior that could reduce successful recruitment (Simpson et al. 2011).

Icebreaking associated with the Proposed Action would be short-term and temporary as the vessel moves through an area, and it is not anticipated that this short-term noise would result in significant harm via masking; nor is it expected to result in more than a temporary behavioral reaction of marine invertebrates in the vicinity of the icebreaking event. It is expected that invertebrates would return to their normal behavior shortly after exposure.

Alternative 1

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessel would be utilized for both alternatives. Icebreaking noise, if perceived by an invertebrate, would likely result in temporary behavioral reactions and would not result in any population level impacts. In accordance with E.O. 12114, icebreaking noise associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessel would be utilized for both alternatives. Icebreaking noise, if perceived by an invertebrate, would likely result in temporary behavioral reactions and would not result in any population level impacts. In accordance with E.O. 12114, icebreaking noise associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.1.3 Impulsive Sources

Potential Harm

The Proposed Action would use both the compact sound source and airguns. No studies have been conducted on the effects to invertebrates from the compact sound source. Effects to invertebrates from airguns are discussed below.

Caged snow crabs (*Chionoecetes opilio*) were exposed to repeated air gun firings in the field (Christian et al. 2003). Crabs exposed to a single air gun were placed at depths of 7–49 ft (2–15 m), while crabs exposed to air gun arrays were placed at depths of 13–559 ft (4–170 m). Air guns were fired during multiple sessions, with each session consisting of a firing every 10 seconds for 33 minutes. Peak received levels were up to 207 dB re 1 µPa and 187 decibels referenced to 1 squared micropascal (dB re 1 μPa^2) (single gun), and 237 dB re 1 µPa and 175 dB re 1 μPa^2 (array). Post-experimental examination showed no physical damage to statocysts, hepatopancreata, heart muscle or surrounding tissue, carapace, or appendages. As a comparison, air guns operated at full capacity during the Proposed Action would produce a maximum sound pressure level (SPL) of 181 dB re 1 µPa at 1 m, and single air guns would be used. Furthermore, air guns would have a count of 80 shots per day with 10 minutes between shots and no more than 3 days of testing. Air guns are also operated at less than full capacity, decreasing the sound levels produced.

In a similar experiment designed to control for possible confounding effects of experimental tank walls, Mediterranean jellyfish (*Cotylorhiza tuberculate*) and barrel jellyfish (*Rhizostoma pulmo*) were exposed to two hours of low-frequency sweeps (50–400 Hz; 100 percent duty cycle with a one-second sweep period; approximately 157-175 dB re 1 µPa received SPL) in an offshore environment. After the experiment was completed statocyst damage was found (Solé et al. 2016). In the context of overall invertebrate population numbers, most animals exposed to similar sound levels during the Proposed Action would be in the far field, and the duty cycle of the air guns would be less than one percent compared to the continuous low frequency exposure of jellyfish in the study. This limited information suggests that the potential for statocyst damage may differ according to the type of sound (impulsive or continuous) or among invertebrate taxa (e.g., crustaceans and cephalopods). Although invertebrate occurrence varies based on location, depth, season, and time of day (for example, the rising of the deep scattering layer which contains numerous invertebrate taxa), individuals could be present in the vicinity of impulsive sounds produced by the Proposed Action. The number of individuals affected would be influenced by sound sensing capabilities. Invertebrate acoustic sensing is probably limited to the particle motion component of sound. Water particle motion is most detectable near a sound source and at lower frequencies, which likely limits the range at which invertebrates can detect sound.

Stress response consists of one or more physiological changes (e.g., production of certain hormones) that help an organism cope with a stressor. However, if the magnitude or duration of the stress response is too great or too prolonged, there can be negative consequences to the organism. Physiological stress is typically evaluated by measuring the levels of relevant biochemicals. The results of two investigations of physiological stress in adult invertebrates caused by impulsive noise, varied by species. Some biochemical stress markers and changes in osmoregulation were observed in American lobsters exposed to air gun firings at distances of approximately 7–13 ft (2–4 m) from the source (Payne et al. 2007). Increased deposits of carbohydrates suggesting possible stress response were noted in digestive gland cells four months after exposure. Conversely, repeated air gun exposures caused no changes in biochemical stress markers in snow crabs located from 7 to 558 ft (2 to 170 m) from the source (Christian et al. 2003).

The results of these studies indicate that invertebrates of at least some taxa would respond behaviorally to various levels of sound and substrate vibration produced within their detection capability. Comprehensive investigations of the range to effects of different sound and vibration sources and levels are not available. However, sound source levels for Navy air gun use are within the range of received levels that have caused behavioral effects in some species.

Alternative 1

Impulsive sources associated with the Proposed Action would be from the compact sound source and airgun firings, and would only occur in Alternative 1. Impulsive sources, if perceived by an invertebrate, would likely result in temporary behavioral reactions and would not result in any population level impacts. In accordance with E.O. 12114, impulsive sources associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Impulsive sources would not be used under Alternative 2. In accordance with E.O. 12114, impulsive sources associated with Alternative 2 would not result in harm to invertebrates.

4.3.2.1.4 Vessel Noise

Potential Harm

As addressed in Section 3.2.2.1.5, hearing capabilities of invertebrates are largely unknown, although they are not expected to hear sources above 3 kHz (Lovell et al. 2005; Popper 2008). Impacts to invertebrates from vessel noise is relatively unknown, but it is likely that some species would be able to perceive the low frequency sources generated from the vessels (see Section 2.2.2) used during the Proposed Action, which could result in masking acoustic communication in invertebrates such as crustaceans (Staaterman et al. 2011). Masking of important acoustic cues used by invertebrates during larval orientation and settlement may lead to maladaptive behavior that could reduce successful recruitment (Simpson et al. 2011). Recent research suggests that some invertebrates may experience sub-lethal physiological impacts from prolonged exposure to high amplitude, low frequency sound (Celi et al. 2014; Wale et al. 2013); however, much of the Study Area is over deeper water, which would limit the exposure of benthic invertebrates, and since vessels are generally transiting through, prolonged exposure to high amplitudes such as those used in these studies is unlikely. The low-frequency component of vessel noise would likely be detected by some invertebrates, although the number of individuals affected would be limited to those near enough to a source to experience particle motion.

Several studies have found physiological and behavioral responses in some invertebrate species in response to playback of vessel noise, although one study found no reaction by krill to an approaching vessel. Physiological effects included biochemical changes indicative of stress in crustacean species, decreased growth and reproduction in shrimp, and changes in sea hare embryo development. Nedelec et al. (2014) exposed sea hares to vessel noise playback for 45 seconds every five minutes over a 12-hour period and found reduced embryo development and increased larvae mortality, but no effect on the rate of embryo development. It is also possible that vessel noise may contribute to masking of relevant environmental sounds, such as predator detection. Behavioral effects resulting from vessel noise playback have been observed in various crustacean, cephalopod, and bivalve species and include shell closing and changes in feeding, coloration, swimming, and other movements.

Vessel noise associated with the Proposed Action would be short-term and temporary as the vessel moves through an area, and it is not anticipated that this short-term noise would result in significant harm via masking; nor is it expected to result in more than a temporary behavioral reaction of marine invertebrates in the vicinity of the vessel noise. It is expected that invertebrates would return to their normal behavior shortly after exposure.

Alternative 1

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessels would be utilized for both Alternatives. Vessel noise, if perceived by an invertebrate, would likely result in temporary behavioral reactions and would not result in any population level impacts. In accordance with E.O. 12114 vessel noise associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessels would be utilized for both Alternatives. Vessel noise, if perceived by an invertebrate, would likely result in temporary behavioral reactions and would not result in any population level impacts. In accordance with E.O. 12114 vessel noise associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.1.5 Icebreaking (Physical Impacts)

Potential Harm

The population of invertebrates with the most potential for harm from icebreaking associated with the Proposed Action are the sympagic invertebrates that live on or in the sea ice (Guglielmo et al. 2000; Kohlbach et al. 2016; Kramer et al. 2011). Individuals of these species could be killed or displaced by the icebreaking. Because the impact would be localized to the immediate path of the vessel, icebreaking disturbance would not be expected to harm the vast majority of the biomass of sympagic invertebrates and therefore, no population level impacts would be expected. Though many other communities are also dependent on sympagic production (Kohlbach et al. 2016), the impact on those food web dynamics would be similarly small, since the ratio of affected area to unaffected area is extremely small.

Alternative 1

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessels would be utilized for both alternatives. Although some invertebrates could be disturbed or killed by icebreaking, population level effects are not anticipated. In accordance with E.O. 12114, physical impacts from icebreaking associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessels would be utilized for both alternatives. Although some invertebrates could be disturbed or killed by icebreaking, population level effects are not anticipated. In accordance with E.O. 12114, physical impacts from icebreaking associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.1.6 Vessel and In-Water Device Strike

Potential Harm

Vessels and in-water devices have the potential to harm marine invertebrates by disturbing the water column or directly striking organisms (Bishop 2008). Vessel movement may result in short-term and localized disturbances to invertebrates, such as zooplankton and cephalopods, utilizing the upper water column. Propeller wash (water displaced by propellers used for propulsion) from vessel, and vehicle movement can potentially disturb marine invertebrates in the water column and are a likely cause of zooplankton mortality (Bickel et al. 2011). Since most of the macroinvertebrates within the Study Area are benthic and the Proposed Action takes place within the water column, potential for macroinvertebrate vessel or vehicle strike is extremely low. No measurable effects on invertebrate populations in the water column would occur because the number of organisms exposed to vessel movement would be low relative to total invertebrate biomass.

Alternative 1

Vessel and in-water device strike from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessels and in-water devices would be utilized for both Alternatives. Although some invertebrates could be disturbed or killed by vessel and in-water device strike, population level effects are not anticipated. In accordance with E.O. 12114, vessel and in-water device strike associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Vessel and in-water device strike from both Alternatives 1 and 2 would result in the same potential for effects to invertebrates, in that the same vessels and in-water devices would be utilized for both Alternatives. Although some invertebrates could be disturbed or killed by vessel and in-water device strike, population level effects are not anticipated. In accordance with E.O. 12114, vessel and in-water device strike associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.1.7 Bottom Disturbance

Potential Harm

Effects to invertebrates from bottom disturbance would be either from the temporary and localized disturbance of the sediment, removal of habitat due to coring activities, or the bottom habitat changing from a soft bottom habitat to hard bottom due to the expended material. Expended material that would eventually sink may cause disturbance, injury, or mortality within the footprint of the device, may disturb marine invertebrates outside the footprint of the device, and would cause temporary local increases in turbidity near the seafloor. The overall footprint of the expended materials is minor compared to the size of the Study Area. The sediment disturbance would be temporary causing increased turbidity in the water locally. Objects that sink to the seafloor or are moored to the seafloor may attract invertebrates, or provide temporary attachment points for invertebrates. Some invertebrates attached to the devices would be removed from the habitat when the objects are recovered. In the immediate area where the expended material settled the bottom type would change from soft to hard substrate and may displace any invertebrates requiring soft bottom habitat. This may also attract invertebrates that attach to hard bottom substrate. Coring activities may cause mortality to invertebrate species if they are pulled up from the sediment sample. Mobile invertebrates are expected to be able to move out of the path of the coring equipment since it only travels at 1 m per hour. The cores removed are small (3.14 in [8 cm] in diameter; 10 to 20 ft [3 to 6 m] long), and only 50 samples are taken each year. The impact of expended materials and coring samples on invertebrates is likely to cause injury or mortality to individuals, but impacts to populations would be inconsequential due to the short-term disturbance during installation and removal of these devices or coring samples.

Alternative 1

Under Alternative 1, bottom disturbance would occur from the deployment of arrays, anchors, moorings, and coring samples at the deep water and shallow water portions of the Study Area. Invertebrates may be displaced, temporarily disturbed, or killed, but no population level effects are expected to occur. Under Alternative 1, the disturbance associated with the Proposed Action would be localized and temporary. In accordance with E.O. 12114, bottom disturbance associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Under Alternative 2 there could be a decreased amount of moorings and expended anchors due to permitted shallow sources not being included. Invertebrates may be displaced, temporarily disturbed, or killed, but no population level effects are expected to occur. Under Alternative 2, the disturbance associated with the Proposed Action would be localized and temporary. In accordance with E.O. 12114, bottom disturbance associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.1.8 Entanglement

Potential Harm

A marine invertebrate that might become entangled may only be temporarily confused and escape unharmed, it could be held tightly enough that it could be injured during its struggle to escape, it could be preyed upon while entangled, or it could starve while entangled. The likelihood of these outcomes cannot be predicted with any certainty because interactions between invertebrate species and entanglement hazards are not well known. Potential entanglement scenarios are based on observations of how marine invertebrates are entangled in marine debris that typically floats at the sea surface for long periods of time (e.g., plastic bags and food wrappers), which is far more prone to tangling than weighted sensors dangling from buoys or floats, lines from acoustic arrays, or towed devices, because these devices would not have materials prone to developing loops (Environmental Sciences Group 2005; Ocean Conservancy 2010). Deployments of the moorings, floats, and acoustic arrays could cause short-term and localized disturbances to invertebrates utilizing the upper water column. Since most of the invertebrates within the Study Area are benthic, the risk of entanglement from deployment of moorings and arrays is extremely low.

Weather balloon parachutes post a potential, though unlikely, entanglement risk to susceptible marine invertebrates. The most likely method of entanglement would be a marine invertebrate crawling through the fabric or cord that could then tighten around it. The number of parachutes expended across the whole Study Area is extremely small relative to the presumed number of marine invertebrates.

Invertebrates also have an entanglement risk from the expended materials as they sink and land on the seafloor. Since all devices are lowered from a winch system in a controlled manner, the risk of entanglement from deployment of moorings and arrays is extremely low. Unlike marine mammals and fish, some invertebrates are sessile and would not be able to move out of the path of an expended material as it sinks and settles on the seafloor. Although there is a risk of an expended material entangling around and potentially injuring or killing an individual invertebrate, there would be no long term population level effects due to the small amount of expended materials over the large Study Area and the limited number of organisms potentially exposed to the material.

Alternative 1

Under Alternative 1, the potential for entanglement would be from mooring lines, arrays, and weather balloons. Lines extending from the moorings would be retrieved at the completion of the Proposed Action. In the upper portion of the water column object deployment would be controlled, which would extremely limit entanglement with invertebrates found in the sympagic or pelagic zones. Invertebrates within the benthic zone may be displaced, temporarily disturbed, or killed, but no population level effects are expected to occur. Therefore, in accordance with E.O. 12114 entanglement associated with Alternative 1 would not result in significant harm to invertebrates.

Alternative 2 (Preferred Alternative)

Under Alternative 2, the potential for entanglement would be from mooring lines, arrays, and weather balloons, though Alternative 2 has less mooring lines associated with it than Alternative 1. In the upper portion of the water column object deployment would be controlled, which would extremely limit entanglement with invertebrates found in the sympagic or pelagic zones. Invertebrates within the benthic zone may be displaced, temporarily disturbed, or killed, but no population level effects are expected to occur. Therefore, in accordance with E.O. 12114 entanglement associated with Alternative 2 would not result in significant harm to invertebrates.

4.3.2.2 Marine Birds

A combination of short-distance migrants, long-distance migrants, and year-round resident marine bird species occur within the Study Area (Section 3.2.2.2). Of all the marine birds that occur in the vicinity of the Study Area, only the thick-billed murre exhibits foraging diving behaviors at distances greater than 90 nm (167 km) from the shoreline during the timeframe of the Proposed Action. Therefore, only the thick-billed murre may be foraging at the shallow water Study Area. No birds are expected to be foraging or migrating through the deep water Study Area. All other marine bird species in the area would either not travel over 90 nm (167 km) offshore or are not expected to forage underwater within the Study Area. No ESA-listed birds would be present in the Study Area during the Proposed Action.

Acoustic stressors that may have potential impacts on birds include non-impulsive acoustic sources, aircraft noise, icebreaking noise, and vessel noise. The only physical stressor that may have potential impacts on birds is aircraft strike, and the only stressor associated with expended materials would be ingestion.

4.3.2.2.1 Non-Impulsive Acoustic Sources

Potential Harm

Information regarding the impacts of sonar on birds is unavailable. Little is known about the ability for birds to hear underwater, although researches have recently begun to examine this topic (Section 3.2.2.2.1). The limited information indicates that diving birds have a more narrow hearing range in water (Dooling and Therrien 2012; Johansen et al. 2016). Birds have been reported to hear best at mid-frequencies (1 to 5 kHz), and are likely to be able to hear the low- and mid-frequency signals associated with the Proposed Action. Only the thick-billed murre is known to forage at distances over 90 nm (167 km) offshore and may be present in the shallow water portion of the Study Area.

The exposure of sounds associated with the Proposed Action by birds present in the Study Area is likely to be negligible because they spend only a very short time under water (plunge-diving or surface-dipping) or forage only at the water surface. In addition to diving behavior, the likelihood of a bird being exposed to underwater sound depends on factors such as duty cycle (the portion of time that a sound source actually generated sound, defined as the percentage of the time during which a sound is generated over a total operational period), whether the source is moving or stationary, and other activities that might be occurring in the area.

A physiological impact, such as hearing loss, would likely only occur if a seabird were close to an intense sound source. An underwater sound exposure would have to be intense and of a sufficient duration to cause hearing loss. Avoiding the sound by returning to the surface would limit extended or multiple sound exposures underwater. Diving birds have adaptations to protect the middle ear and tympanum from pressure changes during diving that may affect hearing (Dooling and Therrien 2012). The limited information on bird hearing underwater suggests that the hearing range of diving birds underwater is narrower than in air (Dooling and Therrien 2012; Johansen et al. 2016), and that while some adaptations may exist to aid in underwater hearing, other adaptations to protect in-air hearing may limit aspects of underwater hearing (Hetherington 2008). Because of these reasons, the likelihood of a diving bird experiencing an underwater exposure to sonar that could result in an impact to hearing is considered very low. Because diving birds may rely more on vision for foraging, hearing range is more limited under water than in air, and there is no evidence that diving birds rely on acoustic communication, the masking of important acoustic signals under water by sonar is unlikely.

There have been no studies documenting diving seabirds' reactions to sonar. However, given the information and adaptations discussed above, diving seabirds are likely to detect mid-frequency and low-frequency sources in close proximity. If a diving bird is exposed to an underwater source, it may either not respond or respond by altering its dive behavior, perhaps by reducing or ceasing a foraging bout. It is expected that any behavioral interruption would be temporary as the source or the bird changes location.

Alternative 1

Under Alternatives 1, marine birds could encounter non-impulsive acoustic sources at the shallow water portion of the Study Area. The potential for a marine bird to be underwater and within receiving distant of an acoustic source is unlikely due to short duration of their dives, the ice cover in the Study Area, and the spread nature of the acoustic sources. However, if a thick-bill murre were to perceive a non-impulsive acoustic source, it is expected to either not react to the source or exhibit short-term behavior responses such as swimming away from the source. Therefore, pursuant to E.O. 12114, non-impulsive acoustic sources associated with the Proposed Action would not result in significant harm to marine birds.

Pursuant to the MBTA, non-impulsive acoustic sources associated with the Proposed Action would not result in a significant adverse effect on migratory bird populations.

Alternative 2 (Preferred Alternative)

There would be no shallow water permitted non-impulsive acoustic sources under Alternative 2, only the use of *de minimis* sources. Therefore, there would be no harm to marine birds from non-impulsive acoustic sources associated with Alternative 2.

Pursuant to the MBTA, non-impulsive acoustic sources associated with the Proposed Action would not result in a significant adverse effect on migratory bird populations.

4.3.2.2.2 Aircraft Noise

Potential Harm

Most migrating birds would be present below the altitude of fixed-wing aircraft flights, but could potentially be exposed to nearby noise from helicopters at lower altitudes. Altitudes at which migrating birds fly can vary greatly based on the type of bird, where they are flying (over water or over land), and other factors such as weather. Approximately 95 percent of bird flight during migrations occurs below 10,000 ft (3,048 m) with the majority below 3,000 ft (914 m) (Lincoln et al. 1998). While there is considerable variation, the favored altitude for most large birds varies based upon wind currents, and some have been observed flying at heights just above sea level to over 19,685 ft (6,000 m) (Warnock et al. 2002).

Unlike fixed-wing aircraft, helicopters typically operate below 1,000 ft (305 m) in altitude and often as low as 75–98 ft (23–30 m). This low altitude increases the likelihood that birds would respond to noise from helicopter overflights. Helicopters travel at slower speeds (less than 100 knots), which increases durations of noise exposure compared to fixed-wing aircraft. In addition, some studies have suggested that birds respond more to noise from helicopters than to fixed-wing aircraft (Larkin et al. 1996). Noise from low-altitude helicopter overflights may elicit short-term behavioral or physiological responses, such as alert responses, startle responses, or temporary increases in heart rate, in exposed birds. Repeated exposure of individual birds or groups of birds is unlikely, based on the dispersed nature of the overflights during the Proposed Action. The general health of individual birds would not be compromised.

If a bird is close to an intense sound source, it could suffer auditory fatigue. Studies have examined hearing loss and recovery in only a few species of birds, and none studied hearing loss in marine birds (Hashino et al. 1988; Ryals et al. 1999; Ryals et al. 1995; Saunders et al. 1974). A bird may experience PTS if exposed to a continuous sound pressure level over 110 dB referenced to 20 micropascales (re 20 µPa) in air. Continuous noise exposure at levels above 90-95 dB(A) re 20 µPa can cause TTS (Dooling et al. 2012), while physical damage to birds' ears occurs with short-duration but very loud sounds (>140 dBA re 20 µPa for a single blast or 125 dBA re 20 µPa for multiple blasts) (Dooling and Popper 2007). Unlike many other species, birds have the ability to regenerate hair cells in the ear, usually resulting in considerable anatomical, physiological, and behavioral recovery within several weeks. Still, intense exposures are not always fully recoverable, even over periods up to a year after exposure, and damage and subsequent recovery vary significantly by species, though a species' appearance, behavior, or lifestyle cannot be used to predict the time-course of loss or recovery from acoustic trauma (Dooling and Popper 2007; Ryals et al. 1999). Though hair cell regeneration may restore hearing sensitivity, there are subtle, enduring changes to complex auditory perception, though these changes do not appear to provide any obstacle to future auditory and vocal learning for affected birds (Ryals et al. 2013). Birds may be able to protect themselves against damage from sustained sound exposures by regulating inner ear pressure, an ability that may protect ears while in flight (Ryals et al. 1999).

Chronic stress due to disturbance may compromise the general health and reproductive success of birds (Kight et al. 2012), but a physiological stress response is not necessarily indicative of negative consequences to individual birds or to populations (Bowles et al. 1991; National Parks Service 1994). It is possible that individuals would return to normal almost immediately after exposure, and the individual's metabolism and energy budget would not be affected long-term. Studies have also shown that birds can habituate to noise following frequent exposure and cease to respond behaviorally to the noise (Larkin et al. 1996; National Parks Service 1994; Plumpton 2006). However, the likelihood of habituation is dependent upon a number of factors, including species of bird (Bowles et al. 1991), and frequency of and proximity to exposure. A study by Komenda-Zehnder et al. (2003) examined the stressed behavioral shift during airplane and helicopter overflights at different altitudes. They observed that flights operating at lower altitudes elicited a greater behavioral response, and that larger, slower moving aircrafts also lead to greater stressed response. However, this study also concluded that the stressed behaviors exhibited decreased to a normal level around five minutes after the overflight occurred; thus the behavioral responses were temporary and of very short duration.

Responses by birds to aircraft overflights include flying, swimming (which would not be applicable within the Study Area), and displaying alert behaviors (Conomy et al. 1998; Mallory 2016; Ward et al. 1999). In a study in the Canadian Arctic by Mallory (2016), ground-nesting marine birds responded by flushing from their nests when aircraft flew within 0.6 mi (1 km) of their nesting sites. Even if a behavioral response is not observed, studies have shown that birds physiologically may be affected based on increased heart rates during aircraft overflights (Wooley Jr. and Owen Jr. 1978). Occasional startle or alert reactions to aircraft are not likely to disrupt major behavior patterns (such as migrating) or to result in serious injury to any marine bird. Helicopter overflights would be more likely to elicit responses than fixed-wing aircraft, but the general health of individual birds would not be compromised.

Alternative 1

Aircraft noise associated with Alternatives 1 and 2 would be the same. Noise associated with the aircraft proposed for use during the Proposed Action may elicit responses in individual birds potentially migrating through the area. However, individual stress responses do not necessarily result in negative consequences to populations. Due to the limited duration of activities and the small number of marine birds that are expected to be within the Study Area on a sustained basis, population-level effects are not anticipated. Therefore, in accordance with E.O. 12114, aircraft noise associated with Alternative 1 would not result in significant harm to birds.

Pursuant to the MBTA, aircraft noise associated with Alternative 1 would not result in a significant adverse effect on migratory bird populations.

Alternative 2 (Preferred Alternative)

Aircraft noise associated with Alternatives 1 and 2 would be the same. Noise associated with the aircraft proposed for use during the Proposed Action may elicit responses in individual birds potentially migrating through the area. However, individual stress responses do not necessarily result in negative consequences to populations. Due to the limited duration of activities and the small number of birds that are expected to be within the Study Area on a sustained basis, population-level effects are not anticipated. Therefore, in accordance with E.O. 12114, aircraft noise associated with Alternative 2 would not result in significant harm to birds.

Pursuant to the MBTA, aircraft noise associated with Alternative 2 would not result in a significant adverse effect on migratory bird populations.

4.3.2.2.3 Icebreaking Noise

Potential Harm

Auditory masking related to marine bird hearing would not have an impact on marine birds, as they spend a limited amount of time underwater and it is not thought that they use underwater sound related to their biologically relevant sounds. However, icebreaking noise could elicit short-term behavioral (startle response, swimming away, looking up) or physiological responses (increased heart rate), but are not likely to disrupt major behavior patterns, such as migrating, breeding, feeding, and sheltering, or to result in serious injury to any seabirds. Beason (2004) notes that birds exposed to up to 146 dBA re 20 µPa sound pressure level in air within 325 ft (99 m) of the noise source flushed, but then returned within minutes of the disturbance. Icebreaking noise from the Proposed Action is not expected to be as high as the noise level in this study.

Alternative 1

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to marine birds, in that the same vessels would be utilized for both alternatives. Due to the insignificant and short-term reactions to icebreaking noise, and in accordance with E.O. 12114, icebreaking noise associated with Alternative 1 would not result in significant harm to marine birds.

Pursuant to the MBTA, icebreaking noise associated with Alternative 1 would not result in a significant adverse effect on migratory bird populations.

Alternative 2 (Preferred Alternative)

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to marine birds, in that the same vessels would be utilized for both alternatives. Due to the insignificant and short-term reactions to icebreaking noise, and in accordance with E.O. 12114, icebreaking noise associated with Alternative 2 would not result in significant harm to marine birds.

Pursuant to the MBTA, icebreaking noise associated with Alternative 2 would not result in a significant adverse effect on migratory bird populations.

4.3.2.2.4 Vessel Noise

Potential Harm

Auditory masking related to marine bird hearing would not have an impact on marine birds, as they spend a limited amount of time underwater and it is not thought that they use underwater sound related to their biologically relevant sounds. However, vessel noise could elicit short-term behavioral (startle response, flying away, looking up) or physiological responses (increased heart rate), but are not likely to disrupt major behavior patterns, such as migrating, breeding, feeding, and sheltering, or to result in serious injury to any seabirds. Beason (2004) notes that birds exposed to up to 146 dB re 20 µPa sound pressure level in air within 325 ft (99 m) of the noise source flushed, but then returned within minutes of the disturbance. Vessel noise from the Proposed Action is not expected to be as high as the noise level in this study.

Alternative 1

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to marine birds, in that the same vessels would be utilized for both alternatives. Due to the insignificant and short-term reactions to vessel noise and in accordance with E.O. 12114, vessel noise associated with Alternative 1 would not result in significant harm to marine birds.

Pursuant to the MBTA, vessel noise associated with Alternative 1 would not result in a significant adverse effect on migratory bird populations.

Alternative 2 (Preferred Alternative)

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to marine birds, in that the same vessels would be utilized for both alternatives. Due to the insignificant and short-term reactions to vessel noise and in accordance with E.O. 12114, vessel noise associated with Alternative 2 would not result in significant harm to marine birds.

Pursuant to the MBTA, vessel noise associated with Alternative 2 would not result in a significant adverse effect on migratory bird populations.

4.3.2.2.5 Aircraft Strike

Potential Harm

The majority of bird flight is below 3,000 ft (914 m) and approximately 95 percent of bird flight during migrations occurs below 10,000 ft (3,048 m) (U.S. Geological Survey 2006). Bird and aircraft encounters are more likely to occur during aircraft takeoffs and landings than when the aircraft is engaged in level, low-altitude flight. In a study of reported bird strikes to civil aircraft from 1990 to 2005, 60 percent of strike occurred below 100 ft (30.5 m), 73 percent of strike occurred below 150 m, and 92 percent of strike occurred below 2,001 ft (610 m) (Dolbeer and Wright 2008). Bird strike potential is greatest in foraging or resting areas, in migration corridors, and at low altitudes. Since 1981, naval aviators reported

16,550 bird strikes. About 90 percent of wildlife/aircraft collisions involve large birds or large flocks of smaller birds (Federal Aviation Administration 2003), and more than 70 percent involve gulls, waterfowl, or raptors. From 2000 to 2009, the Navy Bird Aircraft Strike Hazard program recorded 5,436 bird strikes with the majority occurring during the fall period from September to November. Though bird strikes can occur anywhere aircraft are operated, Navy data indicate they occur more often over land or close to shore.

Strike of a marine bird by an aircraft associated with the Proposed Action is possible, though not likely. Although marine birds are likely to hear and see approaching aircraft, they cannot avoid all collisions. Birds are known to be attracted to aircraft lights, which can lead to collisions (Gehring et al. 2009; Poot et al. 2008). Those marine bird species that would be found within the Study Area during the Proposed Action typically occur in groups smaller than 20 animals, though they may occasionally be in larger groups in the case of black guillemot, which may flock in larger groups due to highly concentrated prey species. In this context, the loss of several or even dozens of birds due to physical strikes would not constitute a population-level impact, as these species would not be gathered in large flocks. Some bird strikes and associated bird mortality or injuries could occur as a result of aircraft use; however, population-level impacts to marine birds would not likely result from aircraft strikes due to the limited duration of aircraft operation, the likely flight response of marine birds to in-air noise and general aerial disturbance, and the fact that marine birds are not likely to approach an aircraft while it is in operation (Mallory 2016). A temporary increase in flights through the region would not be expected to result in significantly increased risk to marine birds.

Alternative 1

Aircraft strike risk associated with Alternatives 1 and 2 would be the same. Although unlikely, aircraft strike with an individual marine bird is possible. However, because the marine birds are not expected to be traveling in large flocks, and aircraft operations would be limited, one or more isolated incidents of aircraft strike would not result in any population level impacts. In accordance with E.O. 12114, aircraft strike associated with Alternative 1 would not result in significant harm to marine birds.

Pursuant to the MBTA, aircraft strike associated with Alternative 1 would not result in a significant adverse effect on migratory bird populations.

Alternative 2 (Preferred Alternative)

Aircraft strike risk associated with Alternatives 1 and 2 would be the same. Although unlikely, aircraft strike with an individual marine bird is possible. However, because the marine birds are not expected to be traveling in large flocks, and aircraft operations would be limited, one or more isolated incidents of aircraft strike would not result in any population level impacts. In accordance with E.O. 12114, aircraft strike associated with Alternative 2 would not result in significant harm to marine birds.

Pursuant to the MBTA, aircraft strike associated with Alternative 2 would not result in a significant adverse effect on migratory bird populations.

4.3.2.2.6 Ingestion

Potential Harm

The potential for ingestion of materials by marine birds would be limited to shredded pieces of burst weather balloons. Physiological harm to birds from ingesting foreign materials generally include blocked digestive tracts and subsequent food passage, blockage of digestive enzymes, lowered steroid hormone levels, delayed ovulation (egg maturation), reproductive failure, nutrient dilution (nonnutritive debris displaces nutritious food in the gut), and altered appetite satiation (the sensation of feeling full), which can lead to starvation (Azzarello and Vleet 1987). While ingestion of marine debris has been linked to bird mortalities, non-lethal harm is more common (Moser and Lee 1992; Trevail et al. 2015).

Many species of marine birds are known to ingest floating plastic debris and other foreign matter while feeding on the surface of the ocean (Auman et al. 1997; Yamashita et al. 2011). For example, 21 of 38 marine bird species (55 percent) collected off the coast of North Carolina from 1975 to 1989 had ingested plastic particles, including both hard pieces of plastic and pieces of soft plastics such as shreds of balloons (Moser and Lee 1992). Some marine birds have used plastic and other marine debris for nest building which may lead to ingestion of that debris (Votier et al. 2011).

Birds of the order procellariiformes, which include petrels and shearwaters, tend to accumulate more plastic than other species, including chadriiformes (Azzarello and Vleet 1987; Kain et al. 2016; Moser and Lee 1992; Pierce et al. 2004). Some birds, including those of the order chadriiformes, commonly regurgitate indigestible parts of their food items such as shell and fish bones. However, the structure of the digestive systems of most procellariiformes makes it difficult to regurgitate solid material such as plastic (Azzarello and Vleet 1987; Moser and Lee 1992; Pierce et al. 2004).

Moser and Lee (1992) found no evidence that marine bird health was influenced by the presence of plastic, but other studies have documented negative consequences of plastic ingestion (Carey 2011). As summarized by Pierce et al. (2004), Auman et al. (1997), and Azzarello and Van Vleet (1987), the consequences of plastic ingestion by marine birds that have been documented include blockage of the intestines and ulceration of the stomach, reduction in the functional volume of the gizzard leading to a reduction of digestive capability, and distention of the gizzard leading to a reduction in hunger.

Alternative 1

Ingestion associated with Alternatives 1 and 2 would be the same. The execution of research activities would introduce additional materials that would be available for ingestion (e.g., balloon fragments). Weather balloons typically disperse from the release point to another area based on meteorological conditions, where the direction would be dictated by wind and air masses. The density of the balloons returning to the earth surface would be low enough that even if a few individuals were to ingest some balloon fragments, there would be no population level impacts. In accordance with E.O. 12114, ingestion associated with Alternative 1 would not result in significant harm to marine birds.

In accordance with the Migratory Bird Treaty Act, the risk of ingestion associated with Alternative 1 would not result in a significant adverse effect on migratory bird populations.

Alternative 2 (Preferred Alternative)

Ingestion associated with Alternatives 1 and 2 would be the same. The execution of research activities would introduce additional materials that would be available for ingestion (e.g., balloon fragments). Weather balloons typically disperse from the release point to another area based on meteorological conditions, where the direction would be dictated by wind and air masses. The density of the balloons returning to the earth surface would be low enough that even if a few individuals were to ingest some balloon fragments, there would be no population level impacts. In accordance with E.O. 12114, ingestion associated with Alternative 2 would not result in significant harm to marine birds.

In accordance with the Migratory Bird Treaty Act, the risk of ingestion associated with Alternative 2 would not result in a significant adverse effect on migratory bird populations.

4.3.2.3 Fish

The fish species located in the Study Area include those that are closely associated with the deep ocean habitat of the Beaufort Sea (Section 3.2.2.3). Only about 30 are known to occur in the Arctic waters of the Beaufort Sea (Christiansen and Reist 2013). Aquatic systems of the Arctic undergo extended seasonal periods of ice cover and other harsh environmental conditions. Fish inhabiting such systems must be biologically and ecologically adapted to surviving such conditions. Important environmental factors that Arctic fish must contend with include reduced light, seasonal darkness, ice cover, low biodiversity, and low seasonal productivity. No ESA-listed fish species occur within the Study Area.

Acoustic stressors that may have potential impacts on fish include non-impulsive acoustic sources, icebreaking noise, impulsive sources, and vessel noise. Physical stressors that may have potential impacts on fish include icebreaking (physical impacts), vessel and in-water device strike, and bottom disturbance. The only stressor associated with expended materials that may have potential impacts on fish is entanglement.

4.3.2.3.1 Non-Impulsive Acoustic Sources

Potential Harm

As discussed in Section 3.2.2.3.2, data on hearing sensitivities of fish species occurring in the Study Area are not known. Research on fish hearing is limited; however, there is the potential for a fish with hearing sensitivities yet to be determined to perceive the sound of the Proposed Action. The region of hearing sensitivity in fish is generally lower frequencies, ranging from 100 to 400 Hz (Popper 2003). PTS has not been documented in fish. A study regarding mid-frequency sonar exposure by Halvorsen et al. (2012) found that for temporary hearing loss or similar negative impacts to occur, the noise needed to be within the fish's individual hearing frequency range; external factors, such as developmental history of the fish or environmental factors, may result in differing impacts to sound exposure in fish of the same species. The sensory hair cells of the inner ear in fish can regenerate after they are damaged, unlike in mammals where sensory hair cell loss in permanent (Lombarte et al. 1993; Smith et al. 2006). As a consequence, any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Smith et al. 2006), and no permanent loss of hearing in fish would result from exposure to sound.

Studies of the effects of long-duration sounds with SPLs below 170–180 dB re 1 µPa indicate that there is little to no effect of long-term exposure on species that lack notable anatomical hearing specialization (Amoser and Ladich 2003; Scholik and Yan 2001; Smith et al. 2004a, 2004b; Wysocki et al. 2006). The longest of these studies exposed young rainbow trout (*Onorhynchus mykiss*) to a level of noise equivalent to one that fish would experience in an aquaculture facility (e.g., on the order of 150 dB re 1 µPa) for about nine months. The investigators found no effect on hearing (i.e., TTS) as compared to fish raised at 110 dB re 1 µPa. Though these studies have not directly determined impacts to the fish expected to be present within the Study Area, it can be assumed that they would react in a similar manner to sound exposure.

Behavioral responses to noise in wild fish could alter the behavior of a fish in a manner that would affect its way of living, such as where it tries to locate food or how well it can locate a potential mate. Behavioral responses to loud noise could include a startle response, such as the fish swimming away from the source, the fish "freezing" and staying in place, or scattering (Popper 2003).

Fish use sounds to detect both predators and prey, and for schooling, mating, and navigating (Myrberg 1981; Popper 2003). Masking of sounds associated with these behaviors could have impacts to fish by reducing their ability to perform these biological functions. Any noise (i.e., unwanted or irrelevant sound, often of an anthropogenic nature) detectable by a fish can prevent the fish from hearing biologically important sounds including those produced by prey or predators (Myrberg 1981; Popper 2003). The immediate elevated stress response to anthropogenic noise can inhibit the survival of certain prey fish, reducing their ability to react to predator attacks during noise exposure (Simpson et al. 2016).

The frequency of the sound is an important consideration for fish because many marine fish are limited to detection of the particle motion component of low frequency sounds at relatively high sound intensities (Amoser and Ladich 2005). Many of the frequencies of the non-impulsive acoustic sources associated with the Proposed Action are higher than those expected to be perceived by those species within the Study Area; therefore, masking is not likely as the mid- and high-frequency sources are not within the hearing range a fish would use to detect predators or prey. Behavioral responses are possible for those fish close to the active sonar sources, but there is little evidence of these responses at most of the frequency levels of the Proposed Action. Towed sources associated with the Proposed Action would operate for up to 60 hours total annually; while some are within the low-frequency range of fish, noise and movement associated with the towing vessel would likely be an additional factor in eliciting some sort of behavioral response. Individual fish may avoid an area in which a low-frequency moored source is present, but the population level effects would not be anticipated from placement of these sources.

Alternative 1

Non-impulsive acoustic sources from both Alternatives 1 and 2 would result in the same potential for effects to fish. There is a chance that fish within the Study Area would be able to perceive the non-impulsive acoustic sources, and if perceived, that an individual fish would react; this reaction would be temporary or minimal, and the fish would be expected to resume normal behavior after exposure. In accordance with E.O. 12114, non-impulsive acoustic sources associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

Non-impulsive acoustic sources from both Alternatives 1 and 2 would result in the same potential for effects to fish, though Alternative 2 would only include deep water and *de minimis* sources. There is a chance that fish within the Study Area would be able to perceive the non-impulsive acoustic sources, and if perceived, that an individual fish would react; this reaction would be temporary or minimal, and the fish would be expected to resume normal behavior after exposure. In accordance with E.O. 12114, non-impulsive acoustic sources associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.2 Icebreaking Noise

Potential Harm

Icebreaking noise has the potential to expose fish to both sound and general disturbance, which could result in short-term behavioral or physiological responses (e.g., avoidance, stress, increased heart rate). Misund (1997) found that fish ahead of a ship showed avoidance reactions at ranges of 160 to 489 ft (49 to 149 m). When the vessel passed over them, some species of fish exhibited sudden escape responses that included lateral avoidance or downward compression of the school. Avoidance behavior of vessels, vertically or horizontally in the water column, has been reported for cod and herring, and was attributed to vessel noise; similar behavioral response could be expected due to icebreaking noise. Vessel activity can also alter schooling behavior and swimming speed of fish (United Nations Environment Programme 2012).

It is not anticipated that temporary behavioral reactions (e.g., temporary cessation of feeding) would harm the individual fitness of a fish as individuals are expected to resume feeding upon cessation of the sound exposure and unconsumed prey would still be available in the environment. Furthermore, while icebreaking noise may influence the behavior of some fish species (e.g., startle response, masking), other fish species can be equally unresponsive (Becker et al. 2013).

Alternative 1

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to fish, in that the same vessel would be utilized for both Alternatives. Due to the insignificant and short-term reactions to icebreaking noise, and in accordance with E.O. 12114, icebreaking noise associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to fish, in that the same vessel would be utilized for both Alternatives. Due to the insignificant and short-term reactions to icebreaking noise, and in accordance with E.O. 12114, icebreaking noise associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.3 Impulsive Sources

Potential Harm

Impulsive sound sources include stressors such as explosions from underwater detonations and explosive ordnance, swimmer defense airguns, pile driving, and noise from weapons firing, launch, and impact with the water's surface; the Proposed Action would only utilize airguns and the compact sound source as impulsive sources. Potential acoustic effects to fish from impulsive sources may be considered in four categories, as detailed in Section 4.1.1.1: (1) direct injury, (2) hearing loss, (3) auditory masking, and (4) physiological stress and behavioral reactions.

Single, small airguns (60 cubic inches [in^3; 983 cubic centimeters [cm^3]) are unlikely to cause direct trauma to marine fish. Impulses from airguns lack the strong shock wave and rapid pressure increase, as would be expected from explosive sources that can cause primary blast injury or barotrauma. Primary blast injury refers to those injuries that result from the initial compression of a body exposed to a blast wave. Primary blast injury is usually limited to gas-containing structures (e.g., swim bladder) and the auditory system. Barotrauma refers to injuries caused when the swim bladder or other gas-filled structures vibrate in response to the signal, particularly if there is a relatively sharp rise-time and the walls of the structure strike near-by tissues and damage them.

It has been suggested that impulsive sounds, such as that produced by seismic airguns, may cause damage to the cells of the lateral line in fish larvae and fry when in close proximity (15 ft [5 m]) to the sound source (Booman et al. 1996).Similar to adult fishes, the presence of a swim bladder contributes to shock wave-induced internal damage in larval and juvenile fishes (Settle et al. 2002). Shock wave trauma to internal organs of larval pinfish and spot from shock waves was documented by Govoni et al. (2003). These were laboratory studies, however, and have not been verified in the field.It has been suggested that impulsive sounds, such as those produced by seismic airguns, may cause damage to the cells of the lateral line in fish larvae and juveniles when in proximity (16 ft [4.9 m]) to the sound source (Booman et al. 1996). There is little evidence that airguns can cause direct injury to adult fish, with the possible exception of injuring small juvenile or larval fish nearby (approximately 16 ft [4.9 m]). Therefore, larval and small juvenile fish within a few meters of the airgun may be injured or killed. Considering the small footprint of this hypothesized injury zone, and the isolated and infrequent use of the impulsive sources, population consequences would not be expected.

Auditory masking only occurs when the interfering signal is present. The bulk of the studies regarding auditory masking in fish have been done with goldfish, a freshwater fish with well-developed anatomical specializations that enhance hearing abilities; the data on other species are much less extensive. As a result, less is known about masking in marine species, many of which lack the notable anatomical hearing specializations. However, Wysocki and Ladich (2005) suggest that ambient sound regimes may limit acoustic communication and orientation, especially in animals with notable hearing specializations. Studies have been performed on Atlantic cod at five frequency bandwidths in the 20 to 340 Hz region and showed masking across all hearing ranges (Buerkle 1968, 1969). Chapman and Hawkins (1973) found that ambient noise at higher sea states in the ocean has masking effects in cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and pollock (*Pollochinus pollachinus*), and similar results were suggested for several sciaenid species by Ramcharitar and Popper (2004). Thus, based on limited data, it appears that for fish, as for mammals, masking may be most problematic in the frequency region near the signal.

Due to the limited duration of individual shots and the limited number of shots proposed, only brief, isolated auditory masking to marine fish would be expected. Population consequences would not be expected. In addition, fish that are able to detect the airgun impulses may exhibit alterations in natural behavior.

Alternative 1

Impulsive sources associated with the Proposed Action would be from the compact sound source and airgun firings, and would occur in Alternative 1 in the deep water and shallow water areas. Temporary hearing loss in fish could occur if fish were exposed to impulses from airguns, although some studies have shown no hearing loss from exposure to airguns within 16 ft (4.9 m). Therefore, fish within a few meters of the airgun may receive temporary hearing loss. However, due to the relatively small size of the airgun, and their limited use, impacts would be minor, and may only harm a few individual fish; population consequences would not be expected. Therefore, in accordance with E.O. 12114 impulsive sources associated with Alternative 1 would result in no significant harm to fish.

Alternative 2 (Preferred Alternative)

Impulsive sources would not be used under Alternative 2. In accordance with E.O. 12114, impulsive sources associated with Alternative 2 would not result in harm to fish.

4.3.2.3.4 Vessel Noise

Potential Harm

Vessel noise has the potential to expose fish to both sound and general disturbance, which could result in short-term behavioral or physiological responses (e.g., avoidance, stress, increased heart rate). Noise from the vessels associated with the Proposed Action is not expected to impact fish, as available evidence does not suggest that ship noise can injure or kill a fish (Popper 2014). Misund (1997) found that fish ahead of a ship showed avoidance reactions at ranges of 161 to 489 ft (49 to 149 m). When the vessel passed over them, some species of fish exhibited sudden escape responses that included lateral avoidance or downward compression of the school. Avoidance behavior of vessels, vertically or horizontally in the water column, has been reported for cod and herring, and was attributed to vessel noise. Vessel activity can also alter schooling behavior and swimming speed of fish (United Nations Environment Programme 2012).

It is not anticipated that temporary behavioral reactions (e.g., temporary cessation of feeding) would harm the individual fitness of a fish as individuals are expected to resume feeding upon cessation of the sound exposure and unconsumed prey would still be available in the environment. Furthermore, while vessel sounds may influence the behavior of some fish species (e.g., startle response, masking), other fish species can be equally unresponsive (Becker et al. 2013).

Alternative 1

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to fish, in that the same vessels would be utilized for both alternatives. Due to the insignificant and short-term reactions to vessel noise and in accordance with E.O. 12114, vessel noise associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to fish, in that the same vessels would be utilized for both alternatives. Due to the insignificant and short-term reactions to vessel noise and in accordance with E.O. 12114, vessel noise associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.5 Icebreaking (Physical Impacts)

Potential Harm

Fish species within the Study Area are distributed throughout the surface, water column, and seafloor. Based on the existing scientific information on Arctic cod in the Beaufort Sea, Arctic cod would be nearshore in the Study Area, feeding, in late summer and early autumn. As the autumn ice thickens and eventually freezes to the bottom in shallow nearshore areas, Arctic cod would move farther offshore where they spawn under the ice between November and February (Office of Environment Alaska OCS Region 2012). Icebreaking associated with the Proposed Action is scheduled to during the warm season, between August and October in the deep water area of the Study Area. Arctic cod are expected to be nearshore during this timeframe and would not likely be exposed to icebreaking activities. However, Arctic cod have been observed among broken ice floes in the wake of icebreakers or splashed on top of ice floes (Crawford 2003; Gradinger and Bluhm 2004) indicating that individual Arctic cod and other ice-associated fish could be injured or killed along the icebreaker track lines. However, mortality is unlikely, because fish are highly mobile and are likely to avoid icebreaking activities since during icebreaking activities CGC HEALY would travel at a maximum speed of 3 knots.

Alternative 1

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to fish, in that the same vessel would be utilized for both alternatives. The icebreaking may result in short-term and local displacement of fishes in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness, or population recruitment, and are not expected to result in any harm at the population-level. Isolated cases of icebreaking striking a fish would potentially injure or result in the mortality of individuals, but would not result in population-level effects. In accordance with E.O. 12114 physical impacts from icebreaking associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to fish, in that the same vessel would be utilized for both alternatives. The icebreaking may result in short-term and local displacement of fishes in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness, or population recruitment, and are not expected to result in any harm at the population-level. Isolated cases of icebreaking striking a fish would potentially injure or result in the mortality of individuals, but would not result in population-level effects. In accordance with E.O. 12114 physical impacts from icebreaking associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.6 Vessel and In-Water Device Strike

Potential Harm

Fish species within the Study Area are distributed throughout the surface, water column, and seafloor. Seafloor species would be unlikely to come into contact with vessels and in-water devices. Arctic cod would be exposed to vessels and in-water devices, as their distribution within the water column is from the surface to 1,312 ft (400 m), as discussed in Section 3.2.2.3.

The potential for fish to be struck by vessels or in-water devices from the Proposed Action would be extremely low because most fish can detect and avoid vessel and in-water device movements. Fish would not be impacted by any wave produced by a vessel in motion. The fish lateral line system can detect changing water flow, which would allow fish to evade approaching objects (Stewart et al. 2014). As a vehicle approaches a fish, the fish could have a behavioral or physiological response (e.g., swimming away and increased heart rate) as the passing vehicle displaces them. Potential harm from exposure to vessels, vehicles, and devices is not expected to result in substantial changes to an individual's overall behavior patterns, or species fitness and recruitment, and is not expected to result in any harm at the population-level. Any isolated cases of vessels or vehicles striking an individual could injure that individual, impacting its fitness, but not to the extent that there would be harm to the viability of populations based on the small number of vessels involved and the normal response of fish avoiding vessels and in-water devices.

Alternative 1

The potential for vessel and in-water device strike would be the same under Alternatives 1 and 2. Vessel and in-water device use may result in short-term and local displacement of fishes in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness, or species recruitment, and are not expected to result in any harm at the population-level, for the reasons described above. Isolated cases of vessel strike would potentially injure individuals, but would not result in population-level effects. In accordance with E.O. 12114, vessel and in-water device strike associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

The potential for vessel and in-water device strike would be the same under Alternatives 1 and 2. Vessel and in-water device use may result in short-term and local displacement of fishes in the water column. However, these behavioral reactions are not expected to result in substantial changes to an individual's fitness, or species recruitment, and are not expected to result in any harm at the population-level, for the reasons described above. Isolated cases of vessel strike would potentially injure individuals, but would not result in population-level effects. In accordance with E.O. 12114, vessel and in-water device strike associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.7 Bottom Disturbance

Potential Harm

Items on the seafloor may attract benthic fish, including fish of the Orders Scorpaeniformes and Perciformes, but their sensory abilities allow them to avoid colliding with expended materials (Bleckmann and Zelick 2009). Those materials expended by the Proposed Action would fall to the seafloor in a manner dictated by ocean currents, but would be unlikely to do so nearby each other. Since fish are able to sense and avoid materials within their path, and expended materials would be drifting with the currents, rather than being self-propelled, it is highly unlikely that a fish would collide with an anchor or other tethering mechanism, either while it is sinking to the ocean floor or once it is on the ocean floor.

The equipment that would be used for coring would move very slowly during operation, and is unlikely to have any contact with any pelagic (while traveling through the water column) or benthic (during operation) fish. While moving through the soft sediments at slow speeds, the equipment would not create any detectable acoustic signal within the water column. Very low levels of acoustic transmissions could be created in the mud; these transmissions would be within the hearing frequency range of fish, but would not extend past the sediment-water barrier. Any increase in turbidity caused by the coring activities would be temporary, and the suspended sediments would disperse quickly into the larger water body.

Alternative 1

The impact to bottom habitats from bottom disturbance under Alternative 1 would be slightly higher than that under Alternative 2, based on the increased number of expended anchors. The disturbance would be localized and temporary as the equipment hit the seafloor, which may cause scatter behavior in fish. However, the overall effects would be minimal due to the large size of the area and the low number of items expended over the expanse of the Study Area. Therefore, in accordance with E.O. 12114, expended material associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

The impact to bottom habitats from bottom disturbance under Alternative 2 would be slightly lower than that under Alternative 1, based on the decreased number of expended anchors. The disturbance would be localized and temporary as the equipment hit the seafloor, which may cause scatter behavior in fish. However, the overall effects would be minimal due to the large size of the area and the low number of items expended over the expanse of the Study Area. Therefore, in accordance with E.O. 12114, expended material associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.8 Entanglement

Potential Harm

The likelihood of fish being affected by an entanglement stressor is a function of the physical properties, location, and buoyancy of the object, as well as the behavior of the fish. Most entanglement observations involve abandoned or discarded nets, lines, and other materials that form loops or incorporate rings (Derraik 2002; Keller et al. 2010; Laist 1987; Macfadyen et al. 2009). A 25-year dataset assembled by the Ocean Conservancy (2010) reported that fishing line, rope, and fishing nets accounted for approximately 68 percent of fish entanglements, with the remainder due to encounters with various items such as bottles, cans, and plastic bags.

Fish entanglement occurs most frequently at or just below the surface or in the water column where objects are suspended; however, the physical properties (taught lines with no slack) of the materials associated with ARA are not expected to cause any entanglement. More fish species are entangled in coastal waters and the continental shelf than elsewhere in the marine environment because of higher concentrations of human activity (e.g., fishing, sources of entangling debris), higher fish abundances, and greater species diversity (Helfman et al. 2009; Macfadyen et al. 2009). The consequences of entanglement range from temporary and inconsequential to major physiological stress or mortality. Two balloons would be released per day (a maximum of forty balloons total), and would travel varying distances before bursting, based on meteorological conditions and upper atmosphere air currents; therefore, weather balloons would not present a large entanglement threat to fish populations so much as individual animals.

Some fish are more susceptible to entanglement in derelict fishing gear and other marine debris, compared to other fish groups. Physical features, such as rigid or protruding snouts of some elasmobranchs (e.g., the wide heads of hammerhead sharks), increase the risk of entanglement compared to fish with smoother, more streamlined bodies (e.g., lamprey and eels). Most other fish, except for jawless fish and eels that are too smooth and slippery to become entangled, are susceptible to entanglement gear specifically designed for that purpose (e.g., gillnets); however, no items would be expended that are designed to function as entanglement objects, nor are they designed to have slack or form loops. Expended materials have the potential to strike fish as they sink to the seafloor. Although individual fish may be at some marginal risk of injury, population-level impacts from these materials would not occur due to the dispersed nature and small amount of the expended material.

Alternative 1

Entanglement risk associated with Alternatives 1 and 2 would be the same. The potential for entanglement would be limited to tethers, tows, and other underwater lines. Entanglement of fish in the lines associated with the Proposed Action is not anticipated, given the mobility of the fish and the weighted (e.g., no slack or loops) lines that would be used. In accordance with E.O. 12114, entanglement associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

Entanglement risk associated with Alternatives 1 and 2 would be the same. The potential for entanglement would be limited to tethers, tows, and other underwater lines. Entanglement of fish in the lines associated with the Proposed Action is not anticipated, given the mobility of the fish and the weighted (e.g., no slack or loops) lines that would be used. In accordance with E.O. 12114, entanglement associated with Alternative 2 would not result in significant harm to fish.

4.3.2.3.9 Ingestion

Potential Harm

Expended materials that may potentially impact fish are those that are of ingestible size and that are present in the water column where fish feed. The likelihood that expended items would cause potential harm to a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item. In this analysis, balloon fragments are considered to be of ingestible size for a fish. For many small fish species, even these items are too large to be ingested. The majority of studies involving plastic ingestion in fish look at the effects of fish eating hard plastic pieces; minimal work has been done evaluating the harm from weather balloon fragment ingestion. A study by Irwin (2012) found that natural latex weather balloon fragments would not have serious health implications on catfish.

Alternative 1

Ingestion risk associated with Alternatives 1 and 2 would be the same. The execution of research activities would introduce additional potential for ingestion both within the water column and once the material sinks to the seafloor. The highest risk of harm from ingestion would be from the parachute, balloon fragments, and rope from the weather balloons. A total of 40 balloons would be released annually, and they would travel varying directions before bursting. Because of the small numbers of these balloons and expended materials, and the distance at which they would be dispersed, they would not present a significant threat to fish populations, although one or a few individuals could be impacted. In accordance with E.O. 12114, ingestion associated with Alternative 1 would not result in significant harm to fish.

Alternative 2 (Preferred Alternative)

Ingestion risk associated with Alternatives 1 and 2 would be the same. The execution of research activities would introduce additional potential for ingestion both within the water column and once the material sinks to the seafloor. The highest risk of harm from ingestion would be from the parachute, balloon fragments, and rope from the weather balloons. A total of 40 balloons would be released annually, and they would travel varying directions before bursting. Because of the small numbers of these balloons and expended materials, and the distance at which they would be dispersed, they would not present a significant threat to fish populations, although one or a few individuals could be impacted. In accordance with E.O. 12114, ingestion associated with Alternative 2 would not result in significant harm to fish.

4.3.2.4 Essential Fish Habitat

The only species for which Essential Fish Habitat has been designated within the Study Area is Arctic cod. Insufficient information is available to determine Essential Fish Habitat for eggs, larvae, and early juveniles of Arctic cod. Essential Fish Habitat for late juvenile and adult Arctic cod within the Arctic Management Area occurs in waters from the nearshore to offshore areas along the continental shelf (0-656 ft [0-200 m]) and upper slope (656-1,640 ft [200-500 m]) throughout Arctic waters and often associated with ice floes which may occur in deeper waters (North Pacific Fishery Management Council 2009). Essential Fish Habitat designation only occurs within the U.S. Exclusive Economic Zone (EEZ).

Acoustic stressors that may have potential impacts on Essential Fish Habitat include non-impulsive acoustic sources, icebreaking noise, and impulsive sources. The only physical stressor that may have potential impacts on Essential Fish Habitat is the physical impact of icebreaking.

4.3.2.4.1 Non-Impulsive Acoustic Sources

Potential Harm

Non-impulsive acoustic sources could have an effect on the water column within the epipelagic zone, which is designated as Essential Fish Habitats in a large portion of the Study Area, due to the increase in ambient sound level during the transmissions. However, this potential reduction in the quality of the acoustic habitat would be localized to the area of the sound sources. The quality of the water column would only be disturbed while the sound source is broadcasting and only in the area immediately ensonified around the non-impulsive acoustic source.

However, some non-impulsive acoustic sources would be deployed to transmit signals every day for up to three years. Of those sources that would be frequently active, the only ones that would be operating within the frequency range for fish hearing would be the tomography sources and the shallow LF4 moored sources. The tomography sources would be located in the deep water of the Canada Basin, and less than half of the sources would be located within Essential Fish Habitat; the others are located outside of the U.S. EEZ. The tomography sources would operate for 2.25 minutes, with almost four hours of silence between pings, limiting exposure to individual fish, and limiting noise added into the environment. The shallow LF4 moored sources would also be likely to increase ambient noise in the vicinity of the devices; only two would be deployed, which would limit overall impacts. Secondary effects to federally managed fish species (i.e., Arctic cod) are considered in Section 4.3.2.3.1 above.

Alternative 1

Non-impulsive acoustic sources from Alternative 1 would potentially have a slightly higher impact to Essential Fish Habitat than non-impulsive acoustic sources from Alternative 2. The quality of the water column as Essential Fish Habitat would only be affected locally and temporarily overall. In accordance with E.O. 12114, non-impulsive acoustic sources associated with Alternative 1 would not result in significant harm to Essential Fish Habitat.

Pursuant to the Magnuson Stevens Fishery Conservation and Management Act (MSA), an action may adversely affect Essential Fish Habitat when it may reduce the quantity or quality of Essential Fish Habitat, because it could be meaningfully measured or observed individually or cumulatively (regardless of duration or scale), or is likely to occur.

Alternative 2 (Preferred Alternative)

Non-impulsive acoustic sources from Alternative 2 would potentially have a slightly lower impact to Essential Fish Habitat than non-impulsive acoustic sources from Alternative 1, since Alternative 2 would only include deep water sources and *de minimis* sources. The quality of the water column as Essential Fish Habitat would only be affected locally and temporarily overall. In accordance with E.O. 12114, non-impulsive acoustic sources associated with Alternative 2 would not result in significant harm to Essential Fish Habitat.

Pursuant to the MSA, an action may adversely affect Essential Fish Habitat when it may reduce the quantity or quality of Essential Fish Habitat, because it could be meaningfully measured or observed individually or cumulatively (regardless of duration or scale), or is likely to occur. Due to the potential for non-impulsive acoustic sources to alter Arctic cod Essential Fish Habitat, non-impulsive acoustic sources associated with the Proposed Action may result in a reduction of the quantity or quality of Essential Fish Habitat and therefore consultation under the MSA was initiated on February 22, 2018, with concurrence received from NMFS on March 22, 2018 (Appendix B).

4.3.2.4.2 Icebreaking Noise

Potential Harm

Icebreaking noise could have an effect on the features of the Essential Fish Habitat due to the increase in ambient sound level during the icebreaking. However, this potential reduction in the quality of the acoustic habitat would be localized to the area of the icebreaking and would be transient in nature. Since the icebreaker is actively moving during icebreaking the icebreaking noise would only affect the water column in close vicinity to the ship and be temporary in nature, not ensonifing the entire water column, but only the upper few meters. Icebreaking would be limited in nature due to the ice extent from August through October, further reducing the amount of icebreaking noise entering the water column.

Icebreaking activities could have an effect on the features of the Essential Fish Habitat, due to the increase in ambient sound level during icebreaking. However, this potential reduction in the quality of the acoustic habitat would be localized to the area of the icebreaking and would be transient in nature. The icebreaker is actively moving during icebreaking; therefore, any noise generating by the icebreaking activity would only affect the water column in close proximity to the ship and be temporary in nature and would not ensonify the entire water column, but only the upper few meters. Icebreaking would be limited to a short window during a few weeks in August through October, further reducing the amount of icebreaking noise entering the water column. Secondary effects to federally managed fish species (i.e., Arctic cod) are considered in Section 4.3.2.3.2 above.

Alternative 1

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to Essential Fish Habitat. In accordance with E.O. 12114, icebreaking noise associated with Alternative 1 would not result in significant harm to Essential Fish Habitat.

While the quality of the water column as Essential Fish Habitat would only be affected locally and temporarily and cannot be meaningfully measured, in accordance with the MSA there would not be a reduction in the overall quality of Essential Fish Habitat.

Alternative 2 (Preferred Alternative)

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to Essential Fish Habitat. In accordance with E.O. 12114, icebreaking noise associated with Alternative 2 would not result in significant harm to Essential Fish Habitat.

While the quality of the water column as Essential Fish Habitat would only be affected locally and temporarily and cannot be meaningfully measured, in accordance with the MSA there would not be a reduction in the overall quality of Essential Fish Habitat and therefore consultation under the MSA was initiated on February 22, 2018, with concurrence received from NMFS on March 22, 2018 (Appendix B).

4.3.2.4.3 Impulsive Sources

Potential Harm

Impulsive sources could have an effect on the features of the Essential Fish Habitat due to the increase in ambient sound level during use. However, this potential reduction in the quality of the acoustic habitat would be localized to the area of the sound sources. The quality of the water column environment as Essential Fish Habitat would be restored to normal levels immediately following the completion of each individual testing event, which would occur for a maximum of three days. The airgun pulses would occur every 10 minutes, and use would not exceed 80 shots per day. The use of airguns and compact sound sources during the Proposed Action may temporarily degrade the quality of the marine environment during each shot by ensonifying the water column at frequency levels within the range of sensitivity of Arctic cod, but that impact would be minimal due to the short-term nature of the activity. Secondary effects to federally managed fish species (i.e., Arctic cod) are considered in Section 4.3.2.3.3 above.

Alternative 1

Use of airguns and other impulsive sources associated with Alternative 1 may temporarily degrade the quality of the marine environment during each shot, but that impact would be minimal due to the short-term nature of the activity. In accordance with E.O. 12114, impulsive sources associated with the Proposed Action would not result in significant harm to Essential Fish Habitat.

Pursuant to the MSA, an action may adversely affect Essential Fish Habitat when it may reduce the quality or quantity of the water column as Essential Fish Habitat, because it could be meaningfully measured or observed individually or cumulatively (regardless of duration or scale), or is likely to occur. Due to the potential for impulsive sources to alter Arctic cod Essential Fish Habitat, impulsive sources associated with the Proposed Action may result in the reduction of the quality or quantity of Essential Fish Habitat.

Alternative 2 (Preferred Alternative)

Impulsive sources would not be used under Alternative 2. In accordance with E.O. 12114, impulsive sources associated with Alternative 2 would not result in harm to Essential Fish Habitat.

Pursuant to the MSA, an action may adversely affect Essential Fish Habitat when it may reduce the quality or quantity of the water column as Essential Fish Habitat, because it could be meaningfully measured or observed individually or cumulatively (regardless of duration or scale), or is likely to occur. As no impulsive sources would be used under Alternative 2, the Proposed Action under this Alternative would not result in the reduction of the quality or quantity of Essential Fish Habitat and therefore consultation under the MSA for impulsive sources is not required.

4.3.2.4.4 Icebreaking (Physical Impacts)

Potential Harm

Essential Fish Habitat for Arctic cod in the Study Area includes areas of ice floe. Arctic cod are commonly found among ice floes and vessel movement through these areas could alter Essential Fish Habitat via icebreaking activities. Icebreaking activities would be limited to the deep water portion of the Study Area and could occur in the warm season from August to October. Only areas of thick, wide concentrations of sea ice would require icebreaking by CGC HEALY. During this timeframe, these areas are expected to be at a minimum, which would reduce the impact to ice floes and Essential Fish Habitat. Secondary effects to federally managed fish species (i.e., Arctic cod) are considered in Section 4.3.2.3.5 above.

Alternative 1

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to Essential Fish Habitat, in that the same icebreaking vessel (CGC HEALY) would be utilized for both alternatives. The use of an icebreaking vessel may result in localized changes to Essential Fish Habitat as larger sheets of floating ice are broken down into smaller sizes. However, icebreaking is not expected to significantly alter Arctic cod ice floe habitat. Therefore, in accordance with E.O. 12114 physical impacts from icebreaking associated with Alternative 1 would not result in significant harm to Essential Fish Habitat.

Pursuant to the MSA, an action may adversely affect Essential Fish Habitat when it may reduce the quantity or quality of Essential Fish Habitat, because it could be meaningfully measured or observed individually or cumulatively (regardless of duration or scale), or is likely to occur. Due to the potential for icebreaking to alter Arctic cod Essential Fish Habitat, physical impacts from icebreaking associated with the Proposed Action may result in a reduction of the quantity or quality of Essential Fish Habitat.

Alternative 2 (Preferred Alternative)

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to Essential Fish Habitat, in that the same icebreaking vessel (CGC HEALY) would be utilized for both alternatives. The use of an icebreaking vessel may result in localized changes to Essential Fish Habitat as larger sheets of floating ice are broken down into smaller sizes. However, icebreaking is not expected to significantly alter Arctic cod ice floe habitat. Therefore, in accordance with E.O. 12114 physical impacts from icebreaking associated with Alternative 2 would not result in significant harm to Essential Fish Habitat.

Pursuant to the MSA, an action may adversely affect Essential Fish Habitat when it may reduce the quantity or quality of Essential Fish Habitat, because it could be meaningfully measured or observed individually or cumulatively (regardless of duration or scale), or is likely to occur. Due to the potential for icebreaking to alter Arctic cod Essential Fish Habitat, physical impacts from icebreaking associated with the Proposed Action may result in a reduction of the quantity or quality of Essential Fish Habitat and therefore consultation under the MSA was initiated on February 22, 2018, with concurrence received from NMFS on March 22, 2018 (Appendix B).

4.3.2.5 Marine Mammals

Nine marine mammal species, which include three cetaceans, five pinnipeds, and the polar bear, are likely to occur in the Study Area during the Proposed Action. Marine mammals are found throughout the Study Area, including on the sea ice and within the water column. ESA-listed marine mammals, including bearded seal, bowhead whale, ESA-candidate Pacific walrus, polar bear, and ringed seal, would be present in the Study Area.

Acoustic stressors that may have potential impacts on marine mammals include non-impulsive acoustic sources, aircraft noise, icebreaking noise, impulsive sources, and vessel noise. Physical stressors that may have potential impacts on marine mammals include icebreaking (physical impacts) and vessel and in-water device strike. The stressors associated with expended materials that may have potential impacts on marine mammals are entanglement and ingestion.

4.3.2.5.1 Non-Impulsive Acoustic Sources

Potential Harm

The following marine mammals are susceptible to harm from the non-impulsive acoustic sources during the Proposed Action: beluga whales, bowhead whales, bearded seals, ringed seals, and Pacific walrus. Polar bears are anticipated to remain on the ice surface and not be exposed to non-impulsive acoustic sources in the water column. In assessing the potential effects on marine mammals from the Proposed Action, a variety of factors must be considered, including source characteristics, animal presence, animal hearing range, duration of exposure, and impact thresholds for species that may be present. Potential acoustic impacts could include PTS, TTS, or behavioral effects. To make these assessments, a model was used to quantitatively estimate the potential number of exposures that could occur, followed by a qualitative analysis to account for other factors not reflected by the model.

The Navy Acoustic Effects Model (NAEMO) was used to produce a quantitative estimate of PTS, TTS, and behavioral exposures for marine mammals. The Navy then further analyzed the data and conducted an in-depth qualitative analysis of the species distribution and likely responses to the non-impulsive acoustic sources based on available scientific literature. The determination of the effects to marine mammals was based on this combination of quantitative and qualitative analyses. Additional details on the acoustic modeling can be found in Appendix C.

Quantitative Analysis

A quantitative analysis of the potential effects to marine mammals from the proposed non-impulsive acoustic sources was conducted using a method that calculates the total sound exposure level (SEL) and maximum sound pressure level that a marine mammal may receive from the non-impulsive acoustic sources. NAEMO was used for all modeling analysis (U.S. Department of the Navy 2017c). Environmental characteristics (e.g., bathymetry, wind speed, and sound speed profiles) and source characteristics (i.e., source level, source frequency, transmit pulse length and interval, horizontal and vertical beam width and source depth) were used to determine the propagation loss of the acoustic energy, which was calculated using the Comprehensive Acoustic System Simulation/Gaussian Ray Bundle (CASS/GRAB) propagation model. Additionally, an under-ice model (Oceanographic and Atmospheric Master Library [OAML] ICE) for surface interaction was implemented in NAEMO. The propagation loss then was used in NAEMO to create acoustic footprints. The NAEMO model then simulated source movement through the Study Area and calculated sound energy levels around the source. Animats, or representative animals, were distributed based on density data obtained from the Navy Marine Species Density Database (NMSDD) (U.S. Department of the Navy 2017d). The Navy used a Seasonal Relative Environmental Suitability model (Kaschner et al. 2006), based on seasonal habitat preferences and requirements of known occurrences, such as temperature, bathymetry, and distance to land data and literature review, because occurrence information for marine mammals in the Study Area is not well known. Empirical data is coupled with Relative Environmental Suitability modeling data to generate predictions of density data for locations where no survey data exist. The energy received by each animat distributed within the model was summed into a total sound exposure level. Additionally, the maximum sound pressure level received by each animat was also recorded.

NAEMO provides two outputs. The first is the number of animats recorded with received levels within 1 dB bins at and greater than 100 dB re 1 µPa and the total sound exposure level (in dB re 1 $\mu Pa^2 \cdot s$) for each animat, prior to effect thresholds being applied (referred to as unprocessed animat exposures). These results are used to determine if a marine mammal may be exposed to the acoustic energy resulting from the Proposed Action, but they do not infer that any such exposure results in an effect to the animal from the action. The second output, referred to as calculated exposures, is the predicted number of exposures that could result in effects as determined by the application of acoustic threshold criteria. Criteria and thresholds for measuring these effects induced from underwater acoustic energy have been established for marine mammals. Marine mammal criteria was established based on the following hearing groups: low-, mid-, and high-frequency cetaceans, otariid and non-phocid marine carnivores, and phocid pinnipeds. A summary of physiological and behavioral criteria for both non-impulsive acoustic and icebreaking sources are provided in Table 4-2 for groups of marine mammals that are found within the Study Area. The thresholds established for physiological effects (sound exposure levels for PTS and TTS) for groups of marine mammals that area found in the Study Area are described in detail in National Marine Fisheries Service (2016), behavioral criteria were developed in coordination with NMFS to support Phase III environmental analyses and MMPA Letter of Authorization renewals, and are described in detail in U.S. Department of the Navy (2017a).

Table 4-2. Acoustic In-Water Criteria and Thresholds for Predicting Physiological and Behavioral Effects on Marine Mammals Potentially Occurring in the Study Area

Group	Species	Behavioral Criteria		Physiological Criteria	
		Non-Impulsive Acoustic Sources	Icebreaking Sources	Onset TTS	Onset PTS
Low Frequency Cetaceans	Gray whale, bowhead whale	Low-Frequency BRF dose response function*	120 dB re 1 µPa step function	179 dB SEL cumulative	199 dB SEL cumulative
Mid Frequency Cetaceans	Beluga whale	Mid-Frequency BRF dose response function*	120 dB re 1 µPa step function	178 dB SEL cumulative	198 dB SEL cumulative
Phocidae (in water)	Bearded seal, pacific walrus, ribbon seal, spotted seal, ringed seal	Pinniped Dose Response Function*	120 dB re 1 µPa step function	181 dB SEL cumulative	201 dB SEL cumulative
Otariidae (in water) and other non-phocid marine carnivores	Polar bear	Pinniped Dose Response Function*	120 dB re 1 µPa step function	199 dB SEL cumulative	219 dB SEL cumulative

BRF = Behavioral Response Function
*See Figure 4-2

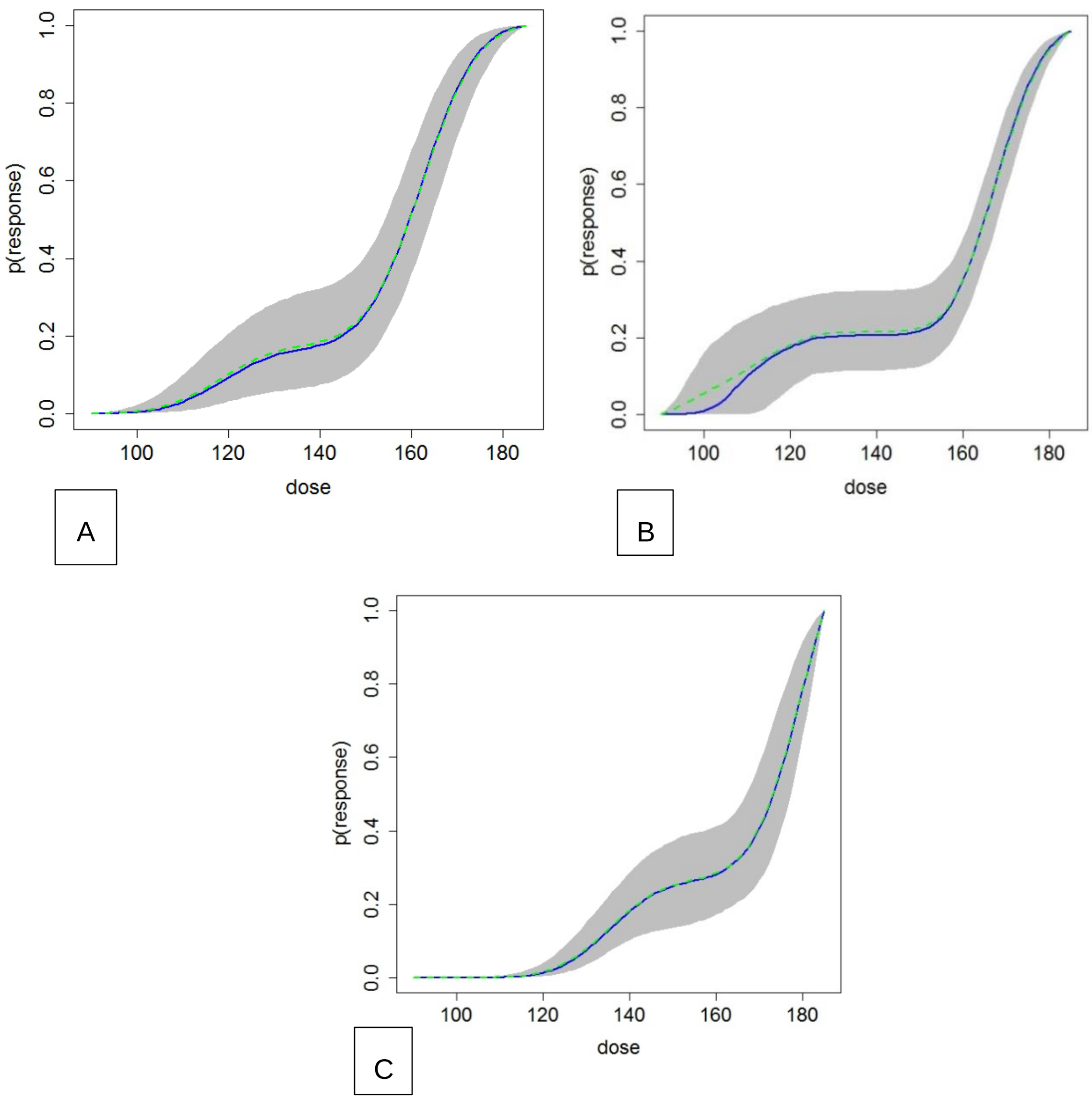

Figure 4-2. A) The Bayesian biphasic dose-response BRF for Odontocetes. B) The Bayesian biphasic dose-response BRF for Pinnipeds C) The Bayesian biphasic dose-response BRF for Mysticetes. The blue solid line represents the Bayesian Posterior median values, the green dashed line represents the biphasic fit, and the grey represents the variance. [X-Axis: Received Level (dB re 1 µPa), Y-Axis: Probability of Response]

The results from the NAEMO acoustic analysis are provided in Table 4-3. Non-impulsive acoustic sources would be active throughout the duration of the three-year Proposed Action. Although, the Proposed Action would occur over a three-year period exposures were calculated on an annual basis. Exposures were calculated based on deployment of all sources during the first cruise. Due to the changing environmental conditions in the Study Area it in unlikely all sources would be deployed in the first permit year, and additional sources would be deployed on subsequent cruises until the maximum amount of sources were deployed. No marine mammals are likely to experience received sound exposure levels that may result in TTS or PTS. Under Alternative 2 (Preferred Alternative) beluga whales, bearded seals, and ringed seals were calculated to potentially be exposed to sound pressure levels that may elicit a behavioral response. Due to the number of behavioral exposures under the Preferred Alternative, the Navy submitted an application for an Incidental Harassment Authorization (IHA) with NMFS for take by Level B harassment of beluga whales, bearded seals, and ringed seals.

Table 4-3. NAEMO-Calculated Marine Mammal Estimated Yearly Exposures

Species	*Alternative 1*			*Alternative 2 (Preferred Alternative)*		
	Behavioral	*TTS*	*PTS*	*Behavioral*	*TTS*	*PTS*
Beluga whale	105	0	0	66	0	0
Bowhead whale[1]	0.34	0	0	0	0	0
Gray whale	0	0	0	0	0	0
Polar bear[1]	0	0	0	0	0	0
Bearded seal[1]	97	0	0	0.39	0	0
Ribbon seal	0	0	0	0	0	0
Ringed seal[2]	3,159	0	0	1,826	0	0
Spotted seal	0	0	0	0	0	0
Pacific Walrus[3]	65	0	0	0	0	0

[1]ESA listed species
[2]ESA listed species pending final judicial resolution of their status.
[3]ESA-Candidate species pending petition for relisting

These quantitative calculations were then analyzed qualitatively, taking into account the best available data on the species itself, and how the species has been observed to respond to similar types of influences.

Qualitative Analysis

No research has been conducted on the potential behavioral responses of ice associated seals and other marine mammals occurring in the Study Area to the type of non-impulsive acoustic sources used during the Proposed Action. However, data are available on effects of non-impulsive acoustic sources (e.g., sonar transmissions) on other phocids and marine mammals which was assessed and incorporated into the findings of this analysis.

<u>Effects of Non-Impulsive Acoustic Sources on Phocids in Water</u>

For non-impulsive sounds (i.e., similar to the sources used during the Proposed Action), data suggest that exposures of pinnipeds to sources between 90 and 140 dB re 1 µPa do not elicit strong behavioral responses; no data were available for exposures at higher received levels for Southall et al., (2007) to include in the severity scale analysis. Reactions of harbor seals (*Phoca vitulina*) were the only available data for which the responses could be ranked on the severity scale. For reactions that were recorded, the majority (17 of 18 individuals/groups) were ranked on the severity scale as a 4 (moderate change in movement, brief shift in group distribution, or moderate change in vocal behavior) or lower; the remaining response was ranked as a 6 (minor or moderate avoidance of the sound source). Additional data on hooded seals (*Cystophora cristata*) indicate avoidance responses to signals above 160–170 dB re 1 µPa (Kvadsheim et al. 2010), and data on gray (*Halichoerus grypus*) and harbor seals indicate avoidance response at received levels of 135–144 dB re 1 µPa (Götz et al. 2010). In each instance where food was available, which provided the seals motivation to remain near the source, habituation to the signals occurred rapidly. In the same study, it was noted that habituation was not apparent in wild seals where no food source was available (Götz et al. 2010). This implies that the motivation of the animal is necessary to consider in determining the potential for a reaction. In one study aimed to investigate the under-ice movements and sensory cues associated with under-ice navigation of ice seals, acoustic transmitters (60–69 kHz at 159 dB re 1 µPa at 1 m) were attached to ringed seals (Wartzok et al. 1992a;

Wartzok et al. 1992b). An acoustic tracking system then was installed in the ice to receive the acoustic signals and provide real-time tracking of ice seal movements. Although the frequencies used in this study are at the upper limit of ringed seal hearing, the ringed seals appeared unaffected by the non-impulsive acoustic sources, as they were able to maintain normal behaviors (e.g., finding breathing holes).

Seals exposed to non-impulsive acoustic sources with a received sound pressure level within the range of calculated exposures, (142–193 dB re 1 µPa), have been shown to change their behavior by modifying diving activity and avoidance of the sound source (Götz et al. 2010; Kvadsheim et al. 2010). Although a minor change to a behavior may occur as a result of exposure to the sources in the Proposed Action, these changes would be within the normal range of behaviors for the animal (e.g., the use of a breathing hole further from the source, rather than one closer to the source, would be within the normal range of behavior) (Kelly et al. 1988).

Effects of Non-Impulsive Acoustic Sources on Other Marine Mammals within the Study Area

While not many studies have been done on mysticete responses to sonar behavioral response studies have been conducted. Although some strong responses have been observed in mysticetes to sonar and other active acoustic sources for the most part mysticete responses appear to be fairly moderate across all received levels. While some responses such as cessation of foraging or changes in dive behavior could carry short-term impacts, in all cases behavior returned to normal after the signal stopped. Mysticete responses also seem to be highly mediated by behavioral state, with no responses occurring in some behavioral states, and contextual factors and signal characteristics having more impact than received level alone. Many of the contextual factors resulting from the behavioral response studies (e.g., close approaches by multiple vessels or tagging) would not occur during the Proposed Action. Mysticete behavioral responses to acoustic transmission from the Proposed Action would likely be a result of the animal's behavioral state and prior experience rather than external variables such as ship proximity; thus, if significant behavioral responses occur they would likely be short-term. In fact, no significant behavioral responses such as panic, stranding or other severe reactions have been observed during monitoring of actual training exercises (Department of the Navy 2011, 2014; Smultea and Mobley 2009; Watwood et al. 2012).

Effects of Non-Impulsive Acoustic Sources on Odobenidae within the Study Area

Typical behavioral responses by Pacific walruses to disturbances include: altered headings; increased swimming rates; increased vigilance; changes in dive, surfacing, respiration, feeding, and vocalization patterns; and hormonal stress production (Ellison et al. 2012; Richardson et al. 1995b; Southall et al. 2007). Low-level reactions are common and can be caused by both natural and anthropogenic sources. Significant behavioral responses include displacement from preferred foraging areas, increased stress levels or energy expenditures, or cessation of feeding. Noise may evoke behavioral responses in addition to the possible impacts to hearing (i.e., TTS or PTS). Passive acoustic monitoring conducted during 2016 cable laying on the Beaufort and Chukchi shelf documented Pacific walruses vocalizing in the local area before and after, but not during, cable-laying work. There is a possibility that the Pacific walruses either moved or ceased vocalizing due to the project's noise (Owl Ridge Natural Resource Consultants Inc 2017). This may be an indication of auditory masking (a change in the ability to detect relevant sounds in the presence of other sounds (Wartzok et al. 2003). The biological implications of anthropogenic masking among walruses are unknown, but if the Pacific walruses' response to masking is to leave the area, then the physiological costs are similar to those of other disturbances that trigger the same response. The response of walruses to disturbance stimuli is highly variable. Observations by walrus hunters and researchers suggest that males tend to be more tolerant of disturbances than females, and individuals tend to be more tolerant than groups; females with dependent calves are considered least tolerant of disturbances.

The most likely behaviorally significant responses that the Proposed Action could evoke among Pacific walruses include temporary cessation of feeding, resting, or communicating. Effects of these types of mid-level responses include increased energy expenditures and stress levels. Energetic costs are incurred from loss of forage and energy expended while travelling to another region.

Similarly, a controlled exposure study to simulated mid-frequency sonar was conducted with U.S. Navy California sea lions (*Zalophus californianus*; an appropriate surrogate for Pacific walrus based on similarities in hearing and ear morphology) at the Navy Marine Mammal Program facility specifically to study behavioral reactions (Houser et al. 2013a). Animals were trained to swim across a pen, touch a panel, and return to the starting location. During transit, a simulated mid-frequency sonar signal was played. Behavioral reactions included increased respiration rates, prolonged submergence, and refusal to participate, among others. Younger animals were more likely to respond than older animals, while some sea lions did not respond consistently at any sound source level.

Alternative 1

As described above, the sound sources in Alternative 1 would be deployed in both the deep and shallow portions of the Study Area. Active acoustic sources are expected to result in, at most, minor to moderate avoidance responses of animals, over short and intermittent periods of time.

The Proposed Action is not expected to cause significant disruptions such as mass haul outs, or abandonment of breeding, that would result in significantly altered or abandoned behavior patterns. Given this, in accordance with the ESA the non-impulsive acoustic sources in the Proposed Action may affect, likely to adversely affect the bowhead whale, bearded seal, ringed seal, and Pacific walrus. Since quantitative modeling in NAEMO showed no exposures for polar bear, non-impulsive acoustic sources associated with the Proposed Action would have no effect on the ESA-listed polar bear.

In accordance with E.O. 12114, non-impulsive acoustic sources from Alternative 1 are not likely to significantly harm marine mammals.

Alternative 2 (Preferred Alternative)

Permitted sound sources in Alternative 2, would only be deployed in the deep water of the Study Area and no towing of active acoustic sources would occur in the shallow water. Active non-impulsive acoustic sources are expected to result in, at most, minor to moderate avoidance responses of animals, over short and intermittent periods of time. As such, the Navy submitted an application for an IHA with NMFS for Level B take of ringed seals, beluga whales, and bearded seals. Since the Proposed Action depends on how many sources can be deployed on each cruise (sources would be deployed each cruise until the maximum amount of sources were deployed) annual requests for IHAs would be completed throughout the duration of the Proposed Action.

The Proposed Action is not expected to cause significant disruptions such as mass haul outs, or abandonment of breeding, that would result in significantly altered or abandoned behavior patterns. Given this, in accordance with the ESA the non-impulsive acoustic sources in the Proposed Action may affect, likely to adversely affect the bearded seal, and ringed seal. Since modeling in NAEMO showed no exposures to the ESA-listed polar bear, bowhead whale, and ESA-candidate Pacific walrus under Alternative 2, non-impulsive acoustic sources would have no effect on the ESA-listed polar bear, bowhead whale, and ESA-candidate Pacific walrus. In accordance with E.O. 12114, non-impulsive acoustic sources from Alternative 2 are not likely to significantly harm marine mammals.

4.3.2.5.2 Aircraft Noise

Potential Harm

Potential effects to mammals from aircraft activity could involve both acoustic and non-acoustic effects. It is uncertain if an animal reacts to the sound of the aircraft or to its physical presence flying overhead, or both. It has been noted that pinniped hearing sensitivity is reduced at frequencies below 2 kHz, and generally pinnipeds are less sensitive than humans to airborne sounds less than 10 kHz (Richardson et al. 1995b). Reactions of hauled out pinnipeds to aircraft flying overhead have been noted, such as looking up at the aircraft, moving on the ice or land, entering a breathing hole or crack in the ice, or entering the water (Blackwell et al. 2004; Born et al. 2004). Reactions depend on several factors including the animal's behavioral state, activity, group size, habitat, and the flight pattern of the aircraft (Richardson et al. 1995b). Walruses, for example, have very varied reactions to aircraft overflights from looking upward to diving underwater (Richardson et al. 1995b). Studies have shown both hauled out ringed and bearded seals sometimes react to low flying aircraft or helicopter by diving into the water (Alliston 1981; Burns 1970; Burns and Frost 1979; Burns and Harbo 1972; Burns et al. 1982). Additionally, a study conducted by Born et al (1999) found that wind chill was also a factor in level of response of ringed seals hauled out on ice (higher wind chill increases probability of leaving the ice), as well as time of day and relative wind direction. Mammal reactions to helicopter disturbance are difficult to predict, though helicopters have been recorded to elicit a stronger behavioral response from ringed and bearded seals than a fixed-wing aircraft (Born et al. 1999; Burns and Frost 1979).

The response by ringed seals to aircraft noise is variable based upon time of year, prevailing weather, and location. Another factor that could impact ringed seal response is whether the animal is hauled out or in a subnivean lair, as the subnivean response is typically stronger than that of a basking ringed seal (Burns et al. 1982). During the Proposed Action, ringed seals may be on the ice, within their subnivean lairs, or in the water during this period. The other ice associated seals (i.e., bearded seals, spotted seals, and ribbon seals) would either be in the water or hauled out on the ice during the Proposed Action. Ringed seals were shown to leave their subnivean lairs and enter the water when a helicopter was at an altitude of less than 1,000 ft (305 m) and within 1 nm (2 km) lateral distance (Richardson et al. 1995b). However, ringed seal vocalizations in water were similar between areas subject to low-flying aircraft and areas that were less disturbed (Calvert and Stirling 1985). These data suggest that although a ringed seal may leave a subnivean lair, aircraft disturbance does not cause the animals to leave the general area. Additionally, ringed seals construct multiple breathing holes and lairs within their home ranges (Smith and Stirling 1975); these additional lairs and breathing holes are used as escape lairs from predators, and therefore would be a suitable alternative in the event they leave a lair directly below the flightpath of an aircraft. The helicopter, would avoid pressure ridges and other sensitive areas where seals would occur, further minimizing potential disturbance. The helicopter, would operate short term and overall flight times and only occur for limited duration (approximately 3 hours per flight transit).Observations of ringed seals within the water column showed some ringed seals surfaced 66 to 98 ft (20 to 30 m) from the edge of an ice pan only a few minutes after a helicopter had landed and shut down near the ice edge (Richardson et al. 1995b). However, the specific responses by ringed seals to aircraft have not been observed frequently.

Spotted seals haul out on sea ice react at considerable distances to aircraft by moving swiftly across ice floes and diving off into the water (Richardson et al. 1995b). Spotted seals on beaches move into the water when a survey aircraft flies over at altitudes up to 1,000 to 2,493 ft (305 to 760 m) or more and at lateral distances up to 0.54 nm (1 km). This fleeing behavior persists despite frequent exposure to aircraft overflights, but the seals return to their haul out sites shortly after exposure (Richardson et al. 1995b). Bearded seals often dive, when hauled out on ice, when approached by low-flying aircraft.

Polar bears have been seen running away from helicopters flying at an altitude of less than 656 ft (200 m) or at a distance of less than 1,312 ft (400 m) (Richardson et al. 1995b). A helicopter approaching close to a polar bear den does not usually cause the polar bear to abandon the den since snow greatly attenuates helicopter noise (Amstrup 1993; Blix and Lentfer 1992). It is unlikely that an individual would be exposed repeatedly for long periods of time due to the short duration of the aircraft overflights during the Proposed Action. Additionally, the Proposed Action would not likely be near polar bear dens, considering the vast size of the polar bear home range leading to a decreased potential for a polar bear to be within the same vicinity of an aircraft overflight from the Proposed Action. Therefore, the likelihood of a bear being under the flight path for multiple flights would be low. Any reactions to aircraft overflights would be short-term, infrequent, and would not be expected to disrupt major behavior patterns such as migrating, breeding, feeding, and sheltering, or injure any polar bears.

Cetaceans exhibit various behavioral reactions to aircraft overflights such as diving underwater, slapping the water's surface with their flukes or flippers, or swimming away from the aircraft track (Richardson et al. 1995b). Belugas may swim away, dive abruptly, look upwards, or turn sharply away from low-altitude overflights (Richardson et al. 1995a). They have also been recorded to have no visual behavioral reaction to aircraft flights within 328 to 656 ft (100 to 200 m) (Richardson et al. 1995b). Bowhead whales react to overflight aircrafts in various ways as well such as diving underwater, turning away from the aircraft, and dispersing away from the area exposed to the aircraft. Bowheads appear to be more susceptible to aircraft overflights while resting and less so when actively feeding, mating, or socializing. Observations of bowhead whales to helicopters showed responses only occurring when the aircraft was at altitudes of less than 492 ft (150 m), and lateral distances less than 820 ft (250 m) (Hutchinson and Ferrero 2011). Gray whales also show variable reactions to aircrafts. Mother-calf pairs appeared to be more sensitive than migrating gray whales, which rarely showed any behavioral reactions (Richardson et al. 1995b). Gray whales showed minor avoidance when they were exposed to playbacks of helicopter noise (Malme et al. 1984).

Alternative 1

Aircraft noise from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals, in that the same aircraft would be utilized for both alternatives. Due to the insignificant and short-term reactions to aircraft noise, aircraft noise associated with the Proposed Action would not result in significant harm to marine mammals. Additionally, aircraft noise associated with the Proposed Action would not result in any reasonable foreseeable takes under the MMPA. Aircraft noise associated with the Proposed Action may affect, but is not likely to adversely affect the ESA-listed bowhead whale, bearded seal, polar bear, ringed seal and the ESA-candidate Pacific walrus. In accordance with E.O. 12114, aircraft noise associated with Alternative 1 would not result in significant harm to marine mammals.

Alternative 2 (Preferred Alternative)

Aircraft noise from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals, in that the same aircraft would be utilized for both alternatives. Due to the insignificant and short-term reactions to aircraft noise, aircraft noise associated with the Proposed Action would not result in significant harm to marine mammals. Additionally, aircraft noise associated with the Proposed Action would not result in any reasonable foreseeable takes under the MMPA. Aircraft noise associated with the Proposed Action may affect, but is not likely to adversely affect the ESA-listed bowhead whale, bearded seal, polar bear, ringed seal and the ESA-candidate Pacific walrus. In accordance with E.O. 12114, aircraft noise associated with Alternative 2 would not result in significant harm to marine mammals.

4.3.2.5.3 Icebreaking Noise

Potential Harm

Icebreaking noise was modeled using similar methods to those described in Section 4.1.1.3. Below is a quantitative analysis of the modeling results for CGC HEALY icebreaking as well as a qualitative analysis for icebreaking noise.

Quantitative Analysis

The underwater radiated noise signature for icebreaking in the central Arctic Ocean by CGC HEALY during different types of ice-cover was characterized in Roth et al. (2013). The radiated noise signatures were characterized for various fractions of ice cover. For modeling, the 8/10 and 3/10 ice cover were used. Each modeled day of icebreaking consisted of 16 hours of 8/10 ice cover and 8 hours of 3/10 ice cover. Icebreaking was modeled for one day during 2018, and for three days each subsequent year of the Proposed Action. Since ice forecasting cannot be predicted more than a few weeks in advance it is unknown if icebreaking would be needed to deploy or retrieve the sources after one year of transmitting. Therefore, icebreaking was conservatively analyzed within this OEA. Figure 5a and 5b in Roth et al (2013) depicts the source spectrum level versus frequency for 8/10 and 3/10 ice cover, respectively. The sound signature of each of the ice coverage levels was broken into 1-octave bins (Table 4-4 and Table 4-5). In the model, each bin was included as a separate source on the modeled vessel. When these independent sources go active concurrently, they simulate the sound signature of CGC HEALY. The modeled source level summed across these bins was 196.2 dB for the 8/10 signature and 189.3 dB for the 3/10 ice signature. These source levels are a good approximation of the icebreaker's observed source level (provided in Figure 4b of (Roth et al. 2013)). Each frequency and source level was modeled as an independent source, and applied simultaneously to all of the animats within NAEMO. Each second was summed across frequency to estimate sound pressure level (root mean square [SPL_{RMS}]). This value was incorporated into the behavioral risk function to estimate behavioral exposures. For PTS and TTS determinations, sound exposure levels were summed over the duration of the test and the transit to the deep water deployment area. The method of quantitative modeling for icebreaking is considered to be a conservative approach; therefore, the number of takes estimated for icebreaking are likely an over-estimate and would not be expected to reach that level.

Table 4-4. Modeled Bins for 8/10 Ice Coverage (Full Power) Ice Breaking on CGC HEALY

25	189
50	188
100	189
200	190
400	188
800	183
1600	177
3200	176
6400	172
12800	167

Table 4-5. Modeled Bins for 3/10 Ice Coverage (Quarter Power) Ice Breaking on CGC HEALY

Frequency (Hz)	*Source Level (dB)*
25	187
50	182
100	179
200	177
400	175
800	170
1600	166
3200	171
6400	168
12800	164

Icebreaking is generally characterized as a low-frequency (10-100 Hz), non-impulsive sound. Icebreaking is a combination of the sounds made by the vessel's engine and propeller while icebreaking and the sound(s) created by the breaking of ice. As such, it is not appropriate to use the behavioral risk function to evaluate potential impacts to marine mammals because the behavioral risk function was derived from mid-frequency sonar sources that are narrow band (versus the broadband noise from icebreaking). Generic received levels (RL) thresholds for behavioral disturbance (120 dB re 1 μPa_{rms}), regardless of functional hearing group, have been applied, although efforts have been made to improve data, including the addition of unique RL thresholds for behavioral disturbance specific to species (harbor porpoise and beaked whales; 80 FR 31738; 2015). Specific to the harbor porpoise, a step function and not a curve (and assuming uniform density) was applied to evaluate take from Level B harassment (80 FR 31738; 2015). Although a step function may over-estimate the effects of icebreaking, a step function at an SPL of 120 dB re 1 μPa was conservatively used.

The output from the acoustic model is the calculated number of marine mammals exposed at or above acoustic effects thresholds listed in Table 4-2. Icebreaking could occur on each CGC HEALY cruise in the deep water area of the Study Area. Exposures were calculated on a daily basis, and summed to calculate a total estimated exposure value for the duration of the Proposed Action. Due to the changing environmental conditions in the Study Area it is unknown how long icebreaking would occur each year. However, it is anticipated from previous cruises that no more than three days of icebreaking would be required to reach the areas for deployment or recovery during the summer months.

As varying levels of icebreaking are expected on a year-to-year basis, modeled exposures have been broken out in the tables below. Exposures provided in Table 4-6 are for the one day of anticipated icebreaking during the CGC HEALY cruise in 2018. Exposures provided in Table 4-7 are for the maximum annual amount of icebreaking during the CGC HEALY cruise for the years 2019, 202, and 2021 (three days per year).

Table 4-6. Model-Calculated Acoustic Exposures for CGC HEALY Icebreaking During the Proposed Action (2018 only)

Species	*Alternatives 1 and 2*		
	Behavioral	*TTS*	*PTS*
Beluga whale	7	0	0
Bowhead whale[1]	0	0	0
Gray whale	0	0	0
Polar bear[1]	0	0	0
Bearded seal[1]	0	0	0
Ringed seal[2]	357	0	0
Ribbon seal	0	0	0
Spotted seal	0	0	0
Pacific walrus[3]	0	0	0

[1]ESA Listed Species
[2]ESA listed species pending final judicial resolution of their status.
[3]ESA-Candidate species pending petition for relisting

Table 4-7. Model-Calculated Yearly Acoustic Exposures for CGC HEALY Icebreaking During the Proposed Action (2019-2021)

Species	*Alternatives 1 and 2*		
	Behavioral	*TTS*	*PTS*
Beluga whale	19	0	0
Bowhead whale[1]	0	0	0
Gray whale	0	0	0
Polar bear[1]	0	0	0
Bearded seal[1]	0	0	0
Ringed seal[2]	888	1	0
Ribbon seal	0	0	0
Spotted seal	0	0	0
Pacific walrus[3]	0	0	0

[1]ESA Listed Species
[2]ESA listed species pending final judicial resolution of their status.
[3]ESA-Candidate species pending petition for relisting

The quantitative analysis calculated that most marine mammals in the Study Area would not experience behavioral response, TTS, or PTS from the Proposed Action under either alternative for sound generated from icebreaking, excluding one possible acoustic exposure to ringed seal above the TTS threshold. However, modeling results indicated that icebreaking would result in 3,020 behavioral exposures to ringed seals and 63 behavioral exposures to beluga whales under either alternative over the course of the Proposed Action, suggesting the possibility of eliciting a behavioral response.

The likelihood of a behavioral response is dependent upon the received sound pressure level. NAEMO provides two outputs. The first is the number of animats recorded with received levels within 1 dB bins at and greater than 100 dB re 1 µPa, prior to effect thresholds being applied (referred to as unprocessed animat exposures). These results are used to determine if a marine mammal may be exposed to the acoustic energy resulting from the Proposed Action, but they do not infer that any such exposure results in an effect from the action. The second output, referred to as calculated exposures (as seen in Table 4-6), is the predicted number of exposures that could result in effects from the Proposed Action after the application of the behavioral risk function and acoustic threshold criteria. Additional details on the acoustic modeling can be found in Appendix C.

As discussed above, the quantitative output calculated that 3,021 ringed seals and 63 beluga whales could be exposed to sound pressure levels that may elicit at least a behavioral response. These quantitative calculations are then analyzed qualitatively by marine biologists and acoustic experts, taking into account the best available data on the species itself, and how the species has been observed to respond to similar types of influences.

Qualitative Analysis – All Species

The Navy conducted the following additional qualitative assessment of acoustic effects to ringed seals to determine whether the calculated exposures from the NAEMO output actually constitute harassment pursuant to the ESA.

The behavioral response function (BRF) is limited in that it mainly differentiates behavioral responses based on the received level of sound. However, many other variables such as the marine mammal's gender, age, the activity it is engaged in during a sound exposure, its distance from a sound source, the number of sound sources, and whether the sound sources are approaching or moving away from the animal can be critically important in determining whether and how a marine mammal would respond to a sound source (Southall et al. 2007). Furthermore, the BRF does not differentiate between different types of behavioral reactions (e.g., area avoidance, diving avoidance, or alteration of natural behavior) or provide information regarding the predicted consequences to the animal of the reaction. At present, available data do not allow for incorporation of these other variables in the current BRF; they must be assessed qualitatively.

Data are available on the effects of icebreakers and impulsive sources (e.g., seismic airguns) on ringed seals and other marine mammals in water, though not physically the same impulsive source sounds would be the closest representative sound to icebreaking due to their wideband frequency spectrum and short duration. The available information was assessed and incorporated into the findings of this analysis.

Effects of Impulsive Sources on Ringed Seals in Water

Southall et al. (2007) summarized data on behavioral reactions of pinnipeds in water to non-impulsive and impulsive sources (termed nonpulse and pulse sources, respectively), and ranked these reactions on a severity scale. For impulsive sources (e.g., airguns), data indicate that exposures between 150 and 180 dB re 1 µPa generally have limited potential to induce avoidance responses in pinnipeds, whereas higher received levels have exhibited some responses (Southall et al. 2007). Data used to identify the severity of behavioral reactions (Southall et al. 2007) are based primarily on ringed seals, but also include bearded and spotted seals (Blackwell et al. 2004; Harris et al. 2001; Miller et al. 2005). For received sound pressure levels between 140 dB re 1 µPa and 200 dB re 1 µPa, responses to impulsive sources were either 0 on the severity scale (no observable response; 49 percent of responses) or 6 on the severity scale (minor or moderate avoidance of the sound source; 51 percent of responses). The majority of the severity 6 responses (92 percent) occurred at sound pressure levels between 190 dB re 1 µPa and 200 dB re 1 µPa. Southall et al. (2007) found that within the range of sound pressure levels of approximately 150–190 dB re 1 µPa, 91 percent of individuals/groups were observed to have no response (severity scale ranking of 0) to the impulsive source. The remaining 9 percent were ranked on the severity scale as a 6, as minor or moderate avoidance reactions were observed. All of the reactions noted as a 6 on the severity scale (avoidance) are attributed to open-water use of a full-array up to eleven 120 in^3 (1,966 cm^3) airguns. The avoidance of the area was relatively minor; some (but not all) seals avoided the zone within 492 ft (150 m) of the source, but did not move much beyond 820 ft

(250 m) from the source. Additionally, the seismic operations with the full-array did not cause seals to desert the general area of the activity (Harris et al. 2001).

Although the icebreaking associated with the Proposed Action is not impulsive in a strict sense, the data on ringed seal reactions during seismic surveys nonetheless indicate that ringed seals have shown little reaction to noise disturbance in general within the sound pressure levels potentially received from the Proposed Action. Any behavioral reaction is expected to be short term, as icebreaking would occur in small areas and would be transient in nature, which reduces the probability of encountering a marine mammal during icebreaking activities. Behavioral reactions would be limited to swimming away, hauling out, diving underwater and, in some cases, avoidance behavior. These short-term reactions are not expected to significantly disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding and sheltering to a point where the behavior pattern is abandoned or significantly altered.

Effects of Icebreaking on Marine Mammals

Marine mammals have been recorded in several instances altering and modifying their vocalizations to compensate for the masking noise from vessels, or other similar sounds (Holt et al. 2011; Parks et al. 2011). Vocal changes in response to anthropogenic noise can occur across the repertoire of sound production modes used by marine mammals, such as whistling, echolocation click production, calling, and singing. Changes to vocal behavior and call structure may result from a need to compensate for an increase in background noise. In cetaceans, vocalization changes have been reported from exposure to anthropogenic sources such as sonar, vessel noise, and seismic surveying.

Icebreaking noise has the potential to disturb marine mammals and elicit an alerting, avoidance, or other behavioral reaction (Huntington et al. 2015; Pirotta et al. 2015; Williams et al. 2014). Icebreaking in fast ice during the spring can cause behavioral reactions in beluga whales. Erbe and Farmer (2000) calculated the zone of impacts to beluga whales from icebreakers in the Beaufort Sea using data from Canadian icebreakers. Beluga whales had a zone of behavioral disturbance out to 25 nm (46 km) in a shipping corridor near Beluga Bay, and 16 nm (30 km) when the icebreaker was over the abyssal plain in response to ramming noise from an icebreaker. Bowheads have been observed avoiding areas within 13 nm (25 km) of an icebreaking site (Richardson et al. 1995b). Icebreaking associated with the Proposed Action would occur in in the August through October timeframe, which lessens the probability of a whale encountering the vessel.

Fay et al. (1984) compared the behavioral reactions of walruses to both icebreaking vessels and vessels in open water. Walruses tended to exhibit behavioral reactions to icebreaking at longer distances than from vessels in open water. Aerial surveys also indicated that walruses appeared to avoid areas within 5 to 8 nm (10 to 15 km) of an icebreaking vessel (Brueggeman et al. 1991). However, walruses are not located in the areas where icebreaking would occur and would not be affected by icebreaking. Ringed seals and bearded seals on pack ice showed various behaviors when approached by an icebreaking vessel; a majority of seals dove underwater when the ship was within 0.5 nm (0.93 km) while others remained on the ice. However, as icebreaking vessels came closer to the seals, most dove underwater. Ringed seals have also been observed foraging in the wake of an icebreaking vessel (Richardson et al. 1995b). In a studies by Alliston (Alliston 1980; Alliston 1981), there was no observed change in the density of ringed seals in areas that had been subject to icebreaking. Alternatively, ringed seals may have preferentially established breathing holes in the ship tracks after the icebreaker moved through the area. Due to the time of year of the activity (August through October), ringed seals are not expected to be within the subnivean lairs nor pupping (Chapskii 1940; McLaren 1958; Smith and Stirling 1975). Therefore, icebreaking would not impact seals which could not visually detect an oncoming vessel.

Polar bears do not appear to be significantly affected by icebreaking noise and show very little reaction to icebreaking vessels (Richardson et al. 1995b). Polar bears that did react to icebreaker presence had the following reactions: walking away, running away, approaching, vigilance, and no reaction. Vigilance was the most common observed reaction in a study by Smultea et al. (2016). Polar bears that did react by walking or running away was brief in duration (less than five minutes) when the icebreaker was within 1,640 ft (500 m) or less.

Alternative 1

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals as the same vessel would be used. Icebreaking noise associated with the Proposed Action may cause a behavioral reaction to the ringed seal and beluga whale. Icebreaking noise associated with the Proposed Action may affect, likely to adversely affect the ESA-listed ringed seal. Since acoustic modeling was completed using NAEMO and there were no takes for ESA-listed bowhead whales, bearded seals, polar bears, and the ESA-candidate Pacific walrus, icebreaking noise associated with the Proposed Action would have no effect on ESA-listed bowhead whales, bearded seal, polar bear, and the ESA-candidate Pacific walrus. In accordance with E.O. 12114 icebreaking noise associated with Alternative 1 would not result in significant harm to marine mammals.

Alternative 2 (Preferred Alternative)

Icebreaking noise from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals as the same vessel would be used. Icebreaking noise associated with the Proposed Action may cause a behavioral reaction to the ringed seal and beluga whale. As such, the Navy submitted an application for an IHA with NMFS for Level B take of ringed seals and beluga whales under the MMPA. Icebreaking noise associated with the Proposed Action may affect, likely to adversely affect the ESA-listed ringed seal. Since acoustic modeling was completed using NAEMO and there were no takes for ESA-listed bowhead whales, bearded seals, polar bears, and the ESA-candidate Pacific walrus, icebreaking noise associated with the Proposed Action would have no effect on ESA-listed bowhead whales, bearded seal, polar bear, and the ESA-candidate Pacific walrus. In accordance with E.O. 12114 icebreaking noise associated with Alternative 2 would not result in significant harm to marine mammals.

4.3.2.5.4 Impulsive Sources

Potential Harm

The potential for direct injury to marine mammals is inferred from terrestrial mammal experiments and from post-mortem examination of marine mammals believed to have been exposed to underwater explosions (Ketten et al. 1993; Richmond et al. 1973; Yelverton et al. 1973). Additionally, noninjurious effects on marine mammals are extrapolated to injurious effects based on data from terrestrial mammals to estimate the potential for injury (Southall et al. 2007). Actual effects on marine mammals may differ due to anatomical and physiological adaptations to the marine environment; e.g., some characteristics such as a reinforced trachea and flexible thoracic cavity (Ridgway and Dailey 1972) may or may not decrease the risk of lung injury.

Vocal changes in response to anthropogenic noise can occur across the repertoire of sound production modes used by marine mammals, such as whistling, echolocation click production, calling, and singing. Differential vocal responses in marine mammals were documented in the presence of seismic survey noise. An overall decrease in vocalization during active surveying was noted in large marine mammal groups (Potter et al. 2007).

The response of a marine mammal to an anthropogenic sound may depend on the frequency, duration, temporal pattern and amplitude of the sound as well as the animal's prior experience with the sound and the context in which the sound is encountered (i.e., what the animal is doing at the time of the exposure) (reviewed in (Nowacek et al. 2007; Richardson et al. 1995b; Southall et al. 2007)). Although sample sizes are small, the data collected to date suggest that different types of sounds potentially cause variable degrees of stress in marine mammals. Belugas demonstrated no catecholamine (hormones released in situations of stress) response to the playback of oil drilling sounds (Thomas et al. 1990) but showed an increase in catecholamines following exposure to impulsive sounds produced from a seismic water gun (Romano et al. 2004).

Quantitative Analysis

A quantitative analysis of the potential effects to marine mammals from the proposed airgun and compact sound source use was conducted. The impulsive approach is the same as the acoustic approach described in Section 4.3.2.5.1 above, with the differences described in this section. The impulsive model for airgun and compact sound source modeling uses the following metrics to describe the sound received by animats: peak SPL, SPL_{RMS}, and SEL. Sound pressure level is the logarithm of the ratio of sound pressure to a relative pressure. The peak sound pressure level is the maximum SPL over time. The root mean square pressure level is an average SPL over the duration of the signal. The SPL_{RMS} criteria is only applied to airguns. Sound exposure level represents both the SPL of a sound as well as its duration. Impulse is the integral of positive pressure over a brief time period. The impulse metric is only applied to explosive impulses.

The impulsive modeling approach also uses CASS/GRAB to create a frequency band-limited transfer function that is combined with a similitude source signature to obtain a pressure time series. The main difference between impulsive and non-impulsive modeling is that the impulsive signal is time-dependent, whereas the pressure field for non-impulsive acoustic sources is modelled as an instantaneous phenomenon (Deavenport and Gilchrest 2015). This is because impulsive signals are time-dependent processes characterized by a rapid rise and subsequent fall in pressure. The time dependence is incorporated by using outputs from CASS/GRAB to build a transfer function, and convolving this with a similitude source signature. Propagation for impulsive sources is run along nine equally spaced radials from an analysis point to 16 nm (30 km). The range is extended to 54 nm (100 km) if any of the metrics are still above threshold at 16 nm (30 km). Each of the above metrics are summarized into tables for each bearing, range, and depth to be used in the impulsive simulator. Additional details on the impulsive modeling process can be found in Department of the Navy (2017c).

As with the acoustic modeling analysis above NAEMO provides the same outputs for impulsive modeling of the airgun and compact sound source. Calculated exposures of marine mammals are determined by the application of the impulsive threshold criteria. Marine mammal criteria for impulsive use the same hearing groups as the acoustic criteria. The thresholds established for physiological effects (sound exposure levels for PTS and TTS) and behavioral effects are provided in Table 4-7 for groups of marine mammals that are found within the Study Area and are described in detail in National Marine Fisheries Service (2016).

Table 4-8. Impulsive In-Water Criteria and Thresholds for Predicting Physiological and Behavioral Effects on Marine Mammals Potentially Occurring in the Study Area

Hearing Group	*Behavioral Threshold*		*TTS Threshold*		*PTS Threshold*	
	Airgun (SPL in dB re 1 µPa [$rms_{90\%}$])	*Compact sound source (SEL in dB re 1 µPa^{2}s)*	*SEL (weighted) (dB SEL)*	*Peak SPL (dB SPL)*	*SEL (weighted) (dB SEL)*	*Peak SPL (dB SPL)*
Low Frequency Cetaceans	160	163 (low frequency weighting function)	168	213	183	219
Mid Frequency Cetaceans	160	165 (mid frequency weighting function)	170	224	185	230
Phocidae (in water)	160	165 (phocid weighting function)	170	212	185	218
Otariidae (in water) and other non-phocid marine carnivores	160	183 (otariid weighting function)	188	226	203	232

Behavioral response criteria are used to estimate the number of exposures that may result in a behavioral response. For airguns determination of a significant behavioral response for marine mammals was based on the SPL on the highest received signal. Both the compact sound source and airguns use the impulsive behavioral criteria for multiple shots. Behavioral criteria for the compact sound source uses SEL along with the weighting functions provided in Figure 4-3. Additionally, mammals must be exposed to this level more than once to receive a behavioral exposure.

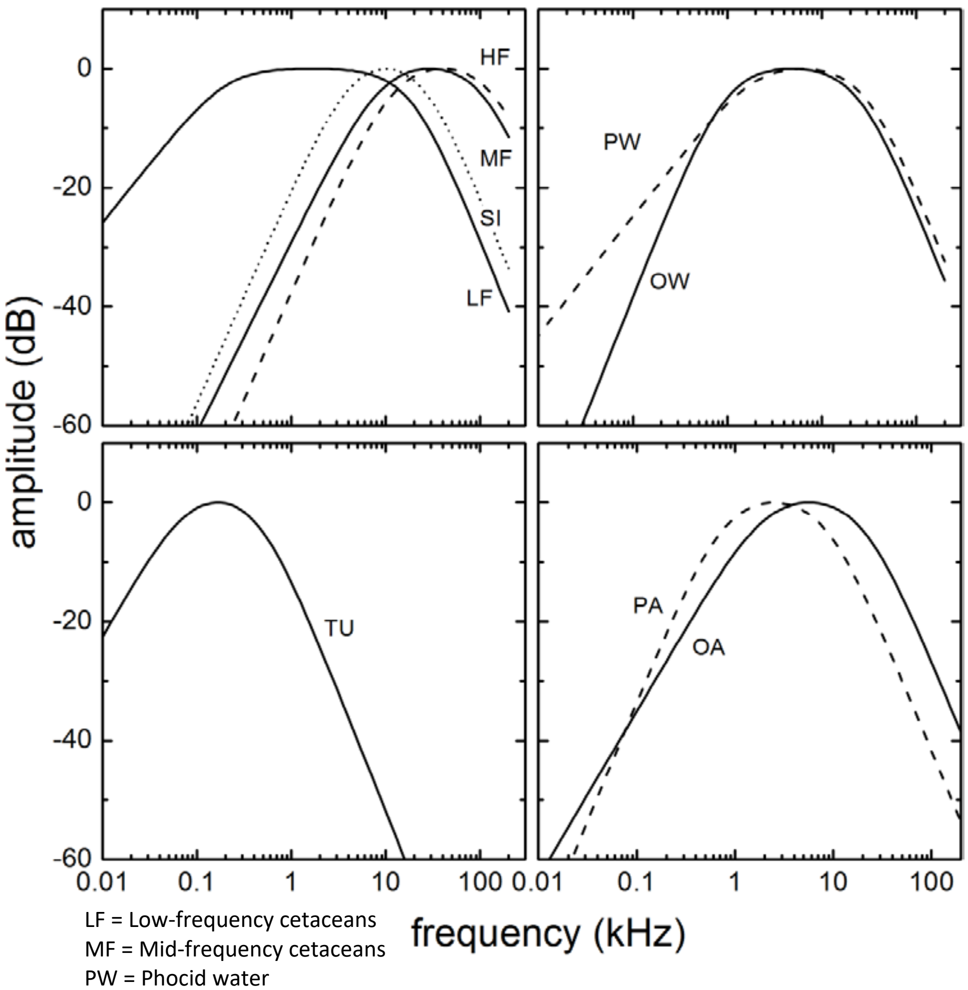

Figure 4-3. Navy Phase III Weighting Functions for all Species Groups. Parameters required to generate the functions that are provided in Table 4-7 above.

The output from the acoustic model is the calculated number of marine mammals exposed at or above acoustic effects thresholds listed in Table 4-8. Impulsive acoustic sources would be active during each cruise over the three-year Proposed Action. Although, the Proposed Action would occur over a three-year period exposures were calculated on an annual basis. Exposures were calculated based on the maximum amount of active time the impulsive sources could be used during each cruise. Due to the changing environmental conditions in the Study Area the actual amount of days impulsive sources would be used is unknown. Only the ringed seal received Level B exposures from the use of airguns and the compact sound source used in the Proposed Action.

Table 4-9. Model-Calculated Yearly Exposures for Impulsive Sources

Species	Alternative 1			Alternative 2 (Preferred Alternative)		
	Behavioral	TTS	PTS	Behavioral	TTS	PTS
Beluga whale	0	0	0	0	0	0
Bowhead whale[1]	0	0	0	0	0	0
Gray whale	0	0	0	0	0	0
Polar bear[1]	0	0	0	0	0	0
Bearded seal[1]	0	0	0	0	0	0
Ringed seal[2]	16	0.25	0	0	0	0
Ribbon seal	0	0	0	0	0	0
Spotted seal	0	0	0	0	0	0
Pacific walrus[3]	0	0	0	0	0	0

[1]ESA listed species
[2]ESA listed species pending final judicial resolution of their status.
[3]ESA-candidate species pending petition for relisting

Qualitative Analysis

Baleen whales have shown a variety of responses to impulsive sound sources, including avoidance, reduced surface intervals, altered swimming behavior, and changes in vocalization rates (Gordon et al. 2003; Richardson et al. 1995b; Southall et al. 2007). Bowhead whales seem to be the most sensitive species, perhaps due to a higher overlap between bowhead whale distribution and seismic surveys in Arctic and sub-Arctic waters, as well as a recent history of being hunted. While most bowhead whales did not show active avoidance until within 4 nm (8 km) of seismic vessels (Richardson et al. 1995b), some whales avoided vessels by more than 11 nm (20 km) at received levels as low as 120 dB re 1 µPa. Additionally, Malme et al. (1988) observed clear changes in diving and breathing patterns in bowheads at ranges up to 39 nm (73 km) from seismic vessels, with received levels as low as 125 dB re 1 µPa. Bowhead whales may also avoid the area around seismic surveys, from 3–4 nm (6–8 km) (Koski and Johnson 1987) out to 11 or 16 nm (20 or 30 km) (Richardson et al. 1999). However, work by Robertson (2014) supports the idea that behavioral responses are contextually dependent, and that during seismic operations bowhead whales may be less "available" for counting due to alterations in dive behavior but that they may not have left the area after all. Bowhead whale calling rates decreased significantly at sites near seismic surveys (22–24 nm [41–45 km]) where median received levels were between 116-129 dB re 1 µPa, and did not decrease at sites further from the seismic surveys (greater than 56 nm [104 km]) where median received levels were 99-108 dB re 1 µPa (Blackwell et al. 2013). In fact, bowhead whale calling rates increased at the lower received levels, began decreasing at around 127 dB re 1 μPa^2-s cumulative SEL, and ceased altogether at received levels over 170 dB re 1 μPa^2-s cumulative SEL (Blackwell et al. 2015).

Gray whales migrating along the U.S. west coast showed avoidance responses to seismic vessels by 10 percent of animals at 164 dB re 1 µPa, and by 90 percent of animals at 190 dB re 1 µPa, with similar results for whales in the Bering Sea (Malme et al. 1988; Malme et al. 1986). In contrast, noise from seismic surveys was not found to impact feeding behavior or exhalation rates while resting or diving in western gray whales off the coast of Russia (Gailey et al. 2007; Yazvenko et al. 2007). Seismic pulses at average received levels of 131 dB re 1 µPa (Di Iorio and Clark 2010). In a study by Malme et al. (1984) gray whales responded to air gun shots by changing swimming speed and direction, moving away from the air gun. Additionally, gray whales have been reported to change feeding (temporary cessation of feeding, resuming after exposure) (Malme et al. 1988), changing call rates and structure (Dahlheim 1987) and modifying surface behavior (Moore and Clarke 2002). Approximately half of the gray whales exposed to single airgun pulses in the Bering Sea showed avoidance and changed their respiration behavior (Malme et al. 1988; Malme et al. 1986).

Mysticetes seem to be the most sensitive taxonomic group of marine mammals to impulsive sound sources, with possible avoidance responses occurring out to 16 nm (30 km) and vocal changes occurring in response to sounds over 54 nm (100 km) away. However, responses appear to be behaviorally mediated, with most avoidance responses occurring during migration behavior and little observed response during feeding behavior.

Few data are available on odontocete responses to impulsive sound sources, with only a few studies on responses to seismic surveys, pile driving and construction activity available. However, odontocetes appear to be less sensitive to impulsive sound than mysticetes, with responses occurring at much closer distances. This may be due to the predominance of low-frequency sound associated with these sources that propagates long distances and overlaps with the range of best hearing for mysticetes but is below that range for odontocetes.

Marine mammal data from impulsive sources are limited: Finneran et al. (2002) reported behaviorally-measured TTSs of 6 and 7 dB in a beluga exposed to single impulses from a seismic water gun. In a different study by Finneran et al. (2000), there was no measureable TTS found when dolphins and belugas were exposed to single impulses from an “explosion simulator”. Odontocete behavioral responses to impulsive sound sources are likely species- and context-dependent, with most species demonstrating little to no apparent response. Responses might be expected within close proximity to a noise source, under specific behavioral conditions such as females with offspring, or for sensitive species such as harbor porpoises.

A review of behavioral reactions by pinnipeds to impulsive noise can be found in (Richardson et al. 1995b; Southall et al. 2007). Blackwell et al. (2004) observed that ringed seals exhibited little or no reaction to pipe-driving noise with mean underwater levels of 157 dB re 1 µPa RMS and in air levels of 112 dB re 20 µPa, suggesting that the seals had habituated to the noise. Southall et al. (2007) summarized data on behavioral reactions of pinnipeds in water to non-impulsive and impulsive sources (termed nonpulse and pulse sources, respectively, in Southall et al. (2007)), and ranked these reactions on a severity scale. For impulsive sources (e.g., airguns), data indicate that exposures between 150 and 180 dB re 1 µPa generally have limited potential to induce avoidance responses in pinnipeds, whereas higher received levels have exhibited some responses (Southall et al. 2007). Data used to identify the severity of behavioral reactions (Southall et al. 2007) are based primarily on ringed seals, but also include bearded and spotted seals (Blackwell et al. 2004; Harris et al. 2001; Miller et al. 2005). For received sound pressure levels between 140 dB re 1 µPa and 200 dB re 1 µPa, responses to impulsive sources were either 0 on the severity scale (no observable response; 49 percent of responses) or 6 on the severity scale (minor or moderate avoidance of the sound source; 51 percent of responses). The majority of the severity 6 responses (92 percent) occurred at sound pressure levels between 190 dB re 1 µPa and 200 dB re 1 µPa; which are both higher SPLs than both the airguns and compact sound source 181 and 184 dB re 1 µPa at 1 m, respectively. Southall et al. (2007) found that, within the range of sound pressure levels of approximately 150–190 dB re 1 µPa, 91 percent of individuals/groups were observed to have no response (severity scale ranking of 0) to the impulsive source. The remaining 9 percent were ranked on the severity scale as a 6, as minor or moderate avoidance reactions were observed. All of the reactions noted as a 6 on the severity scale (avoidance) are attributed to open-water use of a full-array of up to eleven 120 in^3 (1,966 cm^3) airguns. The avoidance of the area was relatively minor; some (but not all) seals avoided the zone within 492 ft (150 m) of the source, but did not move much beyond 820 ft (250 m) from the source. Additionally, the seismic operations with the full-array did not cause seals to desert the general area of the activity (Harris et al. 2001).

The data on ringed seal reactions during seismic surveys nonetheless indicate that ringed seals have shown little reaction to noise disturbance in general within the sound pressure levels potentially received from the Proposed Action.

Pinnipeds may be the least sensitive taxonomic group to most noise sources, although some species may be more sensitive than others, and are likely to only respond to loud impulsive sound sources at close ranges by startling, jumping into the water when hauled out, or even cease foraging, but only for brief periods before returning to their previous behavior (e.g., Southall et al. (2007)). Pinnipeds may even experience TTS before exhibiting a behavioral response (Southall et al. 2007).

Alternative 1

As described above, the compact sound source and air guns would only be permitted in Alternative 1. Impulsive sources are expected to result in, at most, minor to moderate avoidance responses of animals, over short and intermittent periods of time. As such, the Navy submitted an application for an IHA with NMFS for Level B take of ringed seals in accordance with MMPA. Since the yearly amount of impulsive source use is unknown, annual requests for IHAs would be completed throughout the duration of the Proposed Action. The Proposed Action is not expected to cause significant disruptions such as mass haul outs, or abandonment of breeding, that would result in significantly altered or abandoned behavior patterns. Given this along with acoustic modeling impulsive sources associated with the Proposed Action may adversely affect the ESA-listed ringed seal. Since quantitative modeling in NAEMO showed no exposures for the bowhead whale, polar bear, bearded seal, and ESA-candidate Pacific walrus, there would be no effect to the bowhead whale, polar bear, bearded seal, and ESA-candidate Pacific walrus from impulsive sources used during the Proposed Action. In accordance with E.O. 12114, impulsive sources associated with Alternative 1 are not likely to significantly harm marine mammals.

Alternative 2 (Preferred Alternative)

Impulsive sources would not be used under Alternative 2. In accordance with E.O. 12114, impulsive sources associated with Alternative 2 would not result in harm to marine mammals.

Since no impulsive sources would be utilized under Alternative 2, there would be no effect to the bowhead whale, polar bear, bearded seal, ringed seal, and ESA-candidate Pacific walrus from impulsive sources used during the Proposed Action.

4.3.2.5.5 Vessel Noise

Potential Harm

Vessel noise associated with the Proposed Action could result from sound generated by the R/V Sikuliaq, and CGC HEALY. Marine mammals have been recorded in several instances altering and modifying their vocalizations to compensate for the masking noise from vessels, or other similar sounds (Holt et al. 2011; Parks et al. 2011). Vocal changes in response to anthropogenic noise can occur across the repertoire of sound production modes used by marine mammals, such as whistling, echolocation click production, calling, and singing. Changes to vocal behavior and call structure may result from a need to compensate for an increase in background noise. In cetaceans, vocalization changes have been reported from exposure to anthropogenic sources such as sonar, vessel noise, and seismic surveying.

Since many marine mammals rely on sound to find prey, moderate social interactions, and facilitate mating (Tyack 2008), noise from anthropogenic sound sources like ships can interfere with these functions, but only if the noise spectrum overlaps with the hearing sensitivity of the marine mammal (Clark et al. 2009; Hatch et al. 2012; Southall et al. 2007). It is difficult to differentiate between behavioral responses to vessel sound and visual cues associated with the presence of a vessel; thus, it is assumed that both play a role in prompting reactions from animals. Vessel noise has the potential to disturb marine mammals and elicit an alerting, avoidance, or other behavioral reaction (Huntington et al. 2015; Pirotta et al. 2015; Williams et al. 2014). Most studies have reported that marine mammals react to vessel sounds and traffic when received levels were over 20 dB greater than ambient noise levels with short-term interruption of feeding, resting, or social interactions (Huntington et al. 2015; Magalhães et al. 2002; Merchant et al. 2014; Pirotta et al. 2015; Richardson et al. 1995b; Williams et al. 2014). Some species respond negatively by retreating or responding to the vessel antagonistically, while other animals seem to ignore vessel noises altogether (Watkins 1986). Beluga whales can exhibit a variety of reactions from fleeing the area to no response at all to the vessel (Wartzok et al. 2003). Polar bears do not appear to be significantly affected by vessel noise. Some polar bears have been observed walking, running, and swimming away from approaching vessels, but these reactions were brief and localized. Other bears have been observed approaching vessels or having no reaction to vessels (Richardson et al. 1995b).

Overall baleen whale responses to vessel noise and traffic are varied but are generally minor, and habituation or disinterest seems to be the predominant long-term response. When baleen whales do avoid ships they do so by altering their swim and dive patterns to move away from the vessel, but no strong reactions have been observed. In fact, in many cases the whales do not appear to change their behavior at all. This may result from habituation by the whales, but may also result from reduced received levels near the surface due to propagation, or due to acoustic shadowing of the propeller cavitation noise by the ship’s hull. Based on studies on a number of species, mysticetes (such as bowhead and gray whales) are not expected to be disturbed by vessels that maintain a reasonable distance from them, though this varies with vessel size, geographic location, and tolerance levels of individuals. Bernasconi et al. (2012) observed the reactions of six individual baleen whales of unknown species at distances of 164 to 1,312 ft (50 to 400 m) from a fishing vessel conducting an acoustic survey of pelagic fisheries, with only a slight change in swim direction when the vessel began moving around the whales. Bowhead whales avoided the area around icebreaker ship noise and increased their time at the surface and number of blows (Richardson et al. 1995a).The noise generated from the R/V Sikuliaq is at a low source level (less than 160 dB) for the vessel speeds of the Proposed Action (Naval Sea Systems Command 2015), and at very small distances from the vessel the sound would be below the level capable of producing a behavioral response. The noise generated from CGC HEALY is at a similarly low source level at frequencies associated with vessel noise (100-1000 Hz). The noise from CGC HEALY when icebreaking is significantly higher (~ 10 dB) and will have enhanced propagation due to the introduction of additional low-frequency components (Roth et al. 2013).

In general, studies of pinniped reactions to vessels are limited. Pinnipeds have shown substantial tolerance to anthropogenic noise stressors. Pinniped reactions to vessels are variable and reports include a wide spectrum of possibilities from avoidance and alert, to cases where animals in the water are attracted, and cases on land where there is lack of significant reaction suggesting habituation to or tolerance of vessels (Richardson et al. 1995b). Another study of reactions of harbor seals hauled out on ice to cruise ship approaches in Disenchantment Bay, Alaska, revealed that animals are more likely to flush and enter the water when cruise ships approach within 1,640 ft. (500 m) and four times more likely when the cruise ship approaches within 328 ft. (100 m) (Jansen et al. 2010). Brueggeman et al (1992), observed ringed seals hauled out on ice sheets showing a short term behavioral reaction by diving into the water when a vessel came within 0.13-0.27 nm (0.25-0.5 km).

The R/V Sikuliaq, and CGC HEALY vessels would not purposefully approach marine mammals and noise generated by these vessels are not expected to elicit significant behavioral responses. Such reactions are not expected to significantly disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding and sheltering to a point where the behavior pattern is abandoned or significantly altered or result in reasonably foreseeable takes of marine mammals.

Alternative 1

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals as the same vessels would be used. Vessel noise associated with the Proposed Action would not result in reasonably foreseeable takes under the MMPA. Vessel noise associated with the Proposed Action would have no effect on the ESA-listed polar bear. Vessel noise may affect, but is not likely to adversely affect the ESA-listed bowhead whale, bearded seal, ringed seal and ESA-candidate Pacific walrus. In accordance with E.O. 12114 vessel noise associated with Alternative 1 would not result in significant harm to marine mammals.

Alternative 2 (Preferred Alternative)

Vessel noise from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals as the same vessels would be used. Vessel noise associated with the Proposed Action would not result in reasonably foreseeable takes under the MMPA. Vessel noise associated with the Proposed Action would have no effect on the ESA-listed polar bear. Vessel noise may affect, but is not likely to adversely affect the ESA-listed bowhead whale, bearded seal, ringed seal and ESA-candidate Pacific walrus. In accordance with E.O. 12114 vessel noise associated with Alternative 2 would not result in significant harm to marine mammals.

4.3.2.5.6 Icebreaking (Physical Impacts)

Potential Harm

As discussed in Section 4.3.2.5.3, the noise associated with icebreaking activities is most likely to result in marine mammals swimming away from the icebreaking vessel or avoiding the area for a short period of time. Therefore, it is highly unlikely that icebreaking equipment would strike a marine mammal or cause any physical harm. Pinnipeds that haul out on the ice may be more susceptible to impacts caused by icebreaking.

As described in Section 3.2.2.5.1, the proposed critical habitat for ringed seals includes the following essential features:

- Sea ice habitat suitable for the formation and maintenance of subnivean birth lairs used for sheltering pups during whelping and nursing.
- Sea ice habitat suitable as a platform for basking and molting, which is defined as sea ice of 15 percent or more concentration, except for bottom-fast ice extending seaward from the coastline in waters less than 6.56 ft (2 m) deep.
- Primary prey resources to support Arctic ringed seals, which are defined to be Arctic cod, saffron cod, shrimps, and amphipods.

Critical habitat for polar bears includes the following essential features, relative to sea ice:

- Sea ice habitat located over the continental shelf at depths of 984 ft (300 m) or less. In spring and summer, this habitat follows the northward progression of the ice edge as it retreats northward. In fall, this sea ice habitat follows the southward progression of the ice edge as it advances southward.
- Sea ice within 1 mi (1.6 km) of the mean high tide line of barrier island habitat. Barrier islands are used as migration corridors. Polar bears can move freely between barrier islands by swimming or walking on ice or sand bars, thereby avoiding human disturbance.

Though no critical habitat is designated for bearded seals, they are also strongly associated with sea ice habitat in the Arctic. In winter, individuals generally move south as the pack ice advances into the Bering Sea. In late spring and summer, bearded seals move north as the ice edge recedes into the Chukchi and Beaufort seas. However, some bearded seals stay near the edge of shorefast ice all winter and do not migrate south. Leads, polynyas, and other openings in the sea ice are important features of bearded seal habitat. Juvenile bearded seals tend to associate with sea ice less than adults and are often found in ice free areas such as bays and estuaries. The distribution of bearded seals appears to be strongly associated with shallow water and high biomass of the benthic prey they feed on. They are limited to feeding depths of less than 492-656 ft (150–200 m).

Icebreaking activities would be limited to the deep water portion of the Study Area and could only occur for approximately one week during the warm season from August to October 2018-2021. Only areas of thick, wide concentrations of sea ice would require icebreaking by CGC HEALY. During this timeframe, these areas are expected to be at a minimum, which would reduce the impact to sea ice critical habitat. Since icebreaking would only occur in the deep water area it would most likely be outside of polar bear critical habitat. The 2016 September ice extent was far outside of polar bear critical habitat. The 1981-2010 average September ice extent did fall in the outer edge of the polar bear critical habitat. Looking at recent trends in ice extent the past 5-years have been below the average and did not overlap the polar bear critical habitat. Polar bears do not appear to be significantly affected by vessel moment. Some polar bears have been observed walking, running, and swimming away from approaching vessels, but these reactions were brief and localized. Other bears have been observed approaching vessels or having no reaction to vessels (Richardson et al. 1995b). Additionally, icebreaking may result in the temporary displacement of primary prey resources of polar bears and ringed seals, but these species are expected to return to their normal behaviors shortly after the initial disturbance.

In the spring through the fall, these areas are expected to be at a minimum, which would reduce the impact to the ringed seals' proposed critical habitat. The ringed seal subnivean lairs are excavated in drifts over breathing holes in the ice, in which they rest, give birth, and nurse their pups for 5–9 weeks during late winter and spring (Chapskii 1940; McLaren 1958; Smith and Stirling 1975). Most ringed seals are born in early April and about a month after parturition, mating begins in late April and early May. Ringed seals are expected in the Study Area year-round, but during the Arctic summer months, from May to September, pupping will not occur and subnivean lairs will not be occupied. Since icebreaking would occur when sea ice is at its lowest extent icebreaking areas would not likely overlap with subnivean lairs. However, Williams et al. (2006) determined that ringed seals abandoned subnivean lairs in areas where there was high ice deformation. Ringed seals typically construct their lairs in landfast ice (ice securely attached to land) that typically extends 13.5 to 21.6 nm (25 to 40 km) offshore (Kovacs and Mellor 1974; Stringer 1974; Wadhams 2000). Although icebreaking could overlap with ringed seal structures, it is likely that the noise of the icebreaking would alert any seal well before the icebreaker reaches the subnivean lair, and similar to a predator flight response, the seal would abandon the lair. Therefore, it is unlikely that icebreaking would cause injury or mortality to a ringed seal or their pup from the physical presence of the icebreaking.

Alternative 1

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals, in that the same icebreaking vessel (CGC HEALY) would be utilized for both alternatives. The use of an icebreaking vessel may result in localized changes to the proposed ringed seal critical habitat and polar bear critical habitat as larger sheets of floating ice are broken down into smaller sizes. However, icebreaking is not expected to significantly alter proposed critical habitat. Physical impacts from icebreaking associated with the Proposed Action would not result in reasonably foreseeable takes under the MMPA. Physical impacts from icebreaking associated with the Proposed Action would have no effect on ESA-candidate Pacific walrus. Physical impacts from icebreaking may affect, but is not likely to adversely affect the ESA-listed bowhead whale, bearded seal, polar bear, and ringed seal. Physical impacts from icebreaking would not result in destruction or adverse modification of proposed ringed seal critical habitat, and polar bear critical habitat. In accordance with E.O. 12114, physical impacts from icebreaking associated with Alternative 1 would not result in significant harm to marine mammals.

Alternative 2 (Preferred Alternative)

Icebreaking from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals, in that the same icebreaking vessel (CGC HEALY) would be utilized for both alternatives. The use of an icebreaking vessel may result in localized changes to the proposed ringed seal critical habitat and polar bear critical habitat as larger sheets of floating ice are broken down into smaller sizes. However, icebreaking is not expected to significantly alter proposed critical habitat. Physical impacts from icebreaking associated with the Proposed Action would not result in reasonably foreseeable takes under the MMPA. Physical impacts from icebreaking associated with the Proposed Action would have no effect on ESA-candidate Pacific walrus. Physical impacts from icebreaking may affect, but is not likely to adversely affect the ESA-listed bowhead whale, bearded seal, polar bear, and ringed seal. Physical impacts from icebreaking would not result in destruction or adverse modification of proposed ringed seal critical habitat, and polar bear critical habitat. In accordance with E.O. 12114, physical impacts from icebreaking associated with Alternative 2 would not result in significant harm to marine mammals.

4.3.2.5.7 Vessel and In-Water Device Strike

Potential Harm

Interactions between surface vessels and marine mammals have demonstrated that surface vessels represent a source of acute and chronic disturbance for marine mammals (Au et al. 2000; Bejder et al. 2006; Hewitt 1985; Jefferson et al. 2009; Kraus et al. 1986; Magalhães et al. 2002; Nowacek et al. 2004; Richter et al. 2003; Richter et al. 2008; Williams et al. 2009). Studies have established that cetaceans generally engage in avoidance behavior when surface vessels move toward them. In some circumstances, marine mammals respond to vessels with the same behavioral repertoire and tactics they employ when they encounter predators, although it is not clear what environmental cues marine mammals might respond to–the sound of water being displaced by the ships, the sound of the ships' engines, or a combination of environmental cues surface vessels produce while they transit.

Vessel collisions are a well-known source of mortality in marine mammals, and can be a significant factor affecting some large whale populations (Knowlton and Kraus 2001; Laist et al. 2001; van Waerebeek et al. 2007). Bowhead whales often begin avoiding vessels from more than 2.2 nm (4 km) away (Richardson et al. 1995b). Avoidance by this species usually entails altered headings, faster swimming speeds, and shorter amounts of time spent surfacing. Bowhead whales are more tolerant of vessels moving slowly or moving in directions other than towards them. In most studies, observers noted bowhead whales exhibiting avoidance within 1,640 ft (500 m) of vessels, though avoidance at further distances was not able to be judged by observers on vessels (Richardson et al. 1995b). During a review of data on the subject, Laist et al. (2001) compiled historical records of ship strikes, which contained 58 anecdotal accounts. It was noted that in the majority of cases, the whale was either not observed or seen too late to maneuver in an attempt to avoid collision. In the 2016 stranding summary report only the fin whale (1), humpback whale (3), and unidentified cetacean (1) were confirmed strandings from a ship strike, none of which are found within the Study Area (Savage 2017). The most vulnerable marine mammals to collision are thought to be those that spend extended periods at the surface or species whose unresponsiveness to vessel sound makes them more susceptible to vessel collisions (Gerstein 2002; Laist and Shaw 2006; Nowacek et al. 2004). Marine mammals such as dolphins, porpoises, and pinnipeds that can move quickly throughout the water column do not appear to be as susceptible to vessel strikes, though the risk of a strike still exists for these species.

Few authors have specifically described the responses of pinnipeds to vessels, and most of the available information on reactions to boats concerns pinnipeds hauled out on land or ice. Reactions include a wide spectrum of effects from avoidance and alert, to cases where animals in the water are attracted, and cases on land where there is lack of significant reaction suggesting habituation to or tolerance of vessels (Richardson et al. 1995b).No information is available on potential responses to in-water devices. Brueggeman et al., (1992) stated ringed seals hauled out on the ice showed short-term escape reactions when they were within 0.13 to 0.27 nm (0.25 to 0.5 km) of a vessel. A review of seal stranding data from Alaska found that in 2016, within the arctic region of Alaska, 18 ringed seal, 1 bearded seal, 2 spotted, and 19 unknown pinniped strandings were recorded. Of all the strandings reported in all regions of Alaska, there were no pinniped strandings caused by vessel collisions (Savage 2017). From the limited data available, it appears that pinnipeds are not as susceptible to vessel strikes as other marine mammal species. This may be due, at least in part, to the large amount of time they spend on ice (especially when resting and breeding) and their high maneuverability in the water.

Polar bears do not appear to be significantly affected by vessel moment. Some polar bears have been observed walking, running, and swimming away from approaching vessels, but these reactions were brief and localized. Other bears have been observed approaching vessels or having no reaction to vessels (Richardson et al. 1995b).

The speed of the ship is an important factor in predicting the lethality of a strike. Laist et al. (2001) noted that most severe and fatal injuries to marine mammals occurred when the vessel was traveling in excess of 14 knots, and there were no recorded mortalities at speeds less than 10 knots. Although the maximum speed of the vessels associated with the Proposed Action is 12.3 knots for the R/V Sikuliaq, and 17 knots for CGC HEALY, these vessels are expected to operate at much slower speeds (below 10 knots) during most of the Proposed Action. However, slow speed does not eliminate the chance that a collision would result in fatal injury. Vanderlaan and Taggert (2007) concluded that at speeds below 8 knots, there was still a 20 percent risk of death from blunt trauma.

Alternative 1

Vessel and in-water device strike from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals, in that the same vessels and in-water devices would be utilized for both alternatives. The probability of a vessel or in-water devices encountering a marine mammal is expected to be low, which decreases the likelihood of vessels striking marine mammals. Any behavioral avoidance displayed, if marine mammal were to encounter the vessels or in-water device, is expected to be short-term, inconsequential and would not result in any reactions expected to significantly disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding and sheltering to a point where the behavior pattern is abandoned or significantly altered or result in reasonably foreseeable takes of marine mammals. Direct vessel or in-water device strikes could result in injury or fatal injury to marine mammals. However, vessel and in-water device strikes are unlikely given the slow vessel speeds (under 12.3 knots for vessels and 0.5 knots for in-water devices), therefore vessel strike associated with the Proposed Action would not result in significant harm to marine mammals. Additionally, vessel and in-water device strike associated with the Proposed Action would not result in any reasonable foreseeable takes under the MMPA. Polar bears are known to avoid or ignore approaching vessels, and as such, vessel and in-water device strike associated with the Proposed Action would have no effect to ESA-listed polar bears under Alternative 1 and 2. Although unlikely, bowhead whales and ringed seals could be exposed to vessel and in-water device movement. Movement would likely elicit a response to avoid the vessel or in-water device, and therefore may affect, but is not likely to adversely affect, ESA-listed bowhead whales, bearded seals, ringed seals and the ESA-candidate Pacific walrus. In accordance with E.O. 12114 vessel and in-water device strike associated with Alternative 1 would not result in significant harm to marine mammals.

Alternative 2 (Preferred Alternative)

Vessel and in-water device strike from both Alternatives 1 and 2 would result in the same potential for effects to marine mammals, in that the same vessels and in-water devices would be utilized for both alternatives. The probability of a vessel or in-water devices encountering a marine mammal is expected to be low, which decreases the likelihood of vessels striking marine mammals. Any behavioral avoidance displayed, if marine mammal were to encounter the vessels or in-water device, is expected to be short-term, inconsequential and would not result in any reactions expected to significantly disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding and sheltering to a point where the behavior pattern is abandoned or significantly altered or result in reasonably foreseeable takes of marine mammals. Direct vessel or in-water device strikes could result in injury or fatal injury to marine mammals. However, vessel and in-water device strikes are unlikely given the slow vessel speeds (under 12.3 knots for vessels and 0.5 knots for in-water devices), therefore vessel strike associated with the Proposed Action would not result in significant harm to marine mammals. Additionally, vessel and in-water device strike associated with the Proposed Action would not result in any reasonable foreseeable takes under the MMPA. Polar bears are known to avoid or ignore approaching vessels, and as such, vessel and in-water device strike associated with the Proposed Action would have no effect to ESA-listed polar bears under Alternative 1 and 2. Although unlikely, bowhead whales and ringed seals could be exposed to vessel and in-water device movement. Movement would likely elicit a response to avoid the vessel or in-water device, and therefore may affect, but is not likely to adversely affect, ESA-listed bowhead whales, bearded seals, ringed seals and the ESA-candidate Pacific walrus. In accordance with E.O. 12114 vessel and in-water device strike associated with Alternative 2 would not result in significant harm to marine mammals.

4.3.2.5.8 Entanglement

Potential Harm

The likelihood of a marine mammal encountering and becoming entangled in a line depends on several factors. The amount of time that the line is in the same vicinity as a marine mammal can increase the likelihood of it posing an entanglement risk. The length of the line varies (up to approximately 12,303 ft [3,750 m]) and greater lengths may increase the likelihood that a marine mammal could become entangled. The behavior and feeding strategy of a species can determine whether they may encounter items on the seafloor. Given the water depths in both the shallow water and deep water portions of the Study Area, marine mammals would not forage on the seafloor, eliminating the possibility of entanglement with the bottom mounted acoustic sources. As stated in Section 3.2.2.5.1, bearded seals forage on the seafloor, commonly occupying shallow waters (Fedoseev 2000; Kovacs 2002). The preferred depth range is often described as less than 656 ft (200 m) (Allen and Angliss 2014; Fedoseev 2000; Jefferson et al. 2008; Kovacs 2002), although adults have been known to dive to around 984 ft (300 m) (Cameron and Boveng 2009; Kovacs 2002). Although possible, it is unlikely that bearded seals would be as far out as the 49 nm (90 km) from the coastline at the shallow water portion of the Study Area.

During the deployment and removal of the lines and buoys, marine mammals could become entangled. However, all equipment would be deployed from a shipboard winch system in a slow and controlled manner, which would decrease the potential of entanglement. Additionally, the lines are weighted to help with deployment, this would make the line free of loops and slack for marine mammals to become entangled.

Once the moorings and anchors are in place the potential for entanglement with tethered moored equipment is considered negligible based on the tension in the line, small buoy sizes (51 in [130 cm] diameter), shape depth (approximately 656 ft [200 m] or on the seafloor), and the large spacing between shapes (minimum of 40.5 nm [75 km] at the deep water portion of the Study Area). Bearded seals and ribbon seals may dive up to 656 ft (200 m) underwater; however, both species are expected to be closer to shore than the Study Area. Bowhead whales may dive to depths greater than 1,148 ft (350 m) and may encounter expended materials. However, there would be no slack in the mooring tethers which are under approximately 1,190 lb (540 kg) of tension due to the shape buoyancy. The probability of a whale, such as a bowhead, colliding with a moored shape is considered remote. Pinnipeds are highly maneuverable and could easily avoid bottom or tethered shapes and most pinnipeds (bearded seal, ribbon seal, spotted seal) would not be found over 75.6 nm (140 km) from the shore. Moorings will not have a surface expression and the buoy which keeps the line taught would be approximately 164 ft (50 m) below the surface of the ice, negating the chance for a seal to become entangled while utilizing a breathing hole. Based on the estimated concentration of deployed mooring and array lines, impacts from lines are extremely unlikely to occur. Although there is a potential for entanglement from an expended material the amount of materials expended would be low and ringed seals are very mobile within the water column and avoidance of any expended object is expected.

The chance that an individual animal would encounter expended lines is most likely low based on the distribution of both the lines expended, and the depth of the water in the Study Area where these would be expended. In the 2016 NMFS stranding report, 18 reported ringed seal, 8 gray whale, 6 bowhead whale, 2 spotted seal, 1 bearded seal, and 1 beluga whale strandings occurred in the Arctic and Western Alaska regions. Of those 36 strandings, none were documented to be from entanglement (Savage 2017). Given the water depths in the Study Area, marine mammals are not expected to be feeding on the seafloor; any materials that settle to the seafloor would therefore not pose an entanglement risk to marine mammals. An animal would have to swim through loops or become twisted within the lines to become entangled. Based on the limited number of expended lines, harm from lines are extremely unlikely to occur. Although there is a potential for entanglement from an expended material the amount of materials expended would be low and marine mammals are very mobile within the water column and avoidance of any expended object is expected.

Polar bears are normally found in locations of 50 percent ice cover and at water depths of 984 ft (300 m) within the Beaufort Sea and are not expected to occur in the summer months when equipment would be deployed and retrieved. Polar bears swimming in the water column would not likely come in contact with mooring lines in the shallow water Study Area, because they are only known to dive to depths of 10 to 15 ft (3 to 4.5 m) (Barnes 2011). Polar bears would not be foraging or diving to the seafloor at either Study Area. Therefore, the potential of a polar bear becoming entangled in expended materials associated with the Proposed Action is considered negligible. The chance of a polar bear becoming entangled with expended material on the ice is discountable. During winter and spring, polar bears are found on the ice stalking breathing holes, or within their maternal dens, and not located within the water column. Since the weather balloons would pop and could only potentially fall onto the ice as small pieces of shredded plastic, it would not present an entanglement risk to a polar bear (due to the small size of the pieces). Although a polar bear could potentially become entangled within the weather balloon parachute or ropes and twine used to keep all of the components together, it is unlikely; if this were to occur, polar bears are strong and agile and would easily be able to untangle themselves from any potential expended materials on ice.

Alternative 1

Under Alternative 1, the potential for entanglement would be from mooring lines and towed sources. All lines extending from the moorings would be retrieved at the completion of the Proposed Action. Any effects to marine mammals would not be significant and any reactions are not expected to significantly disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding and sheltering to a point where the behavior pattern is abandoned or significantly altered or result in reasonably foreseeable takes of marine mammals. Therefore, in accordance with E.O. 12114, entanglement associated with Alternative 1 would not result in significant harm to mammals.

Entanglement associated with Alternative 1 and Alternative 2 would not result in any reasonably foreseeable takes under the MMPA. Entanglement associated with Alternative 1 and Alternative 2 would have no effect on the ESA-listed polar bear, bearded seal or ringed seal as these species do not dive to depths in which they would encounter expended materials. Entanglement associated with Alternative 1 and Alternative 2 may affect, but is not likely to adversely affect the ESA-listed bowhead whale as this species has an average dive depth of 328 ft (100 m), with maximum recorded dive of 1,155 ft (352 m) (Krutzikowski and Mate 2000) where it could encounter expended materials. Entanglement associated with Alternative 1 and Alternative 2 would have no effect on the ESA-candidate Pacific walrus as they are not expected to occur in the vicinity of the mooring and array lines.

Alternative 2 (Preferred Alternative)

Under Alternative 2, the potential for entanglement would be from mooring lines and towed sources. Alternative 2 has less mooring lines associated with the Proposed Action. Any effects to marine mammals would not be significant and any reactions are not expected to significantly disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding and sheltering to a point where the behavior pattern is abandoned or significantly altered or result in reasonably foreseeable takes of marine mammals. Therefore, in accordance with E.O. 12114, entanglement associated with Alternative 2 would not result in significant harm to mammals.

Entanglement associated with Alternative 1 and Alternative 2 would not result in any reasonably foreseeable takes under the MMPA. Entanglement associated with Alternative 1 and Alternative 2 would have no effect on the ESA-listed polar bear, bearded seal or ringed seal as these species do not dive to depths in which they would encounter expended materials. Entanglement associated with Alternative 1 and Alternative 2 may affect, but is not likely to adversely affect the ESA-listed bowhead whale as this species has an average dive depth of 328 ft (100 m), with maximum recorded dive of 1,155 ft (352 m) (Krutzikowski and Mate 2000) where it could encounter expended materials. Entanglement associated with Alternative 1 and Alternative 2 would have no effect on the ESA-candidate Pacific walrus as they are not expected to occur in the vicinity of the mooring and array lines.

4.3.2.5.9 Ingestion

Potential Harm

Ringed seals feed both within the water column and on the seafloor (Bluhm and Gradinger 2008), but feeding on the seafloor would not occur in the Study Area given the water depths. Since ringed seals spend most of their time either in their subnivean lair or in the water column, the only ingestion potential would be from balloon fragments and radiosondes as they sink to the seafloor. A total of 40 balloons (2 per day) would be would be released over the course of the Proposed Action. It is important to note that the distance and direction each balloon would travel is directly related to the daily weather conditions and they are not anticipated to travel to the same locations on a daily basis. While each balloon could travel over 201 km before bursting and entering the water column, the likelihood of ingestion of a balloon fragment by a ringed seal is extremely low (Federal Aviation Administration (FAA) 2014). Balloon fragments do not resemble prey species of ringed seals; any ingestion of balloon fragments would be limited to small pieces incidentally ingested. The released weather balloons may have a potential effect on ringed seal prey (particularly fish), but would be an instance of ingestion by individual animals rather than populations at large; therefore, there is a possibility of a ringed seal consuming a fish that has small pieces of balloon in their digestive system, though these pieces would most likely be small enough to pass through a ringed seal. However, fish could also become entangled in weather balloon fragments in the water, creating a potential ingestion issue for ringed seals were they to consume the entangled fish. Data on ingestion of marine debris by ringed seals is not available. However, a study by (Irwin 2012) found that natural latex weather balloon fragments would not have serious health implications on catfish. Given the larger size of ringed seals, it is assessed that balloon fragments would similarly not have serious health implication if incidentally ingested.

Polar bears typically find alternate food sources (e.g., land-based trash collection sites) when their primary prey (ringed seals) are unavailable (Lunn and Stirling 1985). In a study by Gormezano and Rockwell (2013), polar bear scats (i.e., excrement) from five sites were surveyed. Sites included the town of Churchill and dens around inland lakes. In areas where humans and polar bears came in close proximity, a higher percentage of garbage was found in the scats than areas where polar bears and humans were not in close proximity. Polar bears have also been known to bite buoys located on the ice. This behavior could be out of curiosity or to determine if the object is edible. The likelihood of a polar bear encountering the autonomous weather station tripod from the ice mass balance buoy on the ice, and potentially taking a bite of the equipment is low since a small number of on-ice measurement systems would be deployed on ice floes in the Study Area. Although ingestion of large pieces of the autonomous weather station or tripod from the ice mass balance buoy is not anticipated, small bits could be ingested. If a polar bear does ingest pieces of the autonomous weather station or tripod from the ice mass balance buoy, the bear would likely excrete the material without detrimental effects, as studies indicate that bears foraging in land-based trash sites show no reproductive or survival advantage or disadvantage from feeding on these materials (Lunn and Stirling 1985). If a polar bear does ingest pieces of expended materials such as balloon fragments or radiosondes while on the ice, the bear would likely excrete the material without detrimental effects, as studies indicate that bears foraging in land-based trash sites show no reproductive or survival advantage or disadvantage from feeding on these materials (Lunn and Stirling 1985). Additionally, due to the relatively small number and wide geographic spread of expended balloons and radiosondes, and the low density of polar bears, the chance of a bear encountering and ingesting expended material is low.

Alternative 1

Under both Alternatives 1 and 2, the potential for ingestion would be limited to exploratory bites of the autonomous weather station or tripod from the ice mass balance buoy on the ice by polar bears. Under ESA, Alternatives 1 and 2 would have no effect on ringed seals, bowhead whales, bearded seals, or the ESA-candidate Pacific walrus. Polar bears, however, may be attracted to the autonomous weather station or tripod from the ice mass balance buoy; therefore, under ESA ingestion associated with the Proposed Action under Alternative 1 may affect, but is not likely to adversely affect, polar bears. Any effects to marine mammals would be minimal and temporary, and therefore would not result in reasonably foreseeable takes under the MMPA. In accordance with E.O. 12114 ingestion of materials associated with Alternative 1 would not result in significant harm to marine mammals.

Alternative 2 (Preferred Alternative)

Under both Alternatives 1 and 2, the potential for ingestion would be limited to exploratory bites of the autonomous weather station or tripod from the ice mass balance buoy on the ice by polar bears. Under

ESA, Alternatives 1 and 2 would have no effect on bowhead whales, bearded seals, or the ESA-candidate Pacific walrus. Polar bears, however, may be attracted to the autonomous weather station or tripod from the ice mass balance buoy; therefore, under ESA ingestion associated with the Proposed Action under Alternative 2 may affect, but is not likely to adversely affect, ringed seals or polar bears. Any effects to marine mammals would be minimal and temporary, and therefore would not result in reasonably foreseeable takes under the MMPA. In accordance with E.O. 12114 ingestion of materials associated with Alternative 2 would not result in significant harm to marine mammals.

4.4 Summary of Potential Impacts to Resources

A summary of the potential impacts associated with each of the action alternatives and the No Action Alternative and impact avoidance and minimization measures are presented in Table 4-9.

Table 4-10. Summary of Potential Impacts to Resource Areas

Resource Area	*No Action Alternative*	*Alternative 1*	*Alternative 2 (Preferred Alternative)*
Physical Resources	No change to baseline.	The potential harm would be temporary and localized due to the minimal number of devices and the infrequency of testing activities, and soft sediment is expected to shift back as it would following a disturbance of tidal energy. No long-term increases in turbidity (sediment suspended in water) would be anticipated. The localized disturbances would not alter the function or habitat provided by marine substrates or sea ice. No significant harm to ambient noise levels would occur as a result of the Proposed Action.	The potential harm would be temporary and localized due to the minimal number of devices and the infrequency of training activities, and soft sediment is expected to shift back as it would following a disturbance of tidal energy. No long-term increases in turbidity (sediment suspended in water) would be anticipated. The localized disturbances would not alter the function or habitat provided by marine substrates or sea ice. No significant harm to ambient noise levels would occur as a result of the Proposed Action.
Invertebrates	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to invertebrates.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to invertebrates.
Marine Birds	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine birds.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine birds.
Fish	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to fish.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to fish.

Resource Area	*No Action Alternative*	*Alternative 1*	*Alternative 2 (Preferred Alternative)*
Essential Fish Habitat	No change to baseline.	With standard operating procedures and mitigation measures, potential adverse effects from the Proposed Action would be considered minimal.	With standard operating procedures and mitigation measures, potential adverse effects from the Proposed Action would be considered minimal.
Marine Mammals	No change to baseline.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine mammals.	With standard operating procedures and mitigation measures, potential harm from the Proposed Action would be temporary and/or minimal. The Proposed Action is not expected to result in population-level impacts to marine mammals.

5 Standard Operating Procedures and Mitigation Measures

Both standard operating procedures and mitigation measures would be implemented during the Proposed Action. Standard operating procedures serve the primary purpose of providing safety and mission success, and are implemented regardless of their secondary benefits (e.g., to a resource), while mitigation measures are used to avoid or reduce potential impacts.

Ships operated by or for the United States (U.S.) Department of the Navy (Navy) have personnel assigned to stand watch at all times, day and night, when moving through the water (underway). Watch personnel undertake extensive training in accordance with the U.S. Navy Lookout Training Handbook or civilian equivalent, including on-the-job instruction and a formal Personal Qualification Standard program (or equivalent program for supporting contractors or civilians), to certify that they have demonstrated all necessary skills (such as detection and reporting of floating or partially submerged objects). Their duties may be performed in conjunction with other job responsibilities, such as navigating the ship or supervising other personnel. While on watch, personnel employ visual search techniques, including the use of binoculars, using a scanning method in accordance with the U.S. Navy Lookout Training Handbook or civilian equivalent. A primary duty of watch personnel is to detect and report all objects and disturbances sighted in the water that may be indicative of a threat to the ship and its crew, such as debris, or surface disturbance. Per safety requirements, watch personnel also report any marine mammals sighted that have the potential to be in the direct path of the ship as a standard collision avoidance procedure.

While underway the ships (including non-Navy ships operating on behalf of the Navy) utilizing active acoustics and towed in-water devices will have at least one watch person during activities. While underway, watch personnel are alert at all times and have access to binoculars.

5.1 Mitigation Measures

- While in transit, ships shall be alert at all times, use extreme caution, and proceed at a "safe speed" so that the ship can take proper and effective action to avoid a collision with any marine mammal and can be stopped within a distance appropriate to the prevailing circumstances and conditions.
- Mitigation zones for active acoustics involve turning off a towed source when a marine mammal is sighted within 200 yard (yd; 183 meters [m]) from the source. Active transmission will re-commence if any one of the following conditions are met: (1) the animal is observed exiting the mitigation zone, (2) the animal is thought to have exited the mitigation zone based on its course and speed and relative motion between the animal and the source, (3) the mitigation zone has been clear from any additional sightings for a period of 30 minutes, (4) the vessel has transited more than 400 yd (366 m) beyond the location of the last sighting.
- During mooring deployment visual observation would start 15 minutes prior to and during the deployment within a mitigation zone of 180 feet (ft; 55 m) around the deployed mooring. Deployment will stop if a marine mammal is visually detected within the mitigation zone. Deployment will re-commence if any one of the following conditions are met: (1) the animal is observed exiting the mitigation zone, (2) the animal is thought to have exited the mitigation zone based on its course and speed, or (3) the mitigation zone has been clear from any additional sightings for a period of 15 minutes.
- During airgun and compact sound source use mitigation will include visual observation immediately before and during the exercise within a mitigation zone of 200 yd (183 m) from the ship. Firing will cease if a marine mammal is visually detected within the mitigation zone. Firing will re-commence if any one of the following conditions are met: (1) the animal is observed exiting the mitigation zone,

(2) the animal is thought to have exited the mitigation zone based on its course and speed, (3) the mitigation zone has been clear from any additional sightings for a period of 30 minutes, or (4) the location for the airgun or compact sound source shots has been repositioned more than 400 yd (366 m) away from the location of the last sighting.

- Ships would avoid approaching marine mammals head on and would maneuver to maintain a mitigation zone of 500 yd (457 m) around observed whales, and 200 yd (183 m) around all other marine mammals, providing it is safe to do so during ice free waters.
- Moored/drifting sources are left in place and cannot be turned off until the following year during ice free months. Once they are programmed they will operate at the specified pulse lengths and duty cycles until they are either turned off the following year or there is failure of the battery and are not able to operate. Due to the ice covered nature of the Arctic is in not possible to recover the sources or interfere with their transmit operations in the middle of the permit year.
- These requirements do not apply if a vessel's safety is at risk, such as when a change of course would create an imminent and serious threat to safety, person, vessel, or aircraft, and to the extent vessels are restricted in their ability to maneuver. No further action is necessary if a marine mammal other than a whale continues to close on the vessel after there has already been one maneuver and/or speed change to avoid the animal. Avoidance measures should continue for any observed whale in order to maintain a mitigation zone of 500 yd (457 m).

5.2 Monitoring and Reporting

There are no specific monitoring plans outside of lookouts aboard the Coast Guard Cutter (CGC) HEALY and Research Vessel (R/V) Sikuliaq. Due to the scientific objectives for data collection acoustic sources would be deployed for an entire year without the ability to be turned off, until a subsequent cruise the following year. Due to the harsh conditions in the Arctic Study Area it is not feasible to tag and monitor marine mammals as it would require additional personnel and equipment.

While there is not monitoring specific to the Proposed Action, the Office of Naval Research (ONR) Marine Mammal Biology Program has funded research in Alaska on ice seals and whales. Currently ONR has funded a study to work with Native subsistence hunters and government agencies in Alaska (North Slope Borough Department of Wildlife Management) and Canada (Department of Fisheries and Oceans) to deploy satellite tags on ringed seals, spotted seals, bearded seals, bowhead whales, and beluga whales. The research is aimed to document year-round movements of each species and document habitat use relative to oceanographic conditions, ice cover, and human disturbance.

The Navy is committed to documenting and reporting relevant aspects of training and research activities to verify implementation of mitigation, comply with current permits, and improve future environmental assessments. If any injury or death of a marine mammal is observed during the 2018 Arctic Research Activities, the Navy will immediately halt the activity and report the incident consistent with the stranding and reporting protocol in other Navy documents such as the Atlantic Fleet Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement.

6 Consistency with Other Federal, State, and Local Laws, Plans, Policies, and Regulations

In accordance with 40 CFR section 1502.16(c), analysis of environmental consequences shall include discussion of possible conflicts between the Proposed Action and the objectives of federal, regional, state and local land use plans, policies, and controls. Table 6-1 identifies the principal federal and state laws and regulations that are applicable to the Proposed Action, and describes briefly how compliance with these laws and regulations would be accomplished.

Table 6-1. Principal Federal and State Laws Applicable to the Proposed Action

Federal, State, Local, and Regional Land Use Plans, Policies, and Controls	***Status of Compliance***
Arctic Research and Policy Act	This Overseas Environmental Assessment (OEA) has been prepared in compliance with the goals of the Arctic Research Policy Act.
Endangered Species Act (16 U.S.C. section 1531 et seq.)	This OEA considers impacts on species listed as threatened or endangered pursuant to this act. In accordance with the ESA, consultation with NMFS and USFWS were initiated based on the determination that the Proposed Action may affect bowhead whales (*Balaena mysticetus*), bearded seals (*Erignathus barbatus*), ringed seals (*Phoca hispida*) and their proposed critical habitat, and may affect, but is not likely to adversely affect the ESA-candidate species Pacific walrus (*Odobenus rosmarus*), and polar bears (*Ursus maritimus*) and their critical habitat. Concurrence was received from NMFS regarding bowhead whales, bearded seals, and ringed seals on XXX, 2017, and from the USFWS regarding Pacific walrus and polar bears on June 15, 2018 (Appendix D).
Marine Mammal Protection Act (16 U.S.C. section 1361 et seq.)	This OEA considers impacts on protected marine mammal species pursuant to this act. Based on the analysis contained within this OEA, the Navy submitted an application for an incidental harassment authorization (IHA) with NMFS for the taking of beluga whales, bowhead whales, bearded seals, and ringed seals on (XX, 2017). Additionally, a request for the intentional take (deterrence) of polar bears was requested for personnel and polar bear safety. A, Incidental Take Authorization was received by NMFS on XX XX, 2018 (Appendix E).
Migratory Bird Treaty Act (16 U.S.C. sections 703-712)	This OEA considers impacts on migratory birds under this Act.
Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (16 U.S.C. section 1801 et seq.)	This OEA considers impacts on fish and wildlife and essential fish habitat under this act. Based on the analysis contained within this OEA, the Navy submitted an Essential Fish Habitat Assessment with NMFS regarding potential impacts on Essential Fish Habitat on February 22, 2018. Concurrence was received by the Navy from NMFS on March 22, 2018 (Appendix B).

Federal, State, Local, and Regional Land Use Plans, Policies, and Controls	***Status of Compliance***
Executive Order 12114, Environmental Effects Abroad of Major Federal Actions	This OEA has been prepared in accordance with E.O. 12114 and Navy E.O. 12114 procedures.

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Appendix A Stressor Matrices

Ten categories of stressors were identified and analyzed within this OEA. Stressors applicable to each activity and resource are provided in Appendix Table A-1 and Appendix Table A-2. A description of each stressor, including the platforms that contribute to the stressor, is provided below.

- **Non-Impulsive Acoustic Sources:** Includes only those active sources that may harm a resource from acoustics that are not considered *de minimis* and require quantitative analysis.
- **Aircraft Noise:** Includes the noise generated by manned (e.g., twin otter fixed wing aircraft and rotary-wing aircraft) and unmanned (rotary-wing unmanned aerial systems) aircraft.
- **Icebreaking Noise:** Includes noise from CGC HEALY when icebreaking.
- **Impulsive Sources:** Includes quantitative analysis of both the airgun and compact sound sources.
- **Vessel Noise:** Includes the noise generated by the R/V Sikuliaq and CGC HEALY. This does not include the sound CGC HEALY generates when icebreaking.
- **Aircraft Strike:** Includes the potential for strike from both manned and unmanned aircraft.
- **Icebreaking (Physical Impacts):** Includes the potential for harm to resources from ice breaking apart, due to CGC HEALY breaking ice as it moves through the Study Area.
- **Vessel and In-Water Device Strike:** Includes the potential for vessels (i.e., surface ships) and in-water devices (e.g., gliders) to come into direct contact with a resource.
- **Bottom Disturbance:** Includes the potential for the material to strike a resource as it sinks and settles on the seafloor. Expended material is also analyzed for potential disturbance to the seafloor.
- **Entanglement:** Includes the potential for a resource to become entangled in a temporarily-deployed device (e.g., vertical array) and those materials that will be expended.
- **Ingestion:** Includes the possibility of ingesting complete objects as well as small pieces of objects to determine if they are edible.

Appendix Table A-1. Stressors by Activity

Action	*Acoustic Stressors*					*Physical Stressors*				*Expended Material*	
	Non-Impulsive Acoustic Sources	*Aircraft Noise*	*Icebreaking Noise*	*Impulsive Sources*	*Vessel Noise*	*Aircraft Strike*	*Icebreaking (Physical Impacts)*	*Vessel and In-Water Device Strike*	*Bottom Disturbance*	*Entanglement*	*Ingestion*
Glider Surveys								X			
Research Vessel Activities			X		X		X	X		X	
Towed Active Acoustic Sources	X							X		X	
Impulsive Acoustic Sources				X				X			
Moored Acoustic Sources	X							X	X	X	
De minimis Sources								X	X		
Drifting Oceanographic Sensors									X	X	
Moored Oceanographic Sensors								X	X	X	
Fixed and Towed Receiving Arrays								X	X	X	
Aircraft and UAV activities		X				X					
On-Ice Measurement Systems											X
Bottom Interaction Systems								X	X		
Weather Balloons									X	X	X

Appendix Table A-2. Stressors by Resource

Resource	***Acoustic Stressors***					***Physical Stressors***				***Expended Material***	
	Non-Impulsive Acoustic Sources	***Aircraft Noise***	***Icebreaking Noise***	***Impulsive Sources***	***Vessel Noise***	***Aircraft Strike***	***Icebreaking (Physical Impacts)***	***Vessel and In-Water Device Strike***	***Bottom Disturbance***	***Entanglement***	***Ingestion***
Ice							X				
Bottom Substrate									X		
Marine Mammals	X	X	X	X	X		X	X		X	X
Marine Birds		X	X		X	X					X
Invertebrates	X		X	X	X		X	X	X	X	
Fish	X		X	X	X		X	X	X	X	X
Essential Fish Habitat	X			X			X				

Appendix B Magnuson-Stevens Fishery Conservation and Management Act Concurrence Letter

Appendix C Non-Impulsive and Impulsive Source Modeling

C.1. Introduction

The marine mammal acoustics effects analysis was conducted in accordance with current Navy sonar policy, as advised by the Chief of Naval Operations Environmental Readiness Division. Accordingly, ensonified areas and exposure estimates for marine mammals were reported based on Sound Exposure Level (SEL) and Sound Pressure Level (SPL) thresholds. Permanent Threshold Shift (PTS) is the criterion used to establish the onset of non-recoverable physiological effects. Temporary Threshold Shift (TTS) is the criterion used to establish the onset of recoverable physiological effects, and a behavioral response function (BRF) is used to determine non-physiological behavioral effects. Environmental parameters were collected and archived, and propagation modeling was performed with the Naval Oceanographic Office's Oceanographic and Atmospheric Master Library CASS/GRAB model (Weinberg and Keenan 2008). The acoustics effects modeling utilized the databases and tools collectively referred to as the Navy Acoustic Effects Model (NAEMO) (U.S. Department of the Navy 2017c). Results were then computed for the defined operational scenario. This section provides a brief discussion of several key components of the acoustics effects modeling process, specifically: environmental inputs, acoustic sources, propagation modeling, and the NAEMO modeling software suite.

C.2. Source Characteristics and Scenario Description

The non-impulsive acoustic sources associated with the Proposed Action fall within bins LF4 (low-frequency sources equal to 180 dB and up to 200 dB), LF5 (low-frequency sources less than 180 dB), and MF9 (active sources [equal to 180 dB and up to 200 dB] not otherwise binned). LF4 was modeled at 185 dB due to source limitations with transmission. The spiral wave beacon, navigation sources, tomography, icebreaking sources, airgun and compact sound source were also modeled and included in the Proposed Action. The parameters for the acoustic and impulsive transmissions associated with research activities can be found in Table 2-1 above, the parameters for icebreaking can be found in Table 4-4 and Table 4-5 above.

C.3. Environmental Characteristics

Data for four environmental characteristics (bathymetry, sound speed profile, sediment characteristics, and wind speed) were obtained for both the cold and warm seasons to support the acoustic and impulsive analysis. The databases used to obtain these data and the resulting parameters are provided in Appendix Table C-1. All of the databases are maintained by the Oceanographic and Atmospheric Master Library.

Appendix Table C-1. Environmental Parameters for ARA

Model / Parameter	*Data Input*	*Database*
Propagation Model	Specific data are not applicable for this parameter.	Comprehensive Acoustic System Simulation Version 4.3b
Absorption Model	Specific data are not applicable for this parameter.	Francois-Garrison (the CASS/GRAB default)
Analysis Locations	Study Area	Database not used for this parameter
Analysis Specifics	Acoustic sources: 18 radials => 1 radial per 20 degrees Impulsive sources: 9 radials => 1 radial per 40 degrees Range increment: 50 meters* Depth increment: 25 meters*	Database not used for this parameter
Bathymetry	Data was obtained from a location centered around 72° 53'N, 146° 28'W. Resolution was at five hundredths (0.5) of a degree.	Digital Bathymetric Data Base Variable Resolution (DBDB-V) Version 6.2
Sound Speed Profiles	Sound speed profiles were extracted at the highest database resolution of 0.25 degree.	Generalized Digital Environmental Model Variable (GDEM-V) Version 3.0
Wind Speed	Wind speed was extracted at the highest database resolution of one (1) degree. Average wind speed: N/A for the cold season since the Study Area is ice covered	Surface Marine Gridded Climatology (SMGC) Version 2.0
Geo-Acoustic Parameters	Sediment type of sand was determined for the Study Area.	High Frequency Environmental Acoustics Version 2 HFEVA
Surface Reflection Coefficient Model	Specific data are not applicable for this parameter.	Navy Standard Forward Surface Loss Model

*Range and depth increments for impulsive source modeling are not uniform. The steps are small when close to the source and spread out when moving away from the source. Increments shown are largest steps.

C.4. Marine Mammal Density Estimates

Marine mammal densities utilized in the acoustic analysis were based on the best available science for the Study Area. Baseline marine mammal distribution and density data from the Navy Marine Species Density Database (NMSDD) (U.S. Department of the Navy 2017d) were first extracted for the Study Area. Datasets that comprise the NMSDD include surveys, average published population estimates, and Relative Environmental Suitability models (Kaschner et al. 2006).

C.5. Criteria and Thresholds

Harassment criteria for marine mammals are evaluated based on thresholds developed from observations of trained cetaceans exposed to intense underwater sound under controlled conditions (Finneran et al. 2003; Kastak and Schusterman 1996; Kastak and Schusterman 1999; Kastak et al. 2005; Kastelein et al. 2012). These data are the most applicable because they are based on controlled, tonal sound exposures within the typical sonar frequency ranges and because the species studied are closely related to the animals expected in the Study Area. Studies have reported behavioral alterations, or deviations from a subject's normal trained behavior, and exposure levels above which animals were observed to exhibit behavioral deviations (Finneran and Schlundt 2003; Schlundt et al. 2000).

Criteria and thresholds used for determining the potential effects from the Proposed Action are from NMFS technical guidance on acoustic and impulsive thresholds for PTS/TTS. The behavioral criteria was developed in coordination with NMFS to support Phase III environmental analyses and MMPA Letter of Authorization renewals (U.S. Department of the Navy 2017a). Appendix Table C-2 and Appendix Table C-3 below provides the criteria and thresholds used in this analysis for estimating quantitative acoustic and impulsive exposures of marine mammals from the Proposed Action, respectively. Weighted criteria are shown in the table below. Frequency-weighting functions are used to adjust the received sound level based on the sensitivity of the animal to the frequency of the sound. For weighting function derivation, the most critical data required are TTS onset exposure levels as a function of exposure frequency. These values can be estimated from published literature by examining TTS as a function of SEL for various frequencies.

The impulsive approach is the same as the acoustic approach with the differences described in this section. The impulsive model for airgun and compact sound source modeling uses the following metrics to describe the sound received by animats: peak sound pressure level, root mean square sound pressure level (SPL_{RMS}), and sound exposure level (SEL). The SPL_{RMS} criteria is only applied to airguns. Sound exposure level represents both the SPL of a sound as well as its duration. Impulse is the integral of positive pressure over a brief time period. The impulse metric is only applied to explosive impulses.

The main difference between impulsive and non-impulsive modeling is that the impulsive signal is time-dependent, whereas the pressure field for non-impulsive acoustic sources is modelled as an instantaneous phenomenon (Deavenport and Gilchrest 2015). This is because impulsive signals are time-dependent processes characterized by a rapid rise and subsequent fall in pressure. The time dependence is incorporated by using outputs from CASS/GRAB to build a transfer function, and convolving this with a similitude source signature.

Appendix Table C-2. Acoustic Injury (PTS) and Disturbance (TTS, Behavioral) Thresholds for Underwater Sounds[1]

Group	*Species*	*Behavioral Criteria*		*Physiological Criteria*	
		Non-Impulsive Acoustic Sources	*Icebreaking Sources*	*Onset TTS*	*Onset PTS*
Low Frequency Cetaceans	Gray whale, bowhead whale	Low-Frequency BRF dose response function[3]	120 dB re 1 µPa step function	179 dB SEL cumulative	199 dB SEL cumulative
Mid Frequency Cetaceans	Beluga whale	Mid-Frequency BRF dose response function[3]	120 dB re 1 µPa step function	178 dB SEL cumulative	198 dB SEL cumulative
Phocidae (in water)	Bearded seal, pacific walrus, ribbon seal, spotted seal, ringed seal	Pinniped Dose Response Function[3]	120 dB re 1 µPa step function	181 dB SEL cumulative	201 dB SEL cumulative
Otariidae (in water) and other non-phocid marine carnivores	Polar bear	Pinniped Dose Response Function[3]	120 dB re 1 µPa step function	199 dB SEL cumulative	219 dB SEL cumulative

[1] The threshold values provided are assumed for when the source is within the animal's best hearing sensitivity. The exact threshold varies based on the overlap of the source and the frequency weighting.
[2] BRF = Behavioral Response Function

[3] See Appendix Figure C-1

Appendix Table C-3. Impulsive Injury (PTS) and Disturbance (TTS, Behavioral) Thresholds for Underwater Sounds[1]`

Hearing Group	Behavioral Threshold		TTS Threshold		PTS Threshold	
	Airgun (SPL in dB re 1 µPa [$rms_{90\%}$])	Compact sound source (SEL in dB re 1 µPa²s)	SEL (weighted) (dB SEL)	Peak SPL (dB SPL)	SEL (weighted) (dB SEL)	Peak SPL (dB SPL)
Low Frequency Cetaceans	160	163 (low frequency weighting function)[2]	168	213	183	219
Mid Frequency Cetaceans	160	165 (mid frequency weighting function)[2]	170	224	185	230
Phocidae (in water)	160	165 (phocid weighting function)[2]	170	212	185	218
Otariidae (in water) and other non-phocid marine carnivores	160	183 (otariid weighting function)[2]	188	226	203	232

[1] The threshold values provided are assumed for when the source is within the animal's best hearing sensitivity. The exact threshold varies based on the overlap of the source and the frequency weighting.
[2] See Appendix Figure C-2

To estimate TTS onset values, only TTS data from behavioral hearing tests were used. To determine TTS onset for each subject, the amount of TTS observed after exposures with different SPLs and durations were combined to create a single TTS growth curve as a function of SEL. The use of (cumulative) SEL is a simplifying assumption to accommodate sounds of various SPLs, durations, and duty cycles. This is referred to as an "equal energy" approach, since SEL is related to the energy of the sound and this approach assumes exposures with equal SEL result in equal effects, regardless of the duration or duty cycle of the sound. It is well-known that the equal energy rule will over-estimate the effects of intermittent noise, since the quiet periods between noise exposures will allow some recovery of hearing compared to noise that is continuously present with the same total SEL (Ward 1997). For continuous exposures with the same SEL but different durations, the exposure with the longer duration will also tend to produce more TTS (Finneran et al. 2010; Kastak et al. 2007; Mooney et al. 2009).

As in previous acoustic effects analysis (Finneran and Jenkins 2012; Southall et al. 2007), the shape of the PTS exposure function for each species group is assumed to be identical to the TTS exposure function for each group. A difference of 20 dB between TTS onset and PTS onset is used for all marine mammals including pinnipeds. This is based on estimates of exposure levels actually required for PTS (i.e. 40 dB of TTS) from the marine mammal TTS growth curves, which show differences if 13 to 37 dB between TTS and PTS onset in marine mammals. Details regarding these criteria and thresholds can be found in National Marine Fisheries Service (2016).

C.5.1. Behavioral Reactions or Responses

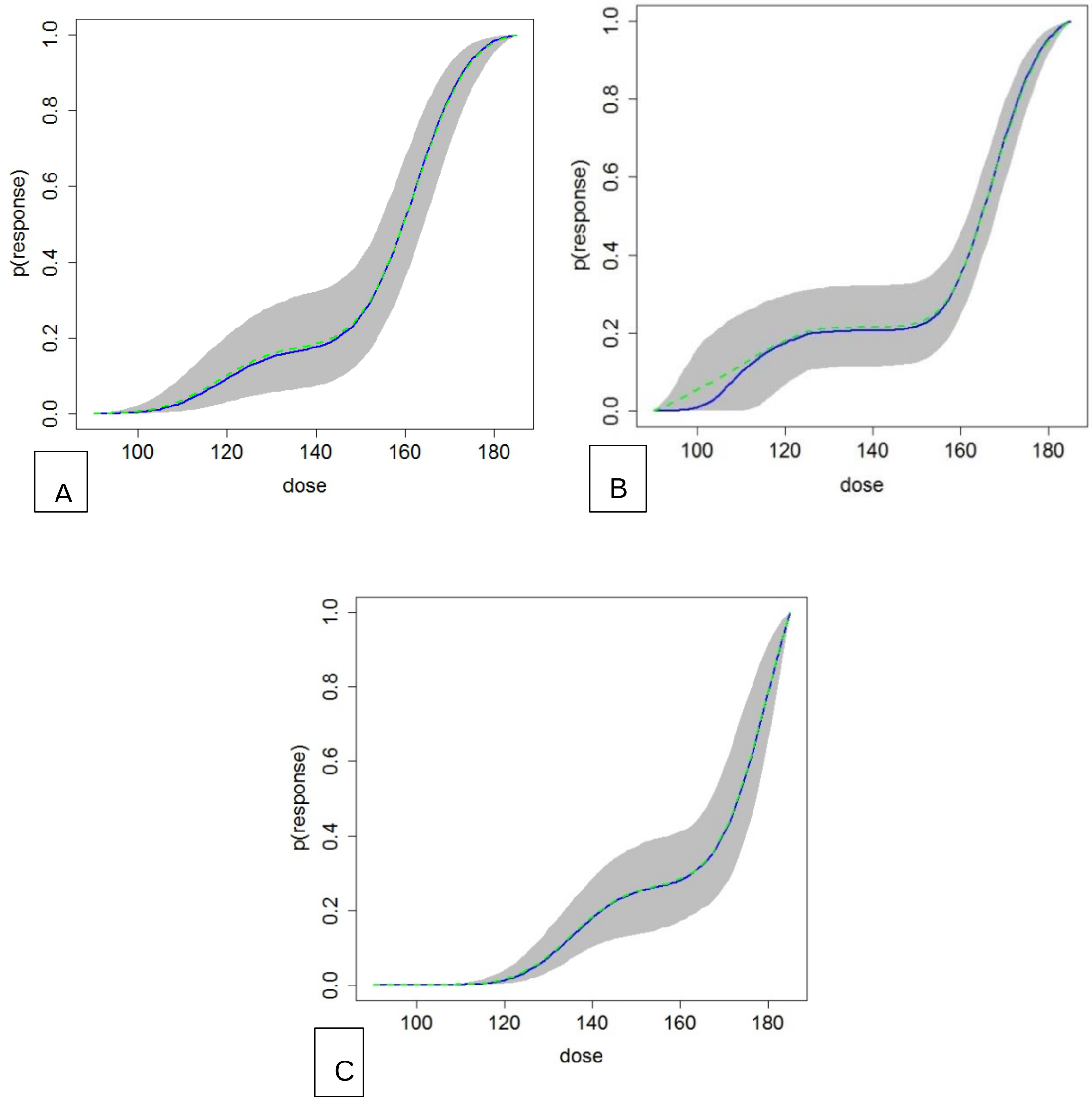
Behavioral criteria for both acoustic and impulsive sources are described below.

C.5.1.1. Acoustic Criteria

The response of a marine mammal to an anthropogenic sound will depend on the frequency, duration, temporal pattern and amplitude of the sound as well as the animal's prior experience with the sound and the context in which the sound is encountered (i.e., what the animal is doing at the time of the exposure). The distance from the sound source and whether it is perceived as approaching or moving away can also affect the way an animal responds to a sound (Wartzok et al. 2003). For marine mammals, a review of responses to anthropogenic sound was first conducted by Richardson *et al*. (1995b). Reviews by Nowacek *et al.* (2007) and Southall *et al.* (2007) address studies conducted since 1995 and focus on observations where the received sound level of the exposed marine mammal(s) was known or could be estimated. Multi-year research efforts have conducted sonar exposure studies for odontocetes and mysticetes (Miller et al. 2012; Sivle et al. 2012). Several studies with captive animals have provided data under controlled circumstances for odontocetes and pinnipeds (Houser et al. 2013a; Houser et al. 2013b). Moretti *et al.* (2014) published a beaked whale dose-response curve based on passive acoustic monitoring of beaked whales during U.S. Navy training activity at Atlantic Underwater Test and Evaluation Center during actual Anti-Submarine Warfare exercises. This new information has necessitated the update of the Navy's behavioral response criteria.

Southall *et al.* (2007) synthesized data from many past behavioral studies and observations to determine the likelihood of behavioral reactions at specific sound levels. While in general, the louder the sound source the more intense the behavioral response, it was clear that the proximity of a sound source and the animal's experience, motivation, and conditioning were also critical factors influencing the response (Southall et al. 2007). After examining all of the available data, the authors felt that the derivation of thresholds for behavioral response based solely on exposure level was not supported because context of the animal at the time of sound exposure was an important factor in estimating response. Nonetheless, in some conditions, consistent avoidance reactions were noted at higher sound levels depending on the marine mammal species or group allowing conclusions to be drawn. Phocid seals showed avoidance reactions at or below 190 dB re 1 µPa at 1m; thus, seals may actually receive levels adequate to produce TTS before avoiding the source.

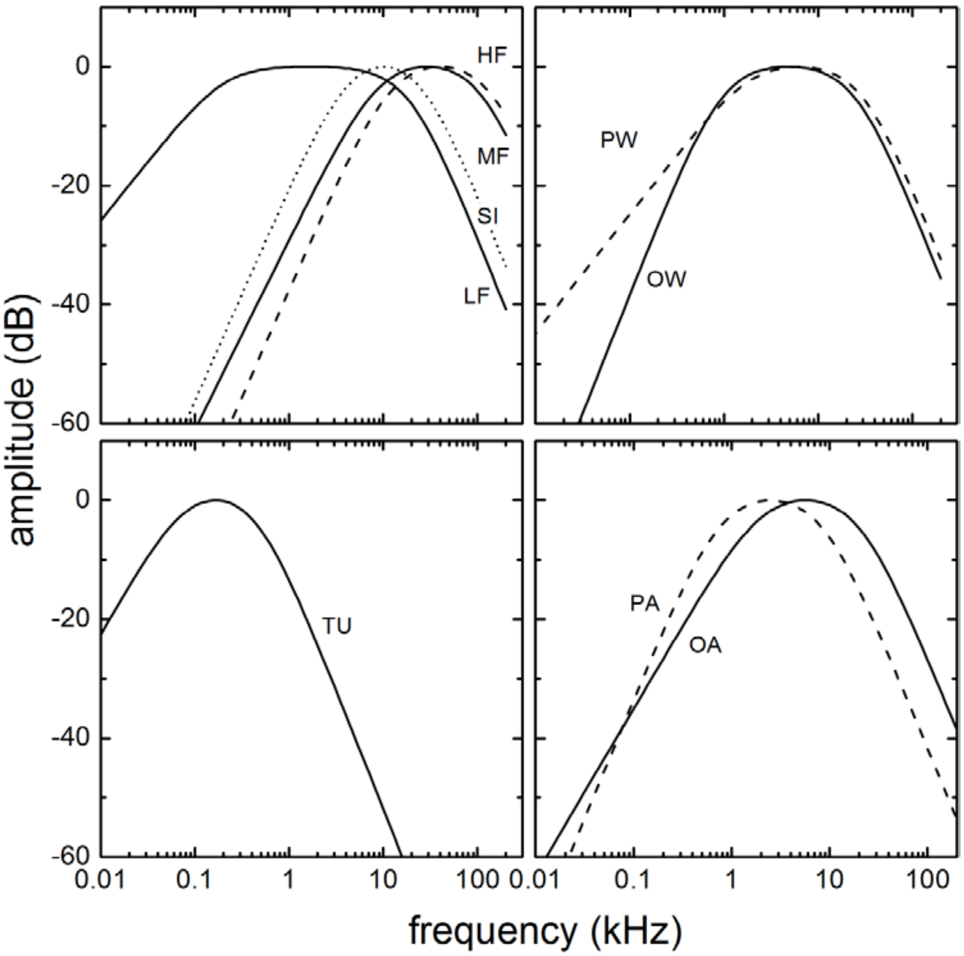
The Phase III pinniped behavioral criteria was updated based on controlled exposure experiments on the following captive animals: hooded seal, gray seal, and California sea lion (Götz et al. 2010; Houser et al. 2013a; Kvadsheim et al. 2010). Overall exposure levels were 110-170 dB re 1 µPa for hooded seals, 140-180 dB re 1 µPa for gray seals and 125-185 dB re 1 µPa for California sea lions; responses occurred at received levels ranging from 125 to 185 dB re 1 µPa. However, the means of the response data were between 159 and 170 dB re 1 µPa. Hooded seals were exposed to increasing levels of sonar until an avoidance response was observed, while the gray seals were exposed first to a single received level multiple times, then an increasing received level. Each individual California sea lion was exposed to the same received level ten times, these exposure sessions were combined into a single response value, with an overall response assumed if an animal responded in any single session. Because these data represent a dose-response type relationship between received level and a response, and because the means were all tightly clustered, the Bayesian biphasic Behavioral Response Function for pinnipeds most closely resembles a traditional sigmoidal dose-response function at the upper received levels (Appendix Figure C-1), and has a 50% probability of response at 166 dB re 1 µPa. Additionally, to account for proximity to the source discussed above and based on the best scientific information, a conservative distance of 5.4 nautical miles (10 km) is used beyond which exposures would not constitute a take under the military readiness definition.



Appendix Figure C-1. A) The Bayesian biphasic dose-response BRF for Odontocetes. B) The Bayesian biphasic dose-response BRF for Pinnipeds C) The Bayesian biphasic dose-response BRF for Mysticetes. The blue solid line represents the Bayesian Posterior median values, the green dashed line represents the biphasic fit, and the grey represents the variance. [X-Axis: Received Level (dB re 1 µPa), Y-Axis: Probability of Response]

C.5.1.2. Impulsive Criteria

Behavioral response criteria are used to estimate the number of exposures that may result in a behavioral response. For airguns determination of a significant behavioral response for marine mammals was based on the SPL on the highest received signal. Both the compact sound source and airguns use the impulsive behavioral criteria for multiple shots. Behavioral criteria for the compact sound source uses SEL along with the weighting functions provided in Appendix Figure C-2. Additionally mammals must be exposed to this level more than once to receive a behavioral exposure.



Appendix Figure C-2. Navy Phase III Weighting Functions for all Species Groups. Parameters required to generate the functions that are provided in Appendix Table C-3 above.

C.6. NAEMO Software

The Navy performed a quantitative analysis to estimate the number of mammals that could be harassed by the underwater acoustic (non-impulsive and impulsive) sources during the Proposed Action. Inputs to the quantitative analysis included marine mammal density estimates obtained from the NMSDD, marine mammal depth occurrence distributions (U.S. Department of the Navy 2017b), oceanographic and environmental data, marine mammal hearing data, and criteria and thresholds for levels of potential effects. The quantitative analysis consists of computer modeled estimates and a post-model analysis to determine the number of potential animal exposures. The model calculates sound energy propagation from the proposed sonars, the sound received by animat (virtual animal) dosimeters representing marine mammals distributed in the area around the modeled activity, and whether the sound received by a marine mammal exceeds the thresholds for effects.

The Navy developed a set of software tools and compiled data for estimating acoustic effects on marine mammals without consideration of behavioral avoidance or Navy's standard mitigations. These databases and tools collectively form NAEMO. In NAEMO, animats are distributed nonuniformly based on species-specific density, depth distribution, and group size information. Animats record energy received at their location in the water column. A fully three-dimensional environment is used for calculating sound propagation and animat exposure in NAEMO. Site-specific bathymetry, sound speed profiles, wind speed, and bottom properties are incorporated into the propagation modeling process. NAEMO calculates the likely propagation for various levels of energy (sound or pressure) resulting from each source used during the testing event.

NAEMO then records the energy received by each animat within the energy footprint of the event and calculates the number of animats having received levels of energy exposures that fall within defined impact thresholds. Predicted effects on the animats within a scenario are then tallied and the highest order effect (based on severity of criteria; e.g., PTS over TTS) predicted for a given animat is assumed. Each scenario or each 24-hour period for scenarios lasting greater than 24 hours is independent of all others, and therefore, the same individual marine animal could be impacted during each independent scenario or 24-hour period. In few instances, although the activities themselves all occur within the Study Area, sound may propagate beyond the boundary of the Study Area. Any exposures occurring outside the boundary of the Study Area are counted as if they occurred within the Study Area boundary. NAEMO provides the initial estimated impacts on marine species with a static horizontal distribution.

There are limitations to the data used in the acoustic effects model, and the results must be interpreted within these context. While the most accurate data and input assumptions have been used in the modeling, when there is a lack of definitive data to support an aspect of the modeling, modeling assumptions believed to overestimate the number of exposures have been chosen:

- Animats are modeled as being underwater, stationary, and facing the source and therefore always predicted to receive the maximum sound level (i.e., no porpoising or pinnipeds' heads above water).
- Animats do not move horizontally (but change their position vertically within the water column), which may overestimate physiological effects such as hearing loss, especially for slow moving or stationary sound sources in the model.
- Animats are stationary horizontally and therefore do not avoid the sound source, unlike in the wild where animals would most often avoid exposures at higher sound levels, especially those exposures that may result in PTS.
- Multiple exposures within any 24-hour period are considered one continuous exposure for the purposes of calculating the temporary or permanent hearing loss, because there are not sufficient data to estimate a hearing recovery function for the time between exposures.
- Mitigation measures that are implemented were not considered in the model. In reality, sound-producing activities would be reduced, stopped, or delayed if marine mammals are detected within the mitigation zones around sound sources.

Because of these inherent model limitations and simplifications, model-estimated results must be further analyzed, considering such factors as the range to specific effects, avoidance, and the likelihood of successfully implementing mitigation measures. This analysis uses a number of factors in addition to the acoustic model results to predict acoustic effects on marine mammals.

For non-impulsive acoustic sources, NAEMO calculates the SPL and SEL for each active emission during an event. This is done by taking the following factors into account over the propagation paths: bathymetric relief and bottom types, sound speed, and attenuation contributors such as absorption, bottom loss and surface loss. Platforms such as a ship using one or more sound sources are modeled in accordance with relevant vehicle dynamics and time durations by moving them across an area whose size is representative of the testing event's operational area. For each modeled iteration, the slow moving platform in this experiment was programmed to move along straight line tracks from a randomly selected initial location with a randomly selected course. Specular reflection was employed at the boundaries to contain the vehicle within the Study Area.

NAEMO records the SPL and SEL received by each animat within the ensonified area of the event and evaluates them in accordance with the species-specific threshold criteria. For each animat, predicted SEL effects are accumulated over the course of the event and the highest order SPL effect is determined. Each 24-hour period is independent of all others, and therefore, the same individual animat could be exposed during each independent scenario or 24-hour period. Initially, NAEMO provides the overpredicted exposures to marine species because predictions used in the model include: all animats facing the source, not accounting for horizontal avoidance and mitigation is not implemented. After the modeling results are complete they are further analyzed to produce final estimates of potential marine mammal exposures.

C.7. Results

For non-impulsive acoustic sources, NAEMO calculates maximum received SPL and accumulated SEL over the entire duration of the event for each animat based on the received sound levels. For the airgun root mean square sound pressure level (SPL_{RMS}) is also used. These data are then processed using a bootstrapping routine to compute the number of animats exposed to SPL and SEL in 1 dB bins across all track iterations and population draws. SEL is checked during this process to ensure that all animats are grouped in either an SPL or SEL category. Additional detail on the bootstrapping process is included in Section C.7.1.

A mean number of SPL and SEL exposures are computed for each 1 dB bin. The mean value is based on the number of animats exposed at that dB level from each track iteration and population draw. The behavioral risk function curve is applied to each 1 dB bin to compute the number of behaviorally exposed animats per bin. The number of behaviorally exposed animats per bin is summed to produce the total number of behavior exposures.

Mean 1 dB bin SEL exposures are then summed to determine the number of PTS and TTS exposures. PTS exposures represent the cumulative number of animats exposed at or above the PTS threshold. The number of TTS exposures represents the cumulative number of animats exposed at or above the TTS threshold and below the PTS threshold. Animats exposed below the TTS threshold were grouped in the SPL category.

C.7.1. Bootstrap Approach

Estimation of exposures in NAEMO is accomplished through the use of a simple random sampling with replacement by way of statistical bootstrapping. This sampling approach was chosen due to the fact that the number of individuals of a species expected within an area over which a given Navy activity occurs is often too small to offer a statistically significant sampling of the geographical area. Additionally, NAEMO depends on the fact that individual animats move vertically in the water column at a specified displacement frequency for sufficient sampling of the depth dimension. By overpopulating at the time of animat distribution and drawing samples from this overpopulation with replacement, NAEMO is able to provide sufficient sampling in the horizontal dimensions for statistical confidence. Sampling with replacement also produces statistically independent samples, which allows for the calculation of metrics such as standard error and confidence intervals for the underlying Monte Carlo process.

For each scenario and each species, the number of samples equating to the overpopulation factor is drawn from the raw data. Each sample size consists of the true population size of the species evaluated. Exposure data is then computed for each sample using 1 dB exposure bins. The average number of exposures across the sample and scenario iteration is then computed.

For example, assuming that an overpopulation factor of 10 was defined for a given species and that 15 ship track iterations were completed. The bootstrap Monte Carlo process would have generated statistics for 10 draws on each of the 15 raw animat data files generated by the 15 ship tracks evaluated for this scenario, thereby yielding 150 independent sets of exposure estimates. Samples drawn from the overpopulated population are replaced for the next draw, allowing for the re-sampling of animals. The resultant 150 sets of exposures were then combined to yield a mean number of exposures and a 95 percent confidence interval per species for the scenario. In addition to the mean, the statistics included the upper and lower bounds of all samples.

C.7.2. Estimated Exposures

Based on the methodology contained herein, Appendix Table C-4 provides the modeled marine mammal exposures associated with the thresholds defined in Section C.5 for 2018, and Appendix Table C-5 provides the modeled marine mammal exposures associated with the thresholds defined in Section C.5 for years 2019, 2020, and 2021.

Appendix Table C-4. Predicted Marine Mammal Exposures All Events (Acoustic and Icebreaking) Occurring in 2018.

Species	*Alternative 1*			*Alternative 2 (Preferred Alternative)*		
	Behavioral	*TTS*	*PTS*	*Behavioral*	*TTS*	*PTS*
Beluga whale	112	0	0	73	0	0
Bowhead whale[1]	0.34	0	0	0	0	0
Gray whale	0	0	0	0	0	0
Polar bear[1]	0	0	0	0	0	0
Bearded seal[1]	97	0	0	0.39	0	0
Ribbon seal	0	0	0	0	0	0
Ringed seal[2]	3,532	0	0	2,183	1	0
Spotted seal	0	0	0	0	0	0
Pacific walrus[3]	65	0	0	0	0	0

[1]ESA-listed species
[2]ESA listed species pending final judicial resolution of their status.
[3]ESA-Candidate species pending petition for relisting

Appendix Table C-5. Predicted Yearly Marine Mammal Exposures All Events (Acoustic and Icebreaking) Occuring in 2019, 2020, or 2021.

Species	*Alternative 1*			*Alternative 2 (Preferred Alternative)*		
	Behavioral	*TTS*	*PTS*	*Behavioral*	*TTS*	*PTS*
Beluga whale	124	0	0	85	0	0
Bowhead whale[1]	0.34	0	0	0	0	0
Gray whale	0	0	0	0	0	0
Polar bear[1]	0	0	0	0	0	0
Bearded seal[1]	97	0	0	0.39	0	0
Ribbon seal	0	0	0	0	0	0
Ringed seal[2]	4,063	1	0	2,714	0	0
Spotted seal	0	0	0	0	0	0
Pacific walrus[3]	65	0	0	0	0	0

[1]ESA-listed species
[2]ESA listed species pending final judicial resolution of their status.
[3]ESA-Candidate species pending petition for relisting

Appendix D Endangered Species Act Documentation

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Appendix E Marine Mammal Protection Act Documentation