Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Section 7(a)(4) Conference Report

Lease Sale 193 Oil and Gas Exploration Activities, Chukchi Sea, Alaska

NMFS Consultation Number: *AKR-2015-9422*

Action Agencies: *Bureau of Ocean Energy Management (BOEM), and Bureau of Safety and Environmental Enforcement (BSEE)*

Affected Species and Determinations:

ESA-Listed Species	**Status**	**Is Action Likely to Adversely Affect Species**	**Is Action Likely To Jeopardize the Species?**	**Is Action Likely To Destroy or Adversely Modify Critical Habitat?**
Bowhead Whale (*Balanea mysticetus*)	Endangered	Yes	No	N/A
Fin Whale (*Balaneoptera physalus*)	Endangered	Yes	No	N/A
Humpback Whale (*Megaptera novaeangliae*)	Endangered	Yes	No	N/A
North Pacific Right Whale (*Eubalaena japonica*)	Endangered	No	No	No
Gray Whale, Western North Pacific DPS (*Eschrichtius robustus*)	Endangered	No	No	N/A
Sperm Whale (*Physeter macrocephalus*)	Endangered	No	No	N/A
Ringed Seal, Arctic Subspecies (*Phoca hispida hispida*)	Threatened	Yes	No	No
Bearded Seal, Beringia DPS (*Erignathus barbatus nauticus*)	Threatened	Yes	No	N/A
Steller Sea Lion, Western DPS (*Eumatopias jubatus*)	Endangered	No	No	No

Consultation Conducted By: National Marine Fisheries Service, Alaska Region

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Date: JUNE 4, 2015

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

TERMS AND ABBREVIATIONS

µPa	Micro Pascal
2D	Two-Dimensional
3D	Three-Dimensional
ACIA	Arctic Climate Impact Assessment
AEWC	Alaska Eskimo Whaling Commission
AGL	Above Ground Level
APD	Application for Permit to Drill
ARBO	Arctic Regional Biological Opinion
ASAMM	Aerial Surveys of Arctic Marine Mammals
ASL	Above Sea Level
ATOC	Acoustic Thermometry of the Ocean Climate
BA	Biological Assessment
Bbbl	Billion Barrels
BOEM	Bureau of Ocean Energy Management
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BOSS	Bering Sea and Okhotsk Seas
BSAI	Bering Sea/Aleutian Island
BSEE	Bureau of Safety and Environmental Enforcement
BWASP	Bowhead Whale Feeding Ecology Study
CAA	Conflict Avoidance Agreement
CHIRP	Compressed High Intensity Radar Pulse
CI	Confidence Interval
CNP	Central North Pacific
CPUE	Catch Per Unit Effort
CSEL	Cumulative Sound Exposure Level
CSEM	Controlled Source Electromagnetic
CSESP	Chukchi Sea Environmental Studies Program
cui	Cubic Inches
CV	Coefficient of Varience
CWA	Clean Water Act
dB re 1µPa	Decibel referenced 1 microPascal
DDT	Dichloro-Diphenyltrichloroethane
District Court	U.S. District Court for the District of Alaska
DP	Dynamic Positioning
DPP	Development and Production Plan
DPS	Distinct Population Segment
DWH	Deepwater Horizon
EEZ	Exclusive Economic Zone

EP	Exploration Plan
EPA	Environmental Protection Agency
ERL	Effects Range Low
ERM	Effects Range Medium
ESA	Endangered Species Act
EZ	Exclusion Zone
ft	Feet
FWS	U.S. Fish and Wildlife Service
G&G	Geological & Geophysical
gal	Gallons
Hz	Hertz
IHA	Incidental Harassment Authorization
IPCC	Intergovernmental Panel on Climate Change
ITL	Information to Lessee
ITS	Incidental Take Statement
IWC	International Whaling Commission
km	Kilometers
kn	Knot
km^2	Square Kilometers
L	Liters
LS 193	Lease Sale 193
m	Meter
mi	Mile
ms	Milliseconds
MLC	Mudline Cellar
MLC-ROV	Mudline Cellar Remotely Operated Vehicle
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MODU	Mobile Offshore Drilling Unit
MONM	Marine Operations Noise Model
MWCS	Marine Well Containment System
NEPA	National Environmental Policy Act
Ninth Circuit	U.S. Court of Appeals for the Ninth Circuit
NMFS	National Marine Fisheries Service
NPDES	National Pollution Discharge Elimination System
NTL	Notice to Lessee
OBC	Ocean Bottom Cable
OC	Organochlorine
OCSLA	Outer Continental Shelf Lands Act
Opinion	Biological Opinion
OSR	Oil Spill Response
OSRA	Oil Spill Risk Analysis

OSRV	Oil Spill Response Vessel
OST	Oil Supply Tanker
OSV	Offshore Supply Vessels
PAH	Polycyclic Aromatic Hydrocarbons
PBDE	Polybrominated Diphenyl
PBR	Potential Biological Removal
PBU	Prudhoe Bay Unit
PCB	Polychlorinated Biphenyls
PCE	Primary Constituent Element
PR1	Office of Protected Resources- Permits and Conservation Division
psi	Pound Per Square Inch
PSO	Protected Species Observers
PTS	Permanent Threshold Shift
$R_{95\%}$	Radius of a Circle Encompassing 95% of the Area of the Contour
R_{ea}	Radius of a Circle with Area Equivalent to the Total Area of the Contour
R_{max}	Maximum Distance from Sound Source to the Contour
rms	Root Mean Square
RPA	Reasonable Prudent Alternative
SAE	SAExploration, Inc.
SDR	Satellite Data Recorder
SEIS	Supplemental Environmental Impact Statement
SONAR	Sound Navigation and Ranging
SPLASH	Structure of Populations, Levels of Abundance and Status of Humpback Whales
TAPS	Trans-Alaska Pipeline System
TGS	TGS-Nopec Geophysical Company ASA
TTS	Temporary Threshold Shift
USDOI	United States Department of Interior
USFWS	United States Fish and Wildlife Service
VGP	Vessel General Permit
VLOS	Very Large Oil Spill
VMS	Vessel Monitoring System
VSP	Vertical Seismic Profiling
WNP	Western North Pacific

1. INTRODUCTION

Section 7(a)(2) of the Endangered Species Act of 1973, as amended, (ESA) requires each federal agency to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. When a federal agency's action "may affect" a protected species, that agency is required to consult with the National Marine Fisheries Service (NMFS) or the U.S. Fish and Wildlife Service (FWS), depending upon the endangered species, threatened species, or designated critical habitat that may be affected by the action (50 CFR §402.14(a)). Federal agencies may consult informally if they conclude that an action "may affect, but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS or FWS concurs with that conclusion (50 CFR §402.14(b)).

For the actions described in this document, the action agencies are the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE), which propose to authorize oil and gas exploration activities and ensure compliance with the terms and conditions of leasing and exploration activities on Lease Sale 193 (LS 193) in the Chukchi Sea under the Outer Continental Shelf Lands Act (OCSLA) over a nine-year period beginning June 2015 and ending June 2024. The consulting agency for this proposal is NMFS's Alaska Regional Office. This document represents NMFS's biological opinion and conference report (opinion) on the effects of this proposal on endangered and threatened species and designated and proposed critical habitats.

The opinion and incidental take statement were prepared by NMFS in accordance with section 7(b) of the ESA and implementing regulations at 50 CFR 402.

The opinion is in compliance with section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-5444) ("Data Quality Act") and underwent pre-dissemination review.

1.1 Background

This opinion considers the effects of the authorization of oil and gas exploration activities for LS 193 under the OCSLA from June 2015 to June 2024. These actions have the potential to affect the endangered bowhead whale (*Balaena mysticetus*), endangered fin whale (*Balaenoptera physalus*), endangered humpback whale (*Megaptera novaeangliae*), endangered North Pacific right whale (*Eubalaena japonica*), endangered western North Pacific distinct population segment (DPS) of gray whale (*Eschrichtius robustus*), endangered sperm whale (*Physeter macrocephalus*), endangered western DPS of Steller sea lion (*Eumatopias jubatus*), threatened Arctic subspecies of ringed seal (*Phoca hispida hispida*), and Beringia DPS of bearded seal

(*Erignathus barbatus nauticus*),[1] as well as the designated critical habitats for North Pacific right whale and Steller sea lion, and proposed critical habitat for the Arctic subspecies of ringed seal.

This biological opinion and conference report are based on information provided in the January 2015, Biological Assessment; October 2014, Draft Second Supplemental Environmental Impact Statement (SEIS) on the Effects of Oil and Gas Activities in the Lease Sale 193 in the Chukchi Sea, Alaska; the updated project proposals, clarifying email and telephone conversations between NMFS and BOEM staff; and other sources of information. A complete record of this consultation is on file at NMFS's Juneau Alaska office.

1.2 Consultation History

On June 18, 2010, by Secretarial Order No. 3302, the U.S. Department of the Interior (USDOI), Minerals Management Service (MMS) was renamed the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE). On October 1, 2011, BOEMRE was further re-organized into two independent bureaus: BOEM, which is responsible for managing development of the nation's offshore resources in an environmentally and economically responsible way, and BSEE, which is responsible for enforcement of safety and environmental regulations.

On January 2008, the MMS issued a Final Notice of Sale for Chukchi Sea Outer Continental Shelf Oil and Gas Lease Sale 193 to be conducted in February 2008. On January 31, 2008, a lawsuit was filed in the U.S. District Court for the District of Alaska (District Court) alleging violations pursuant to National Environmental Policy Act (NEPA) and the ESA [Native Village of Point Hope v. Salazar, No. 1:08-cv-00004-RRB (D. Alaska)]. LS 193 was held on February 2008. The MMS issued 487 leases. On July 21, 2010, the District Court issued an Order remanding LS 193 to BOEM to satisfy its obligations under NEPA in accordance with the Court's opinion. BOEM complied with the District Court's remand and released a Final Supplemental Environmental Impact Statement in August 2011. The Secretary of the Interior reaffirmed the lease sale in October 2011. In February 2012, the District Court ruled the USDOI met its NEPA obligations on remand and dismissed the matter. In April 2012, the plaintiffs appealed the District Court's decision to the U.S. Court of Appeals for the Ninth Circuit (Ninth Circuit).

In a January 22, 2014 opinion, the Ninth Circuit found MMS's "reliance in the [Final Environmental Impact Statement] on a one billion barrel estimate of total economically recoverable oil was arbitrary and capricious." The Ninth Circuit explained that "NEPA require[s] [the Agency] to base its analysis on the full range of likely production if oil production were to occur." Id. The Ninth Circuit remanded the case to the District Court which further remanded the

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[1] On July 25, 2014, the U.S. District Court for the District of Alaska issued a decision vacating NMFS's December 28, 2012, listing of the Beringia DPS of bearded seals as a threatened species (*Alaska Oil & Gas Ass'n v. Pritzker*, Case No. 4:13-cv-00018-RPB). NMFS has appealed the district court's decision to the U.S. Court of Appeals for the Ninth Circuit. While the litigation is pending, our Biological Opinions under section 7(a)(2) of the ESA will continue to address effects to bearded seals so that action agencies have the benefit of NMFS's analysis of the consequences of proposed actions on this DPS, even though the listing of the species is not in effect.

matter to BOEM on April 24, 2014.

BOEM prepared a Draft Second SEIS for LS 193 (BOEM 2014a), in accordance with the April 24, 2014, remand order of the District Court. The Draft Second SEIS analyzes the environmental effects of potential oil and gas activities associated with LS 193. The analysis is based on a new exploration and development scenario of 4.3 billion barrels of oil.

BOEM initially contacted NMFS in June 2014 regarding potential reinitiation of consultation in association with the revised NEPA analysis providing a larger exploration and production scenario.

On October 10, 2014, BOEM/BSEE requested an incremental step consultation with NMFS under section 7(a)(2) and conference report under 7(a)(4) of the ESA, but did not provide an initiation package at that time (BOEM 2014b). The first incremental step consists of proposed activities associated with exploring and delineating an anchor field on the current 460 leases within LS 193, and onshore facility construction (years 1-9). However, the consultation also considers potential impacts through the endpoint of the action as described in the hypothetical production and development of an anchor field and if successful, the exploration, development and production of a satellite field, followed by the decommissioning of all of these activities (years 10-77). BOEM/BSEE determined that the proposed action may affect bowhead whale, humpback whale, fin whale, North Pacific right whale, western DPS of Steller sea lion, bearded seal, ringed seal, and their designated and proposed critical habitats. BOEM/BSEE requested that the biological opinion and conference report be completed by March 2015 (BOEM 2014b).

NMFS responded to BOEM/BSEE on October 24, 2014, indicating that the requested March 2015 deadline for the biological opinion and conference report was not practical in light of the fact that NMFS had not received a biological assessment from BOEM on the proposed action. NMFS anticipated completing the biological opinion and conference report by June 2015, prior to the scheduled commencement of exploratory drilling in July 2015, with the understanding that we could not produce a biological opinion and conference report without receiving the requisite information and analysis from BOEM (NMFS 2014).

NMFS received BOEM’s Draft Biological Assessment (BA) on January 20, 2015 (BOEM 2015a). The draft BA omitted North Pacific right whale, western DPS of Steller sea lion, and their designated critical habitats from the analysis.

NMFS reviewed and commented on the draft BA on February 4, 2015. NMFS highlighted inconsistencies between the BA and aspects of NMFS’ developing biological opinion and conference report including: (1) consideration of all interrelated and interdependent actions; (2) consideration of all the listed species and designated critical habitats that may be impacted by the proposed action; (3) nationally consistent mitigation measures; and (4) the BA’s omission of an exposure analysis identifying the spatial and temporal distribution of stressors at particular intensities and the number of individuals of each listed species likely to be exposed by the proposed action (NMFS 2015). Despite the information gaps, NMFS continued developing the opinion and conference report with the understanding that BOEM would continue assisting in gathering the remaining information and contribute to an acoustic propagation modeling effort. Through a collaborative and iterative process, BOEM and NMFS worked to complete the ESA consultation.

NMFS received the Final LS 193 Chukchi Sea Analysis and Acoustic Propagation Modeling Report on May 19, 2015(Austin et al. 2015).

2. DESCRIPTION OF THE PROPOSED ACTION

2.1 Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

This opinion considers the effects of BOEM and BSEE's authorization of oil and gas exploration activities (marine seismic, geohazard, and geotechnical surveys, and exploratory drilling) on the 460 active leases contained within LS 193 in the Chukchi Sea and the construction of onshore facilities between June 2015 and June 2024. The activities comprising the proposed action are further described below.

The purpose for the broader proposed action (of which the first incremental step is part) is for BOEM and BSEE to manage the exploration, development, production and decommissioning of oil and gas resources on the 460 leases issued through LS 193 in the U.S. OCS of the Chukchi Sea pursuant to OCSLA. The OCSLA sets out a four-stage process for planning, leasing, exploration, and development and production of oil and gas resources in the OCS.

2.1.1 Incremental Step Consultation

Regulations at 50 CFR 402.14 (k) allow incremental consultation on part of the entire action as long as that part does not violate section 7(a)(2), there is a reasonable likelihood that the entire action will not violate section 7(a)(2), and the agency continues consultation with respect to the entire action. BOEM and BSEE requested incremental section 7 consultation with the proposed action covering the first step – exploration activities consisting of: (1) marine seismic surveys; (2) geohazard surveys; (3) geotechnical surveys; (4) exploratory drilling; and (5) onshore facility construction. The first incremental step consists of activities associated with exploring and delineating an anchor field on current leases within LS 193, and onshore facility construction (years 1-9).

As required, the consultation also considers potential impacts through the endpoint of the action: the hypothetical production and development of an anchor field and if successful, the exploration, development and production of a satellite field, followed by the decommissioning of all of these activities (years 10-77).

2.1.2 BOEM and BSEE's Process for Permitting

Specific permits and authorizations required by BOEM and BSEE affect the progression of oil and gas exploration activities. The following summarizes BOEM and BSEE's permitting process:

- Geological & Geophysical (G&G) Exploration Permits – In accordance with 30 CFR 551, a permit must be obtained from BOEM prior to conducting geological or geophysical exploration on unleased lands or on lands under lease by a third party. On-lease G&G exploration can be conducted under a G&G permit or an Ancillary Notice in accordance with 30 CFR 550.

- Ancillary Activities – These on-lease activities include geohazard surveys, two-dimensional (2D) and three-dimensional (3D) deep penetration marine seismic, and geotechnical surveys. Ancillary activities are conducted in accordance with 30 CFR 550.
- Exploration Plan (EP) – An exploration plan is submitted to BOEM by the lessee to conduct exploration activities in accordance with 30 CFR 550. An EP is not required to conduct G&G or ancillary activities.
- Application for Permit to Drill (APD) – a permit must be obtained from BSEE prior to conducting drilling operations and requires detailed information on the seafloor and shallow seafloor conditions for the drill site from shallow geophysical surveys in accordance with 30 CFR 250.

The proposed action consists of ancillary activities (marine seismic surveys, geohazard surveys, and geotechnical surveys) which would be conducted by lease holders on their leased area(s) following the notice process under BOEM's regulations, and drilling activities which would be authorized under an exploration plan and a permit to drill. Off-lease G&G activities are covered under a separate Arctic Regional Biological Opinion (NMFS 2013a) and are not included as part of the proposed action but are included in Section 2.3 *Environmental Baseline*.

2.1.3 BOEM and BSEE's Proposed Activities

BOEM and BSEE propose to authorize activities associated with exploring and delineating an anchor field, including marine seismic, geohazard and geotechnical surveys, and exploratory drilling on the 460 current leases in LS 193 in the Chukchi Sea, and may involve the construction of onshore facilities (Table 1).

Table 1. Maximum anticipated level of exploration activities that would occur during the first incremental step.

Activity Type	Maximum Number During First Incremental Step	Activity Period
Open-water season 2D/3D marine seismic survey	1	July-November
In-ice 2D marine seismic survey	1	October-December
Geohazard survey	5	July-November
Geotechnical survey	5	July-November
Exploratory and delineation drilling	28 wells	June-November
Vertical seismic profiling	28	June-November
Onshore facility construction	Up to 3 bases, 2 years of construction	Year Round

The survey and drilling area, within the active leases, consists of 10,541 square kilometers (km^2), and onshore facility construction may cover up to 1.36 km^2 (see Figure 1).

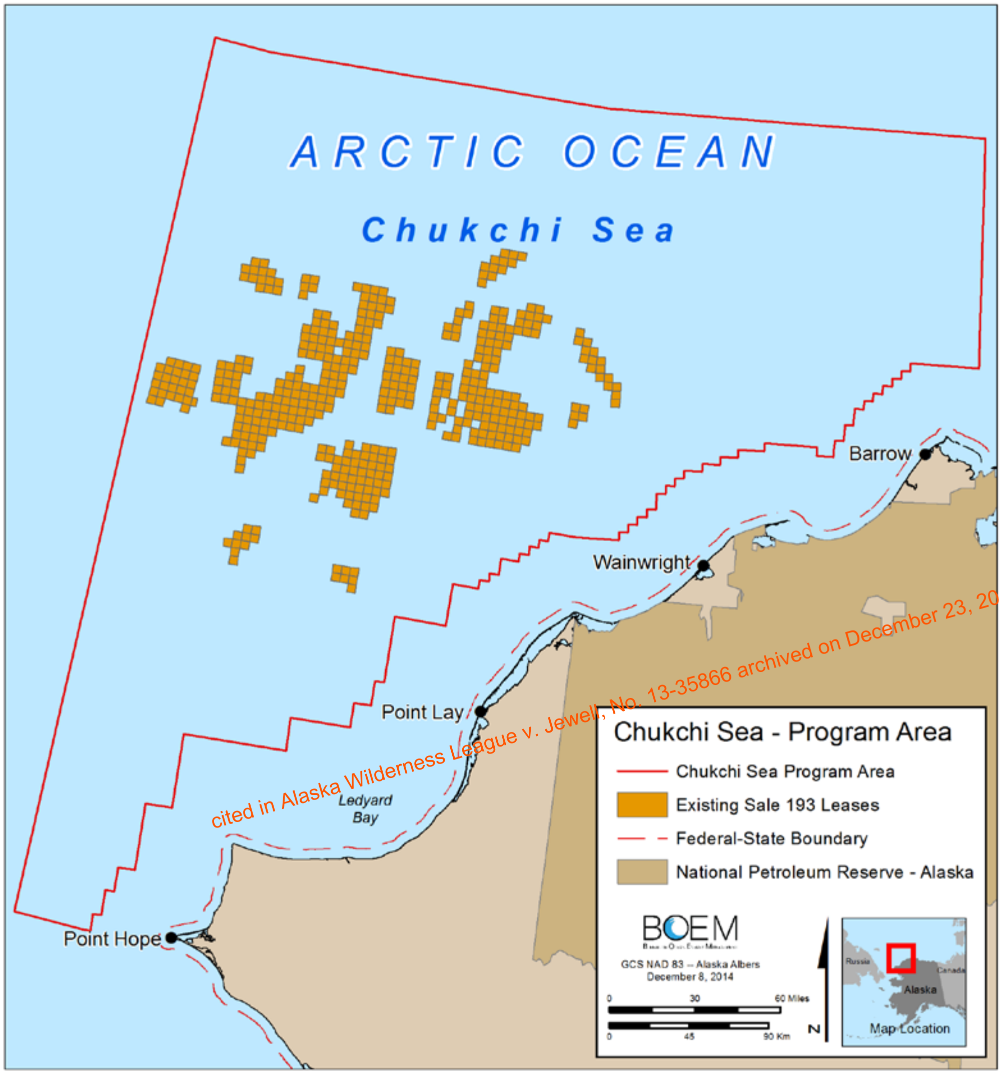

Figure 1. **Chukchi Sea Program Area and 460 Active Leases issued through LS 193.**

A detailed description of marine seismic surveys, geohazard surveys, geotechnical surveys, exploratory drilling and onshore facility construction are provided in Section 2.3.5 of the Final Second SEIS (BOEM 2015e), and in Section 2.0 of the BA (BOEM 2015a), and incorporated here by reference.

2.1.3.1 Marine Seismic Surveys

Marine seismic surveys (also known as deep penetration seismic surveys) are a type of ancillary survey conducted to identify prospective oil and gas deposits and to optimize drilling sites on leases acquired in lease sales. They may include seismic surveys such as: open-water, towed streamer 2D or 3D surveys, and in-ice towed streamer 2D surveys.

2D deep penetration seismic surveying techniques are used to provide broad-scale information over a relatively large area and are mostly used for pre-lease exploration or to provide geologic information. 3D deep penetration seismic surveys are conducted on a closely spaced grid pattern that provides a more detailed image of the prospect which is used to select the proposed drilling locations. BOEM assumes that most of the additional marine seismic surveys would be 3D surveys focusing on specific on-lease targets to identify possible drilling locations. Off-lease 2D/3D deep penetration surveys are typically conducted prior to a lease sale, and were programmatically analyzed in the Artic Regional Biological Opinion. Those surveys will also be considered in future, site-specific biological consultations when NMFS receives permit applications in connection with those surveys. In-ice surveys will also involve towed streamers, but with the use of an icebreaker operating ahead of the seismic acquisition vessel to clear a path through the ice.

Under the proposed action, two marine surveys would be conducted during the first incremental step, with no more than one survey in any given year (see Table 1). One of these surveys would be an open-water towed 2D/3D seismic survey (July-November), and the other would be an in-ice 2D seismic survey (October-December).

Open-Water Towed 2D/3D Surveys

Seismic data are collected over a specific area using a grid pattern. These data are analyzed and a framework of the subsea geology is constructed to assist with locating potential hydrocarbons. The 2D and 3D surveys use similar survey methods but different operational configurations. 2D deep penetration seismic surveying techniques are used to provide broad-scale information over a relatively large area and are mostly used for pre-lease exploration or to provide geologic information. 3D deep penetration seismic surveys are conducted on a closely spaced grid pattern that provides a more detailed image of the prospect which is used to select the proposed drilling locations.

The vessels conducting these surveys generally are 70-120 meters (m) long. Vessels tow one to three source arrays, of six to nine guns each, depending on the survey design specifications required for the geologic target. Most operations use a single-source vessel. However, more than one source vessel will be used when using smaller vessels, which cannot provide a large enough platform for the total seismic gun array necessary to obtain target depth. The overall energy output for multiple source vessels will be the same as a single source vessel, but the firing of the source arrays on the individual vessels will be alternated.

Vessel transit speeds typically range from 8-12 knots (kn) (12.9-19.3 km/hour) depending on a number of factors including the vessel itself, sea state, and ice conditions. Marine 3D surveys are acquired at vessel speeds of approximately 4.5 kn (8.3 km/hour). Seismic surveys are conducted day and night when ocean conditions are favorable, and one survey effort may continue for weeks or months, depending on the size of the survey (BOEM 2015e).

The source array is triggered approximately every 10-15 seconds, depending on vessel speed and on the desired penetration depth. The timing between shots varies and is determined by the spacing required to meet the geological objectives of the survey; typical spacing is either 25 or 37.5 m, but may vary depending on the design and objectives of the survey. Airguns can be fired between 20 and 70 times per km. Modern marine-seismic vessels tow up to 20 streamers with an equipment-tow width of up to approximately 1,500 m between outermost streamers. Streamers may be 8 km or longer. Biodegradable liquid paraffin, kerosene, and solid/gel are materials used to fill the streamer and provide buoyancy.

Data-acquisition is affected by number of streamer cables towed by the survey vessel and by weather/ice conditions. Typically, over the course of a survey, data are not collected between 25% and 30% of the time (or 3-9 days) because of equipment or weather problems. In addition to downtime due to weather, sea conditions, turning between lines, and equipment maintenance, seismic surveys could be suspended for biological reasons (proximity to protected species). Individual seismic surveys could require 15-30 days to cover a 200 square mile (518 km^2) area for an on-lease 3D survey, and 10-30 days to cover 102 line miles for an on-lease 2D survey (BOEM 2015a, c). Approximately 100,000 line-miles (160,900 km) of 2D seismic surveys have been collected in the Chukchi Sea OCS program area. BOEM assumes that most of the additional geophysical seismic surveys would be 3D surveys focusing on specific leasing targets (BOEM 2015a).

In-Ice Towed 2D Surveys

A change in technology has allowed geophysical (seismic reflection and refraction) surveys to be conducted in thicker sea ice concentrations. Sea ice concentration is defined in terms of percent coverage in tenths. An area with 1/10 coverage of ice means the area contains sporadic ice floes that provides for easy vessel navigation; whereas, 10/10 coverage of ice means there is no open water in the area. This new technology uses a 2D seismic source vessel and an icebreaker. The icebreaker generally operates ~0.5–1 km (~0.3-0.62 mi) ahead of the seismic acquisition vessel, which follows at speeds ranging from 4 to 5 kn (7.4 to 9.3 km/hr). Similar to open-water 2D surveys, in-ice surveys operate 24 hrs a day or as conditions permit.

The seismic airgun arrays and streamers used in-ice are similar to those used in open water marine surveys. A single hydrophone streamer, which uses a solid fill material to produce constant and consistent streamer buoyancy, is towed behind the vessel. The streamer receives the reflected signals from the subsurface and transfers the data to an on-board processing system. The survey vessel has limited maneuverability while towing the streamer and thus requires a 10 km (6.2 mi) run-in for the start of a seismic line, and a 4-5 km (2.5-3.1 mi) run-out at the end of the line (BOEM 2015a). The in-ice 2D seismic survey is anticipated to take 10-30 days to cover 102 line miles on-lease (BOEM 2015c).

2.1.3.2 Geohazard Surveys

Geohazard surveys are another type of ancillary activity used to identify and characterize potentially hazardous conditions at or below the seafloor. They also identify potential benthic (occurring on or near the sea bottom), biological communities (or habitats), and archaeological resources (BOEM 2015a). Geohazard surveys are also called high-resolution, site clearance, and shallow hazard surveys.

BOEM assumes that a lessee would proceed from marine seismic exploration of a prospect to exploratory and delineation drilling. At least one year prior to drilling exploratory wells, the lessee would conduct geohazard surveys to further evaluation the site.

Under the Proposed Action, five ancillary geohazard surveys would be conducted during the first incremental step, with no more than one survey in any given year (see Table 1). All geohazard surveys would be in shallow water, and would be conducted between July and November (BOEM 2015a).

A suite of equipment can be used for geohazard surveys. Most basic components of a geohazard system include a sound source to emit acoustic impulses or pressure waves, a hydrophone or receiver that receives and interprets the acoustic signal, and a recorder/processor that documents the data. The active acoustic systems used for geohazard surveys include: devices for seismic reflection profiling, such as airgun arrays and subbottom profilers, and; sonar devices, such as echosounders, and side-scan sonar. Details about each active acoustic system are provided in Section 2.1.3.5.

A typical geohazard seismic operation consists of a vessel towing an airgun source about 25 m (82 ft) behind the ship and a 600 m (1969 ft) streamer cable with a tail buoy. The source array usually is a single array composed of one or more airguns. The ships travel at 3-3.5 kn (5.6-6.5 km/hr), and the source is activated every 7-8 sec (or about every 12.5 m (41 ft))(BOEM 2015a).

Typical seismic surveys cover one proposed drilling location at a time. BOEM regulations require information be gathered on a 300 x 900 m (984 x 2953 ft) grid, which amounts to about 129 line-kilometers (80 mi) of data per site (NTL No. 05-A01). A typical survey will collect data from five different sites for a total of ~644 line-kilometers (400 line-miles) per survey (BOEM 2015d). BOEM anticipates that during the first incremental step a total of four site surveys will be conducted covering a total of 2,575 line-kilometers (1,600 line-miles) (BOEM 2015d). If there is a high probability of archeological resources, the north-south lines are 50 m (164 ft) apart and the 900 m (2953 ft) remains the same. Including line turns, the time to survey a lease block is approximately 36 hrs (BOEM 2015a). In addition, to site surveys, BOEM anticipates that one geohazard pipeline survey covering approximately 1,418 line-kilometers (881 lines-miles) may be conducted during the first incremental step (BOEM 2015c).

Ice gouge surveys generally use echosounders and sidescan sonars to map tracks created by ice keels dragging along the seafloor (BOEM 2015a).

Electromagnetic Surveys can include natural field electromagnetic and controlled source electromagnetic surveys (CSEM). Natural field surveys do not introduce electrical currents into the earth, but use a receiver to detect natural electrical and magnetic fields present. CSEM on the other hand introduce electrical currents into the earth and measures the resistivity of the seafloor substrate. This method uses a mobile horizontal electric dipole source and an array of seafloor electric receivers. The length of the dipole varies between 10-50 m and the system is towed at approximately 24-40 m above the seafloor at a speed of 1-2 kn. The transmitting dipole emits a low frequency (typically 0.5 to 10 Hz) electromagnetic signal into the water column and into the underlying sediments. Subsurface attenuation of the electromagnetic field depends on the subsurface resistivity and frequency of the source signal (Hesthammer et al. 2010). Prior to drilling exploration wells, electromagnetic surveys may be conducted over potential prospects to reduce exploration risk.

2.1.3.3 Geotechnical Surveys

In addition to the ancillary geohazard survey requirements, geotechnical surveys can provide more detailed information about a prospective site. These surveys are important for understanding such site characteristics as sediment properties, ice gouges, and a variety of shallow hazard information (BOEM 2015a).

Geological/geochemical surveys involve collecting bottom samples to obtain physical and chemical data on surface sediments. Sediment samples typically are collected using a gravity/piston corer, grab sampler, or dredge sampler. Shallow coring, using conventional rotary drilling from a boat or drilling barge, is another method used to collect physical and chemical data on near-surface sediments.

Under the Proposed Action, five ancillary geotechnical surveys would be conducted during the first incremental step, with no more than one survey in any given year (see Table 1). All geotechnical surveys would be conducted from July-November (BOEM 2015a).

2.1.3.4 Exploratory Drilling Operations

After marine seismic surveys have identified potential prospects, exploration drilling is needed to discover and appraise the hydrocarbon reservoir. Exploratory drilling activities conducted on the OCS follow BOEM and BSEE regulations at 30 CFR Part 550 and 30 CFR Part 250, respectively. These regulations establish comprehensive requirements for well design based on site specific geohazard information and marine seismic data, redundant pollution prevention equipment, testing and verification that equipment is working properly, and training and testing of personnel in well control procedures. These regulations also establish requirements on the technical specifications for the specific drilling rig and the drilling unit. No drilling activity can be conducted until BOEM has approved an Exploration Plan and BSEE approves an Application for Permit to Drill.

Under the proposed action, exploration drilling operations will use conventional, rotary drilling equipment, and will employ a maximum of two mobile offshore drilling units (MODUs) with icebreakers and other support vessels for drilling exploration wells. Examples of MODUs include drillships, semisubmersibles, and jack-up rigs.

Drilling operations are expected to range between 30 and 90 days at different well sites, depending on the depth of the well, delays during drilling, and time needed for well logging and testing operations. Considering the relatively short open-water season in the Chukchi Sea OCS (June-November), BOEM and BSEE estimate that two wells per drilling rig could be drilled, tested, and abandoned during a single open-water season, assuming both MODUs were operating simultaneously. If a discovery is made during exploration well drilling, MODUs would drill delineation wells to determine the areal extent of economic production. Operators need to verify that sufficient volumes are present to justify the expense of installing a platform and pipelines.

During the first incremental step, a maximum of 28 exploratory and delineation wells may be drilled, including dry wells. No more than 4 wells would be drilled annually (see Table 1). All wells, including successful exploration and delineation wells would likely be plugged and abandoned rather than converted to production wells because it would require several years before platforms and pipelines could be installed and oil produced.

Exploratory drilling will disturb an area of the seafloor. The area of disturbance would vary based on the type of drill rig used, but in general includes disturbance from the mud cellar, the anchoring system for the MODU (e.g., legs of the jack up rig or footprint of the drillship anchors), displacement of sediments, and discharges from the drill hole. For example, a previous drilling operation on the Burger prospect (in the Leased Area) is estimated to have disturbed 1,018 ft^2 of seafloor per well, and each well cellar excavated 619 yd^3 of sediment (BOEM 2015a). Cuttings from the well cellar excavation were deposited on the seafloor below the temperature and salinity stratification layer. It is estimated that the maximum thickness of the sediment deposition onto the seafloor would be 10.4 ft (3.2 m) and the deposition would continue out to a horizontal distance of 449 ft (137 m) from the excavation sites, where it would be 0.4 in (1 cm) thick. The anchoring system of a drill ship with 12 anchors (usually drillships use 8-12 anchors) would disturb an estimated 78,000 ft^2 (7,500 m^2) of the sea floor (BOEM 2015a).

Drillships

A drillship is a maritime vessel that has been equipped with a drilling apparatus. Most are built to the design specification of the company, but some are modified tanker hulls that have been equipped with a dynamic positioning system. Drillships are completely independent, and some of their greatest advantages are their ability to drill in water depths of more than 2,500m (8,202 ft) and their ability to sail between areas worldwide.

For the 2015 drilling season, Shell Oil plans to use both the *Noble Discoverer* and the semisubmersible *Polar Pioneer* for drilling operations in the Chukchi Sea (Shell 2015). The *Discoverer* is a drillship, built in 1976, that has been retrofitted for operating in Arctic waters. It is a 156m (512 ft) drillship with drilling equipment on a turret. It mobilizes under its own power, so it can be moved off the drill site with help of its anchor handler. Depending on the circumstances, the procedure and time needed to move off a drill site can change. In emergencies, this process can be completed in less than one hour. In the event that operations must be temporarily curtailed due to the advance detection of a hazard, the process could take from 4 to 12 hours. Typical transit speed of the *Noble Discoverer* is 8 kn (14.8 km/hour).

Semisubmersibles

A semisubmersible is a MODU with a platform-type deck that contains drilling equipment and other machinery supported by pontoon columns that are submerged into the water. Semisubmersibles may either have their own propulsion or be towed into place. Once in place, they are partially submerged in the water using a pontoon system. This makes them less subject to rolling and pitching than other types of MODU. Semisubmersibles maintain their position either by mooring or dynamic positioning, whereby the vessel uses its propulsion system to maintain position (BOEM 2015a). Semisubmersibles are generally smaller vessels than drillships. Their noise levels would be comparable, but somewhat less because they have smaller engines than drillships. The only subsea footprint would be caused by mooring if the vessel were not dynamically positioned. Support vessels needed for semisubmersibles would be the same as those needed for drillships.

The *Polar Pioneer* is a semisubmersible ship and is 279 ft (85m) in length. Positioning is accomplished with a combination of an eight-point all chain catenary mooring system and dynamic positioning (Shell 2015).

Jack-up Rig

A jack-up rig is an offshore structure composed of a hull, support legs, and a lifting system that allows it to be towed to a site, lower its legs into the seabed and elevate its hull to provide a stable work deck. Because jack-up rigs are supported by the seabed, they are preloaded when they first arrive at a site to simulate the maximum expected support leg load to ensure that, after they are jacked to full airgap (the maximum height above the water) and experience operating loads, the supporting soil will provide a reliable foundation. The actual dimensions of a jack-up rig would depend on the environment in which the unit would be operating and the maximum operating water depth. A typical jack up rig with a maximum operating depth of 50 m (164 ft) is approximately 50 m (164 ft) in length, 44 m (144 ft) beam, and 7 m (23 ft) deep.

Noise levels from jack-up rigs have not been measured in the Arctic or any other environment (Wyatt 2008), because the main structural surface of the jack-up rig is not in direct contact with the water. However, noise levels are expected to be similar to or less than noise levels produced by the drillship discussed above, as jack-up rigs use the same general drilling machinery that is the source of underwater noise for drillships. Sound levels transmitted into the water from bottom-founded structures are anticipated to be less than sound levels from a drillship because the vibrating machinery is not in direct contact with the water because the platform is above water. Because the jack-up rig has fewer structures in direct contact with the water, noise levels are expected to be less.

As with drillships, support vessels are used to assist with ice breaking and ice management, oil spill response, refueling, resupply, and servicing. There is also the potential for re-supply to occur via a support helicopter from the shore to the drill site. The total number of support vessels depends on local conditions and the design of the exploration plan. Section 2.1.3.4 provides further detail on the number and types of vessels anticipated to support exploratory drilling operations (BOEM 2015a).

Vertical Seismic Profiling

Vertical seismic profiling (VSP) is a technique carried out by using geophone receivers (sensor string) located on a cable and placed in a borehole at different depths to record acoustic signals from an external acoustic source near the wellbore (zero-offset VSP) or from a vessel at different distances from the wellbore (walk-away VSP).

In all VSP surveys, sensors are lowered down a borehole before production tubing is placed in the wellbore or the well is abandoned. The sensors lowered down the borehole can be connected together in strings of 16-36 receivers spaced from 15-150 m (49-492 ft) apart, depending on the survey objective and other variables. After lowering the sensor string to the lowest portion of the borehole to be surveyed, the sensors are temporarily attached via a mechanical caliper that clamps to the side of the wellbore and seismic signals are recorded. Subsequently, the sensor string is repositioned and the next sets of seismic signals are recorded. Seismic sources used in VSP surveys are the same as those used in conventional 2D and 3D seismic airgun surveys.

Zero offset surveys are typically conducted using a single airgun suspended approximately 10 m below the sea surface by a crane located on the deck of the drilling rig.

Walk-away surveys utilize a workboat with four to eight airguns towed 7-10 m (23-33 ft) below the surface. These surveys involve a source vessel firing at varying distances from the receivers within the borehole. The airgun arrays used for these surveys can vary from in volume, depending upon the survey objective. One version of walk-away surveys requires the source vessel to travel in a spiral track. The source vessel begins the spiral track at a distance of 200 m (656 ft) from the borehole and keeps the distance between spirals equal to the number of arrays times the array separation. Airgun arrays are fired in an alternating fashion with the first array firing followed by the second array 11-14 s later. At a typical vessel speed of 8.3-9.3 km/hr (4.5-5 knots), the distance between firings is between 28 and 36 m (92 and 118 ft). The source vessel continues firing on the spiral path out to a distance of up to 9 km (4.9 nmi). If the borehole sensor string needs to be raised to another level, the whole procedure is repeated.

Survey duration depends on the type of survey, objectives, cost of the drilling rig, and equipment used. A zero-offset survey can take less than a day to complete. A walk-away survey can be completed in less than one day or may require up to 10 days to complete, however, 30 percent of that time may be with the airguns in standby mode.

In addition to tying well data to seismic data, the VSP also allows for converting seismic data to zero-phase data and distinguishing primary reflections from multiples (BOEM 2015a).

VSP operations are not considered to be a marine seismic survey for analysis purposes in this opinion but rather as part of an exploratory drilling program, even though airguns are used for a short time. It is unlikely that VSPs would be conducted at every exploratory and delineation well, however, for the purposes of this opinion, BOEM conservatively assumes that VSP would be conducted in association with each wellbore, resulting in a maximum of 28 VSP occurring during the first incremental step (see Table 1).

2.1.3.5 Onshore Facility Construction

In conjunction with the beginning of the first incremental step, up to three onshore facilities may be constructed in the vicinity of Barrow or Wainwright over a two-year period. Construction is anticipated to occur in the winter from January through December. These onshore facilities would provide air support, search and rescue capabilities, and personnel housing/equipment storage (BOEM 2015a).

BOEM assumes that all gravel fill and ground disturbance would be to sedge/grass/moss wetland and sedge/moss/dwarf shrub wetland habitat (BOEM 2015a).

- Up to approximately 15 acres (6 ha) of tundra would likely be filled for an exploration camp. The exploration camp would include stationary equipment consisting of generators, pumps, compressors, and jackhammers. The camp would include housing facilities, mess hall(s), and recreation as well as vehicle parking;
- If the air support base is located near Wainwright, up to approximately 5 acres (2 ha) of tundra would be filled to expand the existing Wainwright airport in order to support cargo (C-130 Hercules) and commercial airlines (Boeing 737);
- Up to approximately 7 acres (3 ha) of tundra would be filled to construct a search and rescue (SAR) base with a helipad and a road connection to the village of Wainwright or Barrow. At least one mile of road would be built;
- Gravel would be obtained from approximately 240 acres (100 ha) material site located near Wainwright or Barrow; and
- Up to approximately 70 acres of tundra at the edge of the gravel fill could be exposed to gravel/dust spray and dust shadow as a result of onshore facility construction.

In total, onshore facility construction may cover up to 1.36 km^2.

2.1.3.6 Vessel and Aircraft Operations

Mobilization and demobilization of vessels is anticipated to occur from Dutch Harbor with resupply potentially occurring out of Kotzebue, Barrow, or Wainwright. Oil spill response vessels may be stationed in Kotzebue Sound.

Under the proposed action, marine vessels would be the primary form of transportation during the first incremental step. Aircraft would be used to conduct any search and rescue efforts and would support exploratory drilling activities as well as onshore construction. BOEM anticipates the following support vessels may be associated with authorized exploration activities (Table 2).

Table 2. Summary of activities and support vessels associated with marine seismic, geohazard, and geotechnical surveys, and exploratory drilling activities (BOEM 2015a).

Survey Activity	Support Operations Per Activity
Marine Seismic Surveys	
Deep Penetration Towed-Streamer 2D/3D Surveys	1 source/receiver vessel
	1 support vessel
	1 monitoring vessel
In-Ice Towed Streamer 2D Surveys	1 source/receiver vessel
	1 icebreaker
Ancillary Geohazard Surveys	
Geohazard Airgun Surveys	1 source/receiver vessel
	1-2 support vessel
Geohazard Sonar Surveys	1 source vessel
Electromagnetic Surveys	1 source vessel
Ice Gouge Surveys	1 source vessel
Geotechnical Surveys	
Geological/Geochemical Surveys	1 vessel
Exploratory Drilling Activities	
Drilling from a Drillship[2]	1-2 Drillship
	1-2 Icebreakers/drillship
	2-3 Anchor handler
	1-3 Offshore supply vessel
	1-2 Drilling Discharge Monitoring Science Vessel
	1-2 Shallow water vessel

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[2] Estimated number of vessels associated with drilling from a drillship is based on Shell's Draft IHA Application (Shell 2015).

	1-2 Support Tugs
	1-2 Resupply Tug and Barge
	1 Oil Spill Response Vessel
	1 oil spill response barge and tug (offshore)
	1 oil spill response barge and tug (nearshore)
	1-2 tank vessel for spill storage
	1 Containment barge and tug
	Regular helicopter transport
Drilling from Jack-up Rig	1-2 Icebreakers
	1-2 tank vessel for spill storage
	2-3 small support vessels
	Regular helicopter transport
Onshore Facility Construction	
Onshore facility construction	1-2 barge and tug
	Regular aircraft support
	Construction equipment (dozers, graders, dump trucks, etc.) determined by development plan

[1] The number and type of support vessels being proposed for drillship operations is based on Shell's most recent IHA application (Shell 2015) which provides the maximum number of vessels anticipated for this type of activity (27 vessels).

Marine Seismic Surveys

A vessel may conduct seismic surveys day and night, for days, weeks, or months, depending on the size of the survey and data-acquisition capabilities of the vessel. Vessel operation time includes not only data collection, but also transit to and from the survey site, deployment and retrieval of gear, line turns between survey lines, equipment repair, and other planned or unplanned operations.

During exploration seismic surveys, the vessels would be largely self-contained. Therefore, helicopters would not be used for routine support of operations. Under the Proposed Action, during the open-water season smaller support vessels would make occasional trips (one to three round-trips per survey, depending upon the duration of the survey), probably operating out of Barrow and/or Wainwright). A mitigation vessel might accompany the seismic survey vessel. No support vessels would be associated with the in-ice seismic survey; however, an icebreaker would be present during the survey for ice breaking (Table 2).

Geohazard and Geotechnical Surveys

The maximum number of vessels associated with geohazard surveys are the three vessels potentially used for airgun surveys. Geotechnical surveys are only anticipated to use a single vessel for operations (Table 2).

Exploratory Drilling
For the 2015 open-water drilling season, Shell is proposing to deploy more support vessels and oil spill response vessels than it did during its 2012 exploration drilling in the Chukchi Sea (Shell 2015; see Table 2). While subsequent drilling operations may vary in number and type of vessels from those being proposed, Shell's proposed drilling operation provides the maximum number of vessels that we anticipate will be associated with drilling from a drillship.

BOEM separately defines ice breaking and ice management. Ice-breaking is defined as opening a pathway or lead through pack ice, ice floes or landfast ice for the purpose of moving vessels through sea ice. Ice-breaking occurs in waters with ice. BOEM defines ice management as using an ice-hardened vessel or icebreaker to move floes away from a stationary vessel, such as a drill rig, by pushing, towing or passing back and forth upstream of the stationary vessel or drill rig. Ice management activities take place in an environment that is primarily open water (BOEM 2015a). We anticipate two ice management vessels will support each drilling unit. These vessels will enter and exit the Chukchi Sea with or ahead of the drilling units, and will generally remain in the vicinity of the drilling units during the drilling season. Ice management and ice scouting is expected to occur at distances of 20 mi (32 km) and 30 mi (48 km) respectively. However, these vessels may have to expand beyond these ranges depending on ice conditions (Shell 2015).

Up to three anchor handlers will support the drilling units. These vessels will enter and exit the Chukchi Sea with or ahead of the drilling units, and will generally remain in the vicinity of the drilling units during the drilling season. When the vessels are not anchor handling, they will be available to provide other general support. Two of the three anchor handlers may be used to perform secondary ice management tasks if needed.

The planned exploration drilling activities may use three offshore supply vessels (OSVs) for resupply of the drilling units and support vessels. Drilling materials, food, fuel, and other supplies may be picked up in Dutch Harbor (with possible minor resupply coming out of Kotzebue) and transported to the drilling units and support vessels.

Operators may use up to two drilling discharge monitoring vessels or science vessels; one for each drilling unit, from which sampling of drilling discharges would be conducted. The science vessel specifications are based on larger OSVs, but smaller vessels may be used.

For Shell's operations planned for 2015, two tugs will tow the *Polar Pioneer* from Dutch Harbor to the Burger Prospect. After the *Polar Pioneer* is moored, the tugs will remain in the vicinity of the drilling units to help move either drilling unit in the event they need to be moved off of a drilling site due to ice or any other event (Shell 2015). We anticipate that a similar number of tugs may be used in future drilling operations.

Shell may deploy a ROV system from an OSV type vessel that could be used to construct MLCs prior to a drilling units arriving. If used, this vessel would be located at a drill site on the Burger Prospect. When not in use, the vessel would be outside of the Chukchi Sea LS planning area (Shell 2015).

The oil spill response (OSR) vessel types supporting exploration drilling are listed in Table 2. One dedicated OSR barge and on-site oil spill response vessel (OSRV) will be staged in the vicinity of the drilling unit(s) when drilling into potential liquid hydrocarbon bearing zones. This will enable the OSRV to respond to a spill and provide containment, recovery, and storage for the initial response period in the unlikely event of a well control incident.

The OSR barge, associated tug, and OSRV possess sufficient storage capacity to provide containment, recovery, and storage for the initial response period. Shell plans to use two oil storage tankers (OSTs). An OST will be staged at the Burger Prospect. The OST will hold fuel for Shell's drilling units, support vessels, and have space for storage of recovered liquids in the unlikely event of a well control incident. A second OST will be stationed outside the Chukchi Sea planning area and will be sited such that it will be able to respond to a well control event before the first tanker reaches its recovered liquid capacity.

The tug and barge will be used for nearshore OSR. The nearshore tug and barge will be moored near Goodhope Bay, Kotzebue Sound. The nearshore tug and barge will also carry response equipment, including one 47 ft. (14 m) skimming vessel, 34 ft. (10 m) workboats, mini-barges, boom and duplex skimming units for nearshore recovery and possibly support nearshore protection. The nearshore tug and barge will also carry designated response personnel and will mobilize to recovery areas, deploy equipment and begin response operations (Shell 2015).

Offshore operations will be services by up to three helicopters operated out of an onshore support base. Helicopters would fly from Barrow and/or Wainwright at a frequency of one to six flights per day (approximately 40 roundtrip flights per week). Support-vessel traffic would be one to three round-trips per week, also out of Barrow and/or Wainwright. After completion of the shore-bases, air and vessel traffic might alternatively originate from the onshore air support facility (BOEM 2015e).

Onshore Facility Construction

During onshore facility construction heavy equipment and materials would be moved to the coastal site using barges, aircraft, and perhaps winter ice roads. Under the proposed action, one to two barge trips (possibly from West Dock or Nome) would occur in each of two consecutive open-water seasons. There could be as many as five transport aircraft (C-130 Hercules or larger) trips per day during peak periods of base construction (Table 2).

Utilization of winter ice roads would depend on the location of the onshore facilities in proximity to Wainwright or Barrow, the presence of any existing ice roads, and the Development and Production Plan (DPP) submitted to BOEM by the lessee. Submission of a DPP would trigger initiation of a project-specific NEPA analysis and ESA consultation process that would assess impacts of any proposed ice-roads or additional infrastructure associated with the onshore facilities on threatened or endangered species and critical habitat. The overall frequency of transportation in and out of the onshore facilities would decrease substantially after construction is completed. In construction of the onshore facilities it is anticipated that mobile ground equipment such as dozers, graders, crew vehicles would be used (Table 2).

2.1.3.7 Acoustic Equipment

Marine seismic and geohazard surveys, as well as exploratory drilling, may involve a variety of active and passive acoustic sources. Active systems are those that emit acoustic energy or sound into the water. Passive acoustic systems do not generate acoustic energy in the water, but are used to listen for sound in the water.

The active acoustic systems under the proposed action include devices for seismic reflection profiling, such as airgun arrays and subbottom profilers; sonar devices, such as echosounders, and sidescan sonar; and other acoustic sources, such as vessels and aircraft (Table 3). More information on the acoustic propagation modeling effort, source levels, and modeling assumptions, for the LS 193 proposed action is provided in Appendix A.

Table 3. Primary Acoustic Sources Associated with the Proposed Action (BOEM 2015e)(Austin et al. 2015).

Active Acoustic Source	Frequency (kHz)	Approximate Broadband Source Level (dB re 1 μPa at 1m)
4500 cui marine seismic airgun array (broadside)	<1	~232
3200 cui marine seismic airgun array (broadside)	<1	~231
500 VSP cui airgun array (broadside)	<1	~223
40 cui geohazard survey (broadside)	<1	~217
Subbottom profiler	2-16	~216
Side Scan Sonar	100-1600	~249
Single beam EchoSounder	3.5-1000	~205
Multi beam EchoSounder	180-500	~242
Pinger	35-55	~197

Transponder	35-55	~187
Vessel Noise Transit[1]	<1	<200
Icebreaker Vessel Noise	.01-10	~198
Ice Management Vessel	.01-10	~192
Vessel Noise in Dynamic Positioning	<1	178
Drilling Operations	.02-10	181
Rotary Aircraft	<1	~162

[1] Vessel Noise includes source vessels, crew transport vessels, and bow pickers. The loudest vessel is anticipated to be the crew change vessel (Aerts et al. 2008).

SEISMIC

Seismic reflection profiling systems are used to search for commercially and economically valuable subsurface deposits of crude oil, natural gas, and minerals by the recording, processing, and interpretation of reflected seismic waves from the substrates by introducing controlled source energy (such as seismic air gun impulses and vibratory waves) into the earth.

Airguns

Airguns fire highly compressed air bubbles into the water that transmit seismic wave energy into the subsurface rock layers. Seismic waves reflect and refract off subsurface rock formations and travel back to acoustic receivers called hydrophones. The characteristics of the reflected seismic waves (such as travel time and intensities) are used to locate subsurface geologic formations that may contain hydrocarbon deposits and to help facilitate the location of prospective drilling targets (BOEM 2011).

BOEM is proposing to authorize one open-water (July-November), and one in-ice (October-December) deep penetration marine seismic survey. An individual airgun can range from five to 1,500 cubic inches (cui) (0.081 to 24.58 liters). A combination of airguns is called an array; operators vary the source-array size to optimize the resolution of the geophysical data collected. For the proposed action, the seismic surveys will use towed airgun arrays with an average discharge volume of 3200 cubic inches (cui), and a maximum discharge volume of 4500 cui. The sound source level associated with the 4500 and 3200 cui array is estimated at 232 decibels and 231 decibels referenced to 1 micro Pascal root mean squared (dB re 1 μPa rms), respectively (Table 3). For the 3200 cui array, individual airgun volumes are anticipated to be between 40 and

250 cui. Gun volumes were adjusted to achieve a total volume of 3200 cui. The array depth was assumed to be a standard 6m. The individual gun volumes for the 4500 cui array are anticipated to be between 40 and 300 cui, and these were adjusted to achieve the total volume of 4500 cui. The array depth is assumed to be the standard 8.5 m (Austin et al. 2015). The Rmax radii of rms SPL based on average sound speed profile and high-reflectivity geoacoustics is anticipated to reach ~9 km for the 3200 cui array and 15.4 km for the 4500 cui array (see Appendix A).

Geohazard airgun arrays are anticipated to have a discharge volume of 10-500 cui, and a source level of 217-223 dB re 1 μPa rms (Austin et al. 2015)(see Table 3). For the proposed action, we assumed that the 40 cui array layout consisted of four 10 cui guns, with two at 1.75 m water depth and two directly below them at 2.25m. The horizontal spacing between the guns was assumed to be 80 cm (Austin et al. 2015). The 500 cui array had an assumed layout of two 110 cui guns and two 140 cui gun, all operating at 6m water depth (Austin et al. 2015). The modelled to the 120 dB re 1 μPa threshold based on Rmax average sound speed profile and high-reflectivity geoacoustics ranged between 1.7 and 4.1 for the 40 cui and 500 cui airgun array respectively (Austin et al. 2015).

Airgun pressures typically are 2,000 pounds per square inch (psi), although they can be used at 3,000 psi for higher signal strength to collect data from deep in the subsurface (BOEM 2015e). The pressure output of an airgun array is proportional to (1) its operating pressure, (2) the number of airguns, and (3) the cube root of the total gun volume. For consistency with the underwater acoustic literature, airgun-array source levels are back-calculated to an equivalent source concentrated into a one-meter-radius volume (Greene and Moore 1995). The far field pressure from an airgun array is focused vertically, being about 6 dB stronger in the vertical direction than in the horizontal direction for typical arrays. The peak pressure levels for industry arrays are in the 5-300 Hz range (Hildebrand 2004). The spacing between airguns results in offset arrival timing of the sound energy. These delays "smear" the sound signature as offset energy waves partially cancel each other, which reduces the amplitude in the horizontal direction (SAE 2013). Airgun arrays have dominant energy at low frequencies, where long-range propagation is likely.

Subbottom Profiler

The purpose of the subbottom profiler is to provide an accurate digital image of the shallow sub-surface sea bottom, below the mud line. Subbottom profilers are usually hull mounted or pole-mounted. These systems range in frequency from 0.2- 200 kHz, with source levels between 200-250 dB re 1 μPa at 1 m (rms) (Greene and Moore 1995, Laban et al. 2009). The beam width is 15 to 24 degrees, depending on the center frequency. Typical pulse rate is between 3 and 6 Hz.

SONAR

Sound Navigation And Ranging, (SONAR), is a technique that uses sound propagation to navigate, communicate, or detect objects on or under the surface of the water. The proposed action anticipates the use of side-scan sonar, single- and multi-beam echosounders, and pinger and transponder systems as described below.

Side Scan Sonar

Side scan sonar is a sideward-looking, narrow-beam instrument that emits a sound pulse and “listens” for its return. The side scan sonar can be a two or multichannel system with single frequency monotonic or multiple frequency Compressed High Intensity Radar Pulse (CHIRP) sonar acoustic signals. The frequency of individual side scan sonars can range from 100 to 1600 kHz with source levels between 194 and 249 dB re 1 µPa at 1 m (rms). Pulse lengths will vary with according to the specific system, monotonic systems range between 0.125 and 200 milliseconds (ms) and CHIRP systems range between 400 and 20,000 ms. (HydroSurveys 2008, Dorst 2010).

Echosounder

Echosounders measure the time it takes for sound to travel from a transducer to the seafloor and back to a receiver. The travel time is converted to a depth value by multiplying it by the sound velocity of the water column. Single beam echosounders measure the distance of a vertical beam below the transducer. The frequency of individual single beam echosounders can range from 3.5 to 1000 kHz with source levels between 192 to 205 dB re 1 µPa at 1 m (rms) (Koomans 2009). Multibeam echosounders emit a swath of sound to both sides of the transducer with frequencies between 180 and 500 kHz and source levels between 216 and 242 dB re 1 µPa at 1 m (rms) (HydroSurveys 2010).

Pinger and Transponder

Transponders may be used by the oil and gas industry to position drill rigs and other equipment. Pingers and transponders communicate via sonar, they produce underwater sound levels. The anticipated source level for the pinger is 197 dB re 1 µPa at 1 m with operational frequencies between 35 and 55 kilohertz. The transponder produces short pulses of 181 to 212 dB re 1 µPa at 1 m at frequencies also between 8 and 55 kilohertz (HydroSurveys 2008).

Vessel Noise

Vessel Transit

Vessel noises are often at source levels of 165-200 dB re 1 µPa at 1 m (Aerts et al. 2008), and typically operate at frequencies from 20-300 Hz (Greene and Moore 1995). Aerts et al. (2008) found the recording and deployment vessels to have a source level of approximately 165.3 dB re 1 µPa, while the smaller bow pickers produce more cavitation resulting in source levels of 171.8 dB re 1 µPa. In addition, Aerts et al. (2008) found the housing vessel to produce the loudest propeller noise of all the vessels in the fleet (200.1 dB re 1 µPa), but this vessel is mostly anchored up once it gets on site. The crew transfer vessel also travels only infrequently relative to other vessels, and is usually operated at different speeds. During higher speed runs shore the vessel produces source noise levels of about 191.8 dB re 1 µPa, while during slower on-site movements the vessel source levels are only 166.4 dB re 1 µPa (Aerts et al. 2008).

Ice Management and Icebreaker

Some exploration activities require ice management and icebreaker support. This support can introduce loud noise episodes into the marine environment when actively engaged in ice management or breaking due to cavitation of the propellers when higher power levels are required to move ice or ram/run up on ice for breakage. The greatest sound generated during ice breaking operations is produced by cavitations of the propeller as opposed to the engines or the ice on the hull (Greene and Moore 1995). Cavitation frequencies range broadly from 10-10,000 Hz (Greene and Moore 1995), with short (~5 sec) bursts of maximum source levels of 197-205 dB re 1 μPa at 1 m (Davis and Malme 1997, Erbe and Farmer 1998, Roth et al. 2013). Source levels for ice management activities were based on measurement from *Tor Viking* as it managed ice as part of the *Noble Discover* drilling activities on the Burger prospect in 2012 (Austin et al. 2013). In the Davis and Malme (1997) study, noise levels from the M/V *Arctic* were 5-10 dB higher for ice breaking astern compared to ice breaking ahead. Based on measurement of USCG *Healy*, assuming 80% ice cover, and ~5m source depth, the broadband source levels for modeled icebreaking scenarios were ~198 dB re 1 μPa (Austin et al. 2015). The anticipated distance to the 120 dB re 1 μPa rms isopleth associated with icebreaking activity in 80% ice cover is ~45 km based on acoustic propagation modeling with mixed sound speed profile and high-reflectivity geoacoustics (Austin et al. 2015)(see Appendix A).*Dynamic Positioning and Anchor Handling*
When support vessels arrive to transfer materials to or from drilling units, or to conduct other drilling support activities, dynamic positioning (DP) thrusters are commonly used to keep the vessel stationary next to the drilling unit or on location. The setting of anchors, as well as the process of connecting the drillship(s) to the anchors, generates sound levels above those of drilling alone. Vessel noises are often at source levels of 180 dB re 1 μPa at 1 m while in dynamic positioning, and typically operate at frequencies between 20-300 Hz (Greene and Moore 1995). The *Noble Discoverer* was used as the sound source for the single site drilling and source levels for support vessel in DP was calculated from mean 1/3-octave-band levels for each measured vessel (*Ocean Pioneer, Fennica, and Nordica*), and averaged levels across the vessels to derive an average source level for vessels on DP (Austin et al. 2015). The maximum distance to the 120 dB re 1 μPa threshold for a drillship drilling with a support vessel on DP was ~7.6 km based on modelling Rmax radii with average sound speed profile and high-reflectivity geoacoustics (Austin et al. 2015)(See Appendix A).

Distance to the 120 dB re 1 μPa rms during anchor handling by the *Tor Viking* was estimated to be 14 km during Shell's exploration drilling program at Burger (JASCO Applied Sciences 2013). A 1.3 dB correction factor was applied to this distance to adjust the levels that were measured at the seafloor to the expected maximum over the depth value of 16.0 km 120 dB re 1 μPa threshold (Austin et al. 2015).

Drilling Noise

Drilling from Drillship
During the 2012 exploration drilling activities, measurements of sounds produced by the *Discoverer* were made on the Burger prospect in the Chukchi Sea. The recorded data show a number of tonal components likely produced by vibrations from rotating machinery. Most of the acoustic energy was contained in the 100-1000 Hertz (Hz) and 1-10 kHz frequency bands, both of which typically were at levels just below 120 dB re 1 µPa rms (Shell 2015). Broadband source levels of the *Discoverer* ranged from 177 to 185 dB re 1 µPa rms (Austin M. and Warner 2010). When no other vessels were present near the *Discoverer* and drilling was occurring, broadband sound levels fell below 120 dB re 1 µPa rms at 1.5 km (Austin et al. 2013).

Measured sound levels for the semi-submersible *Polar Pioneer* while drilling were not available, therefore the ≥ 120 dB re 1 µPa sound footprint was estimated using JASCO Applied Science's Marine Operations Noise Model (MONM). An average source level for the *Polar Pioneer* was derived from a number of acoustic measurements of comparable semi-submersible drill units. The model yielded a propagation range of 350 m for rms sound pressure levels of 120 dB re 1 µPa rms for the *Polar Pioneer* while drilling at the Burger Prospect (Shell 2015).

Mudline Cellar
A Mudline Cellar remotely Operated Vehicle (MLC-ROV) System may be used to construct the mudline cellar (MLC) portion of a well at one or more exploration drill sites, or may occur off the drilling units themselves. A MLC is a relatively large-diameter hole constructed so that equipment at the top of the well can be installed below the level of the seabed, hence below the greatest depth of a potential ice keel gouge. The construction of this hole during Shell's 2012 exploration drilling program in the Chukchi Sea generated broadband sounds that were recorded by hydrophones moored to the seafloor (Shell 2015). JASCO (2013) calculated that these sounds diminished below the 120 dB re 1 µPa at 1 m (rms) threshold at 8.2 km from the drill site. However, since these measurement were made at the seafloor, an additional 1.3 dB correction factor was applied to the expected maximum over the depth value of 9.3 km. The MLC ROV system is expected to be quieter than constructing an MLC with a drilling unit (Shell 2015).

Aircraft Noise

Exploration surveys and drilling operations may be supported be fixed-wing and rotary aircraft. Surveys and drilling operations may involve variable numbers of trips daily or weekly depending on the specific operation. Fixed-wing monitoring surveys are typically conducted with aircraft flying 1,500 ft (above ground level (AGL) or above sea level (ASL)) unless safety due to weather or other factors becomes an issue (see Section 2.1.4 *Mitigation Measures*). Greene and Moore (1995) determined that fixed wing aircraft typically used in offshore activities were capable of producing tones mostly in the 68 to 102 Hz range and at noise levels up to 162 dB re 1 µPa-m at the source.

Rotary aircraft operations are conducted 1,000 to 1,500 feet AGL/ASL unless safety due to weather or other factors becomes an issue (see mitigation measures). Greene and Moore (1995) explained helicopters commonly used in offshore activities radiate more sound forward than backwards, and are capable of producing tones mostly in the 68 to 102 Hz range and at noise levels up to 151 dB re 1 μPa-m at the source. By radiating more noise forward of the helicopter, noise levels will be audible at greater distances ahead of the aircraft than to the rear. For a helicopter operating at an altitude of 1,000 ft (305 m), there were no measured sound levels at a water depth of 121 ft (37 m) (Greene 1985).

2.1.4 Future Incremental Steps

BOEM is currently in the third stage of the OCSLA four-stage oil and gas review process, which involves the exploration of the leased tracts on LS 193 in the Chukchi Sea. The fourth stage, development, is reached only if a lessee finds a commercially viable oil and/or gas discovery. A lessee must submit a detailed development and production plan that BOEM must review under NEPA. Development activities will also require ESA section 7 consultation (BOEM 2015e).

While the proposed action is focused on exploration activities, this consultation also considers potential impacts through the endpoint of the action as described below in the hypothetical scenarios of production and development of an anchor field and if successful, the exploration, development and production of a satellite field, followed by the decommissioning of all of these activities (years 10-77)(See Table 4).

Oil would be produced first, as it can be shipped to market via the Trans-Alaska Pipeline System (TAPS), while the gas would initially be re-injected to aid oil recovery. Gas production would likely occur much later in time after a gas transportation system (anticipated to be via pipelines) has been constructed. BOEM and BSEE assume that infrastructure to transport gas across the state will be available in the later years of the prospects' production (BOEM 2015e).

2.1.4.1 Development and Production Scenarios

Using data from the existing leased prospects to more accurately develop the proxy fields analyzed here, BOEM estimated the anchor field could contain 2.9 billion barrels (Bbbl) of recoverable oil, and the satellite field could contain 1.4 Bbbl of recoverable oil. Development of these fields would entail the drilling of 465 oil producing wells, 93 service wells, and installation of 8 platforms. The modeled anchor field and even the satellite field are larger than any field in the Gulf of Mexico OCS. The size of this scenario represents an extreme "high case" of oil and gas activities from the proposed action. The discussion below explains how this scenario would unfold over the course of several decades (BOEM 2015e).

Despite the development of these scenarios, BOEM anticipates that zero production remains the most likely outcome from LS 193 for the following reasons (BOEM 2015e):

- Finite lease terms (the analysis assumes the full 10 year primary term for the purpose of this analysis, despite the fact that roughly five of these years have passed). The leases have been suspended twice, and that extended the lease terms. OCSLA sets a primary lease term for five years; however, the Secretary can extend to up to ten years if the Secretary finds that such longer period is necessary to encourage exploration and development in areas because of unusually deep water or other unusually adverse conditions. Further, the Secretary can continue the lease because of drilling or well reworking operations.

- Short drilling seasons (lessees drill in open water, which exists for roughly four to six months per year in the Chukchi Sea).
- Limited availability of suitable drilling rigs (only a few rigs worldwide are suitable now for drilling in Chukchi Sea conditions).
- Other infrastructure requirements (i.e. the capital, materials, machinery, vessels, qualified personnel, etc. required to pursue development of this scale in a frontier area; available capacity of the Trans-Alaska Pipeline System).
- Engineering challenges and expense associated with producing hydrocarbons and transporting them to market from a frontier area.

In this scenario, a large prospect, Anchor A, and a smaller satellite prospect, A-2, are discovered, developed, and produced from sale 193 leases. Their combined potential oil and condensate are 4.3 Bbbl. Producing this volume of oil and its associated natural gas would require eight platforms of a new Arctic-class design and drilling 589 wells (exploration, delineation, production, and service).[3] The time from exploration to final production is 74 years with an additional 3 years for decommissioning (BOEM 2015e). Table 4 details the exploration and development scenario schedule for Anchor A and Satellite A-2 as described in the proposed action (BOEM 2015e).

Table 4. Exploration and Development Scenario Schedule for Anchor A and Satellite A-2 (BOEM 2015e); see Table B-1)).

Activity	Beginning Year	Ending Year	Total Years	TOTAL ACTIVITY
Exploration Activities on Anchor Field A (Proposed Action)				
Marine Seismic Surveys	1	9	2	2 surveys
Geohazard Surveys	1	7	5	5 surveys
Geotechnical Surveys	1	7	5	5 surveys

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[3] 28 wells during initial exploration of Anchor field A (proposed action), 12 wells during exploration of satellite prospect A-2 (subsequent consultation), 459 production wells (subsequent consultation), and 90 service wells (subsequent consultation) = 589 total wells.

Drill Exploration and Delineation Wells	3	9	7	28 wells
VSP Surveys	3	9	7	28 surveys
MODU Platforms	3	9	7	14 rigs
Construction of Onshore Facilities	1	2	2	up to 3 bases
Production Anchor A and Exploration and Production Satellite A-2				
Marine Seismic Surveys	11	29	6	6 surveys
Geohazard Surveys	11	28	8	8 surveys
Geotechnical Surveys	11	28	8	8 surveys
Drill Exploration and Delineation Wells	20	22	3	12 wells
VSP Surveys	20	22	3	12 surveys
Drill Production Wells	10	34	25	459 wells
Sub-Sea Service Wells	12	23	12	90 wells
Install Onshore Oil Pipeline	6	9	4	300 miles
Install Offshore Oil Pipelines	6	30	25	160 miles
Install Onshore Gas Pipeline	27	31	4	300 miles
Install Offshore Gas Pipelines	27	50	24	160 miles
Construction of Production bases	5	6	2	1 base
Oil Production Anchor A	10	46	36	2,875 MMbbl

Oil Production A-2	24	53	29	1,384 MMbbl
Gas Production Anchor A	31	67	36	1,179 BCF
Gas Production A-2	45	74	29	1,024 BCF

In the future incremental steps, under BOEM's development scenario, development of the anchor field would begin in approximately the 5th year and the majority of development activities associated with the anchor field and the satellite field would occur over the next 20 years (installation of supplemental offshore gas pipeline could continue into the later years). BOEM anticipates that production activities would begin in approximately the 10th year and continue for roughly 50 years (BOEM 2015e).

Infrastructure Development

Offshore and onshore development would commence simultaneously. Development would begin with the installation of oil pipelines (on- and off-shore) over the course of several years and the installation of processing and waste management facilities and a supply boat terminal at the exploration base, which would become processing base and first pump station. The lessee would coordinate with landowner(s) to obtain all necessary permits and authorizations for onshore activities, which may include separate ESA consultation processes.

At the coast, the existing exploration camp would be converted to a production facility. This facility would support offshore operations, including oil and gas processing, and would serve as the first pump station. The location of this facility is unknown, but BOEM considers the likely location near Wainwright or Barrow. The production base likely would be composed of the landfall valve pad with, protective ice berm, valve enclosure control building, pipeline riser well, onshore pipeline trench and backfill, a pump station, pipeline pigging facilities, and a land-farm for barged drilling waste treatment.

In association with the production facility, a supply boat terminal would be constructed. The boat terminal would include the barge dock with lay-down area and material storage, fuel tank farm, and vehicle parking.

From the production base, vertical support members would suspend communication cables and oil pipelines approximately 300-320 mi east to connect to existing North Slope oilfield infrastructure. Onshore oil pipeline placement would occur during winter. BOEM assumes that a large scale onshore gas transport system (similar to TAPS) will be developed in the future. On that assumption, BOEM anticipates that a chilled high-pressure gas pipeline would be buried in the same corridor, approximately 20 years after the oil pipeline is installed.

Offshore pipeline installation would occur during the open water season. All pipelines would be trenched in the seafloor as a protective measure against damage by floating ice masses. BOEM anticipates that the depth and width of subsea pipeline trenches would be similar to those dug for Northstar (7-11 ft deep and 8-52 ft wide), with pipelines at greater depths requiring deeper and wider trenches. Approximately 6-9 ft of backfill would cover trenched pipelines.

An estimated 160 mi of trunk oil pipelines would connect the anchor field hub platform (1st installed platform) to the onshore processing facility (discussed below). An additional estimated 30 mi of oil pipeline would connect the satellite field hub platform to the anchor field hub. Subsea gas pipelines would be installed approximately 20 years after the oil pipelines and along the same routes.

After pipeline installation, offshore production platforms would be installed over the course of several open water seasons. BOEM anticipates that large, bottom-founded platforms would be used, which would be pinned to the seafloor and stabilized by their wide base, anchoring system, and ballast. Platforms would likely be constructed in large sections which would be transported to the site by boat during the open water season, before they are mated together. Five platforms would be located in the anchor field. Additional exploratory surveys and drilling (as described in Section 2.1.3) conducted during development of the anchor field would reveal a smaller discovery in the satellite field approximately 20 mi from the anchor field hub platform. An additional three platforms would be installed at the satellite field.

Each platform would have two drilling rigs capable of drilling year round. Each platform would also house processing equipment, fuel and production storage capacity, and quarters for personnel. It is assumed that oil would be piped to the shore as soon as it is processed. There would be some storage capacity on the platforms to accommodate periods of processing equipment downtimes. The first platform would serve as the hub. Additional anchor field platforms would be located approximately 5 mi from the hub platform, with buried subsea flowlines (placed during pipeline installation) connecting each platform to the hub. One of the three satellite field platforms would act as a secondary hub, delivering oil and gas to the anchor field hub via 20 mi of subsea flowline. The two remaining satellite field platforms would connect to the secondary hub via 5 mi of subsea flowline.

A total of 15 subsea templates would be installed during open water seasons. Template would be located within 2 mi of the host platform and connected via subsea flowline (BOEM 2015e).

Production Drilling

Production well and service well drilling would be conducted both from production platforms and from MODUs. An estimated annual maximum of eight wells could be drilled by each production platform rig (e.g., 16 wells total per platform per year). A total of 459 production and service wells would be drilled from production platforms. Subsea wells would be drilled by MODUs. With efficiencies gained by repeated operations, BOEM assumes that a single drillship could drill up to three subsea wells in a single season. BOEM estimates that 6 to 9 subsea wells would be drilled per open water season, requiring two to three drillships each summer over approximately 12 years. A total of 90 sub-sea production wells would be drilled over the life of the project (BOEM 2015e).

Treated well cuttings and mud wastes for platform and subsea wells could be reinjected in disposal wells or barged to an onshore treatment and disposal facility. The stressors associated with production well drilling (i.e., noise generation, rock cuttings, drilling mud) would be similar in type as those described for exploratory drilling but, production well drilling produces less drilling mud and fewer cuttings than does exploration and delineation well drilling (BOEM 2015e).

Oil and Gas Production

Oil production would commence once sufficient production capability to maintain a minimum level of through put on the line is achieved; the development scenario assumes this would occur with the drilling of the first platform production well, and would ramp up as more wells are drilled. When the oil resources are depleted, oil production and gas injection (service) wells would be converted to gas production. Service wells would continue to reinject produced water throughout oil and gas sales operations (BOEM 2015e).

The delay of gas sales strongly influences the length of time for the production phase, but the current lack of a pipeline from the North Slope to south central Alaska and the need to maximize oil production make this the most likely production strategy (BOEM 2015e).

Production operations would largely involve resupply of materials and personnel, inspection of various systems, and maintenance and repair. Maintenance and repair work would be required on the platforms, and processing equipment would be upgraded to remove bottlenecks in production systems. Well repair work would be required to keep both production and service wells operational. Well workovers would likely be made at 5-10 year intervals to restore production flow rates. Pipelines will be inspected and cleaned regularly using internal devices ("pigs"). Crews would be rotated at regular intervals (BOEM 2015e).

2.1.4.2 Decommissioning

Decommission would commence after oil and gas reserves at a given platform are depleted and income from production no longer pays operating expenses. To comply with BSEE regulations (30 CFR 250.1710—wellheads/casings and 30 CFR 250.1725—platforms and other facilities), lessees are required to remove all seafloor obstructions from their leases within one year of lease termination or relinquishment. Decommissioning is anticipated begin after approximately 30 years of production (BOEM 2015e).

MODUs (2-3 per open-water season over an estimated 12 years) would be used to permanently plug wells with cement. Wellhead equipment would be removed, and processing modules would be moved off platforms. Subsea pipelines and flowlines would be decommissioned by cleaning the line, plugging both ends, and leaving it in place buried in the seabed. The overland oil and gas pipelines are likely to be used by other fields in the NPR-A and would remain in operation. Lastly, the platforms would be disassembled and removed using vessels, and the seafloor site would be cleared of all obstructions. Post-decommissioning surveys would be required to confirm that no debris remains.

The schedule of activities provided by BOEM is compressed and ambitious. BOEM assumes there would be no construction delays for platforms, regulatory delays, or other delays of any kind. BOEM also assumes immediate commitment from the operator(s) after a successful exploration program, with no funding delays, and that all operators coordinate and cooperate successfully. These assumptions help ensure the potential impacts of the future incremental steps will not be underestimated, while the actual timeline for development of a prospect in the Leased Area would be determined by the lessee and could be affected by any of the variables mentioned above (BOEM 2015e).

2.1.5 Mitigation Measures Proposed by BOEM

BOEM is proposing measures to minimize potential adverse effects to listed species. These measures include: lease stipulations; information to lessees, notice to lessees, vessel speed restrictions, and marine trash and debris awareness briefings. If these measures (or better or equivalent ones) are not incorporated in future actions by BOEM's lessees or permittees, BOEM may need to reinitiate consultation on this action.

Lease Stipulations

Lease Stipulations are binding contractual provisions that apply to all Ancillary Activities, EPs, DPPs, and Development Operations Coordination Documents (see 30 CFR §550.202). Lease Sale Stipulations often consist of protective measures designed to decrease the likelihood of impacts to environmental resources such as marine mammals. A complete list of the stipulations applicable to LS 193 leases is provided in Appendix D of BOEM's Second SEIS (BOEM 2015e). A brief summary of those Lease Stipulations which may serve to reduce impacts to marine mammals is provided below.

1. Protection of Biological Resources
2. Orientation Program
3. Transportation of Hydrocarbons
4. Industry Site-Specific Monitoring for Marine Mammal Subsistence Resources
5. Conflict Avoidance Mechanisms to Protect Subsistence Whaling and Other Subsistence-Harvest Activities
6. Pre-Booming Requirements for Fuel Transfers
7. Measures to Minimize Effects on Spectacled And Steller's Eiders from Exploration Drilling

The lease stipulations that have the most impact on NMFS' trust resources include stipulations 1, 4, and 5. Lease stipulation 1 is intended to protect biological resources that are discovered during the course of operations. If previously unidentified biological populations or habitats that may require additional protection – for example, marine mammal haul out areas – are identified in the lease area, the lessee may be required to conduct biological surveys to determine the extent and composition of such biological populations or habitats. The lessee may also be required to do one of more of the following: relocate the site of operations; establish that its operations will not have a significant adverse effect upon the resource identified, or that a special biological community does not exist; operate during those periods of time that do not adversely affect the biological resources; and/or modify operations to ensure that significant biological populations or habitats deserving protection are not adversely affected. Lease stipulation 4 may be used to require lessees to monitor activities that take place on lease block that are within identified marine mammal subsistence hunting areas in order to minimize the potential impacts to subsistence hunting. Lease stipulation 5 requires all exploration, development, and production operation to be conducted in manner that prevents unreasonable conflicts between oil and gas industry and subsistence activities. This stipulation is designed to protect subsistence harvest practices, but may also serve to reduce potential disturbance to marine mammals.

Information to Lessees

The Information to Lessee (ITLs) are statements for informational purposes. Some ITLs provide information about issues and concerns related to particular environmental or sociocultural resources. Others provide information on how lessees might plan their activities to meet BOEM requirements or reduce potential impacts. Still other ITLs provide information about the requirements or mitigation required by other federal and State agencies. ITLs are effective in lowering potential impacts by alerting and informing lessees and their contractors about mitigation measures. The ITLs listed below apply to all OCS activities in the Chukchi Sea conducted pursuant to LS 193 leases and are considered part of the Proposed Action (BOEM 2015e). Section II.B.3.c(3) of the 2007 FEIS provides the full text and discussion of each ITL listed below. Applicable ITLs are also available at http://www.boem.gov/ak193/.

No. 1 –Community Participation in Operations Planning
No. 2 –Bird and Marine Mammal Protection
No. 3 –River Deltas
No. 4 –Endangered Whales and MMS Monitoring Program
No. 5 –Availability of Bowhead Whales for Subsistence-Hunting Activities
No. 6 –High-Resolution Geological and Geophysical Survey Activity
No. 7 –Spectacled Eider and Steller's Eider
No. 8 –Sensitive Areas to be Considered in Oil-Spill-Response Plans
No. 9 –Coastal Zone Management
No. 10 –Navigational Safety
No. 11 –Offshore Pipelines
No. 12 –Discharge of Produced Waters
No. 13 –Use of Existing Pads and Islands
No. 14 –Planning for Protection of Polar Bears
No. 15 – Possible listing of Polar Bear under ESA
No. 16 – Archaeological and Geological Hazards Reports and Surveys
No. 17 – Response Plans for Facilities Located Seaward of the Coast Line
No. 18 – Oil Spill Financial Responsibility for Offshore Facilities
No. 19 – Good Neighbor Policy
No. 20 – Rentals/Minimum Royalties and Royalty Suspension Provisions
No. 21 – MMS Inspection and Enforcement of Certain Coast Guard Regulations
No. 22 – Statement Regarding Certain Geophysical Data
No. 23 – Affirmative Action Requirements

No. 24 – Bonding Requirements
No. 25 – Review of Development and Production Plans

Notice to Lessees

Notices to Lessees (NTL) are formal documents that provide clarification, description, or interpretation of a regulation or OCS standard; provide guidelines on the implementation of a special lease stipulation or regional requirement; provide a better understanding of the scope and meaning of a regulation by explaining BOEM interpretation of a requirement; or transmit administrative information. NTLs are either applicable nationally to the OCS program or are issued by and applicable to specific regions of the OCS. The National NTLs are posted to BOEM's website at http://www.boem.gov/notices-to-lessees-and-operators.

Vessel Strike Avoidance

All authorizations for shipboard surveys and drilling operations would include guidance for protected species identification, vessel strike avoidance and injured/dead protected species reporting. The lessee and/or operator must ensure that all vessels conducting exploration activities comply with the vessel strike avoidance measures specified below except under extraordinary circumstances when the safety of the vessel or crew are in doubt or the safety of life at sea is in question.

The vessel strike avoidance measures have been included in the proposed action, and include maintaining a vigilant watch for listed whales and pinnipeds and slowing down or stopping vessels to avoid striking protected species by observing the 5 kn (9.26 km/h) speed restriction when within 900ft of cetaceans or pinnipeds. In addition, the lessee and/or operator will avoid transits within designated North Pacific right whale critical habitat. If transit within North Pacific right whale critical habitat cannot be avoided, vessel operators are requested to exercise extreme caution and observe the 10 kn (18.52 km/h) vessel speed restriction while within North Pacific right whale critical habitat. Lessee and/or operators transiting through North Pacific right whale critical habitat will have PSOs actively engaged in sighting marine mammals. PSOs would increase vigilance and allow for reasonable and practicable actions to avoid collisions with North Pacific right whales. Lessee and/or operators will maneuver vessels to keep 800 m away from any observed North Pacific right whales while within their designated critical habitat, and avoid approaching whales head-on consistent with vessel safety. Vessels should take reasonable steps to alert other vessels in the vicinity of whale(s), and report of any dead or injured listed whales or pinnipeds.

Marine Debris Awareness

All authorizations for shipboard surveys and drilling operations would include guidance for marine debris awareness. The deliberate discharge of containers and other similar materials (i.e., trash and debris) into the marine environment is generally prohibited unless it is passed through a comminutor that breaks up solids so they can pass through a 25-mm mesh screen. Discharge of plastic is prohibited regardless of size. Durable identification marking on equipment, tools and containers (especially drums), and other material are also required as well as recording and reporting of items lost overboard. Special precautions would be taken when handling and disposing of small items and packaging materials, particularly those made of non- biodegradable, environmentally persistent materials such as plastic or glass that can be lost in the marine environment and washed ashore.

Entanglement in marine debris is a threat to marine mammals worldwide. A 2014 global study found that ingestion of debris has been documented in 56% of cetacean species, with rates of ingestion as high as 31% in some populations (Baulch and Perry 2014). In Alaska, many species of cetaceans and pinnipeds are known to become entangled in or ingest marine debris. Manufactured packing bands are a particular problem for pinnipeds and should always be cut before disposal to prevent neck entanglements.

All vessel operators, employees and contractors actively engaged in exploration surveys or drilling operations must be briefed on marine trash and debris awareness elimination, consistent with 30 CFR 250.300. BOEM will not require operators, employees and contractors to undergo formal training or to post placards. However, the operator will be required to ensure that its employees and contractors are made aware of the environmental and socioeconomic impacts associated with marine trash and debris and their responsibilities for ensuring that trash and debris are not intentionally or accidentally discharged into the marine environment.

2.1.6 Mitigation Measures Proposed by NMFS

The mitigation measures below have typically been included in recent Incidental Harassment Authorizations (IHAs) for oil and gas activities in the U.S. Arctic. NMFS expects that all of these measures, depending on the activity specified, will be included in its future Marine Mammal Protection Act (MMPA) authorizations for similar activities. If these measures (or better or equivalent ones) are not incorporated in future actions by BOEM's lessees or permittees (or their agents) through the MMPA permitting process or otherwise, BOEM may need to reinitiate consultation on this action.

A) Detection-based measures intended to reduce near-source acoustic exposures and impacts on marine mammals under NMFS' authority within a given distance of the source

Monitoring and Mitigating the Effects of Marine Seismic Surveys, Geohazard Surveys, and VSP

1. Protected Species Observers ([PSOs], formerly referred to as Marine Mammal Observers or [MMOs]) are required on all vessels engaged in activities that may result in an incidental take through acoustic exposure.

2. Establishment of radii associated with received sound level thresholds for 180 dB shutdown/power down for cetaceans and 190 dB shutdown/power down radius for pinnipeds under NMFS authority.

- Establish and monitor a preliminary exclusion zone (EZ) for cetaceans and pinnipeds surrounding the airgun array on the source vessel where the received level would be at or above 180 dB for cetaceans and 190 dB for pinnipeds with trained PSOs. The radius for the zone will vary based on the configuration of the airgun array, water depth, temperature, salinity, and other factors related to the water and seafloor properties. The final distance of the radius will be established by modeling and may be verified with sound source verification tests.

- Immediately reduce the size of the size of the EZ (180 or 190 isopleth) by reducing the power level of the array whenever any cetaceans are sighted approaching close to or within the area delineated by the 180 dB, or pinnipeds are sighted approaching close to or within the area delineated by the 190 dB isopleth, until the marine mammal is not close to or within the zone.

- If the power-down operation cannot reduce the sound pressure level received by any cetacean or pinniped to less than 180 dB or 190 dB, respectively, then the holder of the Incidental Harassment Authorization or Letter of Authorization must immediately shutdown the seismic airgun array.

3. Use of start-up and ramp-up procedures for airgun arrays.

   - PSOs will monitor the entire EZ for at least 30 minutes prior to starting the airgun array (day or night). If PSO finds a marine mammal within the EZ, the operator must delay the start-up of seismic airguns until the marine mammal(s) has left the area. If the PSO sees a marine mammal that surfaces then dives below the surface, the PSO shall continue the watch for 30 min. If the PSO sees no marine mammals during that time, the PSO can assume that the animal has moved beyond the exclusion zone. If for any reason the entire EZ cannot be seen for the entire 30 min period (i.e., rough seas, fog, darkness), or if marine mammals are near, approaching, or in the EZ, the airguns may not be started;

   - If one airgun (mitigation) is already running at a source level of at least 180 dB re 1 µPa (rms), the operator may start the second airgun, provided no marine mammals are known to be near the EZ;

   - After a shut-down, additional airguns may be added in a sequence such that the source level of the array shall increase in steps not exceeding approximately 6 dB per 5 min period. During ramp-up, the PSOs shall monitor the EZ, and if marine mammals are sighted, a power-down, or shut-down shall be implemented as though the full array were operational. Therefore, initiation of start-up procedures from shutdown requires that the PSOs be able to view the full EZ;

   - Power-down or shutdown the airgun(s) will be implemented if a marine mammal is detected within, approaches, or enters the relevant EZ. A power-down procedure means reducing the number of operating airguns to as low as a single operating mitigation gun, which reduces the exclusion zone to the degree that the animal(s) is no longer in or about to enter it. A shutdown means all operating airguns are shutdown (i.e., turned off).

- If the marine mammal continues to approach the exclusion zone of the mitigation gun, the airguns must then be completely shut down. Airgun activity shall not resume until the PSO has visually observed the marine mammal(s) exiting the EZ and is not likely to return, or has not been seen within the EZ for 15 min for species with shorter dive durations (small odontocetes and pinnipeds) or 30 min for species with longer dive duration (mysticetes);
- Following a power-down or shut-down and subsequent animal departure, airgun operations may resume following ramp-up procedures described above;
- Seismic surveys may continue into night and low-light hours is such segment(s) of the survey is initiated when the entire relevant exclusion zones are visible and can be effectively monitored; and
- No initiation of airgun array operations is permitted from a shutdown position at night or during low-light hours (such as in dense fog or heavy rain) when the entire relevant EZ cannot be effectively monitored by the PSO(s) on duty.

Monitoring and Mitigating the Effects of Onshore Facility Construction

4. All activities must be conducted at least 150 m (500 ft) from any observed ringed seal lair.
    - Travel between a mobile camp and work site shall be accomplished by having vehicles drive on a snow road during transit whenever possible; building ice roads for transit will be minimized as much as is safely possible. Vehicles must avoid pressure ridges, ice ridges, and ice deformation areas where seal structures are likely to be present. If it is not possible to avoid these features, NMFS may require the use of trained dogs to determine that no seal lairs are present before to the onset of activities within 150 m (500 ft) of any of these features;

Monitoring Exploratory Drilling Activities

5. PSOs are required on all drill units and ice management vessels as well as any other vessels currently producing noise exceeding NMFS acoustic thresholds.
    - PSOs would monitor the area around the drill structure for take of any marine mammals by sound exposure.

B) Non-detection-based measures intended to avoid disturbance impacts on marine mammals from aircraft operations.

This measure would be required for all aircraft operations conducted in support of exploration activities.

1. Specified flight altitudes for all support aircraft (except for take-off, landing, emergency situations, and inclement weather).

    - *All aircraft:* Aircraft shall not operate fly within 305 m (1,000 ft) of marine mammals or below 457 m (1,500 ft) AGL or ASL.

C) Measures intended to reduce/lessen non-acoustic impacts on marine mammals

This measure would be required for all vessel operations conducted in support of exploration activities.

1. Specified procedures for vessels to avoid collisions with whales.

    - All vessels shall reduce speed to less than 5 kn prior to coming within 274 m (300 yards) of whales. The reduction in speed will vary based on the situation but must be sufficient to avoid interfering with the whales. Those vessels capable of steering around such groups should do so. Vessels may not be operated in such a way as to separate members of a group of whales from other members of the group. For purposes of this opinion, a group is defined as being three or more whales observed within a 500 m (547 yards) area and displaying behaviors of directed or coordinated activity (e.g., group feeding);

    - Avoid multiple changes in direction and speed when within 274 m (300 yards) of whales and also operate the vessel(s) to avoid causing a whale to make multiple changes in direction;

    - Check the waters immediately adjacent to the vessel(s) to ensure that no whales will be injured when the vessel's propellers (or screws) are engaged.

    - When visibility is reduced, such as during inclement weather (rain, fog) or darkness, adjust vessel speed accordingly to avoid the likelihood of injury to whales.

2. Notification of lost equipment that could pose a danger to marine mammals.

    - The operator shall notify BSEE (dependent upon the type of activity), and NMFS in the event of any loss of cable, streamer, or other equipment that could pose a danger to marine mammals.

2.1.7 Additional Mitigation Measures

Additional mitigation measure may be required by NMFS for site specific activities as specified in an Incidental Take Authorization or by BOEM in a specific exploration plan or by BSEE in a drilling permit. However, since those measures may, or may not, be incorporated in future permits and authorizations, they are not considered as part of this proposed action.

2.2 Action Area

"Action area" means all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). For this reason, the action area is typically larger than the project area and extends out to a point where no measurable effects from the proposed action occur.

The action area for this biological opinion will include: (1) 460 active leases contained within LS 193 in the Chukchi Sea which includes seismic, geohazard, and drilling sites; (2) sound propagation buffer area surrounding LS 193; (3) onshore facilities along Alaska coastline; and (4) transit areas from Dutch Harbor through the Bering Strait into the Chukchi Sea, and from lease areas to the Alaska coastline. The action area encompasses approximately 309,593 square kilometers (see Figure 2).

BOEM is proposing to authorize oil and gas exploration activities within the 460 active leases on LS 193 in the Chukchi Sea. In total, LS 193 covers 10,541 square kilometers of water in depths ranging 20-50 meters. Within this area, the loudest sound source with the greatest propagation distance is anticipated to be the 4500 cui airgun array. Received levels from this marine seismic survey with a nominal source level of 232 dB, may be expected on average to decline to 120 dB re 1 μPa (rms) within 113 km of the lease area assuming a mixed sound speed profile and medium reflectivity geoacoustics (Austin et al. 2015). The 120 dB isopleth was chosen because that's when we anticipate seismic survey noise levels would approach ambient noise levels (i.e. the point where no measurable effect from the project would occur). While project noise may attenuate beyond the 120 dB isopleth, we do not anticipate that marine mammals would respond in a biologically significant manner at these low levels and great distance from the source. The 113 km sound propagation buffer around the LS 193 lease area boundary assumes that a source vessel engaged in transmitting seismic occurred on the boundary of the lease blocks.

Mobilization and demobilization of vessels is anticipated to occur from Dutch Harbor[4] with resupply and support activities potentially occurring out of Kotzebue, Barrow, or Wainwright (BOEM 2015e).

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[4] NMFS reviewed all of the previous IHA applications and 90 day monitoring reports from previous seismic and exploratory drilling operations in the Chukchi Sea from 2006-2013. ION Geophysical (2012) and Beland and Ireland (2010) both started their projects in Canadian Arctic waters; however, both projects ended in Dutch Harbor.

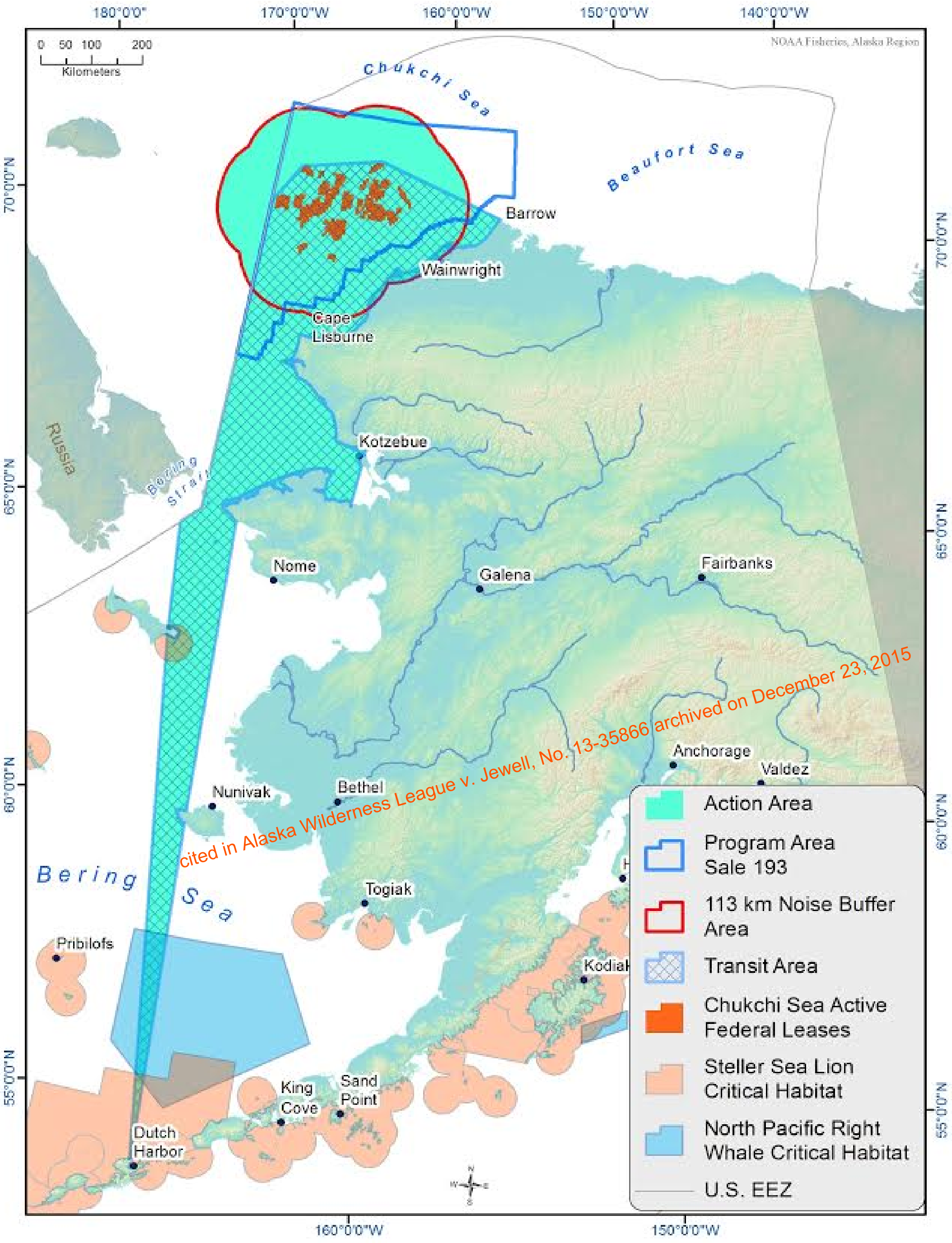


Figure 2. **Action Area (light green) includes: LS 193 active leases (orange) sound propagation buffer (red outline), and transit area (crisscrossed lines).**

3. APPROACH TO THE ASSESSMENT

3.1 Introduction to the Biological Opinion

Section 7(a)(2) of the ESA requires federal agencies, in consultation with NMFS, to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy designated critical habitat. The jeopardy analysis considers both survival and recovery of the species. The adverse modification analysis considers the impacts to the conservation value of the designated critical habitat.

"To jeopardize the continued existence of a listed species" means to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of the survival or recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR 402.02). As NMFS explained when it promulgated this definition, NMFS considers the likely impacts to a species' survival as well as likely impacts to its recovery. Further, it is possible that in certain, exceptional circumstances, injury to recovery alone may result in a jeopardy biological opinion (51 FR 19926, 19934; June 2, 1986).

3.1.1 Assessment Framework

We will use the following approach to determine whether the proposed action described in Section 2 is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Identify those aspects of proposed action that are likely to have direct and indirect effects on the physical, chemical, and biotic environment of the project area. As part of this step, we identify the action area – the spatial extent of these direct and indirect effects.

- Identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action. This section describes the current status of each listed species and its critical habitat relative to the conditions needed for recovery. We determine the rangewide status of critical habitat by examining the condition of its physical or biological features (also called "primary constituent elements" or PCEs in some designations) - which were identified when the critical habitat was designated. Species and critical habitat status are discussed in Section 4.

- Describe the environmental baseline for the proposed action. The environmental baseline includes the past and present impacts of federal, state, or private actions and other human activities *in the action area*. It includes the anticipated impacts of proposed federal projects that have already undergone formal or early section 7 consultation and the impacts of state or private actions that are contemporaneous with the consultation in process. The environmental baseline is discussed in Section 5 of this opinion.

- Analyze the effects of the proposed actions. Identify the listed species that are likely to co-occur with these effects in space and time and the nature of that co-occurrence (these represent our *exposure analyses*). In this step of our analyses, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent.

NMFS also evaluates the proposed action's effects on critical habitat features. The effects of the action are described in Section 6 of this opinion with the exposure analysis described in Section 6.2 of this opinion.

- Once we identify which listed species are likely to be exposed to an action's effects and the nature of that exposure, we examine the scientific and commercial data available to determine whether and how those listed species are likely to respond given their exposure (these represent our *response analyses*). Response analysis is considered in Section 6.3 of this opinion.

- Describe any cumulative effects. Cumulative effects, as defined in NMFS's implementing regulations (50 CFR 402.02), are the effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area. Future federal actions that are unrelated to the proposed action are not considered because they require separate section 7 consultation. Cumulative effects are considered in Section 7 of this opinion.

- Integrate and synthesize the above factors to assess the risk that the proposed action poses to species and critical habitat. In this step, NMFS adds the effects of the action (Section 6) to the environmental baseline (Section 5) and the cumulative effects (Section 7) to assess whether the action could reasonably be expected to: (1) appreciably reduce the likelihood of survival or recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the status of the species (Section 4). Integration and synthesis with risk analyses occurs in Section 8 of this opinion.

- Reach jeopardy and adverse modification conclusions. Conclusions regarding jeopardy and the destruction or adverse modification of critical habitat are presented in Section 9. These conclusions flow from the logic and rationale presented in the Integration and Synthesis Section 8.

- If necessary, define a reasonable and prudent alternative to the proposed action. If, in completing the last step in the analysis, NMFS determines that the action under consultation is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat, NMFS must identify a reasonable and prudent alternative (RPA) to the action.

3.1.2 Exposure Analyses

Exposure analyses are designed to identify the listed resources that are likely to co-occur with these effects in space and time and the nature of that co-occurrence. In this step of our analysis, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent. When it is impossible or impracticable to estimate the number of individuals likely to be exposed, we try to estimate the proportion of a population that is likely to be exposed. If we cannot estimate this proportion, we will rely on a surrogate or index.

For our exposure analyses, NMFS generally relies on an action agency's estimates of the number of marine mammals that might be "taken." However, BOEM did not provide a quantitative exposure analysis. Therefore NMFS conducted its own analysis to estimate the number of exposures to listed resources that may result from stressors produced by the proposed action. We have divided the exposure analysis into: exposures to major noise sources (i.e., seismic and drilling operations), exposures to other noise sources (i.e., other impulsive noise, vessel transit, aircraft traffic, and onshore construction), exposures to unauthorized oil spills and gas releases, and finally exposures to other stressors (i.e., vessel strike, habitat disturbance, and marine debris). For stressors associated with major noise sources, we developed activity scenarios, and conducted acoustic propagation modeling associated with the activity scenarios (described in detail below).

Given the many uncertainties in predicting the quantity and types of impacts of sound on marine mammals, it is common practice to estimate how many animals would be present within a particular distance of human activities and/or exposed to a particular level of anthropogenic sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner. One of the reasons for this is that the selected distances/isopleths are based on limited studies indicating that some animals exhibited short-term reactions at this distance or sound level, whereas the calculation assumes that all animals exposed to this level would react in a biologically significant manner.

Another scenario we considered but did not use assumed marine mammals would try to avoid exposure to seismic transmissions (See *Response Analysis* Section 6.1.4), but the data necessary on the rate at which cetacean and pinniped densities would change in response to initial or continued seismic or drilling exposure or when and where BOEM authorized activities would actually occur are not currently available, so we could not reach conclusions based on this scenario. As a result, although we considered alternative exposure scenarios for this consultation, we only report the results of one of those exposure scenarios.

3.1.3 Response Analyses

Once we identify which listed resources are likely to be exposed to stressors associated with the proposed action, and the nature of that exposure, we examine the scientific and commercial data available to determine whether and how (1) endangered or threatened species are likely to respond following exposure and the set of physical, physiological, behavioral, or social responses that are likely and (2) the action is likely to affect the quantity, quality, or availability of one or more of the physical or biological features of critical habitat.

Conceptual Model for Response Analyses

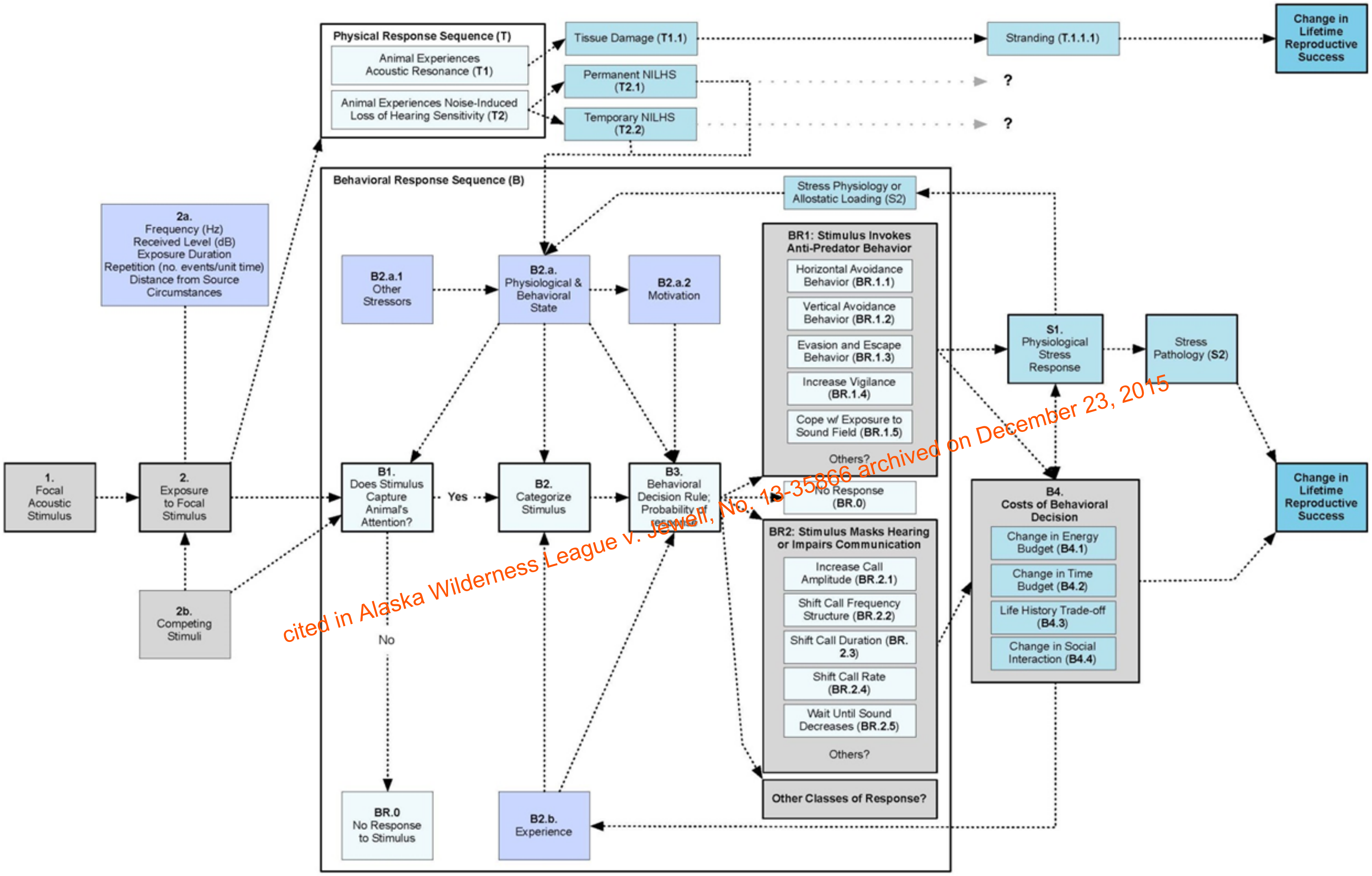
To guide our response analyses, we use a conceptual model of responses to noise (which is the principal stressor included in the proposed action). The model is based on animal behavior and behavioral decision-making (Figure 3) although we continue to recognize the risks presented by physical trauma and noise-induced losses in hearing sensitivity (threshold shift). This model is also based on a conception of "hearing" that includes cognitive processing of auditory cues, rather than focusing solely on the mechanical processes of the ear and auditory nerve. Our model incorporates the primary mechanisms by which behavioral responses affect the longevity and reproductive success of animals: changing an animal's energy budget, changing an animal's time budget (which is related to changes in an animal's energy budget), forcing animals to make life history trade-offs (for example, engaging in evasive behavior such as deep dives that involve short-term risks while promoting long-term survival), or changes in social interactions among groups of animals (for example, interactions between a cow and her calf).

This conceptual model begins with the specific acoustic stimuli that we focus on in an assessment (Box 1 in Figure 3). Although we generally considered different acoustic stimuli separately, we considered a single source of multiple acoustic stimuli as a complex "acoustic object" that has several acoustic properties. For example, we treat pulses produced by seismic sound sources and sounds produced by the source vessel as a single "acoustic object" that produced continuous sounds (engine- noise, propeller cavitation, hull displacement, etc.) and periodic impulsive pulses. Because animals would be exposed to this complex of sounds produced by a single, albeit moving, source over time, we assumed they would generally respond to the acoustic stream associated with this single acoustic object moving through their environment. Multiple ships associated with a particular type of survey, for instance 3D seismic surveys, are expected to also represent a single acoustic object as all vessels are moving in formation at the same speeds while alternating shots. Multiple ships associated with drilling operations, such as support ships that move independently of the survey formation would represent different acoustic objects in the acoustic scene of endangered and threatened marine animals.

Acoustic stimuli can represent two different kinds of stressors: *processive stressors*, which require high-level cognitive processing of sensory information, and *systemic stressors*, which usually elicit direct physical or physiological responses and, therefore, do not require high-level cognitive processing of sensory information (Herman and Cullinan 1997, Anisman and Merali 1999, de Kloet et al. 2005, Wright et al. 2007). Disturbance from surface vessels and airguns would be examples of processive stressors while ship strikes would be an example of a systemic stressor. The proposed action may result in two general classes of responses:

1. responses that are influenced by an animal's assessment of whether a potential stressor poses a threat or risk (see Figure 3: Behavioral Response).

2. responses that are not influenced by the animal's assessment of whether a potential stressor poses a threat or risk (see Figure 3: Physical Response).



18 October 2012

Figure 3. Conceptual model of the potential responses of listed species upon exposure to an active acoustic sources, and the pathways by which those responses might affect the fitness of individual animals that have been exposed.

Our conceptual model explicitly recognizes that other acoustic and non-acoustic stimuli that occur in an animal's environment might determine whether a focal stimulus is salient to a focal animal (the line connecting Box 2b to Box 2 in Figure 3). The salience of an acoustic signal will depend, in part, on its signal-to-noise ratio and, given that signal-to-noise ratio, whether an animal will devote attentional resources to the signal or other acoustic stimuli (or ambient sounds) that might compete for the animal's attention (the line connecting Box 2b to Box B1 in Figure 3).[5] That is, an acoustic signal might not be salient (1) because of a signal-to-noise ratio or (2) because an animal does not devote attentional resources to the signal, despite its signal-to-noise ratio. Absent information to the contrary, we generally assume that an acoustic stimulus that is "close" to an animal (within 10 – 15 kilometers) would remain salient regardless of competing stimuli and would compete for an animal's attentional resources. By extension, we also assume that any behavioral change we might observe in an animal would have been caused by a focal stimulus (the stimulus most immediately confronting the animal) rather than competing stimuli. However, as the distance between the source of a specific acoustic signal and a receiving animal increases, we assume that the receiving animal is less likely to devote attentional resources to the signal.

If we assume that an acoustic stimulus, such as a seismic or drilling source, was salient to an animal or population of animals, we would then ask how an animal might classify the stimulus as a cue about its environment (Box B2 in Figure 3) because an animal's response to a stimulus in its environment depends upon whether and how the animal converts the stimulus into information about its environment (Blumstein and Bouskila 1996, Yost 2007). For example, if an animal classifies a stimulus as a "predatory cue," that classification will invoke a suite of candidate physical, physiological, or behavioral responses that are appropriate to being confronted by a predator (this would occur regardless of whether a predator is, in fact, present).

By incorporating a more expansive concept of "hearing," our conceptual model departs from earlier models which have focused on the mechanical processes of "hearing" associated with structures in the ear that transduce sound pressure waves into vibrations and vibrations to electro-chemical impulses. That conception of hearing resulted in assessments that focus almost exclusively on active acoustic sources while discounting other acoustic stimuli associated with activities that marine animals might also perceive as relevant. That earlier conception of hearing also led to an almost singular focus on the intensity of the sound (its received level in decibels) as an assessment metric and noise-induced hearing loss as an assessment endpoint.

Among other considerations, the earlier focus on received level and losses in hearing sensitivity failed to recognize several other variables that affect how animals are likely to respond to acoustic stimuli:

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[5] See Blumstein and Bouskila (1996) for a review of the literature on how animals process and filter sensory information, which affects the subjective salience of sensory stimuli. See Clark and Dukas (2003), Dukas (2002), and Roitblat (1989) for more extensive reviews of the literature on attentional processes and the consequences of limited attentional resources in animals.

1. “hearing” includes the cognitive processes an animal employs when it analyzes acoustic impulses (see Bregman 1990, Blumstein and Bouskila 1996, Hudspeth 1997, Yost 2007), which includes the processes animals employ to integrate and segregate sounds and auditory streams and the circumstances under which they are likely to devote attentional resources to an acoustic stimulus.

2. animals can “decide” which acoustic cues they will focus on and their decision will reflect the salience of a cue, its spectral qualities, and the animal’s physiological and behavioral state when exposed to the cue.

3. animals not only perceive the received level (in dB) of a sound source, they also perceive their distance from a sound source. Further, animals are more likely to devote attentional resources to sounds that are close than sounds that are distant.

4. both received levels and the spectral qualities of sounds degrade over distance so the sound perceived by a distant receiver is not the same sound at the source.

As a result of this shift in focus, we have to consider more than the received level of a particular low- or mid-frequency wave form and its effects on the sensitivity of an animal’s ear structure. We also have to distinguish between different auditory scenes; for example, animals will distinguish between sounds from a source that is moving away, sounds produced by a source that is approaching them, sounds from multiple sources that are all approaching, sounds from multiple sources that appear to be moving at random, etc.

Animals would then combine their perception of the acoustic stimulus with their assessment of the auditory scene (which include other acoustic stimuli), their awareness of their behavioral state, physiological state, reproductive condition, and social circumstances to assess whether the acoustic stimulus poses a risk and the degree of risk it might pose, whether it is impairing their ability to communicate with conspecifics, whether it is impairing their ability to detect predators or prey, etc. We assume that animals would categorize an acoustic source differently if the source is moving towards its current position (or projected position), moving away from its current position, moving tangential to its current position, if the source is stationary, or if there are multiple acoustic sources it its auditory field.

This process of “categorizing a stimulus” (Box B2 in Figure 3) lends meaning to a stimulus and places the animal in a position to decide whether and how to respond to the stimulus (Blumstein and Bouskila 1996). How an animal categorizes a stimulus will determine the set of candidate responses that are appropriate in the circumstances. That is, we assume that animals that categorizes a stimulus as a “predatory cue” would invoke candidate responses that consisted of anti-predator behavior rather than foraging behavior (Blumstein and Bouskila 1996, Bejder et al. 2009).

We then assume that animals apply one or more behavioral decision rules to the set of candidate responses that are appropriate to the acoustic stimulus as it has been classified (Box B3 in Figure 3). Our use of the term “behavioral decision rule” follows Blumstein and Bouskila (1996), and Lima and Dill (1990b), and is synonymous with the term “behavioral policy” of McNamara and

Houston (1986a): the process an animal applies to determine which specific behavior it will select from the set of behaviors that are appropriate to the auditory scene, given its physiological and behavioral state when exposed and its experience. Because we would never know the behavioral policy of an individual, free- ranging animal, we treat this policy as a probability distribution function that matches a particular response in the suite of candidate behavioral responses.

Once an animal selects a behavioral response from a set of candidate behaviors, we assume that any change in behavioral state would represent a shift from an optimal behavioral state (or behavioral act) to a sub-optimal behavioral state (or behavioral act) as the animal responds to a stimulus such as acoustic sound sources. That selection of the sub-optimal behavioral state or act could be accompanied by *canonical costs*, which are reductions in the animal's expected future reproductive success that would occur when an animal engages in suboptimal behavioral acts (McNamara and Houston 1986a).

Specifically, canonical costs represent a reduction in current and expected future reproductive success (which integrates survival and longevity with current and future reproductive success) that would occur when an animal engages in a sub-optimal rather than an optimal sequence of behavioral acts; given the pre-existing physiological state of the animal in a finite time interval (McFarland and Sibly 1975, McNamara and Houston 1982, McNamara and Houston 1986b, Houston et al. 1993, McNamara 1993, McNamara and Houston 1996, Nonacs 2001, Crone et al. 2013). Canonical costs would generally result from changes in animals' energy budgets (Sapolsky 1997, Moberg 2000, McEwen and Wingfield 2003, Wingfield and Sapolsky 2003, Romero 2004), time budgets (Sutherland 1996, Frid and Dill 2002a), life history trade-offs (Cole 1954, Stearns 1992a), changes in social interactions (Sutherland 1996), or combinations of these phenomena (see Box B4 in Figure 3). We assume that an animal would not incur a canonical cost if they adopted an optimal behavioral sequence (see McNamara and Houston 1986a for further treatment and discussion).

This conceptual model does not require us to assume that animals exist in pristine environments; in those circumstances in which animals are regularly or chronically confronted with stress regimes that animals would adapt to by engaging in sub-optimal behavior, we assume that a change in behavior that resulted from exposure to a particular stressor or stress regime would either contribute to sub-optimal behavior or would cause animals to engage in behavior that is even further from optimal.

3.1.4 Risk Analyses

Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species as those "species" have been defined by the ESA. Because the continued existence of listed species depends on the fate of the populations that comprise them, the viability (that is, the probability of extinction or probability of persistence) of listed species depends on the viability of the populations that comprise the species. Similarly, the continued existence of populations is determined by the fate of the individuals that comprise them.

Our risk analyses begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's effects. Our analyses then integrate those individual risks to identify consequences to the populations those individuals represent. Our analyses conclude by determining the consequences of those population-level risks to the species those populations comprise.

If the quantity, quality, or availability of the primary constituent elements of designated critical habitat are reduced, we consider whether those reductions are likely to be sufficient to reduce the conservation value of the designated critical habitat for listed species in the action area.

If the conservation value of designated critical habitat in the action area is reduced, the final step of our analyses considers whether those reductions are likely to be sufficient to reduce the conservation value of the entire critical habitat designation.

3.1.5 Treatment of Cumulative Impact

The effects analyses of biological opinions consider the impacts on listed species and designated critical habitat that result from the incremental impact of an action by identifying natural and anthropogenic stressors that affect endangered and threatened species throughout their range (the *Status of the Species*) and within an action area (the *Environmental Baseline*, which articulates the pre-existing *impacts* of activities that occur in an action area, including the past, contemporaneous, and future *impacts* of those activities). We assess the effects of a proposed action by adding the direct and indirect effects to the *impacts* of the activities we identify in an *Environmental Baseline* (50 CFR 402.02), in light of the impacts of the status of the listed species and designated critical habitat throughout their range.

3.1.6 Brief Background on Sound

Sound is a wave of pressure variations propagating through a medium (for this consultation, the sounds generated by seismic and electromechanical equipment propagates through marine water as its medium). Pressure variations are created by compressing and relaxing the medium. Sound measurements can be expressed in two forms: *intensity* and *pressure*. Acoustic intensity is the average rate of energy transmitted through a unit area in a specified direction and is expressed in watts per square meter. Acoustic intensity is rarely measured directly, it is derived from ratios of *pressures*; the standard reference pressure for underwater sound is 1 µPa; for airborne sound, the standard reference pressure is 20 µPa (Richardson et al. 1995).

Acousticians have adopted a logarithmic scale for sound intensities, which is denoted in decibels (dB). Decibel measurements represent the ratio between a measured pressure value and a reference pressure value (in this case 1 µPa or, for airborne sound, 20 µPa.). The logarithmic nature of the scale means that each 10 dB increase is a ten-fold increase in power (e.g., 20 dB is a 100-fold increase, 30 dB is a 1,000- fold increase). The term "sound pressure level" implies a decibel measure and a reference pressure that is used as the denominator of the ratio. Throughout this opinion, we use 1 µPa as a standard reference pressure unless noted otherwise.

It is important to note that decibels underwater and decibels in air are not the same and cannot be directly compared. Because of the different densities of air and water and the different decibel standards in water and air, a sound with the same intensity (i.e., power) in air and in water would be approximately 63 dB quieter in air.

Sound frequency is measured in cycles per second, or Hz, and is analogous to musical pitch; high-pitched sounds contain high frequencies and low-pitched sounds contain low frequencies. Natural sounds in the ocean span a huge range of frequencies: from earthquake noise at 5 Hz to harbor porpoise clicks at 150,000 Hz. These sounds are so low or so high in pitch that humans cannot hear them; acousticians call these infrasonic and ultrasonic sounds, respectively. A single sound may be made up of many different frequencies together. Sounds made up of only a small range of frequencies are called “narrowband,” and sounds with a broad range of frequencies are called “broadband;” airguns are an example of a broadband sound source and sonars are an example of a narrowband sound source.

When considering the influence of various kinds of noise on the marine environment, it is necessary to understand that different kinds of marine life are sensitive to different frequencies of sound. Most dolphins, for instance, have excellent hearing at very high frequencies between 10,000 and 100,000 Hz. Their sensitivity at lower frequencies below 1000 Hz, however, is quite poor. On the other hand, the hearing sensitivity of most baleen whales appears to be best at frequencies between about between 20 Hz-5 kHz, with maximum sensitivity between 100-500 Hz (Erbe 2002b). As a result, baleen whales might be expected to suffer more harmful effects from low frequency noise than would dolphins.

When sound travels away from its source, its loudness decreases as the distance traveled by the sound increases. Thus, the loudness of a sound at its source is higher than the loudness of that same sound a kilometer distant. Acousticians often refer to the loudness of a sound at its source as the *source level* and the loudness of sound elsewhere as the *received level*. For example, a humpback whale 9 kilometers from an airgun that has a source level of 230 dB may only be exposed to sound that is 160 dB loud. As a result, is important not to confuse source levels and received levels when discussing the loudness of sound in the ocean.

As sound moves away from a source, its propagation in water is influenced by various physical characteristics, including water temperature, depth, salinity, and surface and bottom properties that cause refraction, reflection, absorption, and scattering of sound waves. Oceans are not homogeneous and the contribution of each of these individual factors is extremely complex and interrelated. Sound speed in seawater is generally about 1,500 meters per second (5,000 feet per second) although this speed varies with water density, which is affected by water temperature, salinity (the amount of salt in the water), and depth (pressure). The speed of sound increases as temperature and depth (pressure), and to a lesser extent, salinity, increase. The variation of sound speed with depth of the water is generally presented by a “sound speed profile,” which varies with geographic latitude, season, and time of day.

Sound tends to follow many paths through the ocean, so that a listener may hear multiple, delayed copies of transmitted signals (Richardson et al. 1995). Echoes are a familiar example of this phenomenon in air. In order to determine what the paths of sound transmission are, one rule is to seek paths that deliver the sound to the receiver the fastest. If the speed of sound were constant throughout the ocean, acoustic rays would consist of straight-line segments, with reflections off the surface and the bottom. However, because the speed of sound varies in the ocean, most acoustic rays do not follow a straight path.

As sound travels through the ocean, the intensity associated with the wave front diminishes, or attenuates. In shallow waters of coastal regions and on continental shelves, sound speed profiles become influenced by surface heating and cooling, salinity changes, and water currents. As a result, these profiles tend to be irregular and unpredictable, and contain numerous gradients that last over short time and space scales. This decrease in intensity is referred to as propagation loss, also commonly called transmission loss. In general, in a homogeneous lossless medium, sound intensity decreases as the square of the range due to simple spherical spreading. In other words, a source level of 235 dB will have decreased in intensity to a received level of 175 dB after about 914 meters (1,000 yards). We will go more in depth on sound speed profiles, spreading loss, and various geoacoustic profiles anticipated for the Chukchi Sea in our discussion on acoustic propagation modeling (see Section 6.1.3.1 and Appendix A).

4. RANGEWIDE STATUS OF THE SPECIES AND CRITICAL HABITAT

Nine species of marine mammals listed under the ESA under NMFS's jurisdiction may occur in the action area. The action area also includes designated and proposed critical habitat for three species (see Table 5).

Table 5. Listing status and critical habitat designation for marine mammal species considered in this opinion.

Species	Status	Listing	Critical Habitat
Balanea mysticetus (Bowhead Whale)	Endangered	NMFS 1970, 35 FR 18319	Not designated
Balaneoptera physalus (Fin Whale)	Endangered	NMFS 1970, 35 FR 18319	Not designated
Megaptera novaeangliae (Humpback Whale)	Endangered	NMFS 1970, 35 FR 18319	Not designated
Eubalaena japonica (North Pacific Right Whale)	Endangered	NMFS 2008, 73 FR 12024	NMFS 2008, 73 FR 19000
Eschrichtius robustus (Western DPS North Pacific Gray Whale)	Endangered	NMFS 1970, 35 FR 18319	Not designated
Physeter macroephalus (Sperm Whale)	Endangered	NMFS 1970, 35 FR 18319	Not designated
Phoca hispida hispida (Arctic Ringed Seal)	Threatened	NMFS 2012, 77 FR 76706	Proposed Designation
Erignathus barbatus nauticus (Beringia DPS Bearded Seal)[6]	Threatened	NMFS 2012, 77 FR76740	Not proposed
Eumetopias jubatus (Western DPS Steller Sea Lion)	Endangered	NMFS 1997, 62 FR 24345	NMFS 1993, 58 FR 45269

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[6] On July 25, 2014, the US District Court for the District of Alaska issued a memorandum decision in a lawsuit challenging the listing of bearded seals under the ESA (Alaska Oil and Gas Association v. Pritzker, Case NO. 4:13-cv-00018-RPB). The decision vacated NMFS's listing of the Beringia DPS of bearded seals as a threatened species. NMFS is appealing that decision. In the interim, our biological opinions under section 7 of the ESA will continue to address effects to bearded seals so that action agencies have the benefit of NMFS's analysis of the consequences of the proposed action on this DPS, even though the listing of the species is not in effect.

4.1 Species and Critical Habitat Not Considered Further in this Opinion

As described in the *Approach to the Assessment* section of this opinion, NMFS uses two criteria to identify those endangered or threatened species or critical habitat that are likely to be adversely affected. The first criterion is *exposure* or some reasonable expectation of a co-occurrence between one or more potential stressors associated with BOEM and BSEE's activities and a listed species or designated critical habitat. The second criterion is the probability of a *response* given exposure. For endangered or threatened species, we consider the *susceptibility* of the species that may be exposed; for example, species that are exposed to sound fields produced by active seismic activities, but are not likely to exhibit physical, physiological, or behavioral responses given that exposure (at the combination of sound pressure levels and distances associated with an exposure), are not likely to be adversely affected by the seismic activity. For designated critical habitat, we consider the *susceptibility* of the constituent elements or the physical, chemical, or biotic resources whose quantity, quality, or availability make the designated critical habitat valuable for an endangered or threatened species. If we conclude that the quantity, quality, or availability of the constituent elements or other physical, chemical, or biotic resources is not likely to decline as a result of being exposed to a stressor and a stressor is not likely to exclude listed individuals from designated critical habitat, we would conclude that the stressor may affect, but is not likely to adversely affect the designated critical habitat.

We applied these criteria to the species and critical habitats listed above and determined that the following species and designated critical habitats were not likely to be adversely affected by the proposed action: North Pacific right whales, Western DPS gray whales, sperm whales, Western DPS Steller sea lions or the designated critical habitats of these species.

4.1.1 Cetaceans

Vessels transiting to and from survey locations in the Chukchi Sea overlap with the ranges of North Pacific right whales, western gray whales, and sperm whales as well as the designated critical habitat of North Pacific right whales in the eastern Bering Sea.

While the specific number of vessels involved per activity will depend on the type of activity being conducted (3D seismic survey, exploratory drilling, etc.) and the number of projects authorized per year, we anticipate that the maximum number of vessels associated with exploratory drilling or seismic operations on LS 193 would be approximately 33 vessels per year.[7]

As part of the proposed action, BOEM/BSEE have included vessel strike avoidance measures including: maintaining a vigilant watch for listed whales and pinnipeds and slowing down or stopping vessels to avoid striking protected species by observing the 5 kn (9.26 km/h) speed restriction when within 900ft of cetaceans or pinnipeds. In addition, the lessee and/or operator will avoid transits within designated North Pacific right whale critical habitat. If transit with North Pacific right whale critical habitat cannot be avoided, vessel operators are requested to exercise extreme caution and observe the of 10 kn (18.52 km/h) vessel speed restriction while

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[7] The specific number of vessels associated with each type of authorized activity is discussed in further detail in Section 2.1. The maximum vessel number assumes two MODUs, a geohazard survey, a geotechnical survey, and support vessels for onshore construction are operating during the same open water season.

within North Pacific right whale critical habitat. Lessee and/or operators transiting through North Pacific right whale critical habitat will have PSOs actively engaged in sighting marine mammals. PSOs would increase vigilance and allow for reasonable and practicable actions to avoid collisions with North Pacific right whales. Lessee and/or operators will maneuver vessels to keep 800 m away from any observed North Pacific right whales while within their designated critical habitat, avoid approaching whales head-on consistent with vessel safety. Vessels should take reasonable steps to alert other vessels in the vicinity of whale(s), and report of any dead or injured listed whales or pinnipeds.

Based on the extremely small number of observations of North Pacific right, western gray, and sperm whales in the Bering Sea, the limited number of vessels potentially being mobilized out of Dutch Harbor associated with the proposed action, the transitory nature of vessels heading to and from project sites, the lack of spatial overlap between North Pacific right, western gray, and sperm whales known distribution and the seismic and exploratory drilling areas in the Chukchi Sea, mitigation measures to avoid cetaceans and North Pacific right whale critical habitat while vessels are transiting, and the decades of vessels transiting in the Bering and Chukchi Seas without a known vessel strike of these species, NMFS concludes that these cetaceans have a sufficiently small probability of being exposed to stressors associated with BOEM and BSEE’s proposed activities such that the potential for these species being exposed to the proposed survey and drilling activities is extremely unlikely to occur, and the risks posed by the proposed action to North Pacific right, western gray, and sperm whales are discountable.

Any noise or visual disturbance from vessels transiting would be brief and so small in scale as to be immeasurable. The resulting effects on cetaceans would be insignificant and would not result in take. Therefore, we conclude that the proposed action is not likely to adversely affect these cetaceans and do not consider them further in this opinion.

Critical habitat for the North Pacific right whale was designated in the eastern Bering Sea and in the Gulf of Alaska on April 8, 2008 (73 FR 19000). Only the eastern Bering Sea critical habitat overlaps with the proposed action (see Figure 4). The primary constituent elements deemed necessary for the conservation of North Pacific right whales include the presence of specific copepods (*Calanus marshallae, Neocalanus cristatus*, and *N. plumchris*), and euphausiids (*Thysanoessa Raschii*) that act as primary prey items for the species.

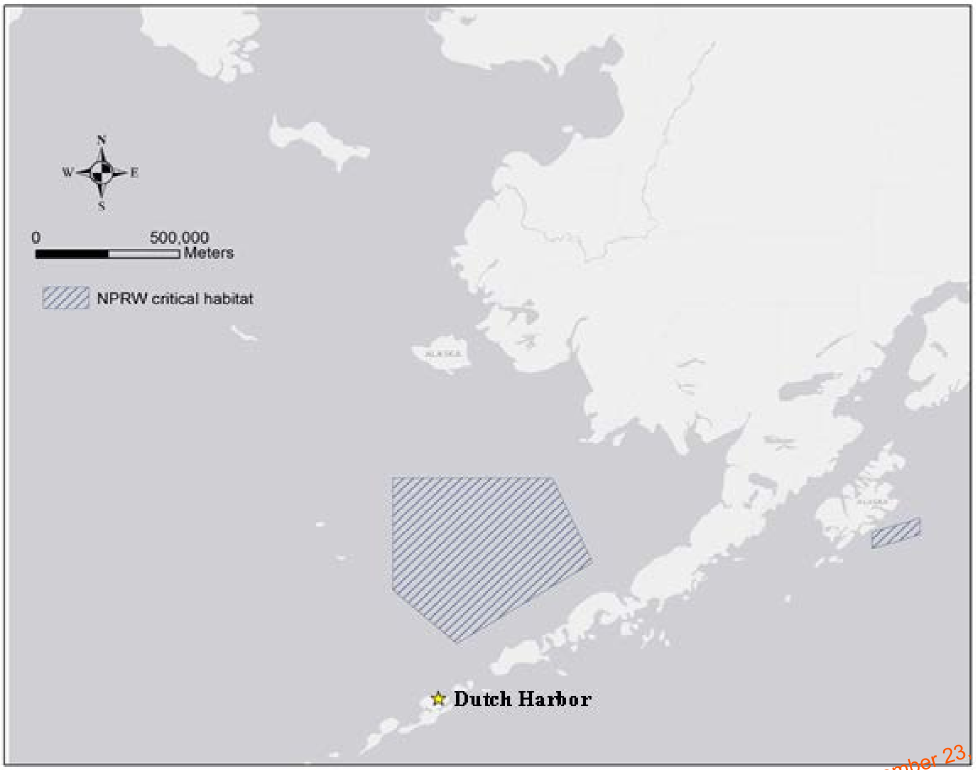

Figure 4. **North Pacific right whale critical habitat shown in both the Bering Sea and Gulf of Alaska. The pentagon area in the Bering Sea is the only section of critical habitat that occurs within the action area.**

Vessels transiting to and from Dutch Harbor may enter the Bering Sea critical habitat for North Pacific right whale. However, vessel traffic is not anticipated to affect aggregations of copepods or euphausiids, and therefore will not affect the PCEs associated with North Pacific right whale critical habitat. In addition, the critical habitat in the Bering Sea would not be exposed to acoustic signals associated with deep penetration surveys, geohazard surveys, or exploratory drilling because those activities would only be authorized to occur on LS 193 in the Chukchi Sea, which is far enough away from the critical habitat area that received sound levels within the habitat will not exceed thresholds of sound pressure levels from broad band sounds that cause behavioral disturbance (160 dB rms re: 1µPa for impulse sound and 120 dB rms re: 1µPa for continuous sound). For these reasons, we do not expect critical habitat for the North Pacific right whale to be adversely affected by acoustic signals or vessel traffic associated with BOEM and BSEE's authorized activities, therefore, we will not consider this critical habitat further in this opinion.

In summary, the proposed action is not likely to adversely affect the following cetacean species: North Pacific right, Western gray, and sperm whales, or the designated critical habitat for North Pacific right whales.

4.1.2 Pinnipeds

Vessels transiting to and from Dutch Harbor in association with BOEM and BSEE's authorized activities on LS 193 in the Chukchi Sea are within the range of the western DPS of Steller sea lions, and overlap with designated critical habitat. Dutch Harbor sits within the Bogoslof designated foraging area and is within the 20 nm aquatic zone associated with rookery and haulout locations (see Figure 5). In addition, depending on the routes vessels take to transit through the Bering Strait, they may also overlap with critical habitat designated on the Pribilof Islands, St. Matthew Island, or St. Lawrence Island. Steller sea lions are anticipated to be within the Bering Sea section of the action area, and may overlap with BOEM/BSEE authorized vessels.

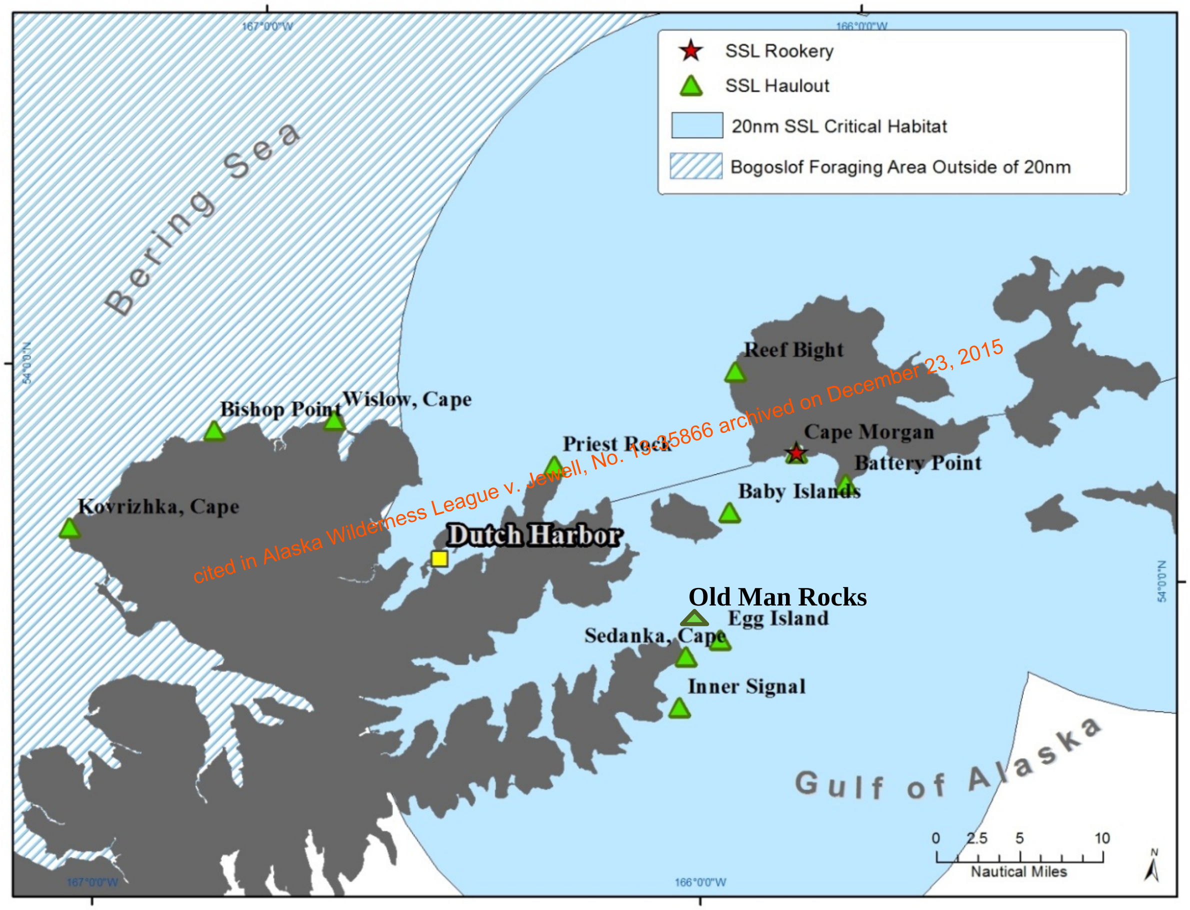

Figure 5. **Haulout and rookery locations for the western DPS of Steller sea lion near Dutch Harbor, the nearby designated Bogoslof foraging area, and the location of Dutch Harbor to and from which BOEM/BSEE authorized vessels will be transiting.**

Designated critical habitat for Steller sea lions includes terrestrial, air, and aquatic habitats that support reproduction, foraging, rest and refuge. These designations were based on the location of terrestrial rookery and haulout sites where breeding, pupping, refuge and resting occurs; aquatic areas surrounding rookeries and haulouts, the spatial extent of foraging trips, and availability of prey items, and rafting sites. Air zones around terrestrial and aquatic habitats are also designated as critical habitat to reduce disturbance in these essential areas. Within the action area, vessels have the potential to transit through the 20nm aquatic zone around rookeries and haulouts, and the Bogoslof foraging area.

The 3-mile no transit zones are established and enforced around rookeries in the area for further protection, and NMFS's guidelines for approaching marine mammals discourage vessels approaching within 100 yards of haulout locations. The Bogoslof foraging area historically supported large aggregations of spawning pollock (Fiscus and Baines 1966, Kajimura and Loughlin 1988). While vessels transiting to and from LS 193 may enter Bogoslof foraging area, noise associated with vessel operations is not anticipated to affect PCEs or impact foraging.

Despite all of the traffic in and around rookery and haulout locations near Dutch Harbor, there have been no incidents of ship strike with Steller sea lions in Alaska. In addition, the Steller sea lion population in and around Dutch Harbor has been increasing at about 3% per year, despite ongoing vessel traffic (Fritz 2012).

Vessels would have a short-term presence in the Bering Sea as they transit to surveys and exploration locations on LS 193 in the Chukchi Sea. NMFS is not able to quantify existing traffic conditions across the entire Bering Sea to provide context for the addition of approximately 33 BOEM authorized vessels per year.[8] However, Dutch Harbor has thousands of vessel transits per year. The addition of ~33 vessels per year would be very small compared to the total number of vessels in the area. In addition, the absence of collisions involving any vessels and Steller sea lions in the Bering Sea despite decades of spatial and temporal overlap suggest that the probability of collision is low.

Based on the small number of vessels associated with the proposed action in comparison to the thousands of vessels known to transit the Bering Sea, the small number of activities being authorized by BOEM/BSEE, the continued growth of the sea lion population near Dutch Harbor despite heavy traffic, mitigation measures in place to avoid marine mammals and designated critical habitat, and the years of spatial and temporal overlap that have not resulted in a known collision, we conclude that some individuals may be exposed to vessel traffic noise but the exposure would be brief and the resulting effects on Steller sea lions would be insignificant and not result in take. In addition, we do not anticipate any adverse effects to designated critical habitat or impacts to foraging, therefore we will not consider Steller sea lions or their designated critical habitat further in this opinion.

4.2 Climate Change

One threat is or will be common to all of the species we discuss in this opinion: global climate change. Because of this commonality, we present this narrative here rather than in each of the species-specific narratives that follow.

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[8] The specific number of vessels associated with each type of authorized activity is discussed in further detail in Section 2.1. The maximum vessel number is based on BOEM's BA and Shell's IHA application which anticipate up to one geohazard survey (3 vessels), one geotechnical survey (1 vessel), 2 drilling operations (27 vessels), and onshore facility construction (2 vessels) may occur within one year during the first incremental step totaling 33 vessels.

There is widespread consensus within the scientific community that atmospheric temperatures are increasing and that this will continue for at least the next several decades (Watson and Albritton 2001, Oreskes 2004). There is also consensus within the scientific community that this warming trend will alter current weather patterns and patterns associated with climatic phenomena, including the timing and intensity of extreme events such as heat waves, floods, storms, and wet-dry cycles. Warming of the climate system is unequivocal, as is evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average seal level (Pachauri and Reisinger 2007).

The Intergovernmental Panel on Climate Change (IPCC) estimated that average global land and sea surface temperature has increased by 0.6°C (±0.2°) since the mid-1800s, with most of the change occurring since 1976. This temperature increase is greater than what would be expected given the range of natural climatic variability recorded over the past 1,000 years (Crowley 2000). The IPCC reviewed computer simulations of the effect of greenhouse gas emissions on observed climate variations that have been recorded in the past and evaluated the influence of natural phenomena such as solar and volcanic activity. Based on its review, the IPCC concluded that natural phenomena are insufficient to explain the increasing trend in land and sea surface temperature, and that most of the warming observed over the last 50 years is likely to be attributable to human activities (Stocker et al. 2013).

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century (Watson and Albritton 2001). According to the IPCC (Stocker et al. 2013), it is likely that there has been an anthropogenic contribution to the very substantial Arctic warming over the past 50 years. In addition, anthropogenic forcings are very likely to have contributed to Arctic sea ice loss since 1979 (Stocker et al. 2013).

The rate of decline of Arctic sea ice thickness and September sea ice extent has increased considerably in the first decade of the 21st century (Stocker et al. 2013). It is estimated that three quarters of summer Arctic sea ice volume has been lost since the 1980s (Stocker et al. 2013). There was also a rapid reduction in ice extent, to 37% less in September 2007 and 49% less in September 2012 relative to the 1979-2000 climatology (Stocker et al. 2013). All recent years have ice extents that fall at least two standard deviations below the long-term sea ice trend (Stocker et al. 2013).

Climate change is projected to have substantial direct and indirect effects on individuals, populations, species, and the structure and function of marine, coastal, and terrestrial ecosystems in the foreseeable future (Houghton 2001, McCarthy 2001, Parry 2007). Climate change would result in increases in atmospheric temperatures, changes in sea surface temperatures, changes in patterns of precipitation, and changes in sea level (Stocker et al. 2013).

The indirect effects of climate change for listed marine mammals would result from changes in the distribution of temperatures suitable for many stages of their life history, the distribution and abundance of prey, and the distribution and abundance of competitors or predators. For example, variations in the recruitment of krill (*Euphausia superba*) and the reproductive success of krill predators have been linked to variations in sea-surface temperatures and the extent of sea-ice cover during the winter months. Thinning and reduced coverage of Arctic sea ice are likely to substantially alter ecosystems that are in close association with sea ice (Loeng et al. 2005). A decrease in the availability of suitable sea ice conditions may not only lead to high mortality of ringed seal pups but may also produce behavioral changes in seal populations (Loeng et al. 2005). Changes in snowfall over the 21st century were projected to reduce ringed seal habitat for lairs by 70% (Hezel et al. 2012). Bowhead whales are dependent on sea-ice organisms for feeding and polynyas for breathing, so the early melting of sea ice may lead to an increasing mismatch in the timing of these sea-ice organisms and secondary production (Loeng et al. 2005). A study reported in George et al. (2006), showed that landed bowheads had better body condition during years of light ice cover. This, together with high calf production in recent years, suggests that the stock is tolerating the recent ice-retreat, at least at present (Allen and Angliss 2014).

4.3 Status of Listed Species

The remainder of this section consists of narratives for each of the endangered and threatened species that occur in the action area and that may be adversely affected by the proposed seismic and geohazard surveys and drilling operations. In each narrative, we present a summary of information on the population structure and distribution of each species to provide a foundation for the exposure analyses that appear later in this opinion. Then we summarize information on the threats to the species and the species' status given those threats to provide points of reference for the jeopardy determinations we make later in this opinion. That is, we rely on a species' status and trend to determine whether an action's direct or indirect effects are likely to increase the species' probability of becoming extinct.

After the *Status* subsection of each narrative, we present information on the feeding and prey selection, and diving and social behavior of the different species because those behaviors help determine how certain activities may impact each species, and help determine whether aerial and ship-board surveys are likely to detect each species. We also summarize information on the vocalization and hearing of the different species to inform our assessment of how the species are likely to respond to sounds produced from the proposed activities.

More detailed background information on the status of these species can be found in a number of published documents including a stock assessment report on Alaska marine mammals by Allen and Angliss (2014), and recovery plans for fin whales (NMFS 2010d), and humpback whales (NMFS 1991). Cameron et al. (2010) and Kelly *et al.* (2010b) provided status reviews of bearded and ringed seals. Richardson *et al.* (1995) and Tyack (2000, 2009) provided detailed analyses of the functional aspects of cetacean communication and their responses to active seismic. Finally, Croll *et al.* (1999), NRC (2000, 2003, 2005), and Richardson *et al.* (1995) provide information on the potential and probable effects of active seismic activities on the marine animals considered in this opinion.

4.3.1 Bowhead Whale

Population Structure

The International Whaling Commission (IWC) recognizes four stocks of bowhead whale for management purposes (Allen and Angliss 2014). Out of all of the stocks, the Western Arctic stock is the largest, and the only stock to inhabit U.S. waters(Allen and Angliss 2014). It is also the only bowhead stock within the action area.

Distribution

Bowhead whales have a circumpolar distribution in high latitudes in the Northern Hemisphere, and range from 54º to 85º N latitude. They live in pack ice for most of the year, typically wintering at the southern limit of the pack ice, or in polynyas (large, semi-stable open areas of water within the ice), and move north as the sea ice breaks up and recedes during the spring. In the North Pacific Ocean in the action area, bowhead whales are distributed in the seasonally ice-covered waters of the Arctic and near-Arctic, generally occurring north of 60°N and south of 75°N in the western Arctic Basin (Braham 1984, Rugh et al. 2003b). They have an affinity for ice and are associated with relatively heavy ice cover and shallow continental shelf waters for much of the year.

The majority of the western Arctic stock migrates annually from wintering areas (December to March) in the northern Bering Sea, through the Chukchi in spring (April through May), to the Beaufort Sea where they spend much of the summer (June through September) before returning again to the Bering Sea in fall (October through December) to overwinter (Allen and Angliss 2014) (see Figure 6). Fall migrating whales typically reach Cross Island in September and October, although some whales might arrive as early as late August. Some of the animals remain in the eastern Chukchi and western Beaufort seas during the summer (Ireland et al. 2009, Clarke et al. 2011b). Aerial surveys of offshore portions of the Chukchi Sea from 2008–2012 have shown a relatively consistent pattern of few bowhead whales being present in June–August, and then increasing numbers in September and October (Clarke et al. 2011c, Clarke et al. 2012, Clarke et al. 2013c). However, satellite tracking of bowheads has also shown that some whales move to the Chukchi Sea prior to September (Quakenbush et al. 2010c). Bowhead whale call count data recorded in the Chukchi Sea in 2012 showed the highest detection number during September and October. Similar to 2012 Chukchi Sea Environmental Studies Program (CSESP) visual data, there were few call detections south of 71°N (Delarue et al. 2013a), which supports satellite tagging data showing that most bowhead whales migrate north of 71°N during the fall (Quakenbush et al. 2010c).

In the Chukchi Sea, bowheads are generally found in waters between 50 and 200 m deep (Clarke and Ferguson. 2010). During spring migration in the Chukchi Sea, bowhead whales typically follow polynyas in the sea ice along the coast of Alaska, generally in the zone between the shorefast ice and mobile pack ice (Allen and Angliss 2014). During the fall migration south into the Bering Sea, bowheads appear to select shallow-shelf waters in low to moderate sea ice conditions, and slope waters in heavy ice conditions (Moore 2000).

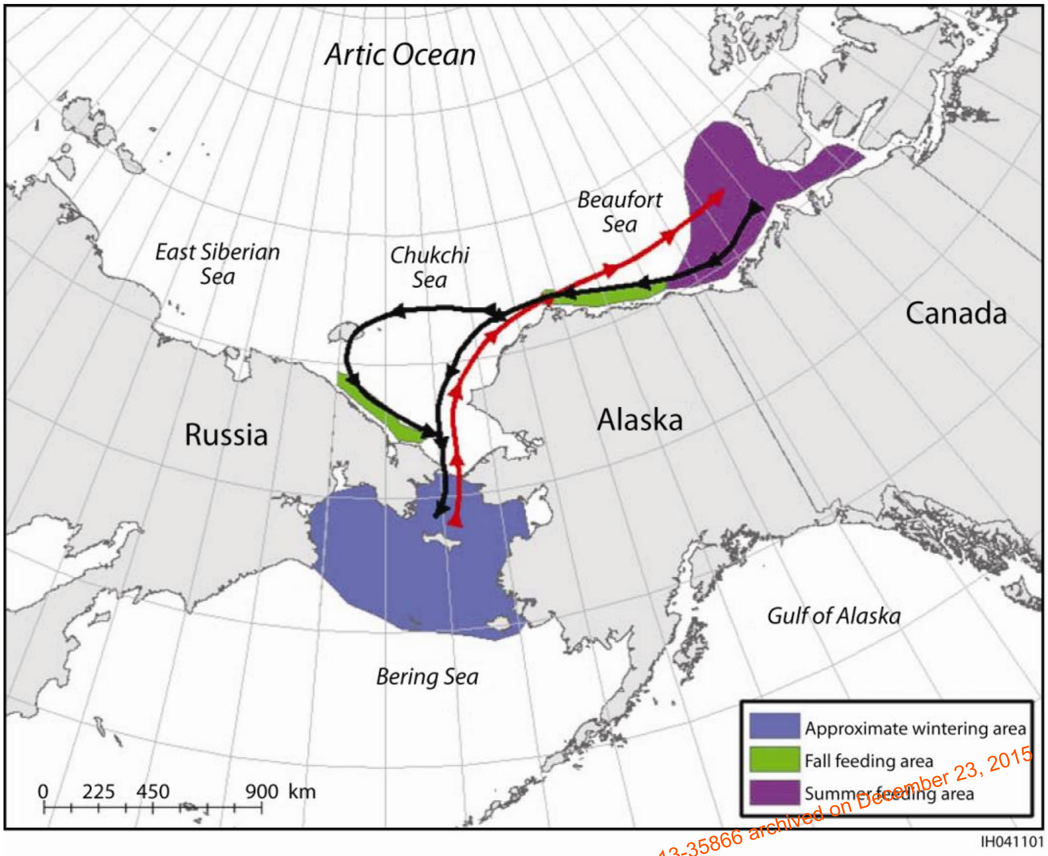

Figure 6. **Generalized Migration Route, Feeding Areas, and Wintering Area for Western Arctic Bowhead Whale**

Most spring-migrating bowhead whales would likely pass through the Chukchi Sea prior to open-water seismic or exploratory drilling activities. However, a few whales may remain in the Chukchi Sea during the summer and could encounter survey and drilling activities or transiting vessels. More encounters with bowhead whales are anticipated during the westward fall migration in late September through October (Shell 2015). Most bowhead migrating in September and October appear to transit across the northern portion of the Chukchi Sea to the Chukotka coast before heading south toward the Bering Sea (Quakenbush et al. 2010c)(see Figure 6). Prior to 2012, the majority of satellite-tagged whales crossed the Chukchi Sea quickly; however tagged whales in 2012 remained in the central Chukchi Sea concurrently with drilling operations before entering the Bering Sea in December, possibly due to opportunistic feeding (Quakenbush et al. 2013).

In the North Atlantic Ocean, three additional populations are found in the Atlantic and Canadian Arctic in the Davis Strait and in Baffin Bay, Hudson Bay, and Foxe Basin, as well as Spitsbergen Island and the Barents Sea.

Threats to the Species

NATURAL THREATS. Little is known about the natural mortality of bowhead whales (Philo et al. 1993). From 1964 through the early 1990s, at least 36 deaths were reported in Alaska, Norway, Yukon and Northwest Territories for which the cause could not be established (Philo et al. 1993). Bowhead whales have no known predators except perhaps killer whales. The frequency of attacks by killer whales upon the Western Arctic stock of bowhead whales is assumed to be low (George et al. 1994). Of 195 whales examined from the Alaskan subsistence harvest (1976-92), only 8 had been wounded by killer whales. Also, hunters on St. Lawrence Island found two small bowhead whales (<9 m) dead as a result of killer whale attacks (George et al. 1994). Predation could increase if the refuge provided to bowhead whales by sea-ice cover diminishes as a result of climate change.

Predation by killer whales may be a greater source of mortality for the Eastern Canada-Western Greenland population. Inuit have observed killer whales killing bowhead whales and stranded bowhead whales have been reported with damage likely inflicted by killer whales (NWMB (Nunavut Wildlife Management Board) 2000). Most beached carcasses found in the eastern Canadian Arctic are of young bowhead whales, and they may be more vulnerable than adults to lethal attacks by killer whales (Finley 1990, Moshenko et al. 2003). About a third of the bowhead whales observed in a study of living animals in Isabella Bay bore scars or wounds inflicted by killer whales (Finley 1990). A relatively small number of whales likely die as a result of entrapment in ice.

ANTHROPOGENIC THREATS. Historically, bowhead whales were severely depleted by commercial harvesting, which ultimately led to the listing of bowhead whales as an endangered species in 1970 (35 FR 8495). Bowhead whales have been targeted by subsistence whaling for at least 2,000 years (Stoker and Krupnik 1993). Subsistence harvest is regulated by quotas set by the IWC and allocated by the Alaska Eskimo Whaling Commission. Bowhead whales are harvested by Alaska Natives in the Beaufort, Bering, and Chukchi Seas. Alaska Native subsistence hunters take approximately 0.1-0.5% of the population per annum, primarily from 11 Alaska communities (Philo et al. 1993, Suydam et al. 2011).

Canadian and Russian Natives also known take whales from this stock. Hunters from the western Canadian Arctic community of Aklavik harvested one whale in 1991 and one in 1996. Twelve whales were harvested by Russian subsistence hunters between 1999-2005 (Allen et al. 2014). No catches for Western Arctic bowheads were reported by either Canadian or Russian hunters for 2006-2007 or by Russia in 2009, but two bowheads were taken in Russia in 2008, and in 2010 (IWC 2012, Allen et al. 2014). The annual average subsistence take (by Natives of Alaska, Russia, and Canada) during the 5-year period from 2007 to 2011 was 39 bowhead whales (Allen et al. 2014).

Some additional mortality may be due to human-induced injuries including embedded shrapnel and harpoon heads from hunting attempts, rope and net entanglement in harpoon lines and crab-pot lines, and ship strikes (Philo et al. 1993). Several cases of rope or net entanglement have been reported from whales taken in the subsistence hunt (Philo et al. 1993). Further, preliminary counts of similar observations based on reexamination of bowhead harvest records indicate entanglements or scarring attributed to ropes may include over 20 cases (Allen and Angliss 2014). There are no observer program records of bowhead whale mortality incidental to commercial fisheries in Alaska. However, some bowhead whales have historically had interactions with crab pot gear. There are several documented cases of bowheads having ropes or rope scars on them. NMFS Alaska Region stranding reports document three bowhead whale entanglements between 2001 and 2005. In 2003 a bowhead whale was found dead in Bristol Bay entangled in line around the peduncle and both flippers; the origin of the line is unknown. In 2004 a bowhead whale near Point Barrow was observed with fishing net and line around the head. A dead bowhead whale found floating in Kotzebue Sound in July 2010 was entangled in crab pot gear similar to that used in the Bering Sea crab fishery (Allen and Angliss 2014). During the 2011 spring aerial survey of bowhead near Point Barrow, one entangled bowhead was photographed (Mocklin et al. 2012). The minimum average annual entanglement rate in U.S. commercial fisheries for the five year period from 2007-2011 is 0.4; however, the overall rate is unknown (Allen and Angliss 2014).

Bowhead whales are among the slowest moving of whales, which may make them particularly susceptible to ship strikes although records of strikes on bowhead whales are rare (Laist et al. 2001). About 1% of the bowhead whales taken by Alaskan Inupiat bore scars from ship strikes (George et al. 1994). Until recently, few large ships have passed through most of the bowhead whale's range but this situation may be changing as northern sea routes become more navigable with the decline in sea ice. This increase in vessel presence could result in an increased number of vessel collisions with bowhead whales. Increasing oil and gas development in the Arctic has led to an increased risk of various forms of pollution in bowhead whale habitat, including oil spills and contaminants. Noise produced by the increased number of seismic surveys and increased vessel traffic resulting from shipping and offshore energy exploration is also a concern (Allen and Angliss 2014). Exposure to manmade noise and contaminants may have short- and long-term effects (Bratton et al. 1993, Richardson and Malme 1993, Richardson et al. 1995), which compromise health and reproductive performance.

Status

The bowhead whale was listed as endangered under the ESA in 1970 (35 FR 8495). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA. Critical habitat has not been designated for bowhead whales. The IWC continued a prohibition on commercial whaling, and called for a ban on subsistence whaling in 1977. The U.S. requested a modification of the ban and the IWC responded with a limited quota. Currently, subsistence harvest is limited to nine Alaskan villages.

WESTERN ARCTIC. Woodby and Botkin (1993) summarized previous efforts to determine a minimum worldwide population estimate prior to commercial whaling of 50,000, with 10,400-23,000 in the Western Arctic stock (dropping to less than 3,000 at the end of commercial whaling). Brandon and Wade (2006b) used Bayesian model averaging to estimate that the Western Arctic stock consisted of 10,960 (9,190-13,950; 5th and 9th percentiles, respectively) bowheads in 1848 at the start of commercial whaling (Allen and Angliss 2014).

From 1978-2011, the Western Arctic stock of bowhead whales has increased at a rate of 3.7% (95% Confidence Interval (CI) = 2.8-4.7%) during which time abundance tripled from approximately 5,000 to approximately 16,000 whales (Givens et al. 2013). Similarly, Schweder et al. (2010b) estimated the yearly growth rate to be 3.2% between 1984 and 2003 using a sight-resight analysis of aerial photographs. The ice-based abundance estimate, based on surveys conducted in 2001, is 10,545 (Coefficient of Variation (CV) = 0.128) (updated from (George et al. 2004a) by (Zeh and Punt 2005)). Ten years later in 2011, the ice-based abundance estimate was 16,892 (95% CI 15,704-18,928) (Givens et al. 2013). See Table 6 for summary of population abundance estimates (Allen and Angliss 2014). Using the 2011 population estimate of 16,892 and its associated CV= 0.2442, the minimum population estimate for the Western Arctic stock of bowhead whales is 13,796 (Allen and Angliss 2014). The population may be approaching carrying capacity despite showing no sign of a slowing in the population growth rate (Brandon and Wade 2006a).

Table 6. Summary of population abundance estimates for the Western Arctic stock of bowhead whales (Allen and Angliss 2014).

Year	Abundance estimate (CV)	Year	Abundance estimate (CV)
Historical estimate	10,400-23,000	1985	5,762 (0.253)
End of commercial whaling	1,000-3,000	1986	8,917 (0.215)
1978	4,765 (0.305)	1987	5,298 (0.327)
1980	3,885 (0.343)	1988	6,928 (0.120)
1981	4,467 (0.273)	1993	8,167 (0.017)
1982	7,395 (0.281)	2001	10,545 (0.128)
1983	6,573 (0.345)	2011	16,892 (0.244)

The current estimate for the annual rate of increase for this stock of bowhead whales is 3.2-3.4% (George et al. 2004a, Schweder et al. 2010b). However, it is recommended that the cetacean maximum theoretical net productivity rate of 4% be used for the Western Arctic stock of bowhead (Wade and Angliss 1997).[9]

The count of 121 calves during the 2001 census was the highest yet recorded and was likely caused by a combination of variable recruitment and the large population size (George et al. 2004a). The calf count provides corroborating evidence for a healthy and increasing population.

The potential biological removal (PBR) for this stock is 103 animals (10,314 x 0.02 x 0.5) (see (Allen and Angliss 2014)). However, the IWC bowhead whale quota takes precedence over the

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[9] The net productivity rate value of 3.2-3.4% should not be used because the population is currently being harvested and because the population has recovered to population levels where the growth is expected to be significantly less than the net productivity rate (Allen and Angliss 2013).

PBR estimate for the purpose of managing the Alaska Native subsistence harvest for this stock. For 2013-2018, the IWC established a block quota of 336 landed bowheads. Because some animals are struck and lost, a strike limit of 67 (plus up to 15 previously unused strikes) could be taken each year.

The Sea of Okhotsk stock, estimated at about 3,000-6,500 animals prior to commercial exploitation (Shelden and Rugh 1995), currently numbers about 150-200, although precise population estimates are not currently available. It is possible this population has mixed with the Bering Sea population, although the available evidence indicates the two populations are essentially separate (Moore and Reeves 1993).

NORTH ATLANTIC. The estimated abundance of the Spitsbergen stock was 24,000 prior to commercial exploitation, but currently numbers less than one hundred. The Baffin Bay-Davis Strait stock was estimated at about 11,750 prior to commercial exploitation (Woodby and Botkin 1993) and the Hudson Bay-Foxe Basin stock at about 450. The current abundance of the Baffin Bay-Davis Straight is estimated at about 350 (Zeh et al. 1993), and recovery is described as "at best, exceedingly slow"(Davis and Koski 1980). No precise estimate exists for the Hudson Bay-Foxe Basin stock; however, Mitchell and Reeves (1981) place a conservative estimate at 100 or less. More recently, estimates of 256-284 whales have been presented for the number of whales within Foxe Basin (Cosens et al. 2006). There has been no appreciable recovery of this population.

Reproduction and Growth

Important winter areas in the Bering Sea include polynyas along the northern Gulf of Anadyr, south of St. Matthew Island, and near St. Lawrence Island. Bowheads congregate in these polynyas before migrating (Moore and Reeves 1993). Most mating occurs in late winter and spring in the Bering Sea, although some mating occurs as late as September and early October (Koski et al. 1993, Reese et al. 2001a). The conception date and length of gestation suggests that calving is likely to occur in mid-May to mid-June, when whales are between the Bering Strait and Point Barrow (BOEM 2011). The calving interval is about three to four years. Juvenile growth is relatively slow. Bowheads reach sexual maturity at about 15 years of age (12 to 14 m [39 to 46 ft] long) (Nerini et al. 1984). Growth for both sexes slows markedly at about 40 to 50 years of age (George et al. 1999).

Given the life history of bowhead whales and gestational constraints on minimum calving intervals (e.g., Reese et al. 2001), and assuming that adult survival rates based on aerial photo-ID data (Zeh et al. 2002; Schweder et al. 2010) and age-at-maturity have remained stable, the trend in abundance implies that the population has been experiencing relatively high annual calf and juvenile survival rates. This is consistent with documented observations of native whalers around St. Lawrence Island, who have reported not only catching more pregnant females but also seeing more young whales than during earlier decades (Noongwook et al. 2007). While the sample size was small, that the pregnancy rate from the 2012 Alaskan harvest data indicate that 2013 calf production could be higher than average (George et al. 2004b; George et al. 2011; Suydam et al. 2013).

A change in either calf production or survival rates (or age-at-sexual maturation) of young whales in the future could be indicative of a population level response to anthropogenic stressors, or alternatively, a signal of the seemingly inevitable event that this population approaches the carrying capacity of its environment (Eberhardt 1977). Since the late 1970s and the initiation of surveys for abundance, the estimates of population size do not indicate that either anthropogenic (e.g., offshore oil and gas activities, subsistence whaling catch quotas, etc.) or natural factors (e.g., prey availability) have resulted in any negative influence on the bowhead whale trend in abundance (LGL Alaska Research Associates Inc. et al. 2013).

Feeding and Prey Selection

Bowheads are filter feeders, filtering prey from the water through baleen (Lowry 1993a). They feed throughout the water column, including bottom feeding as well as surface skim feeding (Würsig et al. 1989). Skim feeding can occur when animals are alone or may occur in coordinated echelons of over a dozen animals (Würsig et al. 1989). Bowhead whales typically spend a high proportion of time on or near the ocean floor. Even when traveling, bowhead whales visit the bottom on a regular basis (Quakenbush et al. 2010a). Laidre *et al.* (2007) and others have identified krill concentrated near the sea bottom and bowhead whales have been observed with mud on heads and bodies and streaming from mouths (Mocklin 2009). Food items most commonly found in the stomachs of harvested bowheads include euphausiids, copepods, mysids, and amphipods (Lowry et al. 2004, Moore et al. 2010). Euphausiids and copepods are thought to be their primary prey. Lowry, Sheffield, and George (2004) documented that other crustaceans and fish also were eaten but were minor components in samples consisting mostly of copepods or euphausiids.

Concentrations of zooplankton appear necessary for bowhead whales and other baleen whales to feed efficiently to meet energy requirements (Kenney et al. 1986, Lowry 1993b). It is estimated that a 60 ton bowhead whale eats 1.5 t of krill each day. Estimated rate of consumption is 50,000 individual copepods, each weighing about 0.004 g, per minute of feeding time (BOEM 2011).

Western Arctic bowhead whales feed in the OCS of the Chukchi and Beaufort Seas and this use varies in degree among years, among individuals, and among areas. It is likely that bowheads continue to feed opportunistically where food is available as they move through or about the Alaskan Beaufort Sea, similar to what they are thought to do during the spring migration. Observations from the 1980s documented that some feeding occurs in the spring in the northeastern Chukchi Sea, but this feeding was not consistently seen (e.g., (Carroll et al. 1987, Ljungblad et al. 1987)). Stomach contents from bowheads harvested off St. Lawrence Island during May, and between St. Lawrence and Point Barrow during April into June also indicated it is likely that some whales feed during the spring migration (Hazard and Lowry. 1984, Carroll et al. 1987, Shelden and Rugh 1995). The stomach contents of one bowhead harvested in the northern Bering Sea indicated that the whale had fed entirely on benthic organisms, predominantly gammarid amphipods and cumaceans (not copepods, euphausiids, or other planktonic ogranisms) (Hazard and Lowry. 1984).

Carroll et al. (1987) reported that the region west of Point Barrow seems to be of particular importance for feeding, at least in some years, but whales may feed opportunistically at other locations in the lead system where oceanographic conditions produce locally abundant food. A bowhead whale feeding “hotspot” (Okkonen et al. 2011) commonly forms on the western Beaufort Sea shelf off Point Barrow in late summer and fall due to a combination of the physical and oceanographic features of Barrow Canyon, combined with favorable wind conditions (Ashjian et al. 2010, Moore et al. 2010, Okkonen et al. 2011).

Local residents report having seen a small number of bowhead whales feeding off Barrow or in the pack ice off Barrow during the summer. Bowhead whales may also occur in small numbers in the Bering and Chukchi seas during the summer (Rugh et al. 2003a). Ireland et al. (2009) also reported bowhead sightings in 2006 and 2007 during summer aerial surveys in the Chukchi Sea.

Diving and Social Behavior

Bowhead diving behavior is situational (Stewart 2002). Calves dive for very short periods and their mothers tend to dive less frequently and for shorter durations. Feeding dives tend to last from 3 to 12 minutes and may extend to the relatively shallow bottom in the Beaufort Sea. “Sounding” dives average between 7 and 14 minutes.

The bowhead whale usually travels alone or in groups of three to four individuals. However, in one day in 2009, researchers observed 297 individual bowheads aggregated near Barrow (Clarke et al. 2011a). During this survey, a group of 180 bowhead whales were seen feeding and milling (Clarke et al. 2011a).

Bowhead whale calls might help maintain social cohesion of groups (Wursig and Clark 1993). (Würsig et al. 1989) indicated that low-frequency tonal calls, believed to be long distance contact calls by a female and higher frequency calls by calf, have been recorded in an instance where the pair were separated and swimming toward each other.

Vocalizations and Hearing

Bowhead whales are among the more vocal of the baleen whales (Clark and Johnson 1984). They mainly communicate with low frequency sounds. Most underwater calls are at a fairly low frequency and easily audible to the human ear. Vocalization is made up of moans of varying pitch, intensity and duration, and occasionally higher-frequency screeches. Bowhead calls have been distinguished by Würsing and Clark (1993): pulsed tonal calls, pulsive calls, high frequency calls, low-frequency FM calls (upsweeps, inflected, downsweeps, and constant frequency calls). However, no direct link between specific bowhead activities and call types was found. Bowhead whales have been noted to produce a series of repeating units of sounds up to 5000 Hz that are classified as songs, produced primarily by males on the breeding grounds (Delarue 2011). It appears that bowhead whale singing behavior differs from that of other mysticetes in that multiple songs are sung each year (Johnson et al. 2014). Also, bowhead whales may use low-frequency sounds to provide information about the ocean floor and locations of ice.

Bowhead whales have well-developed capabilities for navigation and survival in sea ice. Bowhead whales are thought to use the reverberations of their calls off the undersides of ice floes to help them orient and navigate (Ellison et al. 1987, George et al. 1989). This species is well adapted to ice-covered waters and can easily move through extensive areas of nearly solid sea ice cover (Citta et al. 2012). Their skull morphology allows them to break through ice up to 18 cm thick to breathe in ice covered waters (George et al. 1989).

Bowhead whales are grouped among low frequency functional hearing baleen whales (Southall et al. 2007). Inferring from their vocalizations, bowhead whales should be most sensitive to frequencies between 20 Hz-5 kHz, with maximum sensitivity between 100-500 Hz (Erbe 2002b). Bowhead whale songs have a bandwidth of 20 to 5000 Hz with the dominant frequency at approximately 500 Hz and duration lasting from 1 minute to hours. Pulsive vocalizations range between 25 and 3500 Hz and last 0.3 to 7.2 seconds (Clark and Johnson 1984, Wursig and Clark 1993, Erbe 2002b). While there is no direct data on hearing in low-frequency cetaceans, the functional hearing range is anticipated to be between 7 Hz to 30 kHz (Watkins 1986b, Au et al. 2006, Southall et al. 2007, Ciminello et al. 2012, NOAA 2013).

Bowhead whales in western Greenland waters produced songs of an average source level of 185 ±2 dB rms re 1 mPa @ 1 m centered at a frequency of 444 ±48 Hz (Roulin et al. 2012). Given background noise, this allows bowheads whales an active space of 40-130 km (Roulin et al. 2012).

Other Senses

Bowhead whales appear to have good lateral vision. Recognizing this, whalers approach bowheads from the front or from behind, rather than from the side (Rexford 1997, Noongwook et al. 2007b). In addition, whalers wear white parkas on the ice so that they are not visible to the whales when they surface (Rexford 1997).

Olfaction may also be important to bowhead whales. Recent research on the olfactory bulb and olfactory receptor genes suggest that bowheads not only have a sense of smell but one better developed than in humans (Thewissen et al. 2011). The authors suggest that bowheads may use their sense of smell to find dense aggregations of krill upon which to prey.

4.3.2 Fin Whale

Population Structure

Fin whales have two recognized subspecies: *B. p. physalus* occurs in the North Atlantic Ocean (Gambell 1985), while *B. p. quoyi* occurs in the Southern Ocean (Fischer 1829). Most experts consider the North Pacific fin whales a separate unnamed subspecies.

In the North Atlantic Ocean, the IWC recognizes seven management units or “stocks” of fin whales: (1) Nova Scotia, (2) Newfoundland-Labrador, (3) West Greenland, (4) East Greenland-Iceland, (5) North Norway, (6) West Norway-Faroe Islands, and (7) British Isles-Spain-Portugal. In addition, the population of fin whales that resides in the Ligurian Sea, in the northwestern Mediterranean Sea is believed to be genetically distinct from other fin whales populations (as used in this opinion, “populations” are isolated demographically, meaning, they are driven more by internal dynamics — birth and death processes — than by the geographic redistribution of individuals through immigration or emigration. Some usages of the term "stock" are synonymous with this definition of "population" while other usages of "stock" do not).

In U.S. Pacific waters, the IWC recognizes three "stocks": (1) Alaska (Northeast Pacific), (2) California/Washington/Oregon, and (3) Hawaii (Allen and Angliss 2014). However, Mizroch et al. (2009) suggests that this structure should be reviewed and updated, if appropriate, to reflect current data which suggests there may be at least 6 populations of fin whales.

Regardless of how different authors structure the fin whale population, mark-recapture studies have demonstrate that individual fin whales migrate between management units (Mitchell 1974, Rice 1974), which suggests that these management units are not geographically isolated populations.

Distribution

Fin whales are distributed widely in every ocean except the Arctic Ocean (where they have only recently begun to appear). In the North Pacific Ocean, fin whales occur in summer foraging areas in the Chukchi Sea, the Sea of Okhotsk, around the Aleutian Islands, and the Gulf of Alaska; in the eastern Pacific, they occur south to California; in the western Pacific, they occur south to Japan. Fin whales in the eastern Pacific winter from California south; in the western Pacific, they winter from the Sea of Japan, the East China and Yellow Seas, and the Philippine Sea (Gambell 1985).

In the North Atlantic Ocean, fin whales occur in summer foraging areas from the coast of North America to the Arctic, around Greenland, Iceland, northern Norway, Jan Meyers, Spitzbergen, and the Barents Sea. In the western Atlantic, they winter from the edge of sea ice south to the Gulf of Mexico and the West Indies. In the eastern Atlantic, they winter from southern Norway, the Bay of Biscay, and Spain with some whales migrating into the Mediterranean Sea (Gambell 1985).

In the Southern Hemisphere, fin whales are distributed broadly south of 50° S in the summer and migrate into the Atlantic, Indian, and Pacific Oceans in the winter, along the coast of South America (as far north as Peru and Brazil), Africa, and the islands in Oceania north of Australia and New Zealand (Gambell 1985).

Mizroch et al. (2009) summarized information about the patterns of distribution and movements of fin whales in the North Pacific from whaling harvest records, scientific surveys, opportunistic sightings, acoustic data from offshore hydrophone arrays, and from recoveries of marked whales. Mizroch et al. (2009) notes that fin whales range from the Chukchi Sea south to 35° North on the Sanriku coast of Honshu., to the Subarctic boundary (ca. 42°) in the western and Central Pacific, and to 32° N off the coast of California. Berzin and Rovnin (1966) indicate historically "In the Chukchi Sea the finbacks periodically form aggregations in the region to the north of Cape Serdtse-Kamon' along the Chukotka coast."

Recent information on seasonal fin whale distribution has been gleaned from the reception of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, Watkins et al.

2000, Moore et al. 2006, Stafford et al. 2007, Širović et al. 2013, Soule and Wilcock 2013). Moore et al. (1998, 2006), Watkins et al. (2000), and Stafford et al. (2007) all documented high levels of fin whale call rates along the U.S. Pacific coast beginning in August/September and lasting through February, suggesting that these may be important feeding areas during the winter. In addition, fin whale calls were detected in the northeastern Chukchi Sea using instruments moored there in July through October from 2007 through 2010 (Delarue et al. 2013). Call data collected from the Bering Sea suggests that several fin whale stocks may feed in the Bering Sea, but call data collected in the northeast Chukchi Sea suggests that only one of the putative Bering Sea stocks appears to migrate this far north to feed (Delarue et al. 2013b).

Fin whales were seen regularly and sometimes caught by Soviet whalers in the Chukchi Sea until the 1940s (Allen and Angliss 2014). Fin whales are again being seen increasingly during sighting surveys in the Chukchi Sea in summer (Funk et al. 2010a, Aerts et al. 2013b, Clarke et al. 2013b), and have been recorded each year from 2007-2010 in August and September on bottom-mounted hydrophones in the Chukchi (Delarue et al. 2013b) suggesting they may be re-occupying habitat used prior to large-scale commercial whaling (Allen and Angliss 2014).

Threats to the Species

NATURAL THREATS. Natural sources and rates of mortality are largely unknown, but Aguilar and Lockyer (1987) suggest annual natural mortality rates may range from 0.04 to 0.06 (based on studies of northeast Atlantic fin whales). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in fin whales and may be preventing some fin whale stocks from recovering from whaling (Lambertsen 1992b). Killer whale or shark attacks may injure or kill very young or sick whales (Perry et al. 1999).

ANTHROPOGENIC THREATS. Historically, whaling represented the greatest threat to every population of fin whales and was ultimately responsible for listing fin whales as an endangered species. As early as the mid-seventeenth century, the Japanese were capturing fin, blue (*Balaenoptera musculus*), and other large whales using a fairly primitive open-water netting technique (Tønnessen and Johnsen 1982, Cherfas 1989). In 1864, explosive harpoons and steampowered catcher boats were introduced in Norway, allowing the large-scale exploitation of previously unobtainable whale species. After blue whales were depleted in most areas, fin whales became the focus of whaling operations and more than 700,000 fin whales were landed in the Southern Hemisphere alone between 1904 and 1979 (IWC 1995).

Whaling reduced fin whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push fin whales closer to extinction. Otherwise, whaling currently does not the fin whale species, although it may threaten specific populations. There is no authorized subsistence take of fin whales in the Northeast Pacific stock (Allen and Angliss 2014). In the Antarctic Ocean, fin whales are hunted by Japanese whalers were allowed to kill up to 10 fin whales each year for the 2005-2006 and 2006-2007 seasons under an Antarctic Special Permit. The Japanese whalers plan to kill 50 fin whales per year starting in the 2007-2008 season and continuing for the next 12 years.

Fin whales are also hunted in subsistence fisheries off West Greenland. In 2004, 5 males and 6 females were killed and landed; 2 other fin whales were struck and lost in the same year. In 2003 2 males and 4 females were landed and 2 other fin whales were struck and lost (IWC 2005). Between 2003 and 2007, the IWC set a catch limit of up to 19 fin whales in this subsistence fishery (2005); however, the IWC's Scientific Committee recommended limiting the number of fin whale killed in this fishery to 1 to 4 individuals until accurate population estimates are produced.

Despite anecdotal observations from fishermen which suggest that large whales swim through their nets rather than get caught in them, fin whales have been entangled by fishing gear off Newfoundland and Labrador in small numbers: a total of 14 fin whales are reported to have been captured in coastal fisheries in those two provinces between 1969 and 1990 (Perkins and Beamish 1979, Lien 1994). Of these 14 fin whales, 7 are known to have died as a result of that capture, although most of the animals that died were less than 15 meters in length (Lien 1994). Between 1999 and 2005, there were 10 confirmed reports of fin whales being entangled in fishing gear along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole et al. 2005, Nelson et al. 2007). Of these reports, Fin whales were injured in 1 of the entanglements and killed in 3 entanglements. Between 2009 and 2013, there was one observed incidental mortality of a fin whale in the ground tackle of a commercial mechanical jig fishing vessel in Alaska waters (Allen et al. 2014), resulting in a mean annual mortality rate of 0.2. These data suggest that, despite their size and strength, fin whales are likely to be entangled and, in some cases, killed by gear used in modern fisheries.

Fin whales are also killed and injured in collisions with vessels more frequently than any other whale. Of 92 fin whales that stranded along the Atlantic Coast of the U.S. between 1975 and 1996, 31 (33%) showed evidence of collisions with ships (Laist et al. 2001). Between 1999 and 2005, there were 15 reports of fin whales being struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole et al. 2005, Nelson et al. 2007). Of these reports, 13 were confirmed as ship strikes which were reported as having resulted in the death of 11 fin whales.

Jensen and Silber's (2004b) review of the NMFS ship strike database revealed fin whales as the most frequently confirmed victims of ship strikes (26% of the recorded ship strikes [n = 75/292 records]), with most collisions occurring off the east coast, followed by the west coast of the U.S. and Alaska/Hawaii. Five of seven fin whales stranded along Washington State and Oregon showed evidence of ship strike with incidence increasing since 2002 (Douglas et al. 2008b). From 1994-1998, two fin whales were presumed killed by ship strikes. More recently, in 2002, three fin whales were struck and killed by vessels in the eastern North Pacific (Jensen and Silber 2003).

Two fin whale deaths due to ship strikes (one in 2009 and one in 2010) in Alaska waters were reported to the NMFS Alaska Region stranding database between 2009 and 2013 (Allen et al. 2014), resulting in a mean annual mortality rate of 0.4 fin whales due to ship strikes.

The total estimated annual rate of mortality and serious injury for the Northeast Pacific stock is 0.6 based on takes incidental to U.S. commercial fisheries (0.2) and ship strikes (0.4). Because the PBR is unknown, the level of annual U.S. commercial fishery-related mortality that can be considered insignificant and approaching zero mortality and serious injury rate is unknown (Allen and Angliss 2014).

Ship strikes were identified as a known or potential cause of death in 8 (20%) of 39 fin whales that stranded on the coast of Italy in the Mediterranean Sea between 1986 and 1997 (Laist et al. 2001). Throughout the Mediterranean Sea, 46 of the 287 fin whales that are recorded to have stranded between 1897 and 2001 were confirmed to have died from injuries sustained by ship strikes (Panigada et al. 2006). Most of these fin whales (n = 43), were killed between 1972 and 2001 and the highest percentage (37 of 45 or ~82%) killed in the Ligurian Sea and adjacent waters, where the Pelagos Sanctuary for Marine Mammals was established. In addition to these ship strikes, there are numerous reports of fin whales being injured as result of ship strikes off the Atlantic coast of France and the United Kingdom (Jensen and Silber 2004a).

Increased noise in the ocean stemming from shipping seems to alter the acoustic patterns of singing fin whales, possibly hampering reproductive parameters across wide regions (Castellote et al. 2012).

Status

Fin whales were listed as endangered in 1970 (35 FR 18319) and that listing was carried over after Congress enacted the ESA (39 FR 41367). In 1976, the IWC protected fin whales from commercial whaling (Allen 1980). Fin whales are listed as endangered on the IUCN Red List of Threatened Animals (IUCN 2012). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA. Critical habitat has not been designated for fin whales. A Final Recovery Plan for the Fin Whale (*Balaenoptera physalus*) was published on July 30, 2010 (NMFS 2010d).

It is difficult to assess the current status of fin whales because (1) there is no general agreement on the size of the fin whale population prior to whaling and (2) estimates of the current size of the different fin whale populations vary widely. Prior to exploitation by commercial whalers, fin whales are thought to have numbered greater than 464,000 worldwide, and are now thought to number approximately 119,000 worldwide (Braham 1991).

Ohsumi and Wada (1974) estimated that the North Pacific fin whale population ranged from 42,000-45,000 before whaling began. Of this, the “American population” (i.e., the component centered in waters east of 180º W longitude), was estimated to be 25,000-27,000. Based on visual surveys, Moore *et al.* (2002) estimated 3,368 (CV=0.29) and 683 (CV=0.32) fin whales in the central eastern Bering Sea and southeastern Bering Sea, respectively, during summer surveys in 1999 and 2000. However, these estimates are considered provisional because they were never corrected for animals missed on the track line or that may have been submerged when the ship passed. Dedicated line transect cruises were conducted in coastal waters of western Alaska and the eastern and central Aleutian Islands in July-August 2001-2003 (Zerbini et al. 2009). Fin whale sightings (n = 276) were observed from east of Kodiak Island to Samalga Pass, with high aggregations recorded near the Semidi Islands. Zerbini et al. (2006) estimated that 1,652 (95% CI: 1,142-2,389) whales occurred in the area. An annual increase of 4.8% (95% CI: 4.1-5.4%)

was estimated for the period of 1987-2003 (Allen et al. 2014).

The best estimate of the fin whale population west of the Kenai Peninsula is 1,368, the greater minimum estimates from the 2008 and 2010 surveys (Friday et al. 2013). This is a minimum estimate for the entire stock because it was estimated from surveys which covered only a small portion of the range of this stock.

The minimum estimate for the California/Oregon/Washington stock, as defined in the U.S. Pacific Marine Mammal Stock Assessments: 2008, is about 2,316 (Carretta et al. 2009). An increasing trend between1979/80 and 1993 was suggested by the available survey data, but it was not statistically significant (Barlow et al. 1997).

Similarly, estimates of the current size of the different fin whale populations and estimates of their global abundance also vary widely. The final recovery plan for fin whales accepts a minimum population estimate of 2,269 fin whales for the Western North Atlantic stock (NMFS 2010d). However, based on data produced by surveys conducted between 1978-1982 and other data gathered between 1966 and 1989, Hain et al. (1992) estimated that the population of fin whales in the western North Atlantic Ocean (specifically, between Cape Hatteras, North Carolina, and Nova Scotia) numbered about 1,500 whales in the winter and 5,000 whales in the spring and summer. Because authors do not always reconcile "new" estimates with earlier estimates, it is not clear whether the current "best" estimate represents a refinement of the estimate that was based on older data or whether the fin whale population in the North Atlantic has declined by about 50% since the early 1980s.

The East Greenland-Iceland fin whale population was estimated at 10,000 animals (95 % confidence interval = 7,600 - 14,200), based on surveys conducted in 1987 and 1989 (Buckland et al. 1992). The number of eastern Atlantic fin whales, which includes the British Isles-Spain-Portugal population, has been estimated at 17,000 animals (95% confidence interval = 10,400 - 28,900; (Buckland et al. 1992)). These estimates are both more than 15 years old and the data available do not allow us to determine if they remain valid.

Forcada *et al.* (1996) estimated the fin whale population in the western Mediterranean numbered 3,583 individuals (standard error = 967; 95% confidence interval = 2,130-6,027). This is similar to a more recent estimate published by Notarbartolo-di-Sciara *et al.* (2003). Within the Ligurian Sea, which includes the Pelagos Sanctuary for Marine Mammals and the Gulf of Lions, the fin whale population was estimated to number 901 (standard error = 196.1) whales (Forcada et al. 1995).

Regardless of which of these estimates, if any, have the closest correspondence to the actual size and trend of the fin whale population, all of these estimates suggest that the global population of fin whales consists of tens of thousands of individuals and that the North Pacific population consists of at least 5,000 individuals. Based on ecological theory and demographic patterns derived from several hundred imperiled species and populations, fin whales appear to exist at population sizes that are large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself). As a result, we assume that fin whales are likely to be threatened more by exogenous threats such as anthropogenic activities (primarily whaling, entanglement, and ship strikes) or natural phenomena (such as disease, predation, or changes in the distribution and abundance of their prey in response to changing climate) than endogenous threats caused by the small size of their population.

Nevertheless, based on the evidence available, the number of fin whales that are recorded to have been killed or injured in the past 20 years by human activities or natural phenomena, does not appear to be increasing the extinction probability of fin whales, although it may slow the rate at which they recover from population declines that were caused by commercial whaling.

Feeding and Prey Selection

In the North Pacific overall, fin whales prefer euphausiids (mainly *Euphausia pacifica*, *Thysanoessa longipes*, *T. spinifera*, and *T. inermis*) and large copepods (mainly *Calanus cristatus*), followed by schooling fish such as herring, walleye pollock (*Theragra chalcogramma*), and capelin (Nemoto 1970, Kawamura 1982).

Fin whales killed off central California in the early twentieth century were described as having either "plankton" (assumed to have been mainly or entirely euphausiids) or "sardines" (assumed to have been anchovies, *Engraulis mordax*) in their stomachs (Clapham et al. 1997). A larger sample of fin whales taken off California in the 1950s and 1960s were feeding mainly on krill, mostly *Euphausia pacifica*, with only about 10% of the individuals having anchovies in their stomachs (Rice 1963). Fin whales in the Gulf of California prey mainly on zooplankton such as *Nyctiphanes simplex* (Tershy 1992).

Feeding may occur in waters as shallow as 10 m when prey are at the surface, but most foraging is observed in high-productivity, upwelling, or thermal front marine waters (Gaskin 1972, Sergeant 1977, Nature Conservancy Council 1979 as cited in ONR 2001, Panigada et al. 2008).

Diving and Social Behavior

The percentage of time fin whales spend at the surface varies. Some authors have reported that fin whales make 5-20 shallow dives with each of these dive lasting 13-20 seconds followed by a deep dive lasting between 1.5 and 15 minutes (Gambell 1985, Stone et al. 1992, Lafortuna et al. 2003). Other authors have reported that the fin whale's most common dives last between 2 and 6 minutes, with 2 to 8 blows between dives (Watkins 1981, Hain et al. 1992). The most recent data support average dives of 98 m and 6.3 min for foraging fin whales, while non-foraging dives are 59 m and 4.2 min (Croll et al. 2001). However, Lafortuna *et al.* (1999) found that foraging fin whales have a higher blow rate than when traveling. Foraging dives in excess of 150 m are known (Panigada et al. 1999). In waters off the U.S. Atlantic Coast, individuals or duos represented about 75 percent of sightings during the Cetacean and Turtle Assessment Program (Hain et al. 1992). Barlow (2003) reported mean group sizes of 1.1–4.0 during surveys off California, Oregon, and Washington.

There is considerable variation in grouping frequency by region. In general, fin whales, like all baleen whales, are not very socially organized, and most fin whales are observed as singles. Fin whales are also sometimes seen in social groups that can number 2 to 7 individuals. However, up to 50, and occasionally as many as 300, can travel together on migrations (NMFS 2010d).

In waters off the Atlantic Coast of the U.S. individual fin whales or pairs represented about 75% of the fin whales observed during the Cetacean and Turtle Assessment Program (Hain et al. 1992). Individual whales or groups of less than five individuals represented about 90% of the observations (out of 2,065 observations of fin whales, the mean group size was 2.9, the modal value was 1, and the range was 1 – 65 individuals; (Hain et al. 1992)). Fin whales in the Alaska Chukchi Sea have only been observed as individuals or in small groups.

Vocalizations and Hearing

The sounds fin whales produce underwater are one of the most studied *Balaenoptera* sounds. Fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981, Watkins et al. 1987, Edds 1988, Thompson et al. 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels for fin whales are 140-200 dB re 1 µPa m (Patterson and Hamilton 1964, Watkins et al. 1987, Thompson et al. 1992, McDonald et al. 1995, Clark and Gagnon 2004). In temperate waters intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald et al. 1995), Clark personal communication, McDonald personal communication). Each pulse lasts on the order of one second and contains twenty cycles (Tyack 1999).

During the breeding season, fin whales produce a series of pulses in a regularly repeating pattern. These bouts of pulsing may last for longer than one day (Tyack 1999). The seasonality and stereotype of the bouts of patterned sounds suggest that these sounds are male reproductive displays (Watkins et al. 1987), while the individual counter calling data of McDonald *et al.* (1995) suggest that the more variable calls are contact calls. Some authors feel there are geographic differences in the frequency, duration and repetition of the pulses (Thompson et al. 1992).

As with other vocalizations produced by baleen whales, the function of fin whale vocalizations is unknown, although there are numerous hypotheses (which include: maintenance of inter-individual distance, species and individual recognition, contextual information transmission, maintenance of social organization, location of topographic features, and location of prey resources; see the review by (Thompson et al. 1992) for more information on these hypotheses). Responses to conspecific sounds have been demonstrated in a number of mysticetes, and there is no reason to believe that fin whales do not communicate similarly (Edds-Walton 1997). The low-frequency sounds produced by fin whales have the potential to travel over long distances, and it is possible that long-distance communication occurs in fin whales (Payne and Webb 1971, Edds-Walton 1997). Also, there is speculation that the sounds may function for long-range echolocation of large-scale geographic targets such as seamounts, which might be used for orientation and navigation (Tyack 1999).

While there is no direct data on hearing in low-frequency cetaceans, the functional hearing range is anticipated to be between 7 Hz to 30 kHz (Watkins 1986b, Au et al. 2006, Southall et al. 2007, Ciminello et al. 2012, NOAA 2013).

Baleen whales have inner ears that appear to be specialized for low-frequency hearing. In a study of the morphology of the mysticete auditory apparatus, Ketten (1997) hypothesized that large mysticetes have acute infrasonic hearing. Synthetic audiograms produced by applying models to X-ray computed tomography scans of a fin whale calf skull indicate the range of best hearing for fin whale calves to range from approximately 0.02 to 10 kHz, with maximum sensitivities between 1 to 2 kHz (Cranford and Krysl 2015).

4.3.3 Humpback Whale

Population Structure

During winter months in northern or southern hemispheres, adult humpback whales migrate to specific areas in warmer, tropical waters to reproduce and give birth to calves. During summer months, humpback whales migrate to specific areas in northern temperate or sub-arctic waters to forage. In summer months, humpback whales from different reproductive areas congregate to feed; in the winter months, whales migrate from different foraging areas to a single wintering area. In either case, humpback whales appear to form open populations; that is, populations that are connected through the movement of individual animals.

NMFS recently conducted a global status review of humpback whales and proposed dividing the species into 14 DPSs and changing the listing status of most of those populations (80 FR 22304; April 21, 2015). However, the text below refers to existing stock designations.

NORTH PACIFIC OCEAN. NMFS's Stock Assessment Reports recognize three stocks or populations of humpback whales in the North Pacific Ocean, based on genetic and photo-identification studies: (1) the California/Oregon/Washington and Mexico stock, (2) the Central North Pacific stock, and (3) the Western North Pacific stock (Baker et al. 1990, Calambokidis et al. 1997, Perry et al. 1999). Individuals from the Western Pacific stock and the Central North Pacific stock could occur in the Bering Sea with access to the Chukchi and Beaufort Seas.

These stocks are based on where these humpback whales winter: California-Oregon-Washington-Mexico stock winters along coasts of Central America and Mexico, and migrate to the coast of California to southern British Columbia in the summer/fall, whereas the central North Pacific stock winters in the waters around Hawai'i, and migrates primarily to northern British Columbia/Southeast Alaska, the Gulf of Alaska, and the Bering Sea/Aleutian Islands. The western North Pacific stock winters off of Asia and migrates primarily to Russia and the Bering Sea/Aleutian Islands. However, Calambokidis et al. (1997) identified humpback whales from Southeast Alaska (central North Pacific), the California-Oregon-Washington (eastern North Pacific), and Ogasawara Islands (Japan, Western Pacific) groups in the Hawai'ian Islands during the winter; humpback whales from the Kodiak Island, Southeast Alaska, and British Columbia groups in the Ogasawara Islands; and whales from the British Columbia, Southeast Alaska, Prince William Sound, and Shumagin-Aleutian Islands groups in Mexico- indicating that while wintering grounds appear to be separate, there may be considerable overlap in summer feeding grounds.

Herman (1979), however, presented extensive evidence and various lines of reasoning to conclude that the humpback whales associated with the main Hawai'ian Islands immigrated to those waters only in the past 200 years. Winn and Reichley (1985) identified genetic exchange between the humpback whales that winter off Hawai'i and those that winter off Mexico (with further mixing on feeding areas in Alaska) and suggested that the humpback whales that winter in Hawai'i may have emigrated from wintering areas in Mexico. Based on these patterns of movement, we conclude that the various stocks of humpback whales are not true populations or, at least, they represent populations that experience substantial levels of immigration and emigration.

Between 2004 and 2006, an international group of whale researchers coordinated their surveys to conduct a comprehensive assessment of the population structure, levels of abundance, and status of humpback whales in the North Pacific (also known as the SPLASH project)(Calambokidis et al. 2008). That effort identified a total of 7,971 unique individuals from photographs taken during close approaches. SPLASH results suggest that the current view of population structure is incomplete. The overall pattern of movements is complex but indicates a high degree of population structure (Allen and Angliss 2014).

NORTH ATLANTIC OCEAN. In the Atlantic Ocean, humpback whales aggregate in four feeding areas in the summer months: (1) Gulf of Maine, eastern Canada, (2) west Greenland, (3) Iceland and (4) Norway (Katona and Beard 1990, Smith et al. 1999). The principal breeding range for these whales lies from the Antilles and northern Venezuela to Cuba (Winn et al. 1975, Balcomb and Nichols 1982, Whitehead and Moore 1982). The largest contemporary breeding aggregations occur off the Greater Antilles where humpback whales from all of the North Atlantic feeding areas have been identified from photographs (Katona and Beard 1990, Clapham et al. 1993, Mattila et al. 1994, Palsbøll et al. 1997, Smith et al. 1999, Stevick et al. 2003). Historically, an important breeding aggregation was located in the eastern Caribbean based on the important humpback whale fisheries this region supported, (Reeves et al. 2001, Smith and Reeves 2003). Although sightings persist in those areas, modern humpback whale abundance appears to be low (Winn et al. 1975, Levenson and Leapley 1978, Swartz et al. 2003). Winter aggregations also occur at the Cape Verde Islands in the Eastern North Atlantic (Reeves et al. 2002, Moore et al. 2003). In another example of the "open" structure of humpback whale populations, an individual humpback whale migrated from the Indian Ocean to the South Atlantic Ocean and demonstrated that individual whales may migrate from one ocean basin to another (Pomilla and Rosenbaum 2005).

INDIAN OCEAN. A separate population of humpback whales appears to reside in the Arabian Sea in the Indian Ocean off the coasts of Oman, Pakistan, and India (Mikhalev 1997).

Distribution

Humpback whales occur in the Atlantic, Indian, Pacific, and Southern Oceans. Humpback whales migrate seasonally between warmer, tropical or sub-tropical waters in winter months (where they reproduce and give birth to calves) and cooler, temperate or sub-Arctic waters in summer months (where they feed). In their summer foraging areas and winter calving areas, humpback whales tend to occupy shallower, coastal waters; during their seasonal migrations; however, humpback whales disperse widely in deep, pelagic waters and tend to avoid shallower coastal waters (Winn and Reichley 1985).

In the North Pacific Ocean, the summer range of humpback whales includes coastal and inland waters from Point Conception, California, north to the Gulf of Alaska and the Bering Sea, and west along the Aleutian Islands to the Kamchatka Peninsula and into the Sea of Okhotsk and north of the Bering Strait ((Nemoto 1957, Johnson and Wolman 1984b) as cited in (Allen and Angliss 2013)). Humpback whales have also been observed during the summer in the Chukchi and Beaufort Seas(Allen and Angliss 2014).

In August 2007, a mother-calf pair was sighted from a barge approximately 87 km (54.1 mi) east of Barrow in the Beaufort Sea (Hashagen et al. 2009). Additionally, Ireland *et al.* (2008) reported three humpback sightings in 2007 and one in 2008 during surveys of the eastern Chukchi Sea.

Hartin et al.(2013) reported four humpback whales during vessel-based surveys in the Chukchi Sea in 2007, two in 2008, and one in 2010. Five humpback sightings (11 individuals) occurred during the CSESP vessel-based surveys in 2009 and 2010 (Aerts et al. 2012), and a single humpback was observed several kilometers west of Barrow during the 2012 CSESP vessel-based survey (Aerts et al. 2013a).

The Aerial Surveys of Arctic Marine Mammals (ASAMM) reported four humpback whale sightings near the coast between Icy Cape and Pt. Barrow in July and August of 2012, as well as 24 individual humpback whales on 11 September south and east of Pt. Hope (Clarke et al. 2013b). Prior to 2012 only a single humpback had been sighted during the COMIDA (Clarke et al. 2011c).

Humpback whales have been seen and heard with some regularity in recent years (2009-2012) in the southern Chukchi Sea (see Figure 7), often feeding and in very close association with feeding gray whales. Sightings have occurred mostly in September, but effort in the southern Chukchi has not been consistent and it is possible that humpback whales are present earlier than September (Hashagen et al. 2009, Clarke et al. 2011c, Crance et al. 2011). Additional sightings of four humpback whales occurred in 2009 south of Point Hope, while transiting to Nome (Brueggeman 2010). The approximate distribution of humpback whales in Alaskan waters is provided in Figure 7 below.

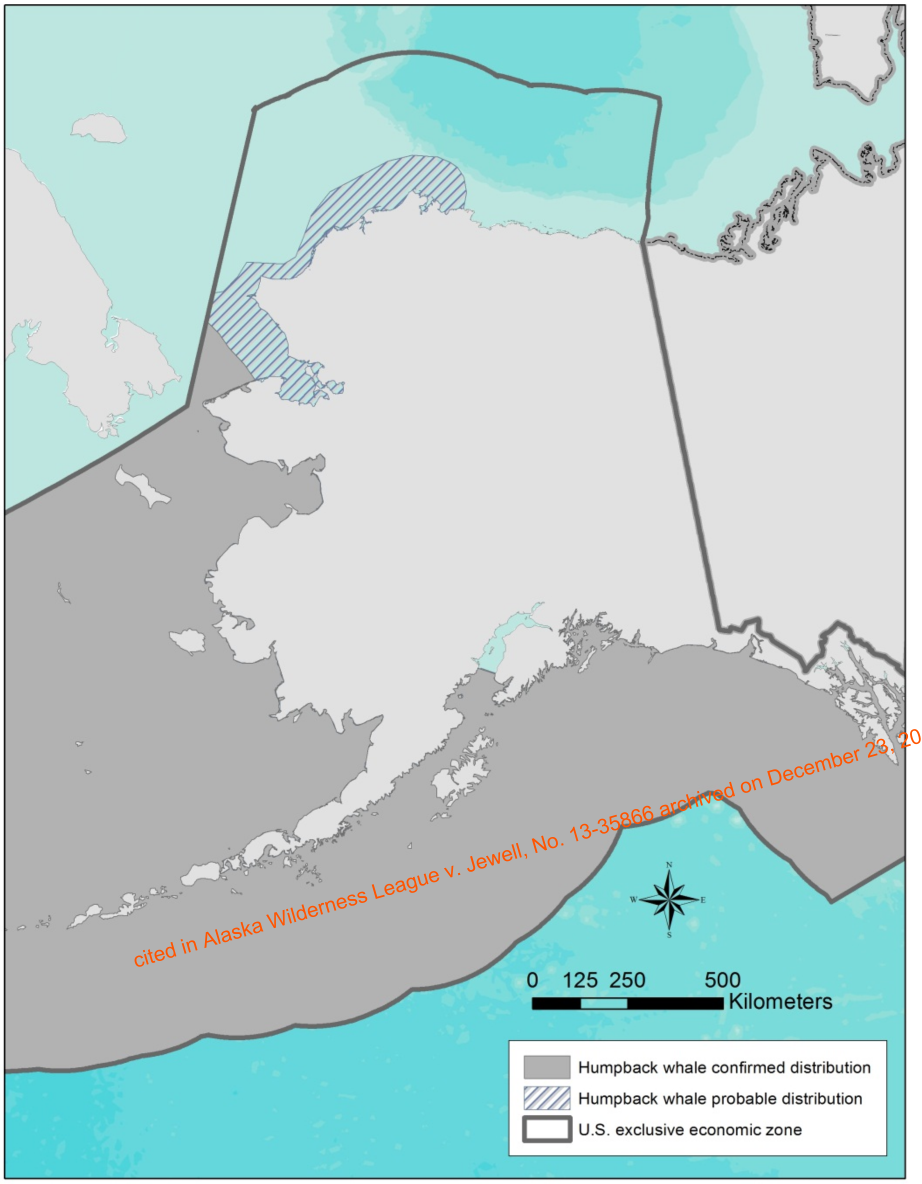

Figure 7. Approximate distribution of humpback whales in the Alaskan waters of the western North Pacific (shaded area). Area within the hash lines is a probable distribution based on recent sightings in the Beaufort Sea (Hashagen et al. 2009) (Source: Allen and Angliss 2014).

Threats to the Species

NATURAL THREATS. There is limited information on natural phenomena that kill or injure humpback whales. Humpback whales are killed by orcas (Whitehead and Glass 1985, Dolphin 1987b, Florezgonzalez et al. 1994, Naessig and Lanyon 2004), and are probably killed by false killer whales and sharks. Calves remain protected near mothers or within a group and lone calves have been known to be protected by presumably unrelated adults when confronted with attack (Ford and Reeves 2008).

Seven female and seven male humpback whales stranded on the beaches of Cape Cod and had died from toxin produced by dinoflagellates between November 1987 and January 1988, and adult and juvenile humpback whales can be killed by naturally-produced biotoxins (Geraci 1990). The occurrence of the nematode *Crassicauda boopis* appears to increase the potential for kidney failure in humpback whales and may be preventing some populations from recovering (Lambertsen 1992a).

Entrapments in ice have been documented in the spring ice pack in Newfoundland (Merdsoy et al. 1979), and up to 25 entrapped in the same event (Lien and Stenson 1986), and some mortalities have been reported. No humpback ice entrapments have been reported in the Chukchi Sea.

ANTHROPOGENIC THREATS. Three human activities are known to threaten humpback whales: whaling, commercial fishing, and shipping. Historically, whaling represented the greatest threat to every population of humpback whales and was ultimately responsible for listing humpback whales as an endangered species. From 1900 to 1965, nearly 30,000 whales were taken in modern whaling operations of the Pacific Ocean. Prior to that, an unknown number of humpback whales were taken (Perry et al. 1999). In 1965, the International Whaling Commission banned commercial hunting of humpback whales in the Pacific Ocean. As its legacy, whaling has reduced humpback whales to a fraction of their historic population size and, as a result, makes it easier for other human activities to push these whales closer to extinction.

Subsistence hunters in Alaska have reported one subsistence take of a humpback whale in South Norton Sound in 2006. There have not been any additional reported takes of humpback whales from this stock by subsistence hunters in Alaska or Russia (Allen and Angliss 2014).

Humpback whales are also killed or injured during interactions with commercial fishing gear, although the evidence available suggests that these interactions on humpback whale populations may not have significant, adverse consequence for humpback whale populations. Like fin whales, humpback whales have been entangled by fishing gear off Newfoundland and Labrador, Canada: a total of 595 humpback whales are reported to have been captured in coastal fisheries in those two provinces between 1969 and 1990 (Perkins and Beamish 1979, Lien 1994). Of these whales, 94 are known to have died as a result of that capture, although, like fin whales, most of the animals that died were smaller: less than 12 meters in length (Lien 1994). From 1979-2008, 1,209 whales were recorded entangled, 80% of which were humpback whales (Benjamins et al. 2012). Along the Pacific coast of Canada, 40 humpback whales have been reported as entangled since 1980, four of which are known to have died (Ford et al. 2009, COSEWIC 2011).

Brownell et al. (2000) compiled records of bycatch in Japanese and Korean commercial fisheries between 1993 and 2000. During the period 1995-99, there were six humpback whales indicated as “bycatch”. In addition, two strandings were reported during this period. Furthermore, analysis of four samples from meat found in markets indicated that humpback whales are being sold. At this time, it is not known whether any or all strandings were caused by incidental interactions with commercial fisheries; similarly, it is not known whether the humpback whales identified in market samples were killed as a result of incidental interactions with commercial fisheries. It is also not known which fishery may be responsible for the bycatch. Regardless, these data indicate a minimum mortality level of 1.1/year (using bycatch data only) to 2.4/year (using bycatch, stranding, and market data) in the waters of Japan and Korea. Because many mortalities pass unreported, the actual rate in these areas is likely much higher. An analysis of entanglement rates from photographs collected for SPLASH found a minimum entanglement rate of 31% for humpback whales from the Asia breeding grounds (Cascadia Research 2003).

A photography study of humpback whales in southeastern Alaska in 2003 and 2004 found at least 53% of individuals showed some kind of scarring from fishing gear entanglement (Neilson et al. 2005). From 2007-2011, 2 humpback whales of the Central North Pacific population were found entangled in fishing gear in Alaska, and one was injured in Hawaii shallow set longline fishery, resulting in an estimated annual human-caused mortality and serious injury rate of 2.15 (Allen and Angliss 2014). Between 2007 and 2011, there was one mortality of a Western North Pacific humpback whale in the Bering Sea/Aleutian Islands pollock trawl fishery, and one mortality in the Bering Sea/Aleutian Islands flatfish trawl (Allen and Angliss 2014). Average minimum annual mortality from observed fisheries was 0.40 humpbacks from this stock (Allen and Angliss 2014).

In 1991, a humpback whale was observed entangled in longline gear and released alive (Hill et al. 1997). In 1995, a humpback whale in Maui waters was found trailing numerous lines (not fishery-related) and entangled in mooring lines. The whale was successfully released, but subsequently stranded and was attacked and killed by tiger sharks in the surf zone. Also in 1996, a vessel from Pacific Missile Range Facility in Hawaii rescued an entangled humpback, removing two crab pot floats from the whale; the gear was traced to a recreational fisherman in southeast Alaska.

Along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada, there were 101 reports of humpback whales being entangled in fishing gear between 2006 and 2010(Henry et al. 2012). Of these, 20 resulted in serious injury, and 9 resulted in mortalities of humpbacks These data suggest that, despite their size and strength, humpback whales are likely to be entangled and, in some cases, killed by gear used in modern fisheries.

The number of humpback whales killed by ship strikes is exceeded only by fin whales (Jensen and Silber 2004a). On the Pacific coast, a humpback whale is killed about every other year by ship strikes (Barlow et al. 1997). There were 108 reports of whale-vessel collisions in Alaska waters between 1978 and 2011. Of these, 93 involved humpback whales (Neilson et al. 2012). The majority of strikes were reported in southeastern Alaska, where the number of humpback whale collisions increased 5.8% annually from 1978 to 2011 (Neilson et al. 2012). Between 2001 and 2009, confirmed reports of vessel collisions with humpback whales indicated an average of five humpback whales struck per year in Alaska; between 2005 and 2009, two humpback deaths were attributed to ship strikes (NMFS 2010c). However, no vessel collisions or prop strikes involving humpback whales have been documented in the Chukchi Sea (BOEM 2011).

Vessel collisions with humpback whales remains a significant management concern, given the increasing abundance of humpback whales foraging in Alaska, as well as the growing presence of marine traffic in Alaska’s coastal waters. Based on these factors, injury and mortality of humpback whales as a result of vessel strike may likely continue into the future (NMFS 2006).

Between 1999 and 2005, there were 18 reports of humpback whales being struck by vessels along the Atlantic Coast of the U.S. and the Maritime Provinces of Canada (Cole et al. 2005, Nelson et al. 2007). Of these reports, 13 were confirmed as ship strikes which were reported as having resulted in the death of 7 humpback whales.

In addition to ship strikes in North America and Hawai'i, there are several reports of humpback whales being injured as result of ship strikes off the Antarctic Peninsula, in the Caribbean Sea, the Mediterranean Sea, off Australia, Bay of Bengal (Indian Ocean), Brazil, New Zealand, Peru, South Africa (NMFS 2010b).

Status

Humpback whales were listed as endangered in 1970 (35 FR 18319) and that listing was carried over after Congress enacted the ESA (39 FR 41367). Humpback whales are listed as endangered on the IUCN Red List of Threatened Animals (Baillie and Groombridge 1996). They are also protected by the Convention on International Trade in Endangered Species of wild flora and fauna and the MMPA. Critical habitat has not been designated for humpback whales. A final recovery plan for the humpback whale was completed in November of 1991 (NMFS 1991). NMFS recently conducted a global status review and proposed changing the status of humpback whales under the ESA such that the Central North Pacific stock would no longer be listed (80 FR 22304; April 21, 2015). However, the CNP and WNP stocks are not discernable by sight, and intermix in the action area.

Winn and Reichley (1985) argued that the global population of humpback whales consisted of at least 150,000 whales in the early 1900s, with the largest population historically occurring in the Southern Ocean. Based on analyses of mutation rates and estimates of genetic diversity, Palumbi and Roman (2006) concluded that there may have been as many as 240,000 (95% confidence interval = 156,000 – 401,000) humpback whales in the North Atlantic before whaling began. In the western North Atlantic between Davis Strait, Iceland and the West Indies, Mitchell and Reeves (1983) estimated there were at least 4,685 humpback whales in 1865 based on available whaling records (although the authors note that this does not represent a pre-exploitation estimate because whalers from Greenland, the Gulf of St. Lawrence, New England, and the Caribbean Sea had been hunting humpback whales before 1865).

NORTH PACIFIC OCEAN. Estimates of the number of humpback whales occurring in the different populations that inhabit the Northern Pacific have risen over time. In the 1980s, estimates ranged from 1,407 to 2,100 (Baker 1985, Darling and Morowitz 1986, Baker and Herman 1987), while recent estimates place the population size at about 6,000 whales (standard error = 474) in the North Pacific (Calambokidis et al. 1997, Cerchio 1998, Mobley et al. 1999). Based on data collected between 1980 and 1983, Baker and Herman (1987) used a capture-recapture methodology to produce a population estimate of 1,407 whales (95% confidence interval = 1,113 - 1,701). More recently, (Calambokidis et al. 1997) relied on resightings estimated from photographic records of individuals to produce an estimate of 6,010 humpback whales occurred in the North Pacific Ocean. Because the estimates produced by the different methodologies are not directly comparable, it is not clear which of these estimates is more accurate or if the change from 1,407 to 6,000 individuals results from a real increase in the size of the humpback whale population, sampling bias in one or both studies, or assumptions in the methods used to produce estimates from the individuals that were sampled. Since the last of these estimates was published almost 20 years ago, we do not know if the estimates represent current population sizes.

Between 2004 and 2006, an international group of whale researchers coordinated their surveys to conduct a comprehensive assessment of the population structure, levels of abundance, and status of humpback whales in the North Pacific (Calambokidis et al. 2008). The SPLASH effort identified a total of 7,971 unique individuals from photographs taken during close approaches. Of this total, 4,516 individuals were identified at wintering regions in at least one of the three seasons in which the study surveyed wintering area and 4,328 individuals were identified at least once at feeding areas in one of the two years in which the study surveyed feeding areas. Based on the results of that effort, Calambokidis *et al.* (2008) estimated that the current population of humpback whales in the North Pacific Ocean consisted of about 18,300 whales, not counting calves.

Individuals from the Western Pacific stock and the Central North Pacific stock could occur in the Bering Sea with access to the Chukchi and Beaufort Seas.

Central North Pacific (CNP) Stock- Initial mark-recapture estimates have been calculated from the SPLASH data with point estimates of abundance for the Central North Pacific stock of humpback whales which winter in Hawaii ranging from 7,469 to 10,103 (Allen and Angliss 2014). The SPLASH abundance estimates ranged from 2,889 to 13,594 combined for the Aleutian Islands and Bering Sea for the Central North Pacific stock in their summer feeding areas (Allen and Angliss 2014).

Although there is no estimate of the maximum net productivity rate for the Central North Pacific stock, the maximum net productivity rate for this stock is assumed to be at least 7% (Allen and Angliss 2014). Using the smallest SPLASH study abundance estimate for 2004-2005 for Hawaii of 7,469 with an assumed CV of 0.300 and its associated N_{min} of 5,833, potential biological removal (PBR) was calculated to be 61.2 animals (5,833 x 0.035 x 0.3) (Allen and Angliss 2014).[10]

Western North Pacific (WNP) Stock- Point estimates of abundance for the Western North Pacific stock which winters in Asia (combined across three areas) for 2004 to 2006 were relatively consistent across models, ranging from 938 to 1,107 (Allen and Angliss 2014). On the summer feeding grounds WNP estimates of abundance, ranged from 6,000 to 14,000 for the Bering Sea and Aleutian Islands (Allen and Angliss 2014).

Similar to the Central North Pacific stock, there is no estimate of the maximum net productivity rate for the Western North Pacific stock. However, the maximum net productivity for this stock is assumed to be at least 7% (Allen and Angliss 2014). Using the smallest SPLASH abundance estimate calculated for 2004-2006 of 938 animals with an assumed CV of 0.300 for the entire

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[10] This is considered the PBR for the entire CNP stock (Allen and Angliss 2014).

Western North Pacific stock of humpback whale, Allen and Angliss (2014) calculated the PBR to be 2.6 animals (732 x 0.035 x 0.1). Alternatively, using the number of unique individuals seen during the SPLASH study results in a PBR of 2.0 (566 x 0.035 x 0.1).

NORTH ATLANTIC OCEAN. Stevick *et al.* (2003) estimated the size of the North Atlantic humpback whale population between 1979 and 1993 by applying statistical analyses that are commonly used in capture-recapture studies to individual humpback whales that were identified based on natural markings. Between 1979 and 1993, they estimated that the North Atlantic populations (what they call the "West Indies breeding population") consisted of between 5,930 and 12,580 individual whales. The best estimate they produced (11,570; 95% confidence interval = 10,290 -13,390) was based on samples from 1992 and 1993. If we assume that this population has grown according to the instantaneous rate of increase Stevick *et al.* (2003) estimated for this population ($r = 0.0311$), this would lead us to estimate that this population might consist of about 18,400 individual whales in 2007-2008.

Regardless of which of these estimates, if any, most closely correspond to the actual size and trend of the humpback whale population, all of these estimates suggest that the global population of humpback whales consists of tens of thousands of individuals, that the North Atlantic population consists of at least 2,000 individuals and the North Pacific population consists of about 18,000 individuals. Based on ecological theory and demographic patterns derived from several hundred imperiled species and populations, humpback whales appear to exist at population sizes that are large enough to avoid demographic phenomena that are known to increase the extinction probability of species that exist as "small" populations (that is, "small" populations experience phenomena such as demographic stochasticity, inbreeding depression, Allee effects, among others, that cause their population size to become a threat in and of itself).

Reproduction and Growth

Humpbacks give birth and presumably mate on low-latitude wintering grounds in January to March in the Northern Hemisphere. Females attain sexual maturity at 5 years in some populations and exhibit a mean calving interval of approximately two years (Clapham 1992, Barlow and Clapham 1997). Gestation is about 12 months, and calves probably are weaned by the end of their first year (Perry et al. 1999).

Although long-term relationships do not appear to exist between males and females, mature females do pair with other females; those individuals with the longest standing relationships also have the highest reproductive output, possibly as a result of improved feeding cooperation (Ramp et al. 2010).

Feeding and Prey Selection

Humpback whales tend to feed on summer grounds and not on winter grounds. However, some opportunistic winter feeding has been observed at low-latitudes (Perry et al. 1999). Humpback whales engulf large volumes of water and then filter small crustaceans and fish through their fringed baleen plates.

Humpback whales are relatively generalized in their feeding compared to some other baleen whales. In the Northern Hemisphere, known prey includes: euphausiids (krill); copepods; juvenile salmonids, Oncorhynchus spp.; Arctic cod, Boreogadus saida; walleye pollock, Theragra chalcogramma; pollock, Pollachius virens; pteropods; and cephalopods (Johnson and Wolman 1984a, Perry et al. 1999). Foraging is confined primarily to higher latitudes (Stimpert et al. 2007), such as the action area.

Diving and Social Behavior

In Hawai'ian waters, humpback whales remain almost exclusively within the 1800 m isobath and usually within waters depths less than 182 meters. Maximum diving depths are approximately 170 m (558 ft) (but usually <60 m [197 ft]), with a very deep dive (240 m [787 ft]) recorded off Bermuda (Hamilton et al. 1997). They may remain submerged for up to 21 min (Dolphin 1987a). Dives on feeding grounds ranged from 2.1-5.1 min in the north Atlantic (Goodyear unpublished manuscript). In southeast Alaska average dive times were 2.8 min for feeding whales, 3.0 min for non-feeding whales, and 4.3 min for resting whales, with the deepest dives to 148m (Dolphin 1987a), while whales observed feeding on Stellwagon Bank in the North Atlantic dove <40m (Hain et al. 1992). Because most humpback prey is likely found above 300 m depths most humpback dives are probably relatively shallow. Hamilton et al. (1997) tracked one possibly feeding whale near Bermuda to 240 m depth.

In a review of the social behavior of humpback whales, Clapham (1996) reported that they form small, unstable social groups during the breeding season. During the feeding season they form small groups that occasionally aggregate on concentrations of food. Feeding groups are sometimes stable for long-periods of times. There is good evidence of some territoriality on feeding (Clapham 1994, 1996), and calving areas (Tyack 1981). In calving areas, males sing long complex songs directed towards females, other males or both. The breeding season can best be described as a floating lek or male dominance polygyny (Clapham 1996). Inter-male competition for proximity to females can be intense as expected by the sex ratio on the breeding grounds which may be as high as 2.4:1.

Average group size near Kodiak Island is 2-4 individuals, although larger groups are seen near Shuyak and Sitkalidak islands and groups of 20 or more have been documented (Wynne et al. 2005). Humpback whales observed in the Alaska Chukchi Sea have been single animals and one cow calf pair was observed in the U.S. Beaufort Sea (Hashagen et al. 2009).

Vocalization and Hearing

While there is no direct data on hearing in low-frequency cetaceans, the functional hearing range is anticipated to be between 7 Hz to 30 kHz (Watkins 1986b, Au et al. 2006, Southall et al. 2007, Ciminello et al. 2012, NOAA 2013). Baleen whales have inner ears that appear to be specialized for low-frequency hearing. In a study of the morphology of the mysticete auditory apparatus, Ketten (1997) hypothesized that large mysticetes have acute infrasonic hearing.

Humpback whales produce a wide variety of sounds. During the breeding season males sing long, complex songs, with frequencies in the 20-5000 Hz range and intensities as high as 181 dB (Payne 1970, Winn et al. 1970, Thompson et al. 1986). Source levels average 155 dB and range from 144 to 174 dB (Thompson et al. 1979). The songs appear to have an effective range of approximately 10 to 20 km. Animals in mating groups produce a variety of sounds (Tyack 1981, Silber 1986b).

Social sounds in breeding areas associated with aggressive behavior in male humpback whales are very different than songs and extend from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz (Tyack and Whitehead 1983, Silber 1986a). These sounds appear to have an effective range of up to 9 km (Tyack and Whitehead 1983).

Humpback whales produce sounds less frequently in their summer feeding areas. Feeding groups produce distinctive sounds ranging from 20 Hz to 2 kHz, with median durations of 0.2-0.8 seconds and source levels of 175-192 dB (Thompson et al. 1986). These sounds are attractive and appear to rally animals to the feeding activity (D'Vincent et al. 1985, Sharpe and Dill 1997).

In summary, humpback whales produce at least three kinds of sounds:

1. Complex songs with components ranging from at least 20 Hz–5 kHz with estimated source levels from 144– 174 dB; these are mostly sung by males on the breeding grounds (Winn et al. 1970, Richardson et al. 1995, Au et al. 2000, Frazer and Mercado 2000, Au et al. 2006);
2. Social sounds in the breeding areas that extend from 50Hz – more than 10 kHz with most energy below 3kHz (Tyack and Whitehead 1983, Richardson et al. 1995); and
3. Feeding area vocalizations that are less frequent, but tend to be 20 Hz–2 kHz with estimated sources levels in excess of 175 dB re 1 Pa at 1m (Thompson et al. 1986, Richardson et al. 1995).

4.3.4 Arctic Ringed Seal

Population Structure

A single Alaskan stock of ringed seal is recognized in U.S. waters. This stock is part of the Artic ringed seal subspecies.

Distribution

Arctic ringed seals have a circumpolar distribution. They occur in all seas of the Arctic Ocean, and range seasonally into adjacent seas including the Bering Sea. In the Chukchi and Beaufort Seas, where they are year-round residents, they are the most widespread seal species.

Arctic ringed seals have an affinity for ice-covered waters and are able to occupy areas of even continuous ice cover by abrading breathing holes in that ice (Hall 1865, Bailey and Hendee 1926, McLaren 1958). Throughout most of their range, Arctic ringed seals do not come ashore and use sea ice as a substrate for resting, pupping, and molting (Kelly et al. 1988, Kelly et al. 2010b). Outside the breeding and molting seasons, they are distributed in waters of nearly any depth; their distribution is strongly correlated with seasonally and permanently ice-covered waters and food availability (e.g. (Simpkins et al. 2003, Freitas et al. 2008).

The seasonality of ice cover strongly influences ringed seal movements, foraging, reproductive behavior, and vulnerability to predation. Three ecological seasons have been described as important to ringed seals: the “open-water” or “foraging” period when ringed seals forage most intensively, the subnivean period in early winter through spring when seals rest primarily in subnivean lairs (snow caves) on the ice, and the basking period between lair abandonment and ice break-up (Born et al. 2004, Kelly et al. 2010a).

Overall, the record from satellite tracking indicates that during the foraging period, ringed seals breeding in shorefast ice either forage within 100 km of their shorefast breeding habitat or they make extensive movements of hundreds or thousands of kilometers to forage in highly productive areas and along the pack ice edge (Freitas et al. 2008, Kelly et al. 2010b). Movements during the foraging period by ringed seals that breed in the pack ice are unknown. During the winter subnivean period, ringed seals excavate lairs in the snow above breathing holes where the snow depth is sufficient. These lairs are occupied for resting, pupping, and nursing young in annual shorefast and pack ice. Movements during the subnivean period are typically limited, especially when ice cover is extensive. During the (late) spring basking period, ringed seals haul out on the surface of the ice for their annual molt.

Because Arctic ringed seals are most readily observed during the spring basking period, aerial surveys to assess abundance are conducted during this period. Frost et al. (2004) reported that water depth, location relative to the fast ice edge, and ice deformation showed substantial and consistent effects on ringed seal densities during May and June in their central Beaufort Sea study area—densities were highest in relatively flat ice and near the fast ice edge, as well as at depths between 5 and 35 m. Bengtson et al. (2005) found that in their eastern Chukchi Sea study area during May and June, ringed seals were four to ten times more abundant in nearshore fast and pack ice than in offshore pack ice, and that ringed seal preference for nearshore or offshore habitat was independent of water depth. They observed higher densities of ringed seals in the southern region of the study area south of Kivalina and near Kotzebue Sound.

Threats to the Species

Threats to Arctic ringed seals are described in detail in the species’ Status Review (Kelly et al. 2010b) and the proposed listing rule (75 FR 77476), and are briefly summarized below. Details about individual threats in the action area will also be discussed in the *Environmental Baseline* section.

Predation. Polar bears are the main predator of ringed seals, but other predators include Arctic and red foxes, walruses, wolves, wolverines, killer whales, and ravens (Burns and Eley 1976, Heptner et al. 1976b, Fay et al. 1990, Derocher et al. 2004, Melnikov and Zagrebin 2005). The threat currently posed to ringed seals by predation is moderate, but predation risk is expected to increase as snow and sea ice conditions change with a warming climate (75 FR 77476).

Parasites and Diseases. Ringed seals have co-evolved with numerous parasites and diseases, and these relationships are presumed to be stable. Since July 2011, more than 60 dead and 75 diseased seals, mostly ringed seals, have been reported in Alaska. The underlying cause of the disease remains unknown. Kelly et al. (2010b) noted that abiotic and biotic changes to ringed seal habitat could lead to exposure to new pathogens or new levels of virulence, but the potential threats to ringed seals were considered low.

Climate Change: Loss of Sea Ice and Snow Cover. Diminishing sea ice and snow cover are the greatest challenges to the persistence of Arctic ringed seals. Within this century, snow cover is projected to be inadequate for the formation and occupation of birth lairs over a substantial portion of the subspecies' range. Without the protection of the lairs, ringed seals–especially newborn–are vulnerable to freezing and predation (75 FR 77476). Additionally, high fidelity to birthing sites exhibited by ringed seals makes them more susceptible to localized degradation of snow cover (Kelly et al. 2010b).

Climate Change: Ocean Acidification. Although no scientific studies have directly addressed the impacts of ocean acidification on ringed seals, the effects would likely be through their ability to find food. The decreased availability or loss of prey species from the ecosystem may have a cascading effect on ringed seals (Kelly et al. 2010b).

Harvest. Ringed seals were harvested commercially in large numbers during the 20th century, which led to the depletion of their stocks in many parts of their range. Arctic ringed seals have been hunted by humans for millennia and remain a fundamental subsistence resource for many northern coastal communities today. The number of seals taken annually varies considerably between years due to ice and wind conditions, which impact hunter access to seals. Currently there is no comprehensive effort to quantify harvest levels of seals in Alaska. As of August 2000 the subsistence harvest database indicated that the statewide annual ringed seal subsistence harvest is 9,567 (Allen and Angliss 2014). Data on community subsistence harvests are no longer routinely being collected and no new annual harvest estimates exist. Kelly et al. (2010b) concluded that although subsistence harvest of Arctic ringed seals is currently substantial in some parts of their range, harvest levels appear to be sustainable.

Commercial Fisheries Interactions. Commercial fisheries may impact ringed seals through direct interactions (i.e., incidental take or bycatch) and indirectly through competition for prey resources and other impacts on prey populations. Based on data from 2007 and 2011, there have been an average of 3.52 (CV=0.06) mortalities of ringed seals incidental to commercial fishing operations per year (Allen and Angliss 2014).

Kelly *et al.* (2010b) noted that commercial fisheries target a number of known ringed seal prey species such as walleye pollock (*Theragra chalcogramma*), Pacific cod, herring (*Clupea* sp.), and capelin. These fisheries may affect ringed seals indirectly through reductions in prey biomass and through other fishing mediated changes in ringed seal prey species. The extent that reduced numbers in individual fish stocks affect the viability of Arctic ringed seals is unknown. However, Arctic ringed seals were not believed to be significantly competing with or affected by commercial fisheries in the waters of Alaska (Frost 1985, Kelly et al. 1988).

Shipping. Current shipping activities in the Arctic pose varying levels of threats to Arctic ringed seals depending on the type and intensity of the shipping activity and its degree of spatial and temporal overlap with ringed seal habitats. These factors are inherently difficult to know or predict, making threat assessment highly uncertain. Most ships in the Arctic avoid areas of ice. This necessarily mitigates many of the risks of shipping to ringed seals. Icebreakers pose risks to ringed seals because they are capable of operating year-round in all but the heaviest ice conditions and are often used to escort other types of vessels (*e.g.*, tankers and bulk carriers) through ice-covered areas.

Contamination. Contaminants research on Arctic ringed seals has been conducted in most parts of the subspecies' range. Pollutants such as organochlorine (OC) compounds and heavy metals have been found in Arctic ringed seals. The variety, sources, and transport mechanisms of the contaminants vary across the ringed seal's range, but these compounds appear to be ubiquitous in the Arctic marine food chain. Statistical analysis of OCs in marine mammals has shown that for most OCs, the European Arctic is more contaminated than the Canadian and U.S. Arctic. Tynan and DeMaster (1997) noted that climate change has the potential to increase the transport of pollutants from lower latitudes to the Arctic, highlighting the importance of continued monitoring of contaminant levels.

Oil and gas activities have the potential to impact ringed seals primarily through noise, physical disturbance, and pollution, particularly in the event of a large oil spill. Within the range of the Arctic ringed seal, offshore oil and gas exploration and production activities are currently underway in the United States, Canada, Greenland, Norway, and Russia. In the United States, oil and gas activities have been conducted off the coast of Alaska since the 1970s, with most of the activity occurring in the Beaufort Sea and in State waters. Although five exploratory wells have been drilled in the past, no oil fields have been developed or brought into production in the Chukchi Sea to date.

Research. Mortalities may occur occasionally incidental to marine mammal research activities authorized under MMPA permits issued to a variety of government, academic, and other research organizations. However, to date no mortalities have resulted from research to ringed seals (Allen and Angliss 2014).

The large range and population size of the Arctic subspecies make it less vulnerable to other perturbations, such as hunting, fisheries interactions, and research takes. Therefore, ESA Section 4(d) protective regulations and Section 9 prohibitions were deemed unnecessary for the conservation of the species (77 FR 76706).

Status

NMFS listed the Arctic ringed seals as threatened under the ESA on December 28, 2012 (77 FR 76706). NMFS proposed designation of critical habitat for the Arctic ringed seal on December 9, 2014 (79 FR 73010).

There are no specific estimates of population size available for the Arctic subspecies of the ringed seal, but experts postulate that the population numbers in the millions. Based on the available abundance estimates for study areas within the Chukchi-Beaufort Sea region and extrapolations for pack ice areas without survey data, Kelly et al. (2010b) indicated that a reasonable estimate for the Chukchi and Beaufort Seas is one million seals, and for the Alaskan portions of these seas is at least 300,000 seals.

Bengtson *et al.* (2005) estimated the abundance of ringed seals from spring aerial surveys conducted along the eastern Chukchi coast from Shishmaref to Barrow at 252,500 seals in 1999 and 208,900 in 2000 (corrected for seals not hauled out). However, the estimates from 1999 and 2000 in the Chukchi Sea only covered a portion of this stock's range, and were conducted over a decade ago(Allen and Angliss 2014). Frost *et al.* (2004) conducted spring aerial surveys along the Beaufort Sea coast from Oliktok Point to Kaktovik in 1996–1999. They reported density estimates for these surveys ($0.98/km^2$), but did not derive abundance estimates. During April-May in 2012 and 2013, U.S. and Russian researchers conducted comprehensive and synoptic aerial abundance and distribution surveys of ice-associated seals in the Bering and Okhotsk Seas (Moreland et al. 2013). Preliminary analysis of the U.S. surveys, which included only a small subset of the 2012 data, produced an estimate of about 170,000 ringed seals in the U.S. Exclusive Economic Zone (EEZ) of the Bering Sea in late April (Conn et al. 2014).

Current and precise data on trends in abundance for the Alaska stock of ringed seals are considered unavailable. PBR for this stock is also unknown at this time (Allen and Angliss 2014).

Feeding and Prey Selection

Many studies of the diet of Arctic ringed seal have been conducted and although there is considerable variation in the diet regionally, several patterns emerge. Most ringed seal prey is small, and preferred prey tends to be schooling species that form dense aggregations. Ringed seals rarely prey upon more than 10-15 prey species in any one area, and not more than 2-4 of those species are considered important prey. Fishes are generally more commonly eaten than invertebrate prey, but diet is determined to some extent by availability of various types of prey during particular seasons as well as preference, which in part is guided by energy content of various available prey (Reeves 1998b, Wathne et al. 2000). Invertebrate prey seem to become more important in the diet of Arctic ringed seals in the open water season and often dominate the diet of young animals (e.g., (Lowry et al. 1980, Holst et al. 2001).

Despite regional and seasonal variations in the diet of Arctic ringed seals, fishes of the cod family tend to dominate the diet from late autumn through early spring in many areas (Kovacs 2007). Arctic cod (*Boreogadus saida*) is often reported to be the most important prey species for ringed seals, especially during the ice-covered periods of the year (Lowry et al. 1980, Smith 1987, Holst et al. 2001, Labansen et al. 2007). Quakenbush et al. (2011b) reported evidence that in general, the diet of Alaska ringed seals sampled consisted of cod, amphipods, and shrimp. They found that fish were consumed more frequently in the 2000s than during the 1960s and 1970s, and identified the five dominant species or taxa of fishes in the diet during the 2000s as: Arctic cod, saffron cod, sculpin, rainbow smelt, and walleye pollock. Invertebrate prey was predominantly mysids, amphipods, and shrimp, with shrimp being the most dominant.

Diving, Hauling out, and Social Behavior

Behavior of ringed seals is poorly understood because both males and females spend much of their time in lairs built in pressure ridges or under snowdrifts for protection from predators and severe weather (ADFG 1994). Figure 5 summarizes the approximate annual timing of reproduction and molting for Arctic ringed seals.

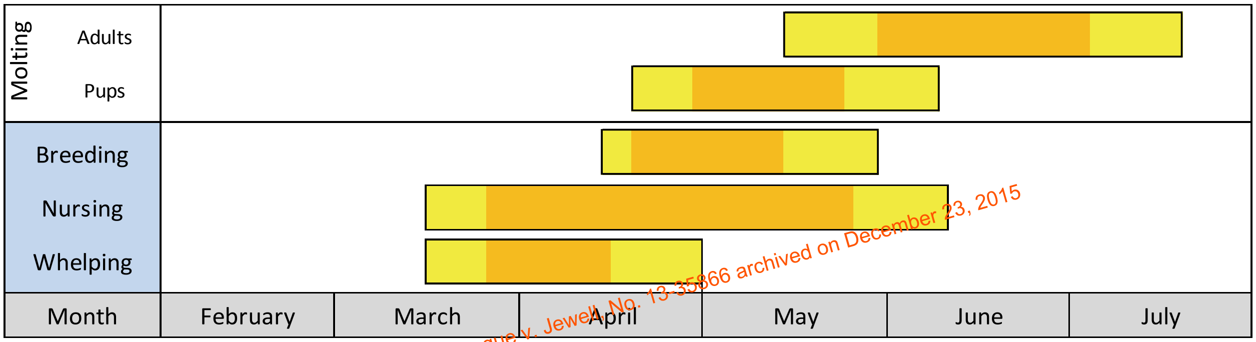

Figure 8. **Approximate annual timing of reproduction and molting for Arctic ringed seals. Yellow bars indicate the "normal" range over which each event is reported to occur and orange bars indicated the "peak" timing of each event (source: (Kelly et al. 2010b).**

Arctic ringed seals use sea ice as a platform for resting throughout the year, and they make and maintain breathing holes in the ice from freeze-up until breakup (Frost et al. 2002). They normally give birth in late winter-early spring in subnivean lairs constructed in the snow on the sea ice above breathing holes, and mating takes place typically in May shortly after parturition. In the spring, as day length and temperature increase, ringed seals haul out in large numbers on the surface of the ice near breathing holes or lairs. This behavior is associated with the annual May-July molt.

Ringed seal pups spend about 50% of their time in the water during the nursing period, diving for up to 12 minutes and as deep as 89 m (Lydersen and Hammill 1993). The pups' large proportion of time spent in the water, early development of diving skills, use of multiple breathing holes and nursing/resting lairs, and prolonged lanugo stage were interpreted as adaptive responses to strong predation pressure, mainly by polar bears (*Ursus maritimus*) and Arctic foxes (*Alopex lagopus*) (Smith and Lydersen 1991, Lydersen and Hammill 1993).

Tagging studies revealed that Arctic ringed seals are capable of diving for at least 39 minutes (Teilmann et al. 1999) and to depths of over 500 m (Born et al. 2004); however, most dives reportedly lasted less than 10 minutes and dive depths were highly variable and were often limited by the relative shallowness of the areas in which the studies took place (Lydersen 1991, Kelly and Wartzok 1996, Teilmann et al. 1999, Gjertz et al. 2000a). Based on three-dimensional tracking, Simpkins *et al.* (2001) categorized ringed seal dives as either travel, exploratory, or foraging/social dives. Ringed seals tend to come out of the water during the daytime and dive at night during the spring to early summer breeding and molting periods, while the inverse tended to be true during the late summer, fall, and winter (Kelly and Quakenbush 1990, Lydersen 1991, Teilmann et al. 1999, Carlens et al. 2006, Kelly et al. 2010b). Captive diving experiments conducted by Elsner et al. (1989) indicated that ringed seals primarily use vision to locate breathing holes from under the ice, followed by their auditory and vibrissal senses for short-range pilotage.

Vocalization, Hearing, and Sensory

Ringed seals vocalize underwater in association with territorial and mating behaviors. Underwater audiograms for phocids suggest that they have very little hearing sensitivity below 1 kHz, though they can hear underwater sounds at frequencies up to 60 kHz and make calls between 90 Hz and 16 kHz (Richardson et al. 1995). A more recent review suggests that the function hearing range phocids should be considered to be 75 Hz to 100 kHz (Hemila et al. 2006, Kastelein et al. 2009, NOAA 2013). The airgun sound sources being proposed for this action are anticipated to be between below 1 kHz, and should be well within the auditory bandwidth for the Arctic ringed seal.

Most phocid seals spend greater than 80% of their time submerged in the water (Gordon et al. 2003). Phocids have good low-frequency hearing; thus, it is expected that they will be more susceptible to masking of biologically significant signals by low frequency sounds, such as those from seismic surveys (Gordon et al. 2003). Masking of biologically important sounds by anthropogenic noise could be considered a temporary loss of hearing acuity. Brief, small-scale masking episodes might have few long-term consequences for individual ringed seals. The consequences might be more serious in areas where many surveys are occurring simultaneously (Kelly et al. 2010b). There is no specific evidence that exposure to pulses of airgun sound can cause permanent threshold shifts to the hearing of any marine mammal, even with large arrays of airguns. Nevertheless, direct impacts causing injury from seismic surveys may occur if animals entered the zone immediately surrounding the sound source (Kelly et al. 2010b).

In addition, noise exposure may affect the vestibular and neurosensory systems. Unlike cetaceans, pinnipeds have a well-developed more conventional vestibular apparatus that likely provides multiple sensory cues similar to those of most land mammals. Marine mammals may be subject to noise-induced effects on vestibular function as has been shown in land mammals and humans (Southall et al. 2007). Noise-induced effects on vestibular function may be even more pronounced than in land mammals considering a single vibrissa on a ringed seal contains ten times the number of nerve fibers typically found in one vibrissa of a land mammal (Hyvärinen 1989). However, more data are needed to more fully assess potential impacts of underwater sound exposure on non-auditory systems in pinnipeds.

Elsner *et al.* (1989) indicated that ringed seals primarily use vision to locate breathing holes from under the ice, followed by their auditory and vibrissal senses for short-range pilotage. Hyvärinen (1989) suggested that ringed seals in Lake Saimaa may use a simple form of echolocation along with a highly developed vibrissal sense for orientation and feeding in dark, murky waters. The vibrissae likely are important in detecting prey by sensing their turbulent wakes as demonstrated experimentally for harbor seals (Dehnhardt et al. 1998). Sound waves could be received by way of the blood sinuses and by tissue conduction through the vibrissae (Riedman 1990).

4.3.5 Beringia DPS of Bearded Seals

Population Structure

There are two recognized subspecies of the bearded seal: *E. b. barbatus,* often described as inhabiting the Atlantic sector (Laptev, Kara, and Barents seas, North Atlantic Ocean, and Hudson Bay; (Rice 1998)); and *E. b. nauticus*, which inhabits the Pacific sector (remaining portions of the Arctic Ocean and the Bering and Okhotsk seas; (Ognev 1935, Scheffer 1958, Manning 1974, Heptner et al. 1976a). Geographic boundaries for the divisions between the two subspecies are subject to the caveat that distinct boundaries do not appear to exist (Cameron et al. 2010). Two distinct population segments were identified for the *E. b. nauticus* subspecies–the Okhotsk DPS in the Sea of Okhotsk, and the Beringia DPS, encompassing the remainder of the range of this subspecies. Only the Beringia DPS of bearded seals is found in U.S. waters (and the action area), and these are of a single recognized Alaska stock.

Distribution

Bearded seals are a boreoarctic species with a circumpolar distribution (Fedoseev 1965, Johnson et al. 1966, Burns 1967, Burns and Frost 1979, Frost et al. 1979, Burns 1981, Smith 1981, Kelly et al. 1988). Their normal range extends from the Arctic Ocean (85°N) south to Sakhalin Island (45°N) in the Pacific, and south to Hudson Bay (55°N) in the Atlantic (Allen 1880, Ognev 1935, King 1983). The range of the Beringia DPS of the bearded seal is defined as extending from an east-west Eurasian dividing line at Novosibirskiye in the East Siberian Sea, south into the Bering Sea (Kamchatka Peninsula and 157°E division between the Beringia and Okhotsk DPSs), and to a north American dividing line (between the Beringia DPS of the E. b. nauticus subspecies and the E. B. barbatus subspecies) at 122°W (midpoint between the Beaufort Sea and Pelly Bay).

Bearded seals are closely associated with sea ice – particularly during the critical life history periods related to reproduction and molting – and can be found in a broad range of ice types. They generally prefer ice habitat that is in constant motion and produces natural openings and areas of open water such as leads, fractures, and polynyas for breathing, hauling out on the ice, and access to water for foraging (Heptner et al. 1976a, Fedoseev 1984, Nelson et al. 1984). The bearded seal's effective range is generally restricted to areas where seasonal sea ice occurs over relatively shallow waters. Cameron et al. (2010) defined the core distribution of bearded seals as those areas over waters less than 500 m deep.

The region that includes the Bering and Chukchi seas is the largest area of continuous habitat for bearded seals (Burns 1981, Nelson et al. 1984). The Bering-Chukchi Platform is a shallow intercontinental shelf that encompasses half of the Bering Sea, spans the Bering Strait, and covers nearly all of the Chukchi Sea. Bearded seals can reach the bottom everywhere along the shallow shelf and so it provides them favorable foraging habitat (Burns 1967). The Bering and Chukchi seas are generally covered by sea ice in late winter and spring and are then mostly ice free in late summer and fall, a process that helps to drive a seasonal pattern in the movements and distribution of bearded seals in this area (Burns 1967, 1981, Nelson et al. 1984). During winter, most bearded seals in Alaskan waters are found in the Bering Sea, while smaller numbers of year-round residents remain in the Beaufort and Chukchi Seas, mostly around lead systems and polynyas. From mid-April to June, as the ice recedes, many bearded seals that overwinter in the Bering Sea migrate northward through the Bering Strait into the Chukchi and Beaufort Seas, where they spend the summer and early fall at the southern edge of the Chukchi and Beaufort Sea pack ice at the wide, fragmented margins of multiyear ice. A small number of bearded seals, mostly juveniles, remain near the coasts of the Bering and Chukchi seas for the summer and early fall instead of moving with the ice edge. These seals are found in bays, brackish water estuaries, river mouths, and have been observed up some rivers (Burns 1967, Heptner et al. 1976a, Burns 1981).

Threats to the Species

Threats to the Beringia DPS of bearded seal are described in detail in the species' Status Review (Cameron et al. 2010) and the proposed listing rule (75 FR 77496), and are briefly summarized below. Details about individual threats in the action area will also be discussed in the *Environmental Baseline* section.

Predation. Polar bears are the primary predator of bearded seals. Other predators include brown bears, killer whales, sharks, and walruses (seemingly infrequent). Predation under the future scenario of reduced sea ice is difficult to assess; polar bear predation may decrease, but predation by killer whales, sharks, and walrus may increase (Cameron et al. 2010).

Parasites and Diseases. A variety of diseases and parasites have been documented to occur in bearded seals. The seals have likely coevolved with many of these and the observed prevalence is typical and similar to other species of seals. However, since July 2011, over 100 sick or dead seals have been reported in Alaska. The cause of the Arctic seal disease remains unknown. Cameron *et al.* (2010) noted that abiotic and biotic changes to bearded seal habitat could lead to exposure to new pathogens or new levels of virulence, but the potential threats to ringed seals were considered low.

Climate Change: Sea Ice Loss. For at least some part of the year, bearded seals rely on the presence of sea ice over the productive and shallow waters of the continental shelves where they have access to food–primarily benthic and epibenthic organisms–and a platform for hauling out of the water. With loss of sea ice, the spring and summer ice edge may retreat to deep waters of the Arctic Ocean basin, which could separate sea ice suitable for pup maturation and molting from benthic feeding areas.

Climate Change: Ocean Acidification. The process of ocean acidification has long been recognized, but the ecological implications of such chemical changes have only recently begun to be appreciated. The waters of the Arctic and adjacent seas are among the most vulnerable to ocean acidification. The most likely impact of ocean acidification on bearded seals will be through the loss of benthic calcifiers and lower trophic levels on which the species' prey depends. Cascading effects are likely both in the marine and freshwater environments. Our limited understanding of planktonic and benthic calcifiers in the Arctic (*e.g.*, even their baseline geographical distributions) means that future changes are difficult to detect and evaluate. However, due to the bearded seals' apparent dietary flexibility, these threats are of less concern than the direct effects of potential sea ice degradation.

Ocean acidification may also impact bearded seals by affecting the propagation of sound in the marine environment. Researchers have suggested that effects of ocean acidification will cause low-frequency sounds to propagate more than 1.5x as far (Hester et al. 2008, Brewer and Hester 2009), which, while potentially extending the range bearded seals can communicate under quiet conditions, will increase the potential for masking when man-made noise is present.

Harvest. Bearded seals were among those species hunted by early Arctic inhabitants (Krupnik 1984), and today they remain a central nutritional and cultural resource for many northern communities (Hart and Amos 2004, ACIA 2005, Hovelsrud et al. 2008). The solitary nature of bearded seals has made them less suitable for commercial exploitation than many other seal species. Still, within the Beringia DPS they may have been depleted by commercial harvests in the Bering Sea during the mid-20th century.

Alaska Native hunters mostly take bearded seals of the Beringia DPS during their northward migration in the late spring and early summer, using small boats in open leads among ice floes close to shore (Kelly et al. 1988). Allen and Angliss (2014) reported that based on subsistence harvest data maintained by ADFG primarily for the years 1990 to 1998, the mean estimated annual harvest level in Alaska averaged 6,788 bearded seals as of August 2000. Data on community subsistence harvests are no longer being collected and no new annual harvest estimates exist (Allen and Angliss 2014). Cameron *et al.* (2010) noted that ice cover in hunting locations can dramatically affect the availability of bearded seals and the success of hunters in retrieving seals that have been shot, which can range from 50-75% success in the ice (Burns and Frost 1979, Reeves et al. 1992) to as low as 30% in open water (Burns 1967, Smith and Taylor 1977, Riewe and Amsden 1979, Davis and Koski 1980). Using the mean annual harvest reported from 1990-1998, assuming 25 to 50% of seals struck are lost, they estimated the total annual hunt by Alaska Natives would range from 8,485 to 10,182 bearded seals.

Assuming contemporary harvest levels in eastern Siberia are similar to Alaska, as was the pattern in the 1970s and 1980s, and a comparable struck-loss rate of 25-50%, the total annual take from the entire Bering and Chukchi Seas would range from 16,970 to 20,364 bearded seals (Cameron et al. 2010). In the western Canadian Beaufort Sea, bearded seal hunting has historically been secondary to ringed seal harvest, and its importance has declined further in recent times (Cleator 1996). Cameron et al. (2010) concluded that although the current subsistence harvest is substantial in some areas, there is little or no evidence that subsistence harvests have or are likely to pose serious risks to the Beringia DPS (Cameron et al. 2010).

Commercial Fisheries Interactions. Commercial fisheries may impact bearded seals through direct interactions (i.e., incidental take or bycatch) and indirectly through competition for prey resources and other impacts on prey populations. Estimates of bearded seal bycatch could only be found for commercial fisheries that operate in Alaska waters. Between 2007 and 2011, there were incidental serious injuries and mortalities of bearded seals in the Bering Sea/Aleutian Islands Pollock trawl and the Bering Sea/Aleutian Islands flatfish trawl. The estimated minimum mortality rate incidental to commercial fisheries is 1.8 (CV= 0.05) bearded seals per year, based exclusively on observer data (Allen and Angliss 2014). For indirect impacts, Cameron *et al.* (2010) noted that commercial fisheries target a number of known bearded seal prey species, such as walleye pollock (*Theragra chalcogramma*) and cod. Bottom trawl fisheries also have the potential to indirectly affect bearded seals through destruction or modification of benthic prey and/or their habitat.

Shipping. Current shipping activities in the Arctic pose varying levels of threats to bearded seals depending on the type and intensity of the shipping activity and its degree of spatial and temporal overlap with bearded seal habitats. These factors are inherently difficult to know or predict, making threat assessment highly uncertain. Most ships in the Arctic avoid areas of ice. This necessarily mitigates many of the risks of shipping to bearded seals. Icebreakers pose risks to bearded seals because they are capable of operating year-round in all but the heaviest ice conditions and are often used to escort other types of vessels (*e.g.*, tankers and bulk carriers) through ice-covered areas.

Research. Mortalities may occasionally occur incidental to marine mammal research activities authorized under the MMPA permits issued to a variety of government, academic, and other research organizations. Between 2007-2011, there was one mortality resulting from research on the Alaska stock of bearded seals, which results in an average of 0.2 mortalities per year from this stock (Tammy Adams, Permits, and Conservation Division, Office of Protected Resources, pers comm. as cited in (Allen and Angliss 2014).

Contamination. Research on contaminants and bearded seals is limited compared to the extensive information available for ringed seals. Pollutants such as OC compounds and heavy metals have been found in most bearded seal populations. The variety, sources, and transport mechanisms of the contaminants vary across the bearded seal's range, but these compounds appear to be ubiquitous in the Arctic marine food chain. Statistical analysis of OCs in marine mammals has shown that, for most OCs, the European Arctic is more contaminated than the Canadian and U.S. Arctic. Tynan and DeMaster (1997) noted climate change has the potential to increase the transport of pollutants from lower latitudes to the Arctic, highlighting the importance of continued monitoring of bearded seal contaminant levels.

Oil and Gas. Within the range of the Beringia DPS, offshore oil and gas exploration and production activities are underway in the United States, Canada, and Russia. Oil and gas exploration, development, and production activities include: seismic surveys; exploratory, delineation, and production drilling operations; construction of artificial islands, causeways, ice roads, shore-based facilities, and pipelines; and vessel and aircraft operations. These activities have the potential to impact bearded seals, primarily through noise, physical disturbance, and pollution, particularly in the event of a large oil spill.

In the United States, oil and gas activities have been conducted off the coast of Arctic Alaska since the 1970s, with most of the activity occurring in the Beaufort Sea and State waters. Although five exploratory wells have been drilled in the past, no oil fields have been developed or brought into production in the Chukchi Sea to date.

Status

NMFS listed the Beringia DPS of bearded seals as threatened under the ESA on December 28, 2012 (77 FR 76740). On July 25, 2014, the U.S. District Court for the District of Alaska issued a decision, vacating this listing (Alaska Oil and Gas Association v. Pritzker, Case No. 4:13-cv-00018-RPB). NMFS is appealing the decision, and we include the species in this opinion for BOEM and BSEE’s information in the event the listing is reinstated.

The population size of the Beringia DPS is highly uncertain. Ver Hoef et al. (2014) calculated an abundance of 61,800 (95% CI 34,900-171,600) bearded seals in a core area (297,880 km^2) of the central and eastern Bering Sea using survey data collected from helicopters operating off of an ice breaker in 2007. In spring of 2012 and 2013, NOAA researchers, in collaboration with Russian colleagues, conducted aerial abundance and distribution surveys of the entire Bering Sea and Sea of Okhotsk (Moreland et al. 2013). The data from these image-based surveys are still being analyzed, but Conn et al. (2014), using a very limited sub-sample of the data collected from the U.S. portion of the Bering Sea in 2012, calculated an abundance estimate of approximately 299,174 (95% CI 245,476 - 360,544) bearded seals in those waters. These data do not include bearded seals in the Chukchi and Beaufort Seas, and so the estimate may be biased low. The differences in abundance estimates from 2007 (Ver Hoef et al. 2014) and 2012 (Conn et al. 2014) are likely attributable to differences in area sampled and refinement of abundance estimates over time.

Reliable data on the minimum population estimate, trends in population abundance or the maximum net productivity rate of the Alaska stock of bearded seals are unavailable, and the PBR for this stock is unknown (Allen and Angliss 2014).

Feeding and Prey Selection

Bearded seals feed primarily on a variety of invertebrates (crabs, shrimp, clams, worms, and snails) and some fishes found on or near the sea bottom (Burns 1981, Kelly et al. 1988, Reeves et al. 1992, Hjelset et al. 1999, Cameron et al. 2010). They primarily feed on or near the bottom, diving to depths of less than 100 m (though dives of adults have been recorded up to 300 m and young-of-the-year have been recorded diving down to almost 500 m; (Gjertz et al. 2000b). Unlike walrus that root in the soft sediment for benthic organisms, bearded seals are believed to scan the surface of the seafloor with their highly sensitive whiskers, burrowing only in the pursuit of prey (Marshall et al. 2006, Marshall et al. 2008). They are also able to switch their diet to include schooling pelagic fishes when advantageous. Satellite tagging indicates that adults, subadults, and to some extent pups, show some level of fidelity to feeding areas, often remaining in the same general area for weeks or months at a time (Cameron 2005, Cameron and Boveng 2009). Diets may vary with age, location, season, and possible changes in prey availability (Kelly et al. 1988).

Quakenbush *et al.* (2011a) reported that fish consumption appeared to increase between the 1970s and 2000s for Alaska bearded seals sampled in the Bering and Chukchi Seas, although the difference was not statistically significant. Bearded seals also commonly consumed invertebrates, which were found in 95% of the stomachs sampled. In the 2000s, sculpin, cod, and flatfish were the dominant fish taxa consumed (Quakenbush et al. 2011a). The majority of invertebrate prey items identified in the 2000s were mysids, isopods, amphipods, and decapods. Decapods were the most dominant class of invertebrates, and were strongly correlated with the occurrence of shrimp and somewhat correlated with the occurrence of crab. Mollusks were also common prey, occurring in more than half of the stomachs examined.

Diving, Hauling out, and Social Behavior

The diving behavior of adult bearded seals is closely related to their benthic foraging habits and in the few studies conducted so far, dive depths have largely reflected local bathymetry (Gjertz et al. 2000b, Krafft et al. 2000). Studies using depth recording devices have until recently focused on lactating mothers and their pups. These studies showed that mothers in the Svalbard Archipelago make relatively shallow dives, generally <100 m in depth, and for short periods, generally less than 10 min in duration. Nursing mothers dived deeper on average than their pups, but by 6 weeks of age most pups had exceeded the maximum dive depth of lactating females (448-480 m versus 168-472 m) (Gjertz et al. 2000b). Adult females spent most of their dive time (47-92%) performing U-shaped dives, believed to represent bottom feeding (Krafft et al. 2000); U-shaped dives are also common in nursing pups (Lydersen et al. 1994).

There are only a few quantitative studies concerning the activity patterns of bearded seals. Based on limited observations in the southern Kara Sea and Sea of Okhotsk it has been suggested that from late May to July bearded seals haul out more frequently on ice in the afternoon and early evening (Heptner et al. 1976a). From July to April, three males (2 subadults and 1 young adult) tagged as part of a study in the Bering and Chukchi Seas rarely hauled out at all, even when occupying ice covered areas. This is similar to both male and female young-of-year bearded seals instrumented in Kotzebue Sound, Alaska (Frost et al. 2008); suggesting that, at least in the Bering and Chukchi Seas, bearded seals may not require the presence sea ice for a significant part of the year. The timing of haulout was different between the age classes in these two studies however, with more of the younger animals hauling out in the late evening (Frost et al. 2008) while adults favored afternoon.[11]

Other studies using data recorders and telemetry on lactating females and their dependent pups showed that, unlike other large phocid seals, they are highly aquatic during a nursing period of about three weeks (Lydersen and Kovacs 1999). At Svalbard Archipelago, nursing mothers spent more than 90% of their time in the water, split equally between near-surface activity and diving/foraging (Holsvik 1998, Krafft et al. 2000), while dependent pups spent about 50% of their time in the water, split between the surface (30%) and diving (20%) (Lydersen et al. 1994, Lydersen et al. 1996, Watanabe et al. 2009). In addition to acquiring resources for lactation, time spent in the water may function to minimize exposure to surface predators (Lydersen and Kovacs 1999, Krafft et al. 2000). Mothers traveled an average 48 km per day and alternated time in the

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[11] M. Cameron, Unpubl. data, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115, as cited in (Cameron et al. 2010).

water with one to four short bouts on the ice to nurse their pups usually between 0900 h and 2100 h (Krafft et al. 2000). This diurnal pattern also coincides with the timing of underwater mating calls by breeding males (Cleator et al. 1989, Van Parijs et al. 2001). In the spring, adult males are suspected to spend a majority of their time in the water vocalizing and defending territories, though a few observations suggest they are not entirely aquatic and may haul out near females with or without pups (Krylov et al. 1964, Burns 1967, Fedoseev 1971, Finley and Renaud 1980).

The social dynamics of mating in bearded seals are not well known because detailed observations of social interactions are rare, especially underwater where copulations are believed to occur. Theories regarding their mating system have centered around serial monogamy and promiscuity, and more specifically on the nature of competition among breeding males to attract and gain access to females (Stirling et al. 1983, Budelsky 1992, Stirling and Thomas 2003). Whichever mating system is favored, sexual selection driven by female choice is predicted to have strongly influenced the evolution of male displays, and possibly size dimorphism, and caused the distinct geographical vocal repertoires recorded from male bearded seals in the Arctic (Stirling et al. 1983, Atkinson 1997, Risch et al. 2007). Bearded seals are solitary throughout most of the year except for the breeding season.

Vocalization, Hearing, and Sensory

Pinnipeds have a well-developed more conventional vestibular apparatus that likely provides multiple sensory cues similar to those of most land mammals (Southall et al. 2007). Bearded seals are believed to scan the surface of the seafloor with their highly sensitive whiskers, burrowing only in pursuit of prey (Marshall et al. 2006). It is possible that marine mammals may be subject to noise-induced effects on vestibular function as has been shown in land mammals and humans (Southall et al. 2007). Responses to underwater sound exposures in human divers and other immersed land mammals suggest that vestibular effects are produced from intense underwater sound at some lower frequencies (Steevens et al. 1997).

The facial whisker pads of bearded seals have 1,300 nerve endings associated with each whisker, making them among the most sensitive in the animal kingdom (Marshall et al. 2006), as reported in (Burns 2009). Schusterman (1981) speculated sightless seals use sound localization and other non-visual, perhaps tactile, cues to locate food.

Most phocid seals spend greater than 80% of their time submerged in the water (Gordon et al. 2003); consequently, they will be exposed to sounds from seismic surveys that occur in their vicinity. Phocids have good low-frequency hearing; thus, it is expected that they will be more susceptible to masking of biologically significant signals by low frequency sounds, such as those from seismic surveys (Gordon et al. 2003).

Bearded seals vocalize underwater in association with territorial and mating behaviors. The predominant calls produced by males during breeding, termed trills, are described as frequency-modulated vocalizations. Trills show marked individual and geographical variation, are uniquely identifiable over long periods, can propagate up to 30 km, are up to 60 s in duration, and are usually associated with stereotyped dive displays (Cleator et al. 1989, Van Parijs et al. 2001, Van Parijs 2003, Van Parijs et al. 2003, Van Parijs et al. 2004, Van Parijs and Clark 2006).

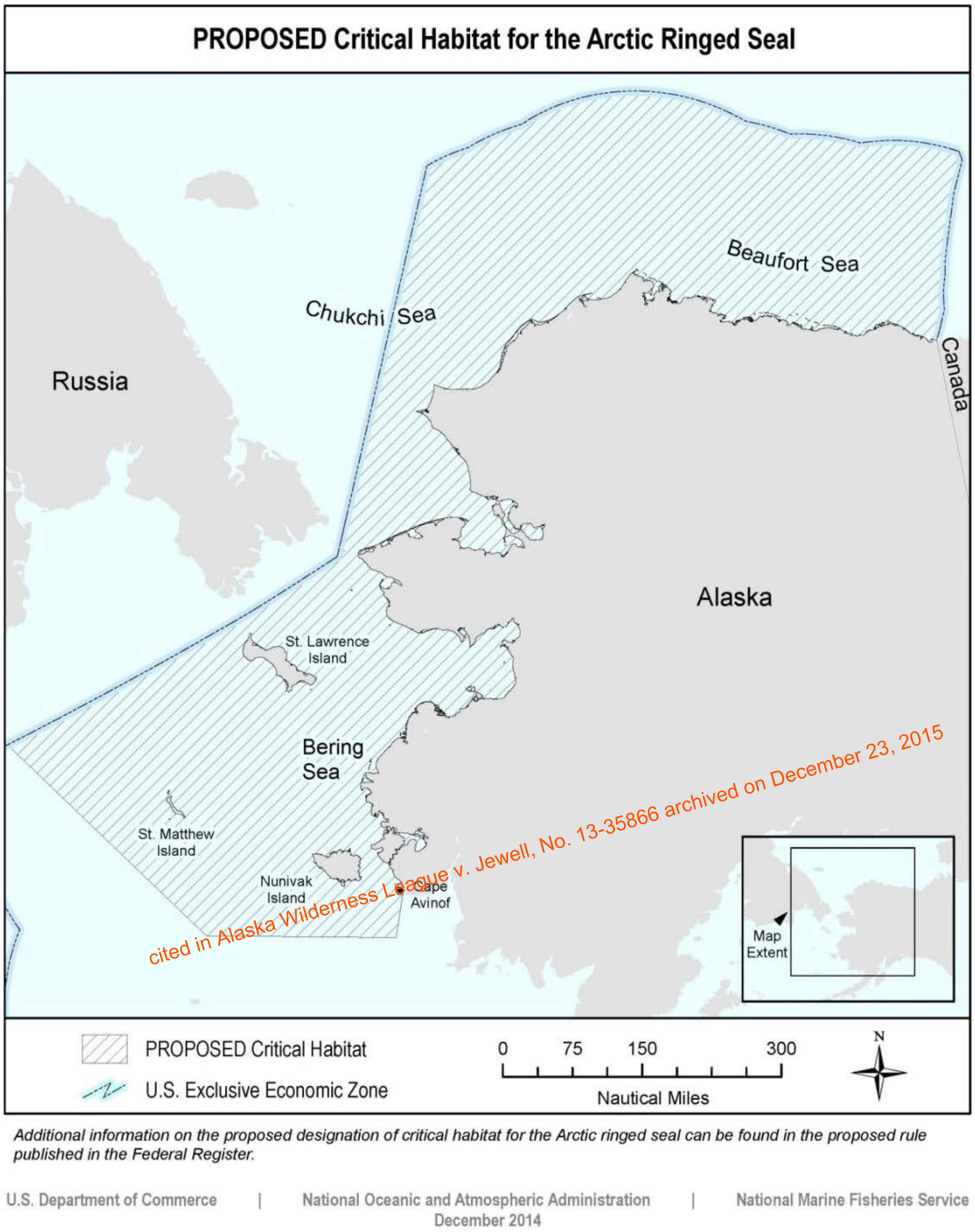
Underwater audiograms for ice seals suggest that they have very little hearing sensitivity below 1 kHz; but hear underwater sounds at frequencies up to 60 kHz; and make calls between 90 Hz and 16 kHz (Richardson et al. 1995). A more recent review suggests that the function hearing range phocids should be considered to be 75 Hz to 100 kHz (Hemila et al. 2006, Kastelein et al. 2009, NOAA 2013).

4.4 Status of Proposed Critical Habitat

The proposed critical habitat for the Arctic subspecies of ringed seal may be impacted by stressors associated with the proposed action.

4.4.1 Proposed Critical Habitat for the Artic Subspecies of Ringed Seal

NMFS proposed to designate critical habitat for the Arctic subspecies of ringed seal on December 9, 2014 (79 FR 73010), based on the location of three features essential to the conservation of the species: sea ice habitat suitable for the formation and maintenance of subnivean birth lairs; sea ice habitat suitable as a platform for basking and molting; and primary prey resources to support Arctic ringed seals. The proposed area encompasses the outer boundary of the EEZ in the Chukchi, Beaufort, and Bering Seas, with a southern boundary north of Bristol Bay. The shoreward boundary is the coastline of Alaska (see Figure 9).



Additional information on the proposed designation of critical habitat for the Arctic ringed seal can be found in the proposed rule published in the Federal Register.

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service
December 2014

Figure 9. Area proposed for designation of critical habitat for the Arctic subspecies of ringed seal (79 FR 73010).

4.4.1.1 Sea Ice Habitat for Subnivian Birth Lairs

NMFS defined sea ice habitat suitable for the formation and maintenace of subnivean birth lairs as (1) seasonal landfast (shorefast) ice, except for any bottom-fast ice extending seaward from the coast line in waters less than 2 m deep, or (2) dense, stable pack ice, that has undergone deformation and contains snowdrifts at least 54 cm deep. This is an essential feature because without the protection of lairs, ringed seal pups are more vulnerable to freezing and to predation. Ringed seals use subnivian lairs for sheltering pups during whelping and nursing.

Arctic ringed seals appear to favor landfast ice as whelping habitat. However, during winter, landfast ice in very shallow water generally freezes to the sea bottom and is unsuitable for lairs. Therefore, only landfast ice extending seaward from the coast line in waters at least 2 m deep is essential to the conservation of the ringed seal. Whelping has also been observed on both nearshore and offshore drifting pack ice.

Snowdrifts of sufficient depth for birth lair formation and maintenance typically occur in deformed ice along pressure ridges or ice hummocks (Smith and Stirling 1975, Lydersen and Gjertz 1986, Kelly 1988, Furgal et al. 1996, Lydersen 1998). NMFS identified 54 cm as the minimum snowdrift depth because this was the average minimum depth reported in several studies of ringed seal lairs.

4.4.1.2 Sea Ice Habitat as a Platform for Basking and Molting

NMFS defined sea ice habitat suitable as a platform for basking and molting, as sea ice of 15 percent or more concentration, except for any bottom-fast ice extending seaward from the coast line in waters less than 2 m deep. During their annual molt (May-July), Arctic ringed seals spend long periods of time basking on the survface of the ice near breathing holes. This feature is essential because molting is a biologically important, energy intensive process that could incur increased energetic costs if it were to occur in water (which has never been witnessed to date), or increased predation risk if it were to occur on land (which has not been witnessed by a healthy seal). If Arctic ringed seals are unable to complete their annual molt, they would be at increased risk from parasites and disease.

4.4.1.3 Primary Prey Resources

Primary prey resources for Arctic ringed seals are defined as Arctic cod, saffron cod, shrimp and amphipods. These prey resources are essential to conserving the Arctic ringed seal because they occupy a prominent role in ringed seal diets in waters along the Alaskan coast and are relied on the most to meet ringed seal annual energy budgets (Quakenbush et al. 2011b). Arctic ringed seals feed on other vertebrates and invertebrates, but to a much lesser extent.

4.4.2 Threats to Essential Features of Critical Habitat

The proposed rule for ringed seal critical habitat identified several categories of human activities and associated threats that could affect the features identified as essential to conservation of the species (79 FR 73010). These include: greenhouse gas emissions; oil and gas exploration, development, and production; shipping and transportation; and commercial fishing. With the exception of commercial fishing, which would only affect primary prey resources, all of the activities could potentially affect all three of the essential features.

5. ENVIRONMENTAL BASELINE

The “environmental baseline” includes the past and present impacts of all federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

A number of human activities have contributed to the current status of populations of large whales and seals in the action area. Some of those activities, most notably commercial whaling, occurred extensively in the past, and no longer appear to affect these whale populations, although the effects of these reductions likely persist today. Other human activities are ongoing and may continue to affect populations of endangered whales and threatened ice seals.

5.1 Stressors for Species in the Action Area

The following discussion summarizes the principal stressors that affect these endangered and threatened species.

5.1.1 Targeted Hunts

Whaling in the Alaskan Arctic and sub-arctic has taken place for at least 2,000 years. Stoker and Krupnik (1993) documented prehistoric hunts of bowhead whales by indigenous peoples of the arctic and subarctic regions. Alaska Natives continue this tradition of subsistence whaling as they conduct yearly hunts for bowhead whales. In addition to subsistence hunting, commercial whaling occurred during the late 19th and early 20th centuries.

Historical Commercial Harvest

Bowhead Whale

Pelagic commercial whaling for the Western Arctic stock of bowheads was conducted from 1849 to 1914 in the Bering, Chukchi, and Beaufort Seas (Bockstoce et al. 2005). Woodby and Botkin (1993) estimated that the historic abundance of bowhead whales in this population was between 10,400 and 23,000 whales before commercial whaling began in 1848. Within the first two decades (1850-1870), over 60% of the estimated pre-whaling abundance was harvested, although effort remained high into the 20th century (Braham 1984). It is estimated that the pelagic whaling industry harvested 18,684 whales from this stock (Woodby and Botkin 1993). During 1848-1919, shore-based whaling operations (including landings as well as struck and lost estimates from U. S., Canada, and Russia) took an additional 1,527 animals (Woodby and Botkin 1993). An unknown percentage of the animals taken by the shore-based operations were harvested for subsistence and not commercial purposes. Estimates of mortality likely underestimate the actual harvest as a result of under-reporting of the Soviet catches (Yablokov 1994) and incomplete reporting of struck and lost animals. Commercial whaling also may have caused the extinction of some subpopulations and some temporary changes in distribution.

Fin Whale

Between 1911 and 1985, 49,936 fin whales were reported killed throughout the North Pacific (Mizroch et al. 2009), although newly revealed information about illegal Soviet catches indicates that the Soviets over-reported catches of about 1,200 fin whales, presumably to hide catches of other protected species (Doroshenko 2000).

Humpback Whale

Rice (1978b) estimated that the number of humpback whales in the North Pacific may have been approximately 15,000 individuals prior to exploitation; however, this was based upon incomplete data and, given the level of known catches (legal and illegal) since World War II, may be an underestimate. Intensive commercial whaling removed more than 28,000 animals from the North Pacific during the 20th century (Rice 1978b). A total of 3,277 reported catches occurred in Asia between 1910 and 1964, with 817 catches from Ogasawara between 1924 and 1944 (Nishiwaki 1966, Rice 1978a). After World War II, substantial catches occurred in Asia near Okinawa (including 970 between 1958 and 1961), as well as around the main islands of Japan and the Ogaswara Islands. On the feeding grounds, substantial catches occurred around the Commander Islands and western Aleutian Islands, as well as in the Gulf of Anadyr (Springer et al. 2006).

Humpback whales in the North Pacific were theoretically fully protected in 1965, but illegal catches by the USSR continued until 1972 (Ivashchenko et al. 2007). From 1961 to 1971, over 6,793 humpback whales were killed illegally by the USSR. Many animals during this period were taken from the Gulf of Alaska and Bering Sea (Doroshenko 2000); however, additional illegal catches were made across the North Pacific, from the Kuril Islands to the Queen Charlotte Islands, and other takes in earlier years may have gone unrecorded.

Ringed and Bearded Seals

While substantial commercial harvest of both ringed and bearded seals in the late 19th and 20th Centuries led to local depletions, commercial harvesting of ice seals has been prohibited in U.S. waters since 1972 by the MMPA. Since that time, the only harvest of ringed and bearded seals allowed in U.S. waters is for subsistence for Alaska Native communities.

<u>Subsistence Harvest</u>

Bowhead Whale

Alaska Natives have been taking bowhead whales for subsistence purposes for at least 2,000 years (Marquette and Bockstoce. 1980, Stoker and Krupnik 1993). Subsistence takes have been regulated by a quota system under the authority of the IWC since 1977. This harvest represents the largest known human-related cause of mortality in the Western Arctic stock. Alaska Native subsistence hunters take approximately 0.1-0.5% of the population per annum, primarily from eleven Alaska communities (Philo et al. 1993). Under this quota, the number of kills has ranged between 14 and 72 per year, the number depending in part on changes in management strategy and in part on higher abundance estimates in recent years (Stoker and Krupnik 1993). Suydam and George (2011) summarized Alaskan subsistence harvests of bowheads from 1974 to 2011 reporting a total of 1,149 whales landed by hunters from 12 villages with Barrow landing the most whales (n = 590) while Shaktoolik each landed only one. Alaska Natives landed 37 bowheads in 2004 (Suydam et al. 2005, 2006), 55 in 2005 (Suydam et al. 2006), 31 in 2006 (Suydam et al. 2007), 41 in 2007 (Suydam et al. 2008), and 38 in 2008 (Suydam et al. 2009), 31 in 2009 (Suydam et al. 2010), 45 in 2010 (Suydam et al. 2011), and 38 in 2011 (Suydam et al. 2012). The number of whales landed at each village varies greatly from year to year, as success is influenced by village size and ice and weather conditions. The efficiency of the hunt (the percent of whales struck that are retrieved) has increased since the implementation of the bowhead quota in 1978. In 1978 the efficiency was about 50%, the mean for 2000-2009 was 77% (SD=7%), and in 2010 it was 63% (Suydam et al. 2011), and in 2011 it was 76% (Suydam et al. 2012).

For 2013-2018, the IWC established a block quota of 306 landed bowheads. Because some animals are struck and lost, a strike limit of 67 plus up to 15 previously unused strikes could be taken each year (Allen and Angliss 2014). This quota includes an allowance of 5 animals to be taken by Chukotka Natives in Russia.

Ringed Seal

Ringed seals are an important species for Alaska Native subsistence hunters. The estimated annual subsistence harvest in Alaska dropped from 7,000 - 15,000 in the period from 1962 to 1972 to an estimated 2,000 - 3,000 in 1979 (Frost 1985). Based on data from two villages on St. Lawrence Island, the annual take in Alaska during the mid-1980s likely exceeded 3,000 seals (Kelly et al. 1988).

The number of seals taken annually varies considerably between years due to ice and wind conditions, which impact hunter access to seals. As of August 2000; the subsistence harvest database indicated that the estimated number of ringed seals harvested for subsistence use per year was 9,567. Data on community subsistence harvests are no longer being collected and no new annual harvest estimates exist (Allen and Angliss 2014). Kelly et al. (2010b) concluded that although subsistence harvest of Arctic ringed seals is currently substantial in some parts of their range, harvest levels appear to be sustainable.

Bearded Seal

Bearded seals are an important species for Alaska subsistence hunters, with estimated annual harvests of 1,784 (SD = 941) from 1966 to 1977 (Burns 1981). Between August 1985 and June 1986, 791 bearded seals were harvested in five villages in the Bering Strait region based on reports from the Alaska Eskimo Walrus Commission (Kelly et al. 1988). Five Alaska Native communities in the Northwest Arctic region of Alaska voluntarily reported a total of 258 bearded seals were harvested during 2012 (Ice Seal Committee 2013).

Information on subsistence harvest of bearded seals was compiled for 129 villages from reports from the Division of Subsistence (Coffing et al. 1998, Georgette et al. 1998, Wolfe and Hutchinson-Scarbrough 1999) and a report from the Eskimo Walrus Commission (Sherrod 1982). Data were lacking for 22 villages; their harvests were estimated using the annual per capita rates of subsistence harvest from a nearby village. Harvest levels were estimated from data gathered in the 1980s for 16 villages; otherwise, data gathered from 1990 to 1998 were used. As of August 2000 the subsistence harvest database indicated that the estimated number of bearded seals harvested for subsistence use per year is 6,788 (Allen and Angliss 2014).

Cameron et al. (2010) noted that ice cover in hunting locations can dramatically affect the availability of bearded seals and the success of hunters in retrieving seals that have been shot, which can range from 50-75% success in the ice (Burns and Frost 1979, Reeves et al. 1992), to as low as 30% in open water (Burns 1967, Smith and Taylor 1977, Riewe and Amsden 1979, Davis and Koski 1980). Using the mean annual harvest reported from 1990-1998, assuming 25 to 50% of seals struck are lost, they estimated the total annual hunt by Alaska Natives would range from 8,485 to 10,182 bearded seals (Cameron et al. 2010).

At this time, there are no efforts to quantify the current level of harvest of bearded seals by all Alaska communities (Allen and Angliss 2014).

5.1.2 Acoustic Noise

Ambient Noise. Generally, a signal would be detectable only if it is stronger than the ambient noise at similar frequencies. The lower the intensity of ambient noise, the farther signals would travel. There are many sources of ambient noise in the ocean, including wind, waves, ice, rain, and hail; sounds produced by living organisms; noise from volcanic and tectonic activity; and thermal noise that results from molecular agitation (which is important at frequencies greater than 30 kHz). We discuss two general categories of ambient noise: (1) variability in environmental conditions (i.e. sea ice, temperature, wind, etc.); and (2) the presence of marine life.

Environmental Conditions. The presence of ice can contribute substantially to ambient sound levels and affects sound propagation. While sea ice can produce substantial amounts of ambient sounds, it also can also function to dampen ambient sound. As ice forms, especially in very shallow water, the sound propagation properties of the underlying water are affected in a way that can reduce the transmission efficiency of low frequency sound (Blackwell and Greene 2001). Temperature affects the mechanical properties of the ice, and temperature changes can result in cracking. The spectrum of cracking ice sounds typically displays a broad range from 100 Hz to 1 kHz, and the spectrum level has been observed to vary as much as 15 dB within 24 hours due to the diurnal change of air temperature (BOEM 2011). Urick (1984) discussed variability of ambient noise in water including under Arctic ice; he states that "…the ambient background depends upon the nature of ice, whether continuous, broken, moving or shore-fast, the temperature of air, and the speed of the wind." Data are limited, but in at least one instance it has been shown that ice-deformation sounds produced frequencies of 4-200 Hz (Greene 1981). As icebergs melt, they produce additional background sound as the icebergs tumble and collide.

During the open-water season in the Arctic, wind and waves are important sources of ambient sound with levels tending to increase with increased wind and sea state, all other factors being equal (Greene and Moore 1995). Wind, wave, and precipitation noise originating close to the point of measurement dominate frequencies from 500 to 50,000 Hz. The marginal ice zone, the area near the edge of large sheets of ice, usually is characterized by quite high levels of ambient sound compared to other areas, in large part due to the impact of waves against the ices edge and the breaking up and rafting of ice floes (Milne and Ganton 1964).

Year-round recordings of background ambient sound levels collected through the CSESP from 2006 to 2013 confirm that the background ambient levels are well below the levels that might affect the acoustic effects zones modeled in this analysis. The CSESP data showed seasonal variation in ambient sound levels, but minimal spatial variability across the LS 193 area. Additionally, long-term data from one recorder that was in the center of the Chukchi Sea revealed little inter-annual variation (mean broadband level: 99.7 dB re 1µPa; standard deviation: 1 dB). This supports the conclusion from the multi-station analysis that there is a significant difference between seasonal ambient levels (median broadband levels: 104.6 dB re 1 µPa and 94.5 dB re 1µPa for summer and winter, respectively)(Austin et al. 2015).

Presence of Marine Life. At least seasonally, marine mammals can contribute to the background sounds in the acoustic environment of the Beaufort Sea. Frequencies and levels are highly dependent on seasons. For example, source levels of bearded seal songs have been estimated to be up to 178 dB re 1 µPa at 1 m (Ray et al. 1969b, Stirling 1983, Richardson et al. 1995, Thomson and Richardson 1995). Ringed seal calls have a source level of 95-130 dB re 1 µPa at 1 m, with the dominant frequency under 5 kHz (Stirling 1973, Cummings et al. 1986, Thomson and Richardson 1995). Bowhead whales, which are present in the Arctic region from early spring to mid- to late fall, produce sounds with estimated source levels ranging from 128-189 dB re 1 µPa at 1 m in frequency ranges from 20-3,500 Hz. Thomson and Richardson (1995) summarized that most bowhead whale calls are "tonal frequency-modulated" sounds at 50-400 Hz. There are many other species of marine mammals in the arctic marine environment whose vocalizations contribute to ambient sound.

Anthropogenic Noise. Levels of anthropogenic (human-caused) sound can vary dramatically depending on the season, type of activity, and local conditions. These noise sources include transportation, dredging, and construction; oil, gas, and mineral exploration in offshore areas; geophysical (seismic) surveys; sonars; explosions; and ocean research activities (Richardson et al. 1995).

Several investigators have argued that anthropogenic sources of noise have increased ambient noise levels in the ocean over the last 50 years (NRC 1994, Richardson et al. 1995, NRC 1996, NRC 2000, NRC 2003, Jasny et al. 2005, NRC 2005). As discussed in the preceding section, much of this increase is due to increased shipping as ships become more numerous and of larger tonnage (NRC 2003).

Sounds from Vessels. Commercial shipping traffic is a major source of low frequency (5 to 500 Hz) human generated sound in the oceans (NRC 2003, Simmonds and Hutchinson 1996).

The types of vessels in the Chukchi Sea typically include barges, skiffs with outboard motors, icebreakers, tourism and scientific research vessels, and vessels associated with oil and gas exploration, development, and production. In the Chukchi Sea, vessel traffic and associated noise presently is limited primarily to late spring, summer, and early autumn.

Shipping sounds are often at source levels of 150-190 dB re 1 μPa at 1m (BOEM 2011). Shipping traffic is mostly at frequencies from 20-300 Hz (Greene and Moore 1995). Sound produced by smaller boats typically is at a higher frequency, around 300 Hz (Greene and Moore 1995). In shallow water, vessels more than 10 km (6.2 mi) away from a receiver generally contribute only to background-sound levels (Greene and Moore 1995). Icebreaking vessels used in the Arctic for activities including research and oil and gas activities produce louder, but also more variable, sounds than those associated with other vessels of similar power and size (Greene and Moore 1995). The greatest sound generated during ice-breaking operations is produced by cavitations of the propeller as opposed to the engines or the ice on the hull; extremely variable increases in broad-band (10 Hz-3 kHz) noise levels of 5-10 dB are caused by propeller cavitation (Greene and Moore 1995, Austin et al. 2015). Broadband source levels for icebreaking operations are anticipated to be ~198 dB re 1 μPa at 1m (Austin et al. 2015). Icebreaking activities are anticipated to be the loudest noise sources associated with the proposed action and noise may reach the 120 dB re 1 μPa rms isopleth at 45 km (Austin et al. 2015).

Sound from Oil and Gas Activities. Anthropogenic noise levels in the Beaufort Sea are higher than the Chukchi Sea due to the oil and gas developments of the nearshore and onshore regions of the North Slope, particularly in the vicinity of Prudhoe Bay. Sound from oil and gas exploration and development activities include seismic surveys, drilling, and production activities.

The oil and gas industry in Alaska conducts marine (open-water) surveys in the summer and fall, and in-ice seismic surveys in the fall and winter to locate geological structures potentially capable of containing petroleum accumulations and to better characterize ocean substrates or subsea terrain. The OCS leaseholders also conduct low-energy, high-resolution geophysical surveys to evaluate geohazards, biological communities, and archaeological resources on their leases.

2D seismic surveys have been conducted in the Chukchi Sea and Beaufort Sea since the late 1960s and early 1970s, resulting in extensive coverage over the area. Seismic surveys vary, but a typical 2D/3D seismic survey with multiple guns would emit sound at frequencies at about 10 Hz-3 kHz (Austin et al. 2015). Seismic airgun sound waves are directed towards the ocean bottom, but can propagate horizontally for several kilometers (Greene and Richardson 1988, Greene and Moore 1995). Analysis of sound associated with seismic operations in the Beaufort Sea and central Arctic Ocean during ice-free conditions also documented propagation distances up to 1300 km (Richardson 1998, 1999, Thode et al. 2010). Because the Chukchi Sea continental shelf has a highly uniform depth of 30-50m, it strongly supports sound propagation in the 50-500 Hz frequency band (Funk et al. 2008). This is of particular interest because most of the industrial sounds from large vessels, seismic sources, and drilling are in this band and this likely overlaps with the greatest hearing sensitivity of listed cetacean species under consideration in this opinion.

NMFS issued an IHA to Conoco Phillips Alaska to take 8 species of marine mammals by Level B behavioral harassment incidental to conducting geophysical surveys in the Chukchi Sea on May 23, 2008 (73 FR 30064). From 2008-2010, NMFS issued Shell three IHAs to take a small number of marine mammals incidental to marine seismic, shallow hazard, and sites clearance survey activities in the Chukchi and Beaufort Seas (73 FR 66106, 74 FR 55368, and 75 FR 27708). In 2010 and 2011, NMFS issued Statoil two IHAs to take small numbers of marine mammals by harassment incidental to marine seismic and shallow hazard surveys in the Chukchi Sea (75 FR 32379, 76 FR 30110). In 2012, NMFS issued an IHA to Shell and ION Geophysical to take small numbers of marine mammals by harassment incidental to conducting an exploratory drilling program in the Chukchi Sea (77 FR 27322), and in-ice 2D seismic surveys in the Beaufort and Chukchi Seas (77 FR 65060; October 24, 2012) respectively.

The Arctic Regional Biological Opinion (ARBO) issued in 2013, was a programmatic incremental step consultation with BOEM/BSEE that covered oil and gas leasing and exploration activities in the Beaufort and Chukchi Sea Planning Areas over a 14-year period. The scope of ARBO was much larger than the LS 193 opinion. ARBO covered all of the activities described under LS 193, but also covered *off-lease* deep penetration marine seismic and geohazard surveys in the Chukchi Sea as well as leasing and exploration activities in the Beaufort Sea Planning Area. Following changes to their assumptions regarding the amount of recoverable oil from LS 193, BOEM/BSEE requested consultation covering *on-lease* exploration activities associated with that sale because they anticipate that the majority of the larger deep penetration marine seismic surveys would have been conducted by applicants prior to purchasing a lease, and these *off-lease* activities were already been analyzed under ARBO (BOEM 2015c).

Under ARBO (NMFS 2013a), annual takes by harassment associated with marine seismic and geohazard surveys in the Chukchi Sea is anticipated to be (124) bowhead whales, (64) fin whales, (64) humpback whales, (2,152) ringed seals, and (4,320) bearded seals.

In 2013, NMFS issued an IHA to Shell and TGS to take small numbers of marine mammals by harassment incidental to site clearance and shallow hazard surveys and equipment recovery and maintenance activities in the Chukchi Sea (78 FR 47495), and marine seismic surveys in the Chukchi (78 FR 51147) respectively. The site specific consultations that were done for these IHAs fall under the umbrella of the take issued by ARBO.

Available information does not indicate that marine and seismic surveys for oil and gas exploration activities have had detectable long-term adverse population-level effects on the overall health, current status, or recovery of marine mammals in the Arctic region. For example, data indicate that the bowhead whale population has continued to increase over the timeframe that oil and gas activities have occurred. There is no evidence of long-term displacement from habitat (although studies have not specifically focused on addressing this issue). Past behavioral (primarily avoidance) effects on bowhead whales from oil and gas activity have been documented in many studies. Inupiat whalers have stated that noise from seismic surveys and some other activities at least temporarily displaces whales farther offshore, especially if the operations are conducted in the main migration corridor. Monitoring studies indicate that most fall migrating whales avoid an area with a radius about 20 - 30 km around a seismic vessel operating in nearshore waters (Miller et al. 2005). NMFS is not aware of data that indicate that such avoidance is long-lasting after cessation of the activity (NMFS 2013b).

During the 2012 exploration drilling activities, measurements of sounds produced by the drillship *Discoverer* were made on the Burger prospect in the Chukchi Sea. Broadband source levels of the *Discoverer* ranged from 177 to 185 dB re 1 µPa rms (Austin M. and Warner 2010). Most of the acoustic energy was contained in the 100-1000 Hz and 1-10 kHz frequency bands, both of which typically were at levels just below 120 dB re 1 µPa rms. When no other vessels were present near the *Discoverer* and drilling was occurring, broadband sound levels fell below 120 dB re 1 µPa rms at 1.5 km (Austin et al. 2013).

The modeled sound-level radii from the *Northern Explorer II,* indicate that the sound would not exceed the 180 dB. The ≥160-dB radius for the drillship was modeled to be 172 ft (52.5 m); the ≥120-dB radius was modeled to be 4.6 mi (7.4 km). Data from the floating platform *Kulluk* in Camden Bay, indicated broadband source levels (20-10,000 Hz) during drilling were estimated to be 191 and 179 dB re µPa at 1 m, respectively, based on measurements at a water depth of 20 m in water about 30 m deep (Greene and Moore 1995). Measured sound levels for the semisubmersible *Polar Pioneer* while drilling were not available, however, JASCO estimated the ≥ 120 dB re 1 µPa sound footprint with a Marine Operations Noise Model. An average source level for the *Polar Pioneer* was derived from a number of acoustic measurements of comparable semi-submersible drill units. The model yielded a propagation rage of 350 m for rms sound pressure level of 120 dB re 1 µPa for the *Polar Pioneer* while drilling on the Burger prospect (Shell 2015).

Measured distance to the 120 dB re 1 µPa threshold of the *Nordica* in dynamic positioning at the Burger prospect when in broadside to the line of recorders was 4.5 km (JASCO Applied Sciences 2013). The noise from mudline cellar construction from the *Discoverer* in the Chukchi Sea in 2012 was calculated to diminish below the 120 dB re 1 µPa rms threshold at 8.2 km from the drill site (JASCO Applied Sciences 2013). Distance to the 120 dB re 1 µPa rms during anchor handling by the *Tor Viking* was estimated to be 14 km during Shell's exploration drilling program at Burger (JASCO Applied Sciences 2013). Sounds produced by vessels managing the ice were recorded and the distance to the 120 dB re 1 µPa rms isopleth was calculated to occur at 9.6 km (JASCO Applied Sciences 2013).

The level and duration of sound received underwater from aircraft depends on altitude and water depth. Received sound level decreases with increasing altitude. For a helicopter operating at an altitude of 1,000 ft (305 m), there were no measured sound levels at a water depth of 121 ft (37 m) (Greene 1985).

Miscellaneous Sound Sources. Other acoustic systems that may be used in the Arctic by researchers, military personnel, or commercial vessel operators include high-resolution geophysical equipment, acoustic Doppler current profilers, mid-frequency sonar systems, and navigational acoustic pingers (LGL 2005, 2006). These active sonar systems emit transient sounds that vary widely in intensity and frequency (BOEM 2011).

5.1.3 Vessel Interactions

The general Arctic maritime season lasts only from June through October, and unaided navigation occurs within a more limited time frame. However, this pattern appears to be rapidly changing, as ice-diminished conditions become more extensive during the summer months. Between 2008 and 2012, vessel activity in the U.S. Arctic went from 120 vessels to 250, an increase of 108 percent (ICCT 2015). This includes only the northern Bering Sea, the Bering

Strait, Chukchi Sea and Beaufort Sea to the Canadian border. The increase in vessel traffic on the outer continental shelf of the Chukchi Sea and the near-shore Prudhoe Bay from oil and gas exploration activity is particularly pronounced (ICCT 2015).

On September 16, 2012, Arctic sea ice reached its lowest coverage extent ever recorded (Biello 2012), paving the way for the longest Arctic navigation season on record. To better understand vessel distribution and density as activity increases, satellite automatic identification system (AIS) data were analyzed for the U.S Arctic above the Aleutian Islands. Vessel projects for the Arctic assume: 1) there will not be a U.S. Arctic deep-water port available in the next decade; 2) no increase in military presence or Coast Guard assets to the region, and 3) number of research vessels, cruise ships and adventure tourism will remain consistent with 2013 levels.

A direct comparison was made of July through November vessel locations for 2011 and 2012. The most apparent pattern between years is the shift from coastal traffic to more offshore traffic. During this time, Shell was involved in offshore drilling, and much of this shift could be attributable to offshore supply and support for oil and gas exploration and drilling on the outer continental shelf of the Chukchi Sea (ICCT 2015). For years when offshore drilling activities are assumed, 2012 serves as an appropriate reference to highlight areas of relative increased activity (ICCT 2015).

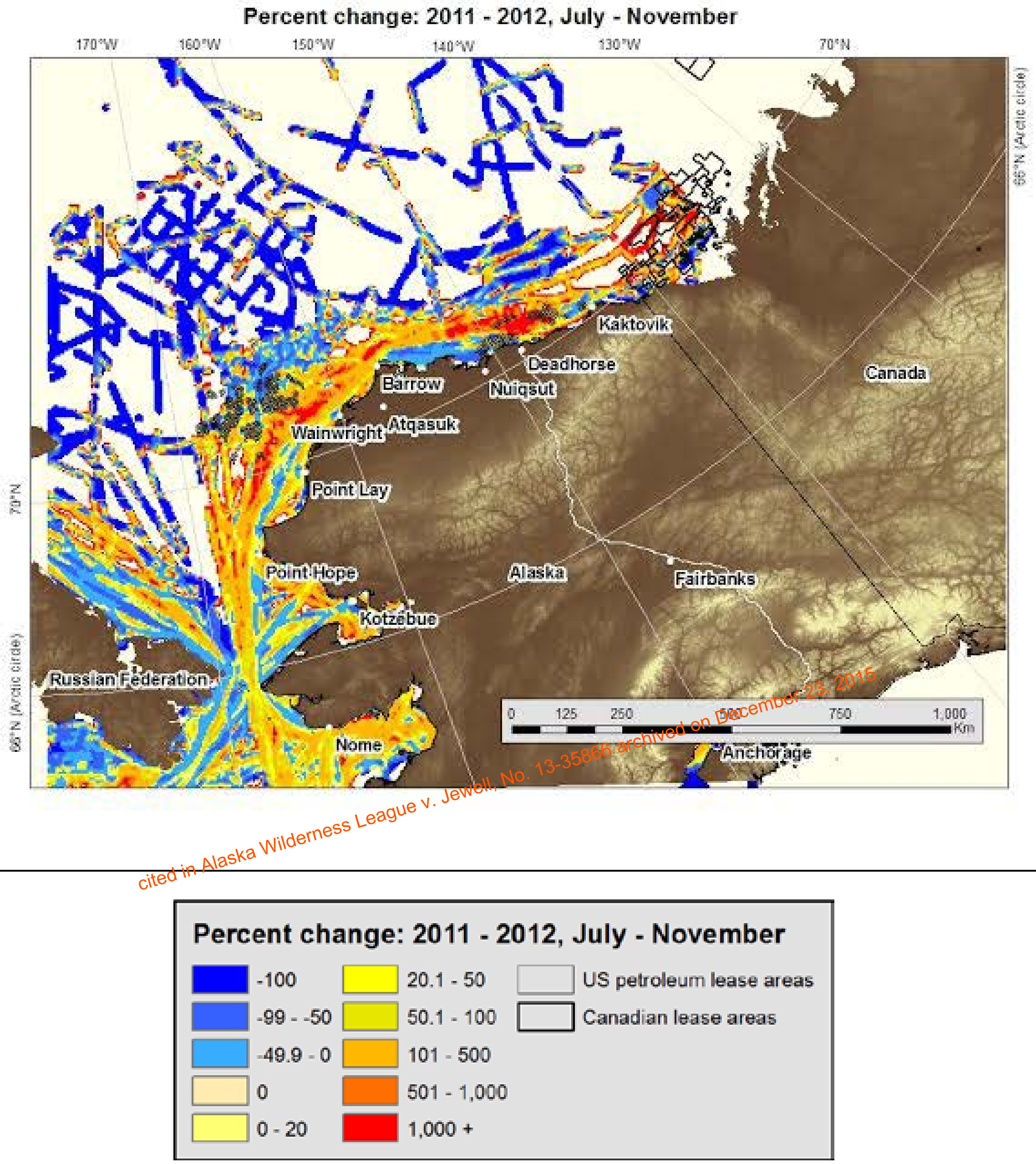


Figure 10. **Percent difference in vessel activity from 2011 to 2012 using 5 km grid cells (ICCT 2015).**

Vessel traffic can pose a threat to marine mammals because of the risk of ship strikes and the disturbance associated with noise from the vessel. Although there is no official reporting system for ship strikes, numerous incidents of vessel collisions with marine mammals have been documented in Alaska (NMFS 2010c). Records of vessel collisions with large whales in Alaska indicate that strikes have involved cruise ships, recreational cruisers, whale watching catamarans, fishing vessels, and skiffs.

The frequency of observations of vessel-inflicted injuries suggests that the incidence of ship collisions with bowhead whales is low. Between 1976 and 1992, only two ship-strike injuries were documented out of a total of 236 bowhead whales examined from the Alaskan subsistence harvest (George et al. 1994). The low number of observations of ship-strike injuries (along with the very long lifespan of these animals) suggests that bowhead whales either do not often encounter vessels or they avoid interactions with vessels.

Two ship strike mortalities of fin whales occurred in Alaska waters between 2007-2011, and have been reported in the Alaska Region stranding database (Allen et al. 2014), resulting in a mean annual mortality rate of 0.4 fin whales.

In addition, the mean annual mortality rate for humpback whales in Alaska waters between 2007-2011 reported to the Alaska Region stranding database was 1.16 (Allen et al. 2014) (see Table 8).

Current shipping activities in the Arctic pose varying levels of threats to ice seals depending on the type and intensity of the shipping activity and its degree of spatial and temporal overlap with ice seal habitats. The presence and movements of ships in the vicinity of some seals can affect their normal behavior (Jansen et al. 2010) and may cause ringed seals to abandon their preferred breeding habitats in areas with high traffic (Smiley and Milne 1979, Mansfield 1983b). To date, no bearded or ringed seal carcasses have been found with propeller marks. However, Sternfield (2004) documented a singled spotted seal stranding in Bristol Bay, Alaska that may have resulted from a propeller strike. Icebreakers pose special risks to ice seals because they are capable of operating year-round in all but the heaviest ice conditions and are often used to escort other types of vessels (*e.g.,* tankers and bulk carriers) through ice-covered areas. Reeves (1998b) noted that some ringed seals have been killed by ice-breakers moving through fast-ice breeding areas.

5.1.4 Commercial Fishing Interactions

While currently no commercial fishing is authorized in the Chukchi Sea OCS, the species present in the action area may be impacted by commercial fishing interactions as they migrate through the Bering Sea to the Chukchi Sea.

Bowhead Whale

Several cases of rope or net entanglement have been reported from bowhead whales taken in the subsistence hunt (Philo et al. 1993). Further, preliminary counts of similar observations based on reexamination of bowhead harvest records indicate entanglements or scarring attributed to ropes may include over 20 cases (Craig George, Department of Wildlife Management, North Slope Borough, pers. comm., as cited in Allen and Angliss 2014).

There are no observer program records of bowhead whale mortality incidental to commercial fisheries in Alaska. However, some bowhead whales have historically had interactions with crab pot gear. There are several documented cases of bowheads having ropes or rope scars on them. In 2003 a bowhead whale was found dead in Bristol Bay entangled in line around the peduncle and both flippers; the origin of the line is unknown. In 2004 a bowhead whale near Point Barrow was observed with fishing net and line around the head. One dead whale was found floating in

Kotzebue Sound in early July 2010 entangled in crab pot gear similar to that used by commercial crabbers in the Bering Sea (Suydam et al. 2011). During the 2011 spring aerial photographic survey of bowhead whales near Point Barrow, one entangled bowhead was photographed (Mocklin et al. 2012). The minimum average annual entanglement rate in U.S. commercial fisheries for the 5-year period from 2007-2011 is 0.4 (Allen and Angliss 2014). However, the overall rate is currently unknown.

Fin Whale

Between 2007 and 2011, there were no observed incidental mortalities of fin whales in any Alaska commercial fisheries (Breiwick 2013).

Humpback whale

Until 2004, there were six different federally-regulated commercial fisheries in Alaska that occurred within the range of the Western North Pacific (WNP) humpback whale stock that were monitored for incidental mortality by fishery observers (Allen and Angliss 2014). As of 2004, changes in fishery definitions in the List of Fisheries have resulted in separating these 6 fisheries into 22 fisheries (69 FR 70094, December 2, 2004). This change does not represent a change in fishing effort, but provides managers with better information on the component of each fishery that is responsible for the incidental serious injury or mortality of marine mammal stocks in Alaska. Between 2007 and 2011, there were two incidental mortalities of humpbacks due to fisheries in Alaska. Since all events occurred within the area of known overlap with WNP and CNP whale stocks, the stock identification is unknown. One mortality occurred in the Bering Sea/Aleutian Islands (BSAI) pollock trawl fishery, and one mortality in the BSAI flatfish trawl (see Table 7) (Allen and Angliss 2014). Average minimum annual mortality from observed fisheries was 0.40 humpbacks from both stocks (Allen and Angliss 2014).

Table 7. **Summary of incidental serious injury and mortality of humpback whales (Western and Central North Pacific stocks) due to commercial fisheries from 2007-2011 and calculation of the mean annual mortality rate (Breiwick 2013). All events occurred within the area of known overlap with the western and central North Pacific humpback whale stocks. Details of how percent observer coverage is measured is included in (Allen and Angliss 2014).**

Fishery name	Years	Data type	Observer coverage	Observed mortality (in given yrs.)	Estimated mortality (in given yrs.)	Mean annual mortality
BSAI flatfish trawl	2007	obs data	72	0	0	0.20 (CV = N/A)
	2008		100	0	0	
	2009		100	0	0	
	2010		100	0(+1)*	0(1)**	
	2011		100	0	0	
BSAI pollock trawl	2007	obs data	85	0	0	0.20 (CV = 0.08)
	2008		85	0	0	
	2009		86	0	0	
	2010		86	1	1.0	
	2011		98	0	0	
Minimum total annual mortality						0.40 (CV = 0.08)

Strandings of humpback whales entangled in fishing gear or with injuries caused by interactions with gear are another source of mortality data. While few stranding reports are received from areas west of Kodiak, we have provided the mean annual human-caused mortality and serious injury rate for 2007-2011 based on fishery and gear entanglements reported in the NMFS Alaska Regional Office stranding database is 0.45 (see Table 8).

Table 8. **Summary of humpback whale mortalities and serious injuries by year and type report to the NMFS Alaska Regional Office, marine mammal stranding database, for the 2007-2011 period (Allen and Angliss 2014).**

Cause of Injury	2007	2008	2009	2010	2011	Mean Annual Mortality
Entangled in unknown gillnet gear	0.75	0	0	0	1	0.15
Entangled in recreational shrimp pot gear	0	0	0	0	0	0
Entangled in unspecified crab gear	0	0	0	0	0	0

Entangled in unspecified longline gear	0	0	0	0	0	0
Entangled in unspecified pot gear	0	0	0	0	0.75	0.15
Entangled in unspecified set net gear	0	0	0	0	0.75	0.15
Total entanglement minimum annual mortality						0.45
Ship strike (charter)	0.52	0.52	0	0	0	0.21
Ship strike (recreational)	0.2	0.56	0	0	0	0.15
Ship strike (research)	0	0	0	0	0	0
Ship strike (unknown)	0	0	0	0	0	0
Unknown marine debris/gear entanglement	0.75	0	0.75	0	2.5	0.8
Total ship strike and marine debris minimum annual mortality						1.16

Minimum total annual mortality	1.61

With given data it is not possible to determine which fishery caused the mortality. The estimated annual mortality rate due to fisheries interactions with all fisheries is 0.85 (0.4 + 0.45) (see Table 7and Table 8) (Allen and Angliss 2014). The total estimated human-related annual mortality rate is 2.01 (0.4+0.45+1.16).

Ringed Seal

Until 2004, there were three different federally-regulated commercial fisheries in Alaska that could have interacted with ringed seals and were monitored for incidental mortality by fishery observers. As of 2004, changes in fishery definitions in the List of Fisheries have resulted in separating these three fisheries into 12 fisheries (69 FR 70094, December 2, 2004). This change does not represent a change in fishing effort, but provides managers with better information on the component of each fishery that is responsible for the incidental serious injury or mortality of marine mammal stocks in Alaska.

Between 2007 and 2011, there were incidental serious injuries and mortalities of ringed seals in the Bering Sea/Aleutian Islands flatfish trawl fishery, the BSAI pollock trawl, BSAI cod trawl, and BSAI cod longline. Based on data from 2007 to 2011, there have been an average of 3.52 (CV = 0.06) mortalities of ringed seals incidental to commercial fishing operations (see Table 9) (Allen and Angliss 2014).

Table 9. Summary of incidental mortality of ringed seals (Alaska stock) due to commercial fisheries from 2007 to 2009 and calculation of the mean annual mortality rate (Allen and Angliss 2014).

Fishery name	Years	Data type	Observer coverage	Observed mortality (in given yrs.)	Estimated mortality (in given yrs.)	Mean annual mortality

BSAI flatfish trawl	2007	obs data	72	0	0	2.0 (CV = 0.02)
	2008		100	2	2.0	
	2009		100	1	1.0	
	2010		100	0	0	
	2011		100	6 (+1)*	6.0 (7)**	
BSAI pollock trawl	2007	obs data	85	0	0	1.0 (CV = 0.04)
	2008		85	1	1.0	
	2009		86	1	1.0	
	2010		86	0	0	
	2011		98	3	3.0	
BSAI Pacific cod trawl	2007	obs data	53	0	0	0.2 (CV = 0.01)
	2008		59	0	0	
	2009		63	0	0	
	2010		66	0	0	
	2011		60	1	1.0	
BSAI Pacific cod longline	2007	obs data	63	0	0	0.32 (CV = 0.06)
	2008		63	0	0	
	2009		60	0	0	
	2010		64	0	0	
	2011		57	1	1.6	
Total estimated annual mortality						3.52 (CV = 0.06)

*Total mortalities observed in unsampled hauls

** Total mortalities observed in sampled and unsampled hauls. Since the total known mortality (7) exceeds the estimated mortality (6.0) for 2011, the sum of actual mortalities observed (7) will be used as a minimum for that year.

Proposed Critical Habitat for Ringed Seals

Commercial fishing could affect proposed critical habitat for ringed seals through depletion of the essential feature of primary prey resources. Commercial fishing is not authorized in the Chukchi Sea portion of the action area. However, commercial fishing operations do overlap with the Bering Sea portion of the action area.

The Bering Sea is one of the world’s most productive ecosystems and supports numerous fisheries. Today, approximately 25 species of fish, crustaceans and mollusks of the Bering Sea are considered commercially important (NRC 1996).

While ringed seals and commercial fisheries may be targeting some of the same resources (e.g. cod), there are no deleterious effects anticipated with this overlap. The U.S. fisheries in the North Pacific are managed to prevent overfishing of individual stocks. As such, strict limits on catch and bycatch are placed on all groundfish species or species groups.

The Bering Sea pollock and Pacific cod fisheries may also impact ringed seals through bycatch of their benthic invertebrate prey. Data from Alaska groundfish fisheries observers is used to estimate bycatch of crab, and other “prohibited species” (e.g., halibut, salmon and herring). The bycatch of Bairdi crab was over ten million crab in 1994 but dropped to five million in 1995 and declined steadily to around one million in 2006. In addition to target and prohibited species, non-target species bycatch is also monitored. Non-targets are divided into four categories: 1) forage species, 2) Habitat Areas of Particular Concern (e.g., sponges, anemones, corals), 3) non-specified species (grenadiers, crabs, starfish, jellyfish, benthic invertebrates, shrimp and others), 4) other species (e.g., sculpins, sharks, octopus). In the BSAI non-specified species comprised the majority of non- target catch from 1997-2007 (Gaichas and Boldt 2010). However, jellyfish, grenadiers and sea stars comprised the majority of the non-specified catch so bycatch of non-targets is not relevant to concerns about impacts of bycatch on ringed seal prey, at least in the Bering Sea.

There is no available scientific information suggesting that the removal of prey associated with these fisheries is adversely affecting ringed seals. Ringed seals are not believed to be competing with the commercial fisheries in the waters of Alaska for prey (Kelly et al. 2010b).

Bearded Seal

Similar to ringed seals, the monitoring of incidental serious injury or mortality of bearded seals changed as of 2004, and provided managers a better insight into how each fishery in Alaska was potentially impacting the species (Allen and Angliss 2014). As of 2004, changes in fishery definitions in the List of Fisheries have resulted in separating the three fisheries that could have interacted with bearded seals into 12 fisheries (69 FR 70094).

Between 2007 and 2011, there were incidental serious injuries and mortalities of bearded seals in the BSAI pollock trawl and the BSAI flatfish trawl (Table 10). The estimated minimum mortality rate incidental to commercial fisheries is 1.8 (CV = 0.05) bearded seals per year, based exclusively on observer data (Allen and Angliss 2014).

Table 10. **Summary of incidental mortality of bearded seals (Alaska stock) due to commercial fisheries from 2007-2011 and calculation of the mean annual mortality rate. Details of how percent observer coverage is measured is included in (Allen and Angliss 2014).**

Fishery Name	Year	Data Type	Observer Coverage	Observed Mortality	Estimated Mortality	Mean Annual Takes (CV in parentheses)
BSAI Pollock Trawl	2007	Obs. data	85	1	1.0	1.4 (CV=0.06)
	2008		85	4	4.1	
	2009		86	1	1.0	
	2010		86	0 (+1)[*]	0 (1)[**]	
	2011		98	0	0	
BSAI Flatfish Trawl	2007	Obs. data	72	0	0	0.4 (CV= 0.03)
	2008		100	1	1.0	
	2009		100	0	0	
	2010		100	0	0	
	2011		100	1	1.0	
Total Estimated Annual Mortality						1.8 (CV= 0.05)

[*] Total mortalities observed in unsampled hauls.

[**] Total mortalities observed in sampled and unsampled hauls. Since the total known mortality (1) exceeds the estimated mortality (0) for 2010, the sum of actual mortalities observed (1) will be used as a minimum estimate for that year.

5.1.5 Pollutants and Contaminants

Anthropogenic pollution in the Chukchi Sea has primarily originated outside of the region, and transported by water, sea ice, air or biota (BOEM 2015a). Aspects of water quality we are primarily concerned with include trace metal and hydrocarbon concentrations.

Regional industrial activities that may influence water quality include the Red Dog port and mine that have been operating since 1989, five offshore exploration wells that were drilled in the Chukchi Sea between 1989 and 1991, and the "top hole" exploratory well drilled in 2012 (BOEM 2015a).

Trace Metals

Previous drilling operations in the LS area may cause elevated trace metals in the sediment. As an example, barium concentrations at 15 sample stations in the northeastern Chukchi Sea were up to 10,000 µg/g within 200m of the 1989 drill hole, whereas natural background levels of barium were around 700 µg/g (Trefry et al. 2014). These results indicate that barium from drilling muds settled at drilling sites and at least a portion of the barium did not disperse despite drilling having occurred over 25 years ago (BOEM 2015a).

Anomalies were also detected for copper, mercury, lead, and zinc at 4 stations within 200 m (656 ft) of 1989 drilling sites. The mercury, they concluded, was part of the cuttings brought up during drilling from the geologic formation and residual mercury that occurred in drilling muds. At present, sediments in the northeastern Chukchi Sea are pristine with respect to trace metals of anthropogenic origin, excluding the area immediately around drilling sites (Trefry et al. 2014). Given that seafloor sediments repeatedly re-suspend, metal concentrations in the seafloor sediments introduce and elevate total-metal concentrations into the bottom water (BOEM 2015a).

Hydrocarbons

Neff et al. (2010) examined the chemical characterization of seafloor sediments in 2008 in the northeastern Chukchi Sea in the region of the Burger and Klondike oil and gas prospects. Their results showed that the concentration and distribution of hydrocarbons varied in surface sediments throughout the Burger and Klondike prospects, with higher concentrations in some surface and subsurface sediment samples at exploration 1989 sites drilled in in these prospects. With the exception of hydrocarbon concentrations in sediments at these two historic drill sites, hydrocarbon concentrations at the other sites sampled within the prospects were within the range of background concentrations reported by other studies in Alaskan coastal and shelf sediments (Neff 2010).

Authorized Discharges

Bioavailability is the extent to which a chemical can be absorbed (bioaccumulated) by a living organism by active (biological) or passive (physical or chemical) processes. Bioavailability of metals and hydrocarbons can be divided into two components: environmental accessibility and environmental bioavailability (Neff 2010).

Environmental accessibility is a measure of the fraction of the total chemical that is in a form or location in the environment that is accessible for bioaccumulation by organisms. Metals of all forms buried in deep layers of sediment or cuttings have a low accessibility to marine organisms.

Environmental bioavailability depends on the interactions of a marine organism with its environment. Exposure occurs at the interface between environmental media (i.e., water, sediment, and food) and permeable biological membranes of the marine organism in contact with the different media (Neff 2010).

Existing development in the action area provides multiple sources of contaminants that may be bioavailable (NMFS 2013c). Although drilling fluids and cuttings can be disposed of through onsite injection into a permitted disposal well, or transported offsite to a permitted disposal location, some drilling fluids are discharged at the sea floor before well casings are in place. Drill cuttings and fluids contain relatively high concentrations of contaminants that have high potential for bioaccumulation, such as dibenzofuran and Polycyclic Aromatic Hydrocarbons (PAHs). Historically, drill cuttings and fluids have been discharged from oil and gas developments in the project area, and residues from historical discharges may be present in the affected environment (Brown et al. 2010). BOEM estimated that drill cuttings and exploration fluids from one exploration well would be 5,800 bbl and 3,200 bbl respectively. The proposed action assumes that the synthetic drilling mud would be reconditioned and reused with an efficiency of 80%. All of the rock cuttings would be discharged at the exploration site (BOEM 2015a). PAHs are also emitted to the atmosphere by flaring water gases at production platforms or gas treatment facilities. Approximately 162,000 million standard cubic feet of waste gas was flared at Northstar in 2004 (Neff 2010).

The aqueous solubility of a contaminant is an important parameter for determining its behavior in the environment, and the potential pathways through which organisms could be exposed to the contaminant. Many of the organic contaminants associated with past development in the project area (*e.g.*, PAH) have low solubility in water due to their nonpolar molecular structures. As a result of low aqueous solubility, these compounds tend to associate with organic material or solid-phase particles (such as sediments) in the environment. Similarly, the elemental forms of some potentially toxic metals, such as lead and mercury, have low aqueous solubility. However, these metals may react with other naturally occurring chemical species to form soluble compounds (BOEM 2015a).

Regulations for Discharge

The principal regulatory method for controlling pollutant discharges from vessels (grey water, black water, coolant, bilge water, ballast, deck wash, etc.) into waters of the Arctic Region OCS is the Clean Water Act (CWA) of 1972. Section 402 establishes the National Pollution Discharge Elimination System (NPDES). The Environmental Protection Agency (EPA) issues general permits for a term of five years.

The EPA Arctic general permit restricts the seasons of operation, discharge depths, and areas of operation, and has monitoring requirements and other conditions. The EPA regulations at 40 CFR 125.122 require a determination that the permitted discharge will not cause unreasonable degradation to the marine environment.

The current NPDES general permit for exploration discharges in the Chukchi Sea is the 2012–2017 NPDES general permit for Oil and Gas Exploration Facilities on the Outer Continental Shelf in the Chukchi Sea (AK 28-8100) (EPA 2012). The terms of this permit are indicative of the expected terms of future General Permits (BOEM 2015e). NMFS consulted on the issuance of the NPDES permits on April 11, 2012. NMFS concurred with the EPA's determination that the planned actions, "may affect, but are not likely to adversely affect" bowhead, fin, and humpback whales, bearded seals and ringed seals in the Beaufort Sea or Chukchi Sea area of coverage (NMFS 2012a, b). Discharges from regulated activities must meet the permit
In addition, EPA issued a Vessel General Permit (VGP) for Discharges Incidental to the Normal Operations of Vessels authorized to discharge under NPDES permit (EPA 2013). The final VGP applies to owners and operators of non-recreational vessels that are 24 m (79 ft) and greater in length, as well as to owners and operators of commercial vessels of less than 79 ft which discharge ballast water. Pollutant constituents in the VGPs may include nutrients, pathogens, oil and grease, metals, biochemical oxygen demand, pH, total suspended solids, aquatic nuisance species, and other toxic and non-conventional pollutants with toxic effects (BOEM 2015e). In addition to complying with NPDES requirements, vessels discharging in the contiguous zone and ocean (seaward of the outer limit of the territorial seas) are subject to the International

Convention for the Prevention of Pollution from Ships (MARPOL 73/78), implemented by the U.S. Coast Guard pursuant to 33 CFR Part 151).

The water quality of the Chukchi Sea meets the qualitative criteria for protection of marine life described in Section 403 of the CWA. As of the most recent listing by the State of Alaska Department of Environmental Quality (ADEC 2014), no water bodies are identified as impaired, as defined by the Section 303d of the CWA, within the Arctic region (BOEM 2015a).

Accidental Discharges - Oil Spills and Gas Releases

BOEM and BSEE define small oil spills as <1,000 barrels (bbl). Large oil spills are defined as 1,000-150,000 bbl, and very large oil spills (VLOS) are defined as ≥ 150,000 bbl (BOEM 2015a).

Small Oil Spills

Offshore petroleum exploration activities have been conducted in State of Alaska waters adjacent to the Beaufort Sea and the OCS of the Chukchi Sea Planning Area since the late 1960s. Small oil spills have occurred with routine frequency and are considered likely to occur during the first incremental step as well as subsequent stages (BOEM 2015e). Small spills during exploration activities are expected to be small and consist of refined oils because crude and condensate oil would not be produced during exploration (BOEM 2015a).

Based on a review of potential discharges and on the historical oil spill occurrence data for the Alaska OCS and adjacent State of Alaska waters, several spills from refueling operations (primarily at West Dock) have been reported to the National Response Center in the Beaufort and Chukchi Seas and all the spills were small (BOEM 2015e).

From 1971-2010 industry drilled 84 exploration wells in the entire OCS offshore the State of Alaska (BOEM 2011). Within the Beaufort and Chukchi OCS, the oil industry drilled 35 exploratory wells. During the time of this drilling, industry has had 35 small spills totaling 26.7 bbl or 1,120 gallons (gal). Of the 26.7 bbl spilled, approximately 24 bbl were recovered or cleaned up (BOEM 2011).

Large Oil Spills and Very Large Oil Spills

BOEM and BSEE analyzed historical data on oil spills over the entire U.S. OCS from 1971-2010, and determined that no crude oil spills ≥1,000 bbl have occurred during exploration, other than the Deepwater Horizon (DWH) incident (BOEM 2015a). No large or very large oil spills have occurred historically in the action area.

Contaminants in Bowhead Whales, Ringed Seals, and Bearded Seals

Metals and hydrocarbons introduced into the marine environment from offshore exploratory drilling activities are not likely to enter the Chukchi Sea food webs in ecologically significant amounts. As an example, none of the metals and hydrocarbons measured in tissues of Beaufort

Sea invertebrates and fish during the MMS ANIMIDA/cAMIMIDA Monitoring Program bioaccumulated to higher than background concentrations (Neff 2010).

However, there is a growing body of scientific literature on concentrations of metals and organochlorine chemicals (e.g., pesticides and polychlorinated biphenyls (PCBs)) in tissues of higher trophic level marine animals such as marine mammals, from cold-water environments. In most cases, these animals were not collected in the immediate vicinity of active drilling operations, so it is not possible to identify sources of contaminants in their tissues (Neff 2010). The organochlorines are not anticipated to occur from drilling operation; in most cases, they enter the Arctic environment in long-range transport in the atmosphere (MacDonald et al. 2005).

There is particular concern about mercury in Arctic marine mammal food webs (Macdonald 2005). Mercury concentrations in marine waters in much of the Arctic are higher than concentrations in temperate and tropical waters due in large part to deposition of metallic and inorganic mercury from long-range transport and deposition from the atmosphere (Outridge et al. 2008). However, there is no evidence that significant amounts of mercury are coming from oil operations around Prudhoe Bay (Snyder-Conn et al. 1997) or from offshore drilling operations (Neff 2010).

Bowhead Whale

Some environmental contaminants, such as chlorinated pesticides, are lipophilic and can be found in the blubber of marine mammals (Becker et al. 1995). Tissues collected from whales landed at Barrow in 1992 (Becker et al. 1995) indicate that bowhead whales have very low levels of mercury, PCB’s, and chlorinated hydrocarbons, but they have elevated concentrations of cadmium in their liver and kidneys. Bratton *et al.* (1993) measured organic arsenic in the liver tissue of one bowhead whale and found that about 98% of the total arsenic was arsenobetaine. Arsenobetaine is a common substance in marine biological systems and is relatively non-toxic.

Bratton *et al.* (1993) looked at eight metals (arsenic, cadmium, copper, iron, mercury, lead, selenium, and zinc) in the kidneys, liver, muscle, blubber, and visceral fat from bowhead whales harvested from 1983-1990. They observed considerable variation in tissue metal concentration among the whales tested. Metal concentrations evaluated did not appear to increase over time between 1983 and 1990. The metal levels observed in all tissues of the bowhead are similar to levels reported in the literature in other baleen whales. The bowhead whale has little metal contamination as compared to other arctic marine mammals, except for cadmium.
Mössner and Ballschmiter (1997) reported that total levels of polychlorinated biphenyls and chlorinated pesticides in bowhead blubber from the North Pacific/Arctic Ocean were many times lower than that in beluga whales or northern fur seals. However, while total levels were low, the combined level of three isomers of the hexachlorocyclohexanes chlorinated pesticides was higher in the bowhead blubber tested than in the North Atlantic’s pilot whale, the common dolphin, and the harbor seal. These results were believed to be due to the lower trophic level of the bowhead relative to the other marine mammals tested.

Fin Whale

Based on studies of contaminants in baleen whales, including fin whales, and other marine mammals, habitat pollutants do not appear to be a major threat to fin whales in most areas where fin whales are found (NMFS 2010d). O'Shea and Brownell (1994) state that concentrations of OCs and metal contaminants in tissues of baleen whales are low, and lower than other marine mammal species. They further state that there is no firm evidence that levels of OCs, organotins, or heavy metals in baleen whales generally are high enough to cause toxic or other damaging effects. Among baleen whales, Aguilar (1983)observed that mean levels of dichloro-diphenyltrichloroethane (DDT) and PCB in a study of North Atlantic fin whales were significantly lower (0.74 and 12.65 respectively) than in a study of North Atlantic sperm whales (4.68 and 26.88 respectively).

Humpback Whale

Concentrations of OC pesticides, heavy metals, and PCB's have been reported in humpback whale tissues from Canadian, United States, and Caribbean waters (Taruski et al. 1975). Biopsy blubber samples from male individuals (n=67) were collected through SPLASH, a multi-national research project, in eight North Pacific feeding grounds. Persistent organic pollutants were measured in the samples and used to assess contaminant distribution throughout the feeding areas, as well as to investigate the potential for health impacts on the study populations.

Concentrations of PCBs, DDTs, and polybrominated diphenyl ethers were more prevalent along the U.S. West Coast, with highest concentrations detected in southern California and Washington whales. A different pattern was observed for chlordanes and hexachlorocyclohexanes, with highest concentrations detected in the western Gulf of Alaska whales and those from other high latitude regions, including southeast Alaska and eastern Aleutian Islands. In general, contaminant levels in humpback whales were comparable to other mysticetes, and lower than those found in odontocete cetaceans and pinnipeds. Concentration levels likely do not represent a significant conservation threat (Elfes et al. 2010).

Ringed Seal

Contaminants research on ringed seals is extensive throughout the Arctic environment where ringed seals are an important part of the diet for coastal human communities. Pollutants such as OC compounds and heavy metals have been found in all of the subspecies of ringed seal (with the exception of the Okhotsk ringed seal). The variety, sources, and transport mechanisms of contaminants vary across ringed seal ecosystems (Kelly et al. 2010b).

Heavy metals such as mercury, cadmium, lead, selenium, arsenic, and nickel accumulate in ringed seal vital organs, including liver and kidneys, as well as in the central nervous system (Kelly et al. 2010b). Gaden et al. (2009) suggested that during ice-free periods the seals eat more Arctic cod (and mercury). They also found that mercury levels increased with age for both sexes. Dehn et al.'s (2005) finding near Barrow also supports this. Becker *et al.* (1995) reported ringed seals had higher levels of arsenic in Norton Sound than ringed seals taken by residents of Point Hope, Point Lay, and Barrow. Arsenic levels in ringed seals from Norton Sound were quite high for marine mammals, which might reflect localized natural arsenic sources.

Ringed Seal Proposed Critical Habitat

Contaminants could affect all three essential features of proposed critical habitat for ringed seals: sea ice suitable for the formation and maintenance of subnivean birth lairs, sea ice habitats suitable as a platform for basking and molting, and primary prey resources to support Arctic ringed seals. Large oil spills represent the main threat of contamination to all three essential features, but to date, no large spills have occurred in the action area. Pollutants such as OCs and heavy metals found in ringed seals were likely acquired through the primary prey resources and other items in the food chain (BOEM 2015a).

Bearded Seal

Research on contaminants and bearded seals is limited compared to the information for ringed seals. However, pollutants such as OC compounds and heavy metals have been found in most bearded seal populations. Similar to ringed seals, climate change has the potential to increase the transport of pollutant from lower latitudes to the Arctic (Tynan and Demaster 1997).

5.1.6 Research

The NMFS Permits Division has issued scientific research permits, for activities that adversely affect ringed and bearded seals in the action area. Permit No. 15142 authorizes the capture of four bearded seals (Beringia DPS); up to two of the captured seals would be placed into permanent captivity for non-invasive sensory research (Permit No. 14535). Permit No. 18537 authorizes the incidental disturbance (i.e., harassment during aerial surveys) of ringed (N = 200) and bearded seals (N = 200), during scientific research targeting the Steller sea lion (Western DPS). Permit No. 14610 authorizes the incidental disturbance (i.e., harassment during vessel surveys) of ringed (N = 10) and bearded seals (N = 10), during scientific research targeting beluga and bowhead whales. Permit No. 15324 authorizes the incidental disturbance (i.e., harassment during aerial and vessel surveys, and incidental to capture) of ringed (N = 300,050) and bearded seals (N = 150,050), the capture, drug, and tagging of ringed (N=200), and bearded seals (N= 200), and the unintentional mortality of ringed (N=5) and bearded seals (N=5).While these authorized numbers of directed takes may seem high, the actual number of take that results from these permits is often low. As an example, between 2003-2007, there was one mortality resulting from research of the Alaska stock of bearded seals, which results in an average of 0.2 mortalities per year from this stock.

5.1.7 Climate Change

“The Arctic marine environment has shown changes over the past several decades, and these changes are part of a broader global warming that exceeds the range of natural variability over the past 1000 years” (Walsh 2008). The changes have been sufficiently large in some areas of the Arctic (e.g., the Bering Sea and Chukchi Sea) that consequences for marine ecosystems appear to be underway (Walsh 2008). The proximate effects of climate change in the Arctic are being expressed as increased average winter and spring temperatures and changes in precipitation amount, timing, and type (Serreze et al. 2000). Increases of approximately 75 days or more days in the number of days with open water occur north of the Bering Strait in the Beaufort, Chukchi, and East Siberian Seas; and increases by 0-50 days elsewhere in the Arctic Ocean have been seen (Walsh 2008).

A general summary of the changes attributed to the current trends of arctic warming indicate sea ice in the Arctic is undergoing rapid changes with little slowing down forecasted for the future (Budikova 2009). There are reported changes in sea-ice extent, thickness, distribution, age, and melt duration. In general, the sea-ice extent is becoming much less in the arctic summer and slightly less in winter. The thickness of arctic ice is decreasing. The distribution of ice is changing, and its age is decreasing. The melt duration is increasing. These factors lead to a decreasing perennial arctic ice pack. It is generally thought that the Arctic will become ice free in summer, but at this time there is considerable uncertainty about when that will happen.

Predictions of future sea-ice extent, using several climate models and taking the mean of all the models, estimate that the Arctic will be ice free during summer in the latter part of the 21st century (Parry 2007). There is considerable uncertainty in the estimates of summer sea ice in these climate models, with some predicting 40-60% summer ice loss by the middle of the 21st century (Holland et al. 2006). Using a suite of models, a 40% loss is estimated for the Beaufort and Chukchi seas (Overland and Wang 2007). Some investigators, citing the current rate of decline of the summer sea-ice extent, believe it may be sooner than predicted by the models (Stroeve et al. 2007). Other investigators suggest that variability at the local and regional level is very important for making estimates of future changes. While the annual minimum of sea ice extent is often taken as an index of the state of Arctic sea ice, the recent reductions of the area of multi- year sea ice and the reduction of sea ice thickness is of greater physical importance. It would take many years to restore the ice thickness through annual growth, and the loss of multi-year sea ice makes it unlikely that the Arctic will return to previous climatological conditions in the foreseeable future. Continued loss of sea ice will be a major driver of changes across the Arctic over the next decades, especially in late summer and autumn.

Increasing ocean acidification predicted to cause changes in the ecosystem processes and present additional stressors to organisms in the Arctic (BOEM 2015e). Ocean acidification occurs as carbon dioxide increases in the atmosphere and is absorbed into ocean waters. The increase in carbon dioxide lowers pH over time and reduces the concentration of calcium carbonate in the sea (BOEM 2015e). Mathis and Questel (2013) studied the carbonate chemistry in the leased area in the northeast Chukchi Sea during August, September, and October 2010 and found low saturation rates of calcite and aragonite (two forms of calcium carbonate) as summer progressed.

These changes are resulting, or are expected to result, in changes to the biological environment, causing shifts, expansion, or retraction of home range, changes in behavior, and changes in population parameters of plant and animal species. Much research in recent years has focused on the effects of naturally-occurring or man-induced global climate regime shifts and the potential for these shifts to cause changes in habitat structure over large areas. Although many of the forces driving global climate regime shifts may originate outside the Arctic, the impacts of global climate change are exacerbated in the Arctic (ACIA 2005). Temperatures in the Arctic have risen faster than in other areas of the world as evidenced by glacial retreat and melting of sea ice. Threats posed by the direct and indirect effects of global climatic change are or will be common to Northern species. These threats will be most pronounced for ice-obligate species such as the polar bear, walrus, and ice seals.

The main concern about the conservation status of ice seals stems from the likelihood that their sea ice habitat has been modified by the warming climate and, more so, that the scientific consensus projects accelerated warming in the foreseeable future. A second concern, related by the common driver of carbon dioxide emissions, is the modification of habitat by ocean acidification, which may alter prey populations and other important aspects of the marine ecosystem (75 FR 77502). According to climate model projections, snow cover is forecasted to be inadequate for the formation and occupation of birth lairs for ringed seals within this century over the Alaska stock's entire range (Kelly et al. 2010b). This would result in a loss of an essential feature of ringed seal proposed critical habitat.

The ringed seal's broad distribution, ability to undertake long movements, diverse diet, and association with widely varying ice conditions suggest resilience in the face of environmental variability. Bearded seals, on the other hand, are restricted to areas where seasonal sea ice occurs over relatively shallow waters where they may forage on the bottom (Fedoseev 2000), and although bearded seals usually associate with sea ice, young seals may be found in ice-free areas such as bays and estuaries.

However, not all arctic species are likely to be adversely influenced by global climate change. Conceptual models by Moore and Laidre (2006) suggested that, overall reductions in sea ice cover should increase the Western Arctic stock of bowhead whale prey availability.

This theory may be substantiated by the steady increase in the Western Arctic bowhead population during the nearly 20 years of sea ice reductions (Walsh 2008). Moore and Huntington (2008) anticipate that bowhead whales will alter migration routes and occupy new feeding areas in response to climate related environmental change. Shelden *et al.* (2003) notes that there is a high probability that bowhead abundance will increase under a warming global climate.

The recent observations of humpback and fin whales in the eastern Chukchi Sea may be due to reoccupation of previous habitats following the population's recovery from whaling; however, given the virtual absence of these species in the region in historical data, it is also possible that these sightings reflect a northward range expansion related to the effects of climate change. The feeding range of fin whales is larger than that of other species and consequently, it is likely that the fin whale may be more resilient to climate change, should it affect prey, than a species with a narrower range. Range expansions in response to habitat change are not uncommon among cetaceans. Since humpback and fin whales are not ice-obligate or ice-associated species, it is unknown how long this habitat will remain viable for the species. However, it is logical to assume these whales will continue to utilize these waters as long as the availability of prey remains.

5.2 Summary of Stressors Affecting Listed Species in the Action Area

Several of the activities described in the *Environmental Baseline* have adversely affected listed marine mammals that occur in the action area:

- Commercial whaling in the 19th and early 20th centuries reduced large whale populations in the North Pacific down to a fraction of historic population sizes. However, the

Western Arctic bowhead stock of the bowhead whale is showing marked recovery with numbers approaching the low end of the historic population estimates.

- Subsistence whaling for bowhead by Alaska Natives represents the largest known human-related cause of mortality for the Western Arctic stock (0.1-0.5% of the stock per year). However, the long-term growth of this stock indicates that the level of subsistence take has been sustainable. Subsistence harvest of Arctic ringed seals and bearded seals is substantial in some regions but is not considered a threat at the population or species level.

- Levels of anthropogenic noise can vary dramatically depending on the season, type of activity, and local conditions. These noise levels may be within the harassment and injury thresholds for marine mammals.

- Numerous incidents of vessel collisions with large whales have been documented in Alaska. Strikes have involved cruise ships, recreational cruisers, whale watching catamarans, fishing vessels, and skiffs. Shipping and vessel traffic is expected to increase in the Arctic Region OCS if warming trends continue.

- Shipping activities in the U.S. Arctic pose varying levels of threats to ice seals depending on the type and intensity of the shipping activity and its degree of spatial and temporal overlap with ice seal habitats. The presence and movements of ships in the vicinity of some ringed and bearded seals may cause some seals to abandon their preferred breeding habitats in areas with high traffic, and ice-breaker activities can kill ringed seals when ice breaking occurs in breeding areas.

- Concentrations of organochlorine and metal contaminants in tissues of baleen whales are low, and are not thought to be high enough to cause toxic or other damaging effects. The relative impact to the recovery of baleen whales due to contaminants and pollution is thought to be low. Pollutants such as OC compounds and heavy metals have been found in both bearded and ringed seals in the Arctic.

- Mortalities incidental to marine mammal research activities authorized under MMPA permits appears to be low. There was only one documented mortality resulting from research on the Alaska stock of bearded seals, which results in an average of 0.2 mortalities per year from this stock.

- Currently, there are insufficient data to make reliable estimations of the effects of Arctic climate change on baleen whales. A study reported in George *et al.* (2006) showed that landed bowheads had better body condition during years of light ice cover. This, together with high calf production in recent years, suggests that the stock is tolerating the recent ice-retreat at least at present (Allen and Angliss 2014). The feeding range of fin whales is larger than that of other species and consequently, as feeding generalists, it is likely that the fin whale may be more resilient to climate change, should it affect prey, than feeding specialists. Recent observations of fin and humpback whales in the Chukchi Sea may be indicative of seasonal habitat expansion in response to receding sea ice or increases in prey availability which these whales now exploit.

- The ringed seal's broad distribution, ability to undertake long movements, diverse diet, and association with widely varying ice conditions suggest resilience in the face of environmental variability. However, ringed seal's long generation time and ability to produce only a single pup each year may limit its ability to respond to environmental challenges such as the diminishing ice and snow cover, particularly the forecast reduced depth of snow on ice for forming birth lairs. Bearded seals are restricted to areas where seasonal sea ice occurs over relatively shallow waters where they may forage on the bottom. The retreat of the spring and summer ice edge in the Arctic may separate suitable sea ice for pup maturation and molting from benthic feeding areas.

Bowhead, fin, and humpback whales in the action area appear to be increasing in population size – or, at least, their population sizes do not appear to be declining – despite their continued exposure to the direct and indirect effects of the activities discussed in the *Environmental Baseline*. While we do not have current abundance estimates for ringed and bearded seals, they also do not appear to be declining as a result of the current stress regime.

Although we do not have information on other measures of the demographic status of these species (for example, age structure, gender ratios, or the distribution of reproductive success) that would facilitate a more robust assessment of the probable impact of the *Environmental Baseline*,[12] we infer from their increasing abundance that the *Environmental Baseline* is not currently preventing their population size from increasing.

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[12] Increase in a population's abundance is only one piece of evidence that a population is improving in status; however, because populations can increase while experiencing low juvenile survival (e.g., if low juvenile survival is coupled with reduced adult mortality) or when those individuals that are most sensitive to a stress regime die, leaving the most resistant individuals, increases in abundance are not necessarily indicative of the long-term viability of a species.

6. EFFECTS OF THE ACTION

"Effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

This biological opinion relies on the best scientific and commercial information available. We try to note areas of uncertainty, or situations where data is not available. In analyzing the effects of the action, NMFS gives the benefit of the doubt to the listed species by minimizing the likelihood of false negative conclusions (concluding that adverse effects are not likely when such effects are, in fact, likely to occur).

We organize our effects analysis using a stressor identification – exposure – response – risk assessment framework for the proposed exploration activities. Then we provide a description of the potential effects of development, production, and decommissioning that could arise from leases issued by BOEM in LS 193 as those effects are currently understood. Future incremental steps (development, production, and decommissioning) are not considered reasonably certain to occur and would require additional NEPA analysis and additional consultation under the ESA.

We conclude this section with an *Integration and Synthesis of Effects* that integrates information presented in the *Status of the Species* and *Environmental Baseline* sections of this opinion with the results of our exposure and response analyses to estimate the probable risks the proposed action poses to endangered and threatened species.

The ESA does not define "harassment" nor has NMFS defined this term through regulation, pursuant to the ESA. The MMPA defines "harassment" as "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild" or "has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering." For the purposes of this consultation, NMFS considers that a take by "harassment" occurs when an animal is exposed to certain sound levels as described below.

6.1 Effects of the First Incremental Step

The first incremental step consists of activities associated with exploring and delineating an anchor field on current leases within LS 193, and onshore facility development (years 1-9).

6.1.1 Project Stressors

Seismic surveys have been conducted in the Chukchi and Beaufort Seas since the late 1960s, resulting in extensive coverage over the area. Exploratory drilling in the area started in the 1980s, and NMFS has issued incidental harassment authorizations to the oil and gas industry for the non-lethal taking of small numbers of marine mammals related to seismic surveys since the early 1990s. BOEM and BSEE may continue to authorize varying levels of oil and gas exploration activities on LS 193 in the Chukchi Sea Planning Area. The potential stressors associated with the activities BOEM and BSEE propose to authorize are stressors that have occurred previously in the action area.

Based on our review of the data available, oil and gas exploration activities may cause these primary stressors:

1. sound field produce by impulsive noise sources such as: 2D/3D seismic surveys, geohazard surveys, and VSP;
2. sound fields produced by continuous noise sources such as: vessels, aircraft, and drilling operations;
3. risk of vessels striking marine mammals;
4. seafloor disturbance from drilling activities and placement of equipment or anchors;
5. entanglement and ingestion of trash and debris; and
6. pollution from unauthorized spills.

6.1.2 Acoustic Thresholds

As discussed in Section 2, *Description of the Proposed Action*, BOEM/BSEE intend to authorize a wide variety of acoustic systems in the action area (see Table 3).

Since 1997, NMFS has used generic sound exposure thresholds to determine whether an activity produces underwater and in-air sounds that might result in impacts to marine mammals (70 FR 1871). NMFS is currently developing comprehensive guidance on sound levels likely to cause injury and behavioral disruption to marine mammals (NOAA 2013). However, until formal guidance is available, NMFS uses conservative thresholds of sound pressure levels from broad band sounds that cause behavioral disturbance (160 dB rms re: 1μPa for impulse sound and 120 dB rms re: 1μPa for continuous sound) and injury (180 dB rms re: 1μPa for whales and 190 dB rms re: 1μPa for pinnipeds). These "disturbance" and "injury" thresholds correlate with the "Level A" harassment and "Level B" harassment thresholds as those terms are defined pursuant to the MMPA (16 U.S.C. § 1362(18)(A)(i) and (ii)).

6.1.3 Exposure Analysis

As discussed in the *Approach to the Assessment* section of this opinion, exposure analyses are designed to identify the listed resources that are likely to co-occur with these effects in space and time and the nature of that co-occurrence. In this step of our analysis, we try to identify the number, life stage, and gender of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent.

For our exposure analyses, NMFS generally relies on an action agency's estimates of the number of marine mammals that might be "taken." However, BOEM/BSEE did not provide a quantitative exposure analysis. Therefore NMFS conducted its own analysis to estimate the number of exposures to listed resources that may result from stressors produced by the proposed action. We have divided the exposure analysis into: exposures to major noise sources (i.e., seismic and drilling operations), exposures to other noise sources (i.e., other impulsive noise, vessel transit, aircraft traffic, and onshore construction), exposures to unauthorized oil and gas spills, and exposures to other stressors (i.e., vessel strike, habitat disturbance, and marine debris). For stressors associated with major noise sources, we developed activity scenarios, and conducted acoustic propagation modeling associated with the activity scenarios (described in detail below).

6.1.3.1 Exposure to Major Noise Sources

Activity Definitions

BOEM/BSEE projected a level of exploration activities during the first incremental step based upon current leases, and industry’s stated needs for exploring those leases. Although the levels of activities can be estimated, the particular strategy used by a company regarding when and where to explore for resources may change depending on what a company found during previous exploration activities, as well as market factors and changes in technology. Therefore, predicting and planning for levels of activity over a longer period of time (i.e. three or more years in the future) can be difficult. While NMFS and BOEM can estimate the level of future activity on an annual basis, there is some uncertainty in projections beyond that point.

Due to the number of surveys and survey types in LS 193, precise calculations associated with specific airgun arrays are impractical. Instead a “typical marine seismic array” and “typical geohazard seismic array” has been defined based on an analysis of previous airguns utilized in the Chukchi Sea operations since 2006 (reports are available on past Arctic oil and gas projects on NMFS’s website: http://www.nmfs.noaa.gov/pr/permits/incidental.htm). The single marine seismic operation during the open-water season is anticipated to use a 3,200 cui airgun array with a 231 dB re 1 µPa rms source level. The single marine seismic operation during the in-ice winter season is anticipated to use a 4,500 cui airgun array with a 232 dB re 1 µPa rms source level. The array size for high resolution geohazard seismic surveys is anticipated to be 40 cui with a source level of 217 dB re 1 µPa rms, and VSP operations are anticipated to use a 500 cui array with a source level of 223 dB re 1 µPa rms (see Table 11 for additional information). Actual array output varies by seismic survey type and can be higher or lower depending on the number of arrays and airguns used. This could result in an increase or decrease of the ensonified area.

Table 11. Activity Definitions Anticipated for First Incremental Step

Activity/Program	# of source vessels	# of support vessels	Type of Energy/Sound Sources Used	# of Days Activities Could Occur in a Season	Months During Which the Activity Could Occur	Extent of the Activity Area and/or # of Wells to be Drilled
2D/3D Marine Seismic Towed Streamer Seismic Survey	1 Source/ Receiver Vessel	• 1 support vessel • 1 vessel for monitoring	• Source array typically consists of one or more sub-arrays of 6-8 airgun sources each • Individual airgun size: 5-1,500 in^3 (0.081-24.58 liter) • Airgun array range from 1,800-3,200 in^3	• 2D 10-30 days • 3D 15-30 days	July – November	• 2D 102 line miles (164 line km) per season • 3D 200 mi^2 (518 km^2) per season
In-ice 2D seismic survey	1 Source/ Receiver vessel	• 1 icebreaker	• Source array typically consists of one or more sub-arrays of 6-8 airgun sources each • Individual airgun size: 5-1,500 in^3 (0.081-24.58 liter) • Airgun array range from 1,800-4,500 in^3	10-30 days	October – December	Approximately 102 line miles per season
Geotechnical CSEM Survey	1	• 1 source and layout vessel	0.5-10 Hertz electromagnetic signal	60 days	July – November	unknown
Geohazard Site Clearance and High-Resolution Shallow Hazard Surveys	1 Source/ Receiver vessel	• 1-2 support vessels	• Four, 10 in^3 (0.16 liter) airguns • Multi-beam echosounders • Sub-bottom profilers • Side-scan sonars	20-36 days	July – November	~80 line miles per site ~400 line miles per site survey ~881 line miles per pipeline survey
Vertical Seismic Profiling	1 Source/ Receiver vessel		• Airgun array range from 40-500 in^3	1 day per well for ZVSP 4 days per year	June-November	unknown

Activity/Program	# of source vessels	# of support vessels	Type of Energy/Sound Sources Used	# of Days Activities Could Occur in a Season	Months During Which the Activity Could Occur	Extent of the Activity Area and/or # of Wells to be Drilled
Exploratory Drilling Program (from a drillship or semisubmersible)	1-2 drillships	• 2 icebreakers • 3 anchor handler • 3 Offshore supply vessels • 2 drilling discharge monitoring vessels • 2 shallow water vessels • 2 support tugs • 2 resupply tug and barge • 1 OSRV • 2 oil spill response barge and tug (nearshore/offshore) • 2 tank vessels for spill storage • 1 containment barge and tug • Aircraft for crew changes	Drill	30 days per well 120 days per year	June – October	25 mile (40 km) radius around the well; 2-4 wells per season
Exploratory Drilling Program (from a jackup rig)	1 jackup rig	• 2 icebreakers • 2 oil spill response vessels (each with two workboats) • 1 oil spill response tug • 1 tank vessel for spill storage • 3 support vessels • Aircraft for crew changes	Drill	30 days per well 120 days per year	June – October	25 mile (40 km) radius around the well 2-4 wells per season

Level of Activity

For the first incremental step, we anticipate the following level of activity on LS 193 (BOEM 2015a):

- Maximum of **one** 2D/3D marine seismic survey during the open water season during the first nine years;
- Maximum of **one** 2D marine seismic survey during the in-ice season during the first nine years;
- Maximum of **one** geohazard site clearance or high resolution shallow hazard surveys per year, and a total of **five** geohazard surveys during the first nine years;
- Maximum of **one** geotechnical survey per year, and a total of **five** geotechnical surveys during the first nine years;
- Maximum of **two** drilling units per year, and a total of **14** drilling units during the first nine years; and
- Maximum of **four** exploration/delineation wells drilled per year, and total of **28** drilled during the first nine years.
- Maximum of **four** vertical seismic profiling surveys per year, and a total of **28** vertical seismic profiling surveys during the first nine years.

Assumptions

Assumptions about the defined activities in the first incremental step are highlighted in Table 12.

This opinion focuses on oil and gas exploration activities (marine seismic, geohazard, and geotechnical surveys, and exploratory drilling) on the active 460 leases on lease area 193 in the Chukchi Sea. Off-lease seismic operations are outside the scope of the proposed action. However, these off-lease surveys were analyzed as part of NMFS's 2013 Arctic Biological Opinion (NMFS 2013a) and thus are included in the *Environmental Baseline*. Seismic work in the Chukchi Sea has traditionally been conducted in open water (ice-free) months (July through November), although this analysis addresses the possibility of one survey utilizing an icebreaker and potentially conducting work October through December. Each survey takes between 10 and 30 days, depending on ice conditions, weather, equipment operations, size of area to be surveyed, timing of subsistence hunts, etc. Typically, data are not collected between 25% and 30% of the time because of equipment or weather problems. Because of the limited time period of open water, it is likely that concurrent surveys would be conducted in the same general time frame and may overlap in time, but will not overlap in space (i.e. within a minimum of approximately 24 km [15 mi] of each independent survey operation) for reasons regarding data integrity. Drilling operations are anticipated to take between 30 and 90 days at each well site for a total of 120 days per year (BOEM 2015a, c).

For the proposed action, the areas of interest are all well offshore in the leased areas, particularly around drill sites from the late 1980s, including Shell's Burger, Crackerjack, and Shoebill prospects; and ConocoPhillips' Klondike prospect in the LS 193 area (BOEM 2015a, c). A conceptual example of temporal and spatial distributions that could occur for exploration activities under the first incremental step is depicted below in Figures 15-17).

Mitigation Measures to Minimize the Likelihood of Exposure to Major Noise Sources

Mitigation measures are described in detail in Sections 2.1.5 and 2.1.6. The following mitigation measures will be required through the MMPA permitting process to reduce the adverse effects of exposure to major noise sources on marine mammals from the proposed oil and gas exploration activities.

1. PSOs are required on all vessels engaged in activities that may result incidental take through acoustic exposure**.**

2. Establishment of radii associated with received sound level thresholds for 180 dB shutdown/power down for cetaceans and 190 dB shutdown/power down for pinnipeds under NMFS authority.

3. Use of start-up and ramp-up procedures for airgun arrays.

Approach to Estimating Exposures to Major Noise Sources

The standard approach for estimating exposure of marine mammals to oil and gas exploration sound sources consists of: (1) determining the estimated distance from a source to a particular isopleth that corresponds to disturbance (the 120/160 dB received level for disturbance for continuous and impulsive noise sources respectively); (2) assuming a source propagates cylindrically to estimate the range to these isopleths; (3) calculating the surface area ensonified by this cylinder; and (4) multiply the resulting surface area by the density of each marine mammal species present to estimate the instances of exposure to each species at various received sound levels, and thus "taken" through disturbance or injury.

We considered, but did not use, an alternative exposure analysis. The alternative approach modeled the acoustic propagation field in 3D, and 3D animal placement and movement to better calculate the potential impacts to marine mammals. This approach assumes that marine mammals will try to avoid exposure to active seismic transmission or drilling operations (for a review of literature supporting this assumption, see *Response Analysis*), but the data necessary on the rate at which whale and pinniped densities would change in response to initial or continued seismic or drilling exposure or when BOEM/BSEE authorized activities would occur were not available for this consultation, so we could not reach conclusions based on this scenario.

We modified the standard approach by considering a variety of activity scenarios consisting of multiple, concurrently-operating sound sources in order to consider additive acoustic effects. In addition, we added a time component to our analysis to account for animal turnover. The narratives that follow present the approach we used to estimate the instances of exposure of marine mammals to certain sound levels and therefore "taken" during seismic and drilling activities BOEM/BSEE plan to authorize (which is described in the *Proposed Action* section of this opinion).

The instances of exposure for listed species to received levels of impulsive sound ≥160 dB rms were estimated by multiplying:

- the expected bowhead whale, fin whale, humpback whale, ringed seal, and bearded seal densities during the applicable season- summer, fall, and winter;
- the anticipated area to be ensonified based on Rea and Rmax (defined below) in high reflectivity environments to the specified levels based on sound source propagation modeling of similar airgun arrays in similar environments by water depth;
- the total area surveyed; and
- number of seismic operations per year and per 1st incremental step

The instances of exposure for listed species to received levels of continuous sound ≥120 dB rms were estimated by multiplying:

- the expected bowhead whale, fin whale, humpback whale, ringed seal, and bearded seal densities during the applicable season- summer, fall, and winter;
- the anticipated area to be ensonified based on Rea and Rmax in high reflectivity environments to the specified levels based on sound source propagation modeling of similar airgun arrays in similar environments by water depth;
- the estimated number of 24-hr days that the source vessels are operating; and
- number of seismic operations per year and per 1st incremental step

Acoustic Propagation Modeling

JASCO conducted hydroacoustic modeling for oil and gas exploration activities for LS 193. Its model incorporated three sound speed profiles (average, downward refracting, and mixed) and three geoacoustic profiles (high-reflectivity, medium-reflectivity, and low reflectivity). Directional acoustic source levels were determined by an Airgun Array Source Model (AASM). The Marine Operations Noise Model (MONM) computed transmission loss estimates by accounting for surface and subsurface reflection, sound speed profile refraction, sub-bottom attenuation pressure wave to shear wave conversion, and bathymetry. MONM was used for continuous-noise sources (e.g., drilling and dynamic positioning). These were run at 1/3-octave band center frequencies (Austin et al. 2015) (see Appendix A for additional information on Acoustic Propagation Modeling for LS 193).

Threshold distances vary over each azimuth so threshold distances are expressed using three metrics (see Figure 11):

- R_{max} represents the maximum distance from source to threshold level under consideration (see red line). This is the most conservative metric.
- $R_{95\%}$ represents the radius of a circle encompassing 95% of the area above the threshold level under consideration (see yellow circle). Five percent of the time animals may be exposed to levels greater than the actual threshold level.
- R_{ea} represents the radius of a circle having equal area to that of the threshold level averaged across all azimuths.[13]

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[13] Rea averages all the radii measured along all the azimuths from the source to estimate a single radii that along some azimuths may under- or over-estimate actual exposure. Rea converts the area of irregular-shaped threshold level (often referred to as a contour) for any directional source into a circle of equal area.

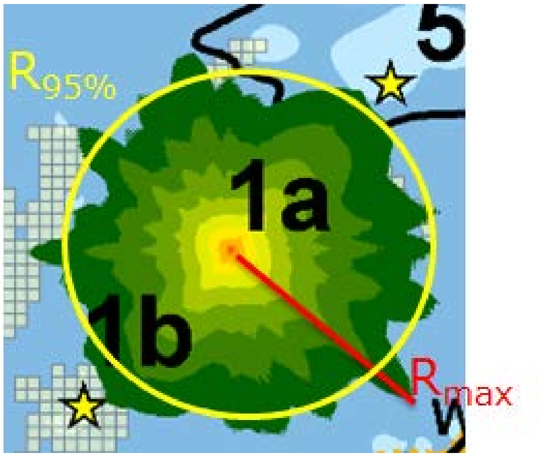

Figure 11. **Visual representation of metrics used to express threshold distances and show variance over azimuth (Austin et al. 2015).**

For the purposes of this opinion, we have provided distances and associated ensonified areas in both R_{ea} and R_{max} to encompass the variability.

We consolidated the 460 active leases in LS 193 into four representative acoustic propagation modeling sites by water depth and bottom substrate type (Figure 12).

Bathymetric Provinces

BOEM's Chukchi Sea program area was divided into five acoustic provinces (Figure 12) based on distinguishing factors including water depth and biological importance. The Province 1 boundary encompasses areas within the BOEM program area with water depth less than 50 m, excluding Hana Shoal. Province 2 encompasses the biologically-important Hana Shoal, the boundary of which was defined to follow the 40 m water depth contour around the shoal. Areas with water depths greater than 50 m fall inside Provinces 3 (50-100m), 4 (100-500m) and 5 (>500m). While provinces 3-5 have distinct sound propagation conditions, they are outside of the scope for the present analysis, as no lease blocks occur within these locations. This acoustic modeling study was limited to analyzing acoustic propagation at the Chukchi Sea LS 193 lease blocks, so it considers only Provinces 1 and 2.

To examine how sound propagation varies with water depth, four modeling sites within Provinces 1 and 2 were chosen based primarily on bathymetry. Three sites were selected within Province 1 to cover the range of water depths within that province. The water depth at Site 1a is 44 m, Site 1b is 36 m, and Site 1c is 41 m. In addition to water depth, 1c was selected for a number of reasons, including its proximity to the shore and the possibility for unique acoustic propagation results, and to Point Lay, a community that relies heavily on subsistence hunting. These modeling sites (Figure 12) define the source locations for each modeled scenario (Table 12).

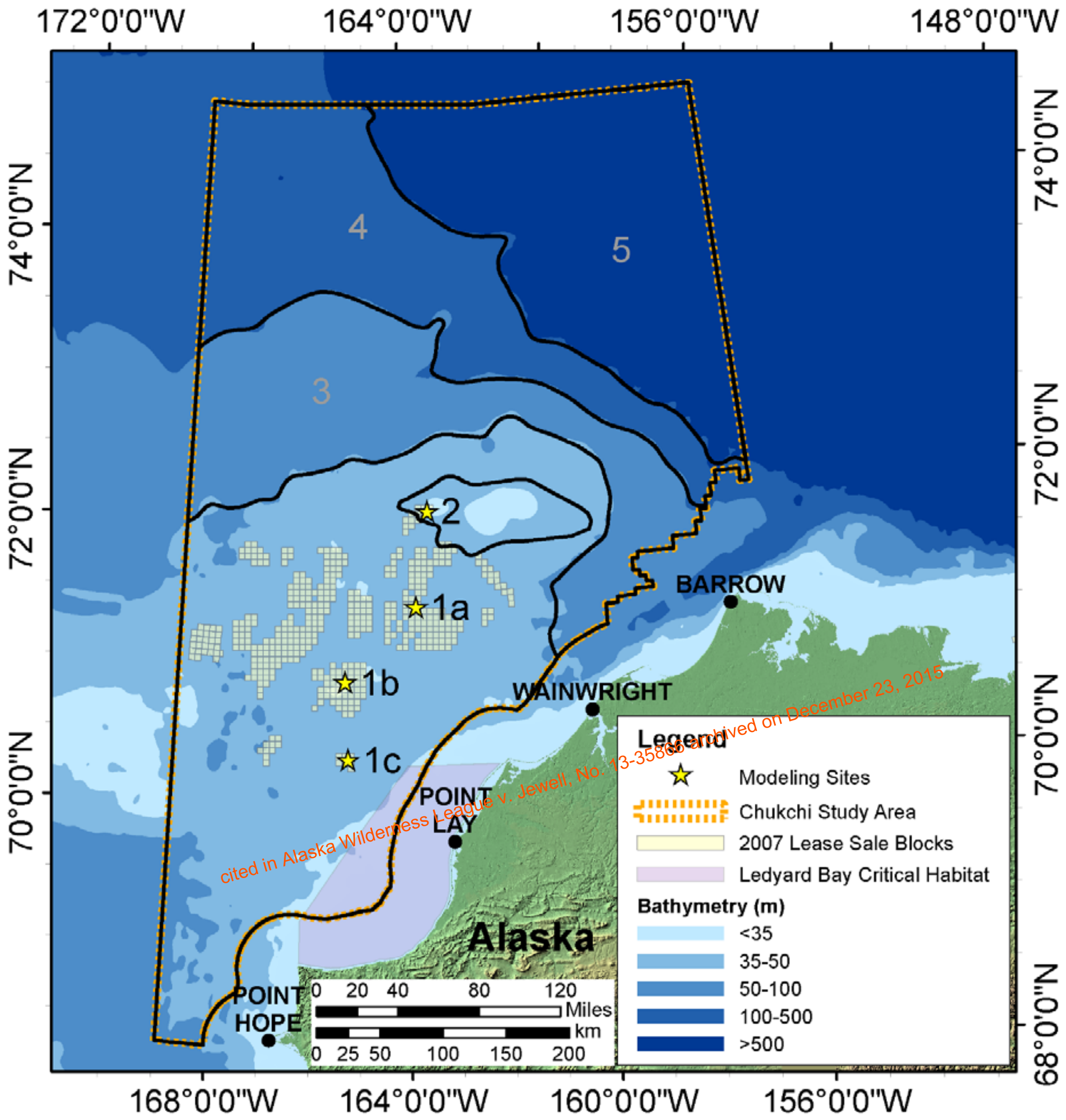

Figure 12. **Modeled source locations on active leases within LS 193 in the Chukchi Sea accounting for bathymetric and biological variability between leases (Austin et al. 2015).**

The radii between modeling sites tended to be relatively consistent due to the similar bathymetry of the modeled regions. There are, however, consistent trends between modeling sites. Sources located at modeling Site 1a produced the greatest radii, whereas those at modeling Site 2 produced the smallest. As bathymetric differences exist between modeling sites, the modeling sites can correspond to ranges of water depths. The leased blocks can then be categorized based on their average water depth and matched to a representative modeling site. Figure 13 shows the lease blocks of LS 193 with their representative modeling sites (Austin et al. 2015).

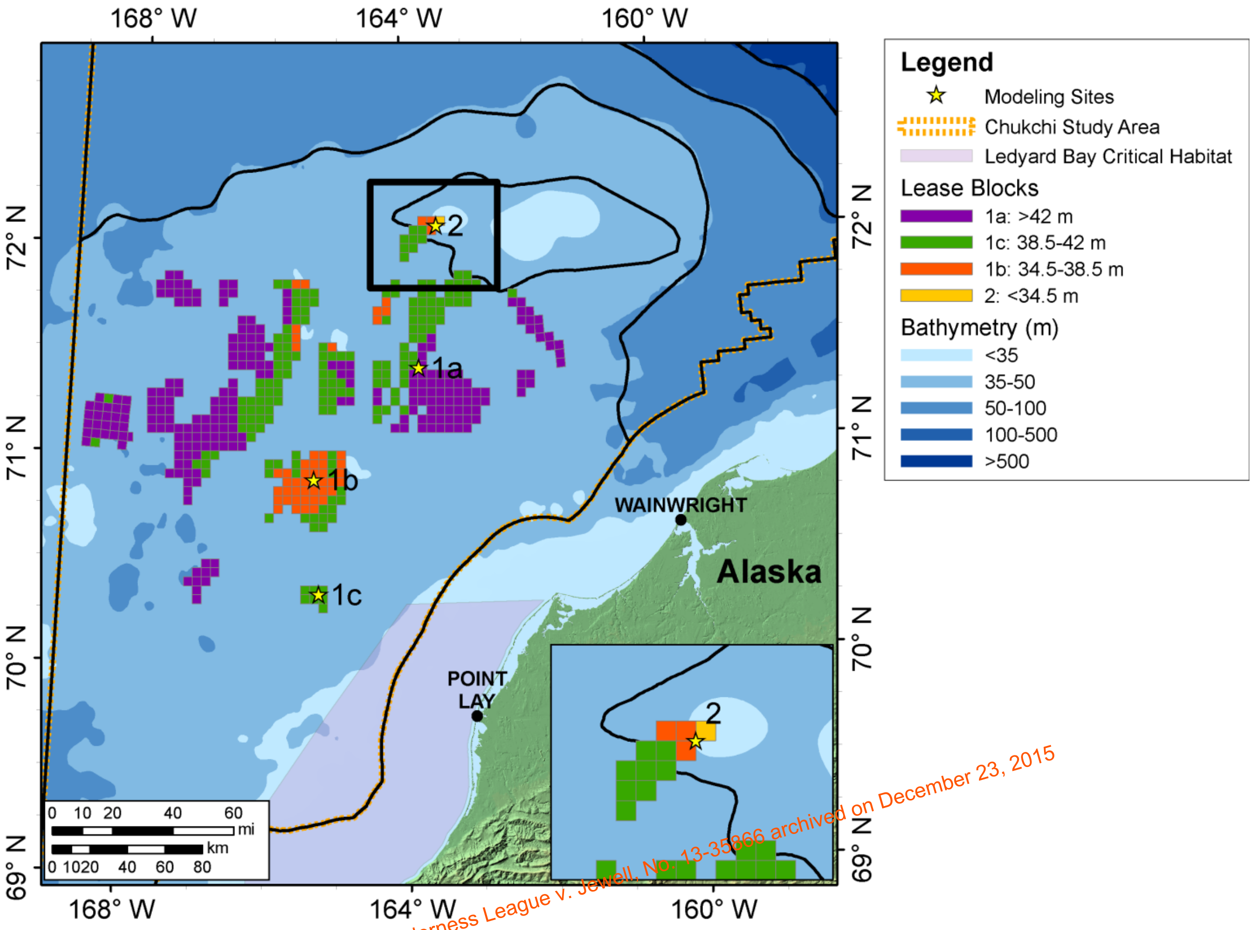

Figure 13. **Chukchi Sea lease blocks with their representative modeling sites, based on water depth (Austin et al. 2015).**

We used the acoustic sources identified by BOEM/BSEE as a starting point, and expanded our source scenarios to encompass other activities associated with seismic and drilling programs (i.e., dynamic positioning, anchor handling, ice management, etc.) for a total of 10 source scenarios that encompass all of the oil and gas exploration activities we anticipate being authorized during the first incremental step (see Table 12). Eight of the ten scenarios were analyzed through numerical sound propagation modeling. Two scenarios (representing anchor handling and mudline cellar construction) were evaluated with reference to empirical data and were not modeled because they represent only a short portion of the drilling program, and can be considered additively to scenarios 1-8 (Austin et al. 2015). The majority of these were modeled as individual sources. However, based on BOEM’s description of potential concurrent authorizations (see Table 17), and the description of Shell’s anticipated 2015 drilling program (Shell 2015), we modeled the potential overlap of sound footprints associated with two drilling operations in close proximity (10 km) with two vessel in dynamic positioning.[14]

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[14] Two drill rigs with 10 km separation distance will have a sound footprint that is larger than 2x the footprint of a single rig due to the additive effects of the overlap creating a greater total area ensonified. For a conservative estimate, we have assumed all drilling authorizations could occur within 10 km of each other.

Table 12. Distance to the 120 and 160 dB Isopleths (km) for continuous and impulsive noise sources associated with Provinces 1 and 2 (standard lease block and Hana Shoal representations) (Austin et al. 2015).

Activity Description	Threshold Level (dB re 1 µPa)	Radii of 120 and 160 dB re 1 µPa (rms) Isopleth (km) for Continuous and Impulsive Noise Sources Respectively			
		Rea Average	Rea High-Reflectivity[1]	Rmax Average	Rmax High-Reflectivity[1]
Impulsive Noise Sources					
3200 cui marine seismic survey at site 1a	160 dB	5.21	7.64	6.32	9.11
3200 cui marine seismic survey at site 2	160 dB	5.02	7.58	6.26	8.52
4500 cui marine seismic survey at site 1b[2]	160 dB	7.26	11.6	9.73	15.4
4500 cui marine seismic survey at site 2	160 dB	6.77	10.3	8.69	13.3
500 cui VSP at site 1a	160 dB	3.14	3.89	3.24	4.06
500 cui VSP at site 2	160 dB	3.13	3.72	3.25	3.94
40 cui geohazard at site 1a	160 dB	1.40	1.43	1.47	1.49
40 cui geohazard at site 2	160 dB	1.42	1.52	1.53	1.66
Continuous Noise Sources					
Drilling and DP Vessel at site 1b[2,3]	120 dB	4.86	6.59	5.48	7.63
Drilling and DP Vessel at site 2	120 dB	4.78	6.51	5.16	7.37
Drilling and DP Vessel (1a site) + Drilling and DP Vessel (2nd site 10 km away)[4]	120 dB	7.80	10.4	10.8	13.2
Drilling and DP Vessel (2 site) + Drilling and DP Vessel (2nd site 10 km away)	120 dB	7.38	9.86	10.3	12.4
Ice Management Vessel site 1a	120 dB	7.70	11.7	8.51	13.0
Ice Management	120 dB	7.61	11.7	8.96	14.4

Vessel site 2					
Ice Breaking Vessel site 1b[2]	120 dB	25.9	36.1	30.2	42.5
Ice Breaking Vessel site 2	120 dB	26.5	38.2	30.1	44.8
Anchor Handling[5]	120 dB	16.0	--	--	--
Mudline Cellar Construction[5]	120 dB	9.3	--	--	--

[1] Highlighted regions indicate the estimated distances we used for our ensonified area estimates using high reflectivity geoacoustics for a conservative estimate.

[2] Source location 1a typically produced the largest radii. However, for the 4500 cui array, drilling with a drillship, and icebreaking, site 1b provided the maximum radii in province 1 (Austin et al. 2015).

[3] The radii are relative to the center point between the drillsip and the support vessel for the 120 dB threshold (Austin et al. 2015).

[4] Maximum Rea radii were used for this source because the acoustic footprint is very irregular (Austin et al. 2015).

[5] Distances associated with Anchor handling and MLC were measured during Shell's 2012 drilling program in the Chukchi Sea and were not modeled at the various source locations (Austin et al. 2013). An additional 1.3 dB correction factor was applied to adjust the levels that were measured at the seafloor to the expect maximum-over-depth values (Austin et al. 2015).

Anticipated Area Ensonified to Specified Levels from Proposed Activity Sources

Previous consultations for offshore Arctic exploration programs estimated areas of water potentially ensonified to ≥120 or ≥160 dB re 1 μPa rms independently for each continuous or impulsive noise source respectively (drilling, dynamic positioning, 2D seismic, etc.). While we continue to use this approach for the majority of the sources whose sound signatures are not anticipated to overlap, we have modeled the potential for two drilling operations to occur within 10 km of each other with the potential for overlapping ensonified areas (see Table 13).

The area of water (in km^2) to be ensonified to ≥120 or ≥160 dB re 1 μPa (rms) (for continuous and impulsive noises respectively) for modeled sources was determined based on the Rea and Rmax radii of rms SPL contours average sound speed profile and high-reflectivity geoacoustics derived by acoustic propagation modeling of various sources at multiple locations on LS 193 (Austin et al. 2015) (see Table 12). If a source was anticipated to occur multiple times annually, then we multiplied the ensonified area of a single source by the number of anticipated annual operations (see Table 13).

As a conservative measure, the locations corresponding to the largest ensonified area were chosen to represent the given activity scenario. In other words, by binning all potential scenarios into the most conservative representative scenario, the largest possible ensonified areas for all activities were identified for analysis. A total of four representative activity sources were modeled to estimate areas exposed to impulsive sounds ≥160 dB re 1 μPa rms for the proposed exploration activities on LS 193, and four representative activity sources were modeled to estimate areas exposed to continuous sounds ≥120 dB re 1 μPa rms for the proposed exploration activities. The remaining two continuous sound sources (anchor handling and mudline cellar construction) were not modeled because they are discrete tasks that are only anticipated to occur with drilling from a drillship (i.e., not all drilling units) (see Table 13).

Table 13. **Sound Propagation Modeling Results of Representative Seismic and Drilling Related Activity Descriptions and Estimates of the Area Potentially Ensonified above Threshold Levels at Sample Sites in the Chukchi Sea During the Proposed First Incremental Step Exploration Activities (Austin et al. 2015).**

Activity Description	Threshold Level (dB re 1 µPa)	Ensonified Area (km^2)	
		Rea High-Reflectivity	Rmax High-Reflectivity
Impulsive Noise Sources			
3200 cui marine 3D seismic survey at site 1a	160 dB	183.3	260.6
4500 cui marine seismic 2D survey at site 1b	160 dB	422.5	744.7
500 cui VSP at site 1a	160 dB	47.5	51.8
40 cui geohazard site survey at site 2	160 dB	7.3	8.7
Continuous Noise Sources			
Drilling and DP Vessel at site 1b	120 dB	136.4	182.8
Drilling and DP Vessel (1a site) + Drilling and DP Vessel (2nd site 10 km away)[1]	120 dB	339.6	--
2 Ice Management Vessels site 2	120 dB	859.7	1,302.2
4 Ice Management Vessels site 2[2]	120 dB	1,719.3	2,604.4
Ice Breaking Vessel site 1b[3]	120 dB	4,092.0	5,671.6
Anchor Handling (2 Vessels)[4]	120 dB	1,607.7	--
4 Mudline Cellar Construction[4]	120 dB	1,086.3	--

[1] Maximum Rea radii was used for exposure estimates for this source because the acoustic footprint is very irregular (Austin et al. 2015).

[2] Shell anticipates up to four ice management vessels may be used to support their 2015 drilling operations (Shell 2015).

[3] Site 2 produced the farthest radii for this source. However, since this source is anticipated to occur in association with the 4500 cui array which has the farthest radii at site 1b, we used the 1b location for icebreaking as well.

[4] Anchor handling is anticipated to occur with two vessels. MLC construction is anticipated to occur at each well site, for a total of 4 per year.

The largest area estimated to be ensonified by continuous sounds of ≥120 dB re 1 µPa rms from a single activity source was 4,092-5,672 km^2 and resulted from ice breaking activities associated with in-ice seismic operations (Table 13; Figure 14). The smallest area estimated to be ensonified by continuous sound levels ≥ 120 dB re 1 µPa rms was 136.4 km^2, which represented drilling with a vessel in DP 500 m from the drillship at site 1b (Table 13; Figure 15). The *Noble Discoverer* was used as the sound source for the single site drilling and source levels for support vessel in DP was calculated from mean 1/3-octave-band levels for each measured vessel (*Ocean Pioneer*, *Fennica, and Nordica*), and averaged levels across the vessels to derive an average source level for vessels on DP (Austin et al. 2015).

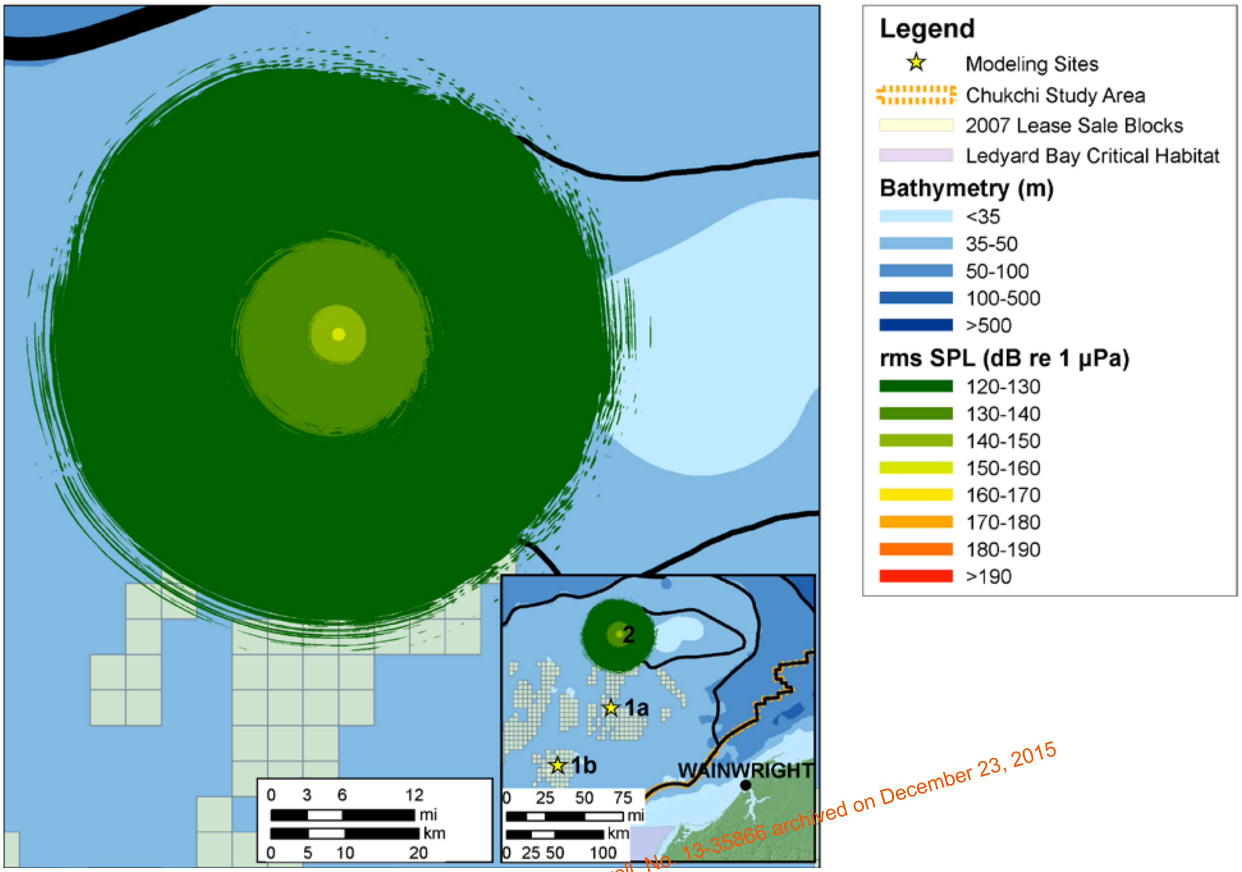

Figure 14. **Ice class vessel transiting through 80% ice cover at site 2. Contours of rms SPL (dB re 1 µPa, maximum over depth) with mixed sound speed profile and high-reflectivity geoacoustics (Austin et al. 2015).**

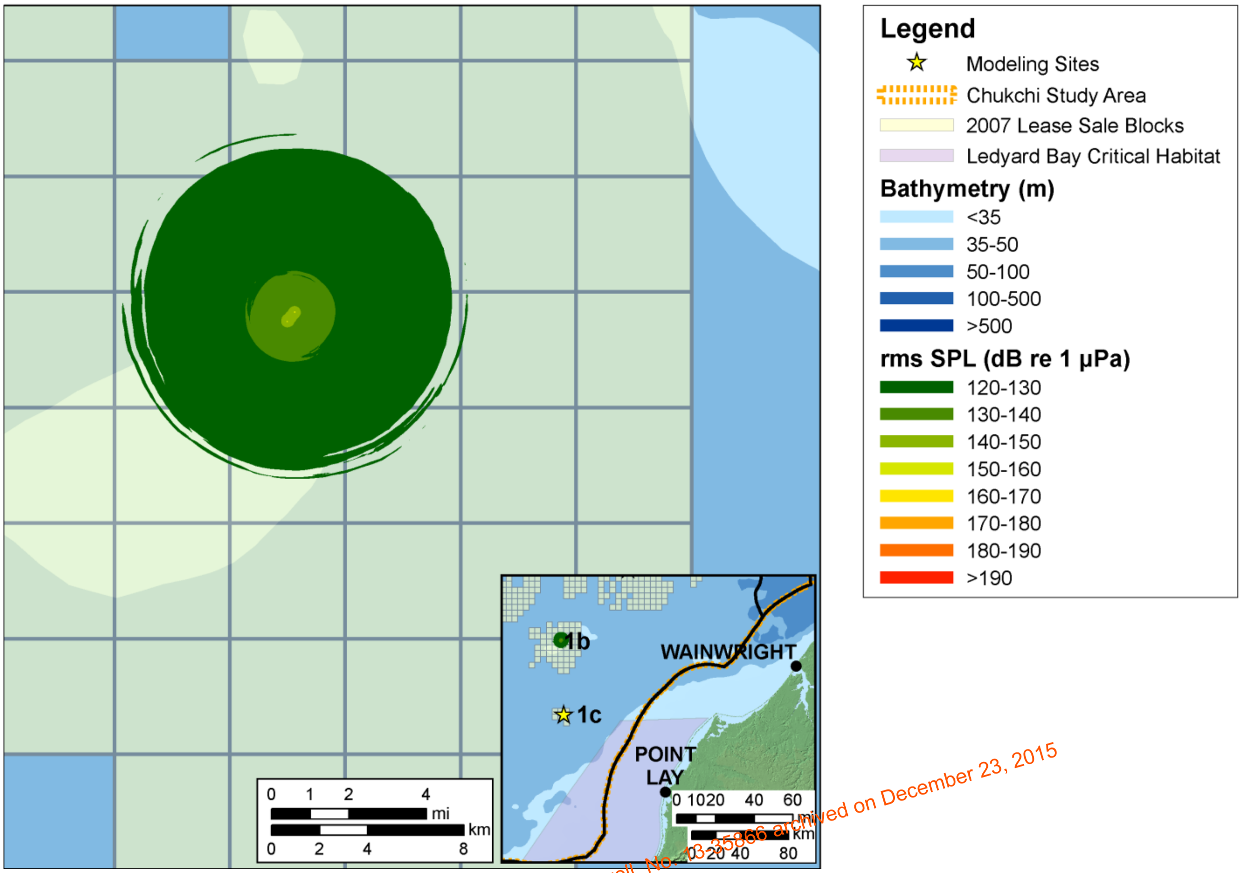

Figure 15. Drillship performing drilling operations with a support vessel on DP at 500m distance. Contours of rms SPL (dB re 1 µPa, maximum over depth) with average sound speed profile and high-reflectivity geoacoustics (Austin et al. 2015).

Ice management and drilling activities could have overlapping acoustic footprints; however, it is difficult to quantify the countless ways in which this could occur due to the temporal and spatial variability of ice conditions. It is also likely that ice management will occur at distances from the drill sites that would result in independent, non-overlapping acoustic footprints with respect to continuous sound sources operating at or near exploration drill sites. For these reasons, concurrent ice management activities were modeled separately from non-ice management activities, and results from each were summed together below to conservatively estimate the maximum total area ensonified to continuous sound levels ≥120 dB re 1 µPa rms for annual scenarios.

Annual Ensonified Area to Specified Levels from Proposed Activity Sources

Beyond the standard method of estimating instances of exposure (i.e., ensonified area x density), we have incorporated variation in the size of the ensonified areas by accounting for the anticipated number of days of operation for stationary sources including drilling and VSP. This method allowed for different ensonified areas corresponding to activity scenarios to be changed on a daily basis to reflect the anticipated operational timeline. To do this, we assumed the number of days of operation were split between each season, and split between the various activities and summed within the two season (Shell 2015). Activity days for ice management and VSP were assigned in addition to the number of days allocated to the other activity scenarios within each season. Ice management could occur at distances far enough from the drill sites to produce independent, non-overlapping acoustic footprints with respect to the other continuous noise sources operating at or near the drill sites.

For moving seismic operations we incorporated the anticipated full length of the survey line for 2D surveys, and the anticipated full area surveyed for a 3D survey. These methods incorporate the area covered by a moving vessel over the extent of the survey based on information provided by BOEM (2015a).

Continuous Noise Sources

Drilling operations are anticipated to take between 30-90 days at each well site for a total of 120 days per drilling season (BOEM 2015a, c). We based our anticipated number of days per drilling activity (i.e., drilling, dynamic positioning, anchor handling, etc.) on the scenario provided by Shell for its 2015 drilling operations (Shell 2015). We anticipate that future drilling operations will be similar to what Shell is proposing (Shell 2015), which involves the maximum number of drilling units and support vessels that BOEM/BSEE anticipate authorizing per year (see Table 14).

Table 14. Number of days per drilling activity anticipated per year during the first incremental step (Shell 2015).[15]

Activity Description	Days per Season Summer (July-Aug)	Days per Season Fall (Sept-Oct)	Days per Season Winter (Nov-Dec)	TOTAL DAYS/YEAR
Drilling and DP Vessel at site 1b	4	4	--	8
Drilling and DP Vessel (site 1a) + Drilling and DP Vessel (2nd site 10 km away)	21	20	--	41
Mudline Cellar Construction at 4 different sites	14	14	--	28
Anchor Handling (2 vessels)	3	3	--	6
Drilling and DP Vessel at 1 site + Anchor Handling at 2nd site	8	8	--	16
MLC 4 sites + Anchor Handling	6	6	--	12
Two-vessel Ice Management site 2	15	15	--	30
Four-vessel Ice Management site 2	4	4	--	8
VSP at 4 different sites	2	2	--	4
Ice Breaking Vessel site 1b*	--	4.5	4.5	9

*The number of days for ice breaking activities is based on BOEM's proposed action for the in-ice 2D survey with an icebreaker which may occur for up to 30 days and operate 30% of the time or 9 days (BOEM 2015a). The number of days was divided equally between fall and winter seasons.

The total ensonified area anticipated annually for each continuous noise source (see Table 15) was estimated by multiplying the daily ensonified area (Table 13) by the total number of days of operation (Table 14).

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[15] We have modified the split of days between seasons from what was presented in Shell's IHA application to present more of an even split, since we do not know how operations of future projects will fall between seasons.

Table 15. Sound Propagation Modeling Results of Continuous Noise Sources and Estimated Total Area Potentially Ensonified above Threshold Levels during Annual Operations (Austin et al. 2015).

Activity Description	Threshold Level (dB re 1 µPa)	Ensonified Area (km^2) Single Day		Total Ensonified Area (km^2)	
		Rea High-Reflectivity	Rmax High-Reflectivity	Rea High-Reflectivity	Rmax High-Reflectivity
Drilling and DP Vessel at site 1b	120 dB	136.4	182.8	1,091.2	1,462.4
Drilling and DP Vessel (1a site) + Drilling and DP Vessel (2nd site 10 km away)[1]	120 dB	339.622	--	13,924.5	--
2 Ice Management Vessels site 2	120 dB	859.67	1,302.22	25,790	39,066.6
4 Ice Management Vessels site 2	120 dB	1,719.3	2,604.4	13,754.7	20,835.5
Anchor Handling (2 Vessels)	120 dB	1,607.7	--	9,646.1	--
4 Mudline Cellar Construction[2]	120 dB	1,086.3	--	30,416.8	--
Drilling and DP Vessel at 1 site + Anchor Handling at 2nd site	120 dB	1,744.1	1,790.5	27,905.6	28,648
MLC 4 sites + Anchor Handling	120 dB	2,694	--	32,328	--
TOTAL				154,856.9	176,327.9
Ice Breaking Vessel site 1b[3]	120 dB	4,092.079	5,671.625	36,828.7	51,044.6

[1] Maximum Rea radii was used for exposure estimates for this source because the acoustic footprint is very irregular (Austin et al. 2015).

[2] MLC construction is anticipated to occur at each well site, for a total of 4 per year.

[3] Site 2 produced the farthest radii for this source. However, since this source is anticipated to occur in association with the 4500 cui array which has the farthest radii at site 1b, we used the 1b location for icebreaking as well.

Impulsive Noise Sources

3D Marine Seismic Surveys

For moving, impulsive sources, the standard method for estimating the ensonified area for a 3D seismic source is to take the total survey area and add a noise buffer around the perimeter representing the distance to the 160 dB isopleth associated with the airgun array (e.g., (SAE 2014). For the proposed action, the estimated distance to the 160 dB isopleth associated with a 3200 cui airgun array ranges from 7.64-9.11 km based on the Rea and Rmax high-reflectivity geoacoustics (see Table 12). BOEM anticipates that the total survey area would be 518 km^2 and the dimensions of the survey are anticipated to be 11.3 x 45.5 km (BOEM 2015c, d).[16] The resulting ensonified area ranges from 1,621 km^2 to 1,887 km^2 (see Table 16).

Table 16. Total Area Potentially Ensonified above Threshold Levels for Annual Operations based on Sound Propagation Modeling Results of Impulsive Sources and Anticipated Survey Distance or Area (Austin et al. 2015, BOEM 2015c, d, f).

Activity Description	Threshold Level (dB re 1 µPa)	Survey Distance or Area	Total Ensonified Area (km^2)	
			Rea High-Reflectivity	Rmax High-Reflectivity
Impulsive Noise Sources				
3200 cui marine 3D seismic survey at site 1a	160 dB	518 km^2	1,621 km^2	1,887 km^2
4500 cui marine seismic 2D survey at site 1b	160 dB	164 km	3,808 km^2	5,056 km^2
500 cui VSP at site 1a	160 dB	4 well surveys	190 km^2	207 km^2
40 cui geohazard site survey at site 2	160 dB	115 km^2	307 km^2	329 km^2
40 cui geohazard pipeline survey at site 2	160 dB	1,418 km	4,310 km^2	4,707 km^2

2D Seismic Surveys

BOEM anticipates that one 2D 4500 cui marine seismic survey may be authorized during the first incremental step and that the length of the survey would cover 164.153 km (BOEM 2015c, d). Based on the acoustic propagation modeling results (Austin et al. 2015), the distance to the 160 dB isopleth is anticipated to range from 11.6 to 15.4 km using the Rea and Rmax high reflectivity estimates (see Table 12). By applying the 160 dB isopleth distance on either side of the survey line, the total ensonified area is anticipated to range from 3,808 km^2 to 5,056 km^2 for the 4500 cui seismic survey see Table 16.

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[16] The exact dimensions of future surveys are unknown. However, BOEM assumed that the survey would be a rectangle with the dimensions of x=4y to be conservative. For a fixed area, as you make one survey side longer than the other, you get a larger perimeter and thus a larger noise buffer zone.

Vertical Seismic Profiling

BOEM anticipates authorizing one VSP 500 cui survey per well for a total of four VSP surveys per year, and 28 surveys during the first incremental step. Based on the acoustic propagation modeling (Austin et al. 2015) (see Table 12), the distance to the 160 dB isopleth is anticipated to range from 3.89 to 4.06 km using the Rea and Rmax high reflectivity estimates. Since VSP is anticipated to be a stationary source, we took the daily ensonified area of each well and multiplied by a total of four well surveys per year. The total ensonified area is anticipated to range from 190 km^2 to 207 km^2 for the 500 cui seismic survey see Table 16.

Geohazard Site Survey

During the first incremental step, BOEM may authorize one 40 cui geohazard site survey per year, for a total of four surveys. Each survey may cover a total of 5 different locations for a total survey area of 115 km^2. Within the survey area, a total of 238 line km may be covered for each survey site. BOEM anticipates the survey will cover a square shaped grid, so we assume the dimensions of each site will be ~ 4.79 km x 4.79km (BOEM 2015f). For the proposed action, the estimated distance to the 160 dB isopleth associated with a 40 cui airgun array ranges from 1.52-1.66 km based on the Rea and Rmax high-reflectivity geoacoustics (see Table 12). By applying the 160 dB isopleth buffer around each survey site, the total ensonified area is anticipated to range from 307 km^2 to 329 km^2 for the 40 cui seismic survey (see Table 16).

Geohazard Pipeline Survey

BOEM anticipates that one 2D geohazard pipeline survey with 40 cui array may be authorized during the first incremental step and that the length of the survey would cover 1,417.83 km. For the proposed action, the estimated distance to the 160 dB isopleth associated with a 40 cui airgun array ranges from 1.52-1.66 km based on the Rea and Rmax high-reflectivity geoacoustics (see Table 12). By applying the 160 dB isopleth distance on either side of the survey line, the total ensonified area is anticipated to range from 4,310 km^2 to 4,707 km^2 for the 40 cui seismic survey see Table 16.

Anticipated Annual Scenarios during First Incremental Step for Activity Sources

A wide range of potential “activity scenarios” were derived from a realistic operational timeline by considering the various combinations of different impulsive and continuous sound sources that may operate at the same time at one or more locations.[17] The total number of possible activity combinations from all sources at multiple sites over nine years would not be practical to assess. While certain impulsive sources may operate concurrently, it is unlikely that they would occur in close enough proximity that they would have overlapping ensonified areas (e.g. geohazard survey and marine seismic survey). In addition, it is not appropriate to consider overlapping ensonified areas of different impulsive noise sources at different locations because even if surveys were to occur at the same time, the impulses would not be emitted simultaneously, the ensonified areas would not completely overlap temporally, and the sounds are not anticipated to overlap in frequency content. In order to be conservative we have treated these sources independently (e.g.

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[17] NMFS created the activity scenarios based on conversations with BOEM/BSEE, and scenarios presented in table B-1 in the Second SEIS (BOEM 2015e).

four VSP surveys may occur during a single year which would result in four times the area of a single VSP survey versus subtracting for overlapped areas). Similarly it does not make sense to overlap impulsive and continuous noise sources when NMFS acoustic thresholds are based on sound pressure level and each source uses a different duration to estimate the anticipated pressure so sources cannot be summed. While these sources may operate concurrently, we have not overlapped their sound footprints. Additionally, combinations such as concurrent drilling and anchor handling in close proximity do not add meaning to the analysis given the negligible contribution of drilling sounds to the total area ensonified by the anchor handling in such a scenario.

Table 17 describes the six conceptual examples we anticipate during the first incremental step. The conceptual examples are provided to help illustrate potential temporal and spatial arrangements of exploration activities for the first nine years described in the proposed action. Figures 16-18 depict the conceptual examples of three annual scenarios (Scenarios 1, 5-6) which have multiple acoustic sources, and the anticipated ensonified areas for each source associated with the various exploration activities BOEM is proposing to authorize.

Table 17. **Annual Scenarios Anticipated During the First Incremental Step for Active Acoustic Sources (BOEM 2014a, 2015a, d, f, e).**

Scenario	Total # Year(s)	Activity Description	Survey Distance or Area
1	1	(1) 3200 cui marine 3D seismic survey and (1) 40 cui geohazard site survey	3D- 518 km^2 Geohazard- 644 km
2	1	(1) 40 cui geohazard site survey	115 km^2
3	3	(2) drilling operations* and (4) VSP	4 wells
4	1	(1) 40 cui geohazard pipeline survey, (2) drilling operations (within 10 km),* and (4) VSP	Geohazard- 1,418 km 4 wells
5	2	(1) 40 cui geohazard site survey, (2) drilling rigs* and (4) VSP	Geohazard- 115 km^2 4 wells
6	1	(2) drilling rigs* and (4) VSP + (1) 4500 cui marine 2D seismic survey and (1) icebreaker	2D- 164 km

* BOEM focused on drilling rigs in their annual scenarios. However, there are many activities associated with drilling operations (MLC construction, anchor handling, dynamic positioning, VSP, etc.). We have provided the ensonified areas associated with these sources above in Table 15, and have incorporated them into the total ensonified area anticipated for drilling scenarios.

Based on these conceptual examples, we estimated the annual ensonified areas of these concurrently operating sources. Such concurrent operations result in additive acoustic effects. Therefore, the ensonified areas associated with each of these scenarios represent the additive acoustic effects from concurrently-operating, continuous and impulsive sound sources at different locations on LS 193.

The areas potentially ensonified by each activity scenario assume all sound sources identified for that annual scenario would be operating concurrently for each season. As an example, in scenario 6, BOEM anticipates that two drilling operations (which consist of multiple activities) and four VSP surveys may operate concurrently during the open water season (summer and fall). An additional 2D 4500 cui in-ice seismic survey with an icebreaker may be authorized during the in-ice season (fall and winter) resulting in multiple activities potentially overlapping during the fall.

BOEM/BSEE intends to authorize up to two drilling operations on LS 193 per year over seven years. However, a drilling authorization is comprised of multiple activities and sources of noise. We based the potential drilling activities that comprise a drilling authorization on Shell’s 2015 drilling program (Shell 2015), and assume that future drilling operations will be similar in scope.

This approach was an attempt to move away from assessing ensonified areas stemming from different sources in isolation, or independently one-by-one, and instead begin assessing the acoustic environment more realistically as an aggregate of multiple sound sources operating concurrently. This approach to sound propagation modeling allows for the consideration of additive acoustic effects from concurrently operating impulsive and continuous sources, and overlapping sound fields produced by drilling operations (e.g., Figures 16-18). Ultimately, this method attempts to more accurately simulate the underwater acoustic environment resulting from concurrent oil and gas exploration authorizations on LS 193.

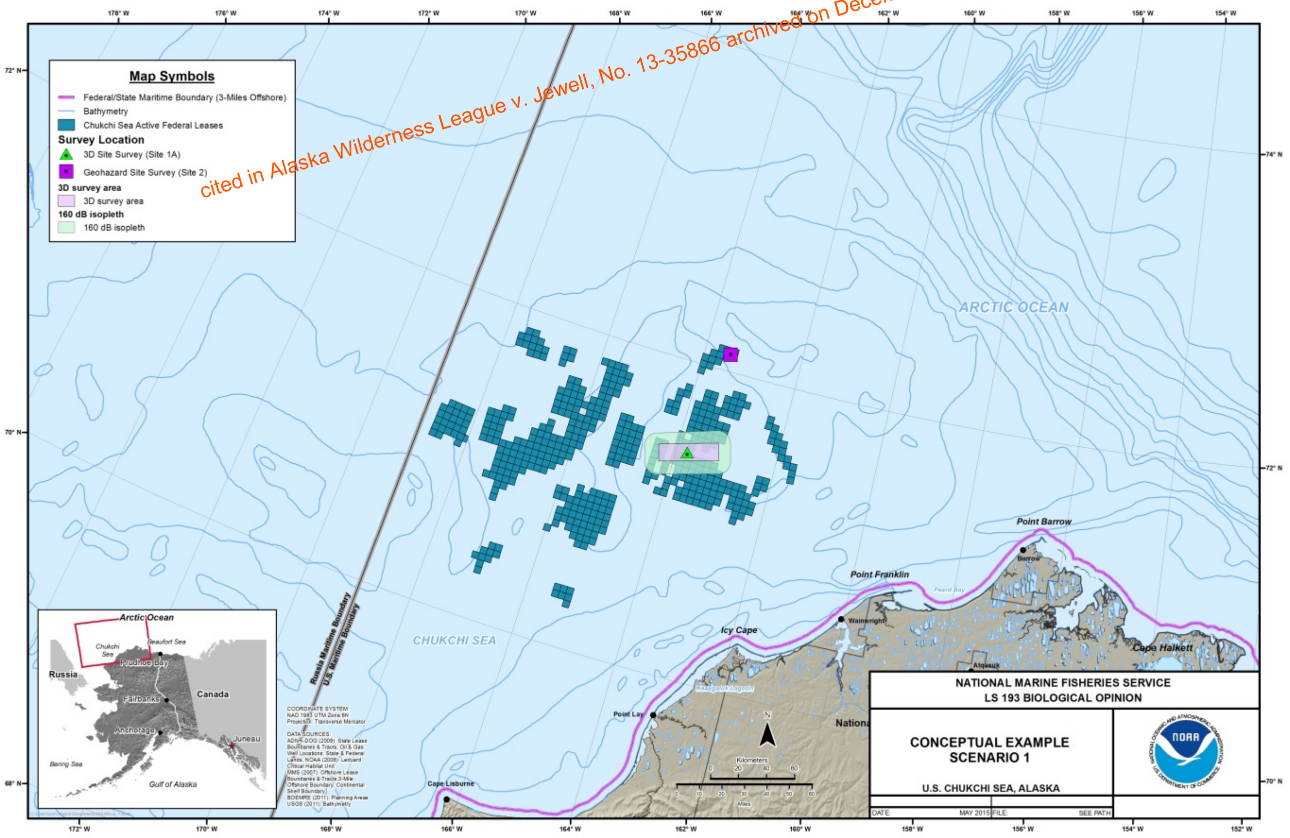

Figure 16. **Conceptual Example for Scenario 1: 3200 cui 3D Seismic Survey and 40 cui Geohazard Site Survey over a Single Year.**

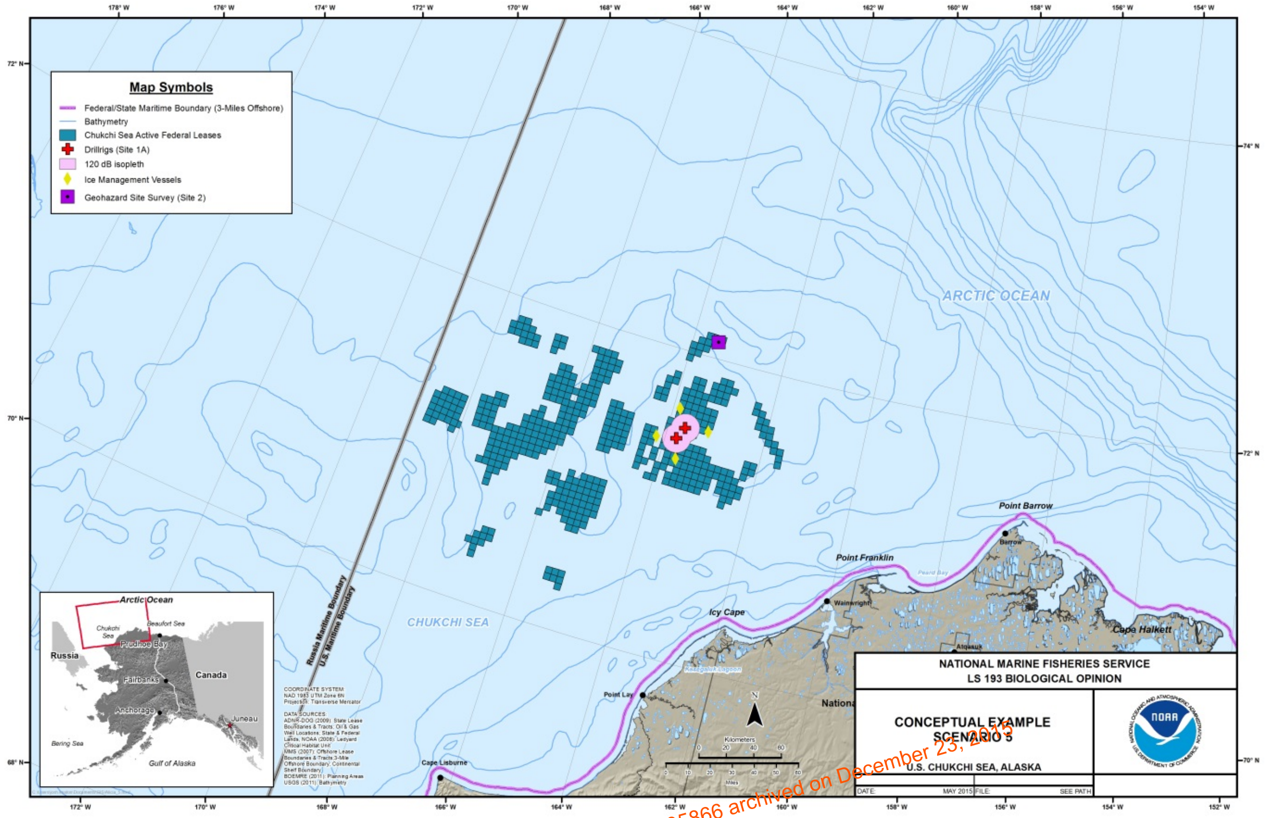

Figure 17. Conceptual Example for Scenario 5: One 40 cui Geohazard Site Survey, Two Drilling Operations, and Four VSP Annually over Two Years.

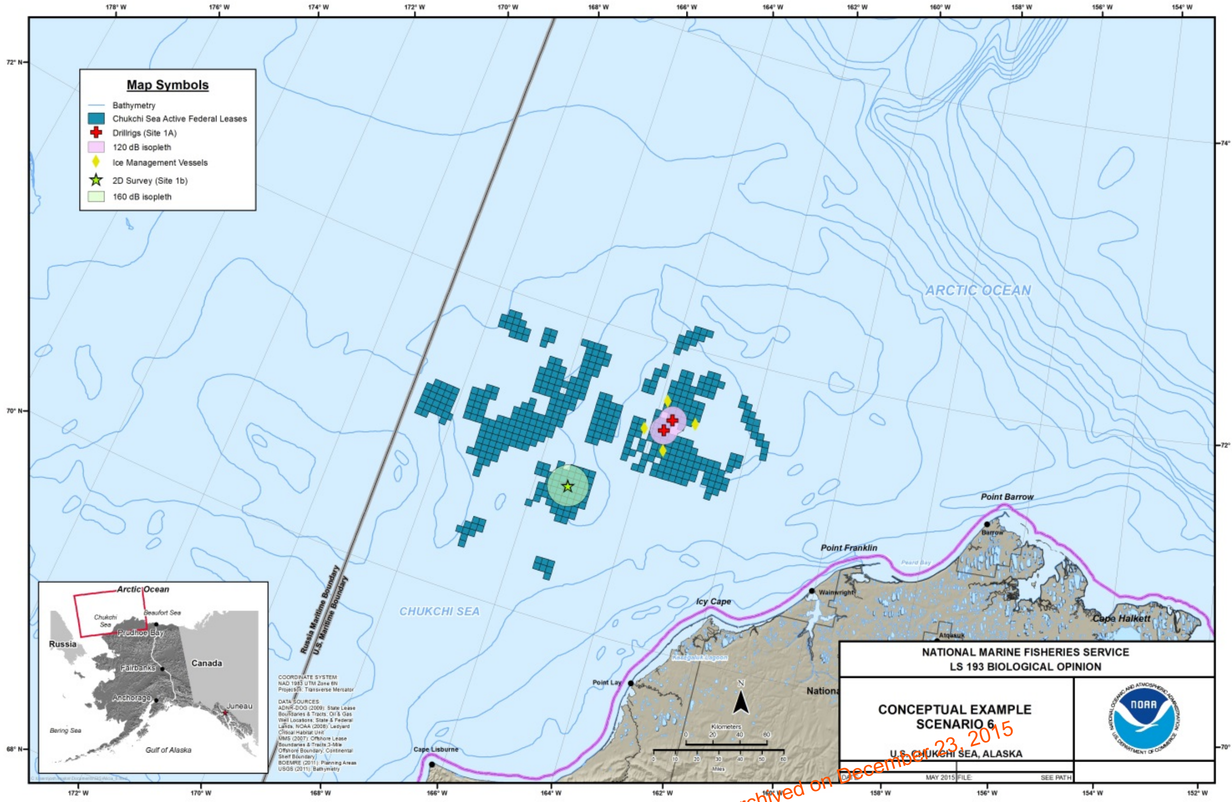

Figure 18. **Conceptual Example for Scenario 6: Two Drilling Operations, and One 4500 cui 2D Seismic Survey over a Single Year (these may only overlap during fall season).**

In general, scenarios that involve ice management, icebreaking, anchor handling and/or MLC construction resulted in the largest estimated areas that would be ensonified to levels ≥120 dB re 1 μPa rms (activity scenarios 3-6; Table 18; Figures 16-18).

Anticipated Densities of Listed Species in the Chukchi Sea

Assumptions taken into account when determining marine mammal density estimates:

- Proposed exploration activities may occur in summer (July-Aug), fall (Sept-Oct), or winter (Nov-Dec), so we estimated density for these three seasons.
- Modeled survey areas on LS 193 were divided into provinces by depth contour, and (if available) listed marine mammal density data were provided for these contours.

Cetacean Density Estimates

To estimate bowhead whale densities, we used data from the 2008 and 2014 ASAMM aerial surveys flown in the Chukchi Sea (Ferguson, pers. comm., 2015b); www.afsc.noaa.gov/nmml/). Only "on-transect" sighting and effort data were used. The analysis was further restricted to sightings made by primary observers, and did not include repeat sightings or sightings of dead animals.

The temporal variability in animal density was incorporated by computing separate density estimates for each month (July-October). Furthermore, to account for inter-annual variability, two types of density estimates were provided. The pooled density estimate is based on combining all valid sightings recorded from 2008-2014. The maximum density estimate represents the greatest density estimate per depth stratum per month in a single year. The year chosen could vary across months for a given depth stratum (Ferguson, pers. comm., 2015b). In order to determine seasonal densities, the pooled monthly data was averaged across two months – summer (July-Aug), and fall (Sept-Oct), and depth contour. For the maximum seasonal estimates we used the greatest density estimate per month; we did not pool maximum estimates across months. We did this to be conservative and account for the potential of large pulses of migrating bowhead whales.

While we have density estimates for multiple depth strata across the Chukchi Sea, we focused on the estimates for 35-50m which is the anticipated depth for the active leases.

Density was computed using a standard line-transect equation[18]:

$$D_{m,z,y} = \frac{n_{m,z,y} s_{m,z,y} f(0)}{2L_{m,z,y} g(0)}$$

Values for *f(0)* were taken from Ferguson and Clarke (2013). Because there currently are no estimates of trackline detection probability for the ASAMM sighting data, values for *g(0)* were taken from Thomas et al. (2002). Resulting density estimates are shown in Table 18.

There is insufficient information to determine quantitatively how bowhead whale densities north of 72°N compare to those within the ASAMM study areas. Quakenbush et al. (2010b, 2013) tracked multiple bowhead whales migrating through the Chukchi Sea north of 72°N. Bowhead densities are anticipated to be similar north and south of 72°N (Ferguson 2015b).

Data are not available from ASAMM surveys to make a quantitative density estimate for winter months (Nov-Dec) for bowhead whales. However, one late season seismic survey occurred from Oct 12-Nov 16 (ION Geophysical 2013), and we used the densities calculated for that survey from observations pooled across all survey days. Densities were corrected for *f(0) and g(0)* (Beland et al. 2013). The bowhead density estimates provided by ION in its 90-day report (avg 0.0489 max 0.2590) were much higher than anticipated in its IHA application (avg 0.0009 to max 0.0037) because it encountered an unexpected patch of ~75 bowhead whales. While we anticipate that the density of bowhead whales on LS 193 in the winter will be less than fall density estimates (Ferguson, pers. comm., 2015a), we based our exposure estimates on the higher density provided by ION Geophysical in order to be conservative and account for the potential late pulses of migrating bowhead whales.

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[18] *m* = month, *z* = depth stratum, *y*= year, *n* = number of sightings, *s* = average group size, *f(0)*= sighting probability density at zero perpendicular distance, or equivalently, 1/effective strip width, *g(0)*= probability of sighting an object located directly on the trackline.

Although there is evidence of the occasional occurrence of fin and humpback whales in the Chukchi Sea, it is unlikely that more than a few individuals will be encountered during the proposed exploration activities. Clarke et al. (2011c, 2013c) and Hartin et al. (2013) reported humpback and fin whale sightings. NMFS (2013c) recently concluded that these whales may be regular visitors to the Chukchi Sea but occur in low numbers there. In the absence of more definitive data regarding humpback and fin whale densities in the Chukchi Sea, we use minimum densities for these species (avg 0.0001 and max 0.0004) across season and depth contours.

Table 18 summarizes the densities used in the calculation of potential exposures.

Table 18. **Estimated listed cetacean density (# whales/km^2) by depth and season. Summer and Fall average data are based on pooled estimates combining ASAMM valid sightings for each month and depth stratum from 2008-2014. Max estimates correspond to the maximum density estimate observed in a given year for each combination of season and depth stratum (Ferguson, pers. comm., 2015b). Winter average estimates were pooled across all survey days during ION seismic survey 12 Oct-16 Nov 2012. Max winter estimates are based on upper confidence limit (Beland et al. 2013).**

	SUMMER (July-Aug)						FALL (Sept-Oct)						Winter (Nov-Dec)	
Species	**Average Density 0-35m (# /km^2)**	**Max Density 0-35m (#/km^2)**	**Average Density 35-50m (# /km^2)**	**Max Density 35-50m (#/km^2)**	**Average Density 50-200m (# /km^2)**	**Max Density 50-200m (#/km^2)**	**Average Density 0-35m (# /km^2)**	**Max Density 0-35m (#/km^2)**	**Average Density 35-50m (# /km^2)**	**Max Density 35-50m (#/km^2)**	**Average Density 50-200m (# /km^2)**	**Max Density 50-200m (#/km^2)**	**Average Density 0-200m (# /km^2)**	**Max Density 0-200m (# /km^2)**
Mysticetes														
Bowhead whale	0.0015	0.0130	0.0010	0.0050	0.0060	0.0200	0.0035	0.006	0.0230	0.078	0.0685	0.1890	0.0489	0.2590
Fin whale	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004
Humpback whale	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004	0.0001	0.0004

Pinniped Density Estimates

The basic approach for estimating ringed and bearded seal densities in the Chukchi Sea lease area during the open-water period (July-Oct) was to make separate estimates for the contributions from local breeding populations in the northern Bering Sea and the summer-autumn migration from the Bering Sea into the Chukchi Sea (Cameron, pers. comm., 2015). For densities during the winter (January-May), we relied on estimates provided by Bengtson et al. (2005).

Most census methods of ringed and bearded seals in the Chukchi Sea count seals basking on the surface of the sea ice during the spring. To account for the proportion of animals present but not hauled out (availability bias), a correction factor should be applied to the “raw” counts. In addition, ringed seals can haul-out within their subnivean lairs, but not be available to be counted. Thus the availability bias must be corrected for both those ringed seals underwater and within lairs. Bearded seals are not known to use subnivean lairs so the availability correction would only apply to seals in the water.

To estimate the daily proportions of ringed seals resting on the sea ice during the 1999-2000 spring surveys, Bengtson et al. (2005) attached satellite data recorders (SDR) to seals to record their movements and patterns of hauling out and reported densities corrected for availability. Bengtson et al. (2005) did not have SDR data for bearded seals so their springtime abundance estimates were provided uncorrected for availability. In the spring of 2012 and 2013, researchers completed aerial surveys for ice-associated seals in the Bering and Okhotsk Seas (BOSS) (Conn et al. 2014). Conn et al (2014) developed a correction factor for bearded seal availability using a model developed for the BOSS program that incorporated data from bearded seals instrumented with SDR tags. They estimated that an average of 60% of the bearded seal population was hauled out on the ice during the May-June survey window. We divided the uncorrected counts for bearded seals on the nearshore Chukchi Sea ice from Bengtson et al. (2005) by the BOSS correction factor (0.600) developed for bearded seals captured in the Bering Sea to provide corrected estimates for the Chukchi Sea (Cameron, pers. comm., 2015). We assumed that springtime densities of all seals in the sea ice beyond the extent of the nearshore survey transects in Bengtson et al. (2005) were the same as those offshore (Cameron, pers. comm., 2015).

To estimate the number of bearded seals that migrate from the Bering Sea into the Chukchi Sea each summer (and back again in the fall), we: 1) proportionally adjusted Conn et al.’s (2014) U.S. Bering Sea abundance estimate to the entire Bering Sea, 2) applied the proportion of bearded seals tagged with SDRs in the Chukchi Sea in late-summer that seasonally migrated south to the Bering Sea in the winter (i.e., ~72%; this could be seen as conservative considering 100% of the instrumented bearded seals that were in the Bering Sea during the breeding season migrated back north to the Chukchi Sea in the summer), and 3) proportionally adjusted this estimate by the area of the US sector of the Chukchi Sea relative to the entire Chukchi Sea. Conn et al. (2014) provided abundance estimates for ringed seals in the Bering Sea; however, they were uncorrected for availability. Therefore we applied the average ringed seal availability correction factor from Bengtson et al. (2005). We did not have sufficient ringed seal SDR data to estimate seasonal migration, but assumed that 100% of ringed seals transited north through the Bering Strait in the summer based on Frost (1985).[19]

In order to calculate the abundances of ringed and bearded seals during the open water season (July-Oct) in the Chukchi Sea, we summed the abundance estimates from Bengtson et al. (2005) and the estimated number of seals that migrated into the U.S. sector of the Chukchi Sea from the Bering Sea. This resulted in an estimated abundance of 399,885 ringed seals, and 159,778 bearded seals for the entire U.S. Chukchi Sea shelf from July through October (Cameron, pers. comm., 2015).[20]

We estimated the average density for ringed and bearded seals by dividing the anticipated abundance (399,885 ringed seals, and 159,778 bearded seals) by the area of the U.S. portion of the Chukchi Sea shelf (i.e., 247,260 km^2). No data are available to correct counts from the spring sea ice to apply to that same area in the summer or fall when sea ice is absent in the Chukchi Sea (see Table 19). In addition, no data are available to correct counts from different depth contours in the Chukchi Sea though Frost et al. (2004) and Moulton et al. (2002) showed ringed seal densities varied significantly by water depth in the Beaufort Sea.

The predicted average density estimates for ringed and bearded seals in the U.S. sector of the Chukchi Sea was estimated for the duration of the proposed action (see Table 19). We used linear interpolation to estimate the density during migration periods (i.e., June and Nov/Dec) using the density estimates of surrounding months (i.e., May and July, October and January respectively) for each species (Cameron, pers. comm., 2015).

Table 19 summarizes the densities used in the calculation of potential exposures. Only average density estimates for ringed and bearded seals were provided. However, since these estimates are based on densities from seals hauled out during the spring molt period versus the open-water foraging period, we anticipate that these estimates are conservative for lease area 193.

Table 19. Ringed and bearded seal average densities in the Chukchi Sea for open water season (July-Oct) and in-ice seasons (Nov-Dec) based on (Cameron, pers. comm., 2015).

Species	Average Seal Density June Migration (# /km^2)	Average Open-Water Seal Density July-October (# /km^2)	Average In-Ice Seal Density November-December (# /km^2)
Ringed	1.275	1.617	1.275
Bearded	0.369	0.646	0.369

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[19] Frost (1985) stated… "a small proportion of the population, mainly juveniles, may remain in ice-free areas during the summer, but most ringed seals spend the summer in the pack ice of the northern Chukchi and Beaufort Seas…"

[20] Ringed and bearded seal avg abundance in nearshore Chukchi Sea in spring (230,673 and 22,719 respectively) (Bengtson et al. 2005), plus the number of seals anticipated to migrate from the Bering Sea into the Chukchi Sea planning area (169,213 and 137,058 respectively) = 399,885 abundance of ringed seals and 159,778 abundance of bearded seals for the open water season (Cameron 2015).

Results of Exposure Analysis

We estimated bowhead whales, fin whales, humpback whales, ringed seals, and bearded seals might be exposed to received levels of continuous noise ≥120 dB re 1 µPa (rms) or to impulsive noise ≥160 dB (rms) annually from drilling and seismic operations on lease sale 193 during the first incremental step (Table 20)**.** The estimated instances of exposure are likely overestimates for the following reasons:

- The estimates assume that marine mammals would avoid oil and gas exploration operations;
- Although there will be an overlap in ensonified areas between acoustic sources, in general, we estimated instances of exposures associated with each source and then added the total number of exposures from each ensonified area together;[21]
- We modeled two drill units at 10km separation in order to overlap their footprints and consider additive effects of overlap;
- The anticipated area to be ensonified for each source was based on Rea and Rmax in high reflectivity environments to produce conservative noise propagation estimates;
- The proportion of time that the seismic array will be operating is very small compared to the proportion of time that operator will be in the project area. This is because each pulse with the full seismic array lasts only about 3 milliseconds, and is repeated at an interval of approximately 10 sec.;
- Instances of exposure associated with stationary noise sources include a multiplier for the estimated number of 24-hr days (8-28 days for drilling operations) that sources are operating. Instances of exposure associated with moving noise sources account for the full area surveyed. This takes into account that different listed whales/pinnipeds may be migrating through the area during seismic and drilling operations;
- Mitigation measures will be employed if any marine mammal is sighted within or near the designated exclusion zone, and will result in the shut down or power down of seismic operations (see Sections 2.1.5 and 2.1.6).
- The relationship between seal counts in the spring, when distribution is limited by sea ice, and distribution in the summer and fall is not clearly understood. Basing density estimates on spring counts is likely an overestimate for the open-water season.

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[21] The exception to this was concurrently operating drill rigs with vessels on DP which were modelled together to produce an overlapping irregular ensonified area that had additive effects associated with the overlap. For the other noise sources, it was more conservative to add their ensonified areas together, and not consider overlap.

Table 20. **Potential instances of exposure of listed marine mammals to received sound levels ≥120 dB re 1 μPa (rms) for continuous noise, or ≥160 dB re 1 μPa (rms) for impulsive noise associated with BOEM/BSEE annual oil and gas exploration authorizations under the first incremental step.[22] The range of exposures represents the Rea vs. Rmax ensonified areas.**

Species	Instances of Exposure/Year/ Activity Scenario to Cont. Sounds ≥120 dB or Impulsive Sounds 160 dB		Total Instances of Exposure for Duration of Proposed Action (9yrs)/Activity Scenario to ≥120 dB or Impulsive Sounds 160 dB
	Rea	Rmax	
Annual Scenario 1 – Impulsive Noise Sources (3D + Geohazard Site)			
Bowhead Whale	23	27	23-27
Fin Whale	0	0	0
Humpback Whale	0	0	0
Ringed Seal	3,117	3,439	3,117-3,439
Bearded Seal	1,245	1,431	1,245-1,431
Annual Scenario 2 - Impulsive Noise Sources (Geohazard Site)			
Bowhead Whale	4	4	4
Fin Whale	0	0	0
Humpback Whale	0	0	0
Ringed Seal	496	532	496-532
Bearded Seal	198	213	198-213
Triannual Scenario 3 -Continuous and Impulsive Noise Sources (2 Drilling Rigs + 4 VSP)*			
Bowhead Whale	2+1,858	3+2,105	1,860-2,108 *3 yrs= 5,580-6,324
Fin Whale	0+16	0+18	16-18*3 yrs= 48-54

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[22] Since we cannot have a fraction of an instance of exposure, we rounded exposure estimates up to the nearest whole number in order to be precautionary.

Humpback Whale	0+16	0+18	16-18*3 yrs= 48-54
Ringed Seal	307+250,404	335+285,122	250,711-285,457*3 yrs= 752,133-856,371
Bearded Seal	123+100,038	134+113,928	100,161-114,062*3 yrs= 300,483-342,186
Annual Scenario 4 - Continuous and Impulsive Noise Sources (Geohazard Pipeline + 2 Drilling Rigs + 4 VSP)			
Bowhead Whale	52 +2+1,858	56 +3+2,105	1,912-2,164
Fin Whale	0.5+ 16	1+18	17-19
Humpback Whale	0.5+16	1+18	17-19
Ringed Seal	7,277+250,404	7,946+285,122	257,681-293,068
Bearded Seal	2,907+100,038	3,174+113,928	102,945-117,102
Biannual Scenario 5 - Continuous and Impulsive Noise Sources (Geohazard Site + 2 Drilling Rigs + 4 VSP)			
Bowhead Whale	6+ 1,858	6 +2,105	1,864-2,111*2yrs= 3,728-4,222
Fin Whale	0+16	0 +18	16-18*2 yrs= 32-36
Humpback Whale	0+16	0 +18	16-18*2 yrs= 32-36
Ringed Seal	803+250,404	867+285,122	251,207-285,989*2 yrs= 502,414-571,978
Bearded Seal	321+100,038	346+113,928	100,359-114,274*2yrs= 200,718-228,548
Scenario 6 - Continuous and Impulsive Noise Sources (2D + Icebreaker+2 Drilling Rigs + 4 VSP)			
Bowhead Whale	2 (vsp)+1,858(drill)+137(2D)+442 (icebreaker)	3+2,105+182(2d)+1,835	2,439-4,125
Fin Whale	0+16+0+4	0+18+1+5	20-24
Humpback Whale	0+16+0+4	0+18+1+5	20-24
Ringed Seal	307+250,404+5,506+53,254	335+285,122+7,311+73,811	309,471-366,579
Bearded Seal	123+100,038+1,933+18,691	134+113,928+2,566+25,905	120,785-142,533

These exposure estimates indicate the instances in which whales and pinnipeds might be exposed to energy accumulations equivalent to a particular exposure level (which we call the estimated instances of exposure). To accumulate energy, we had to assume that a single animal was exposed multiple times as it moved through sound fields generated by a survey and that the time interval between subsequent exposures was small enough for animals not to recover from earlier exposures. However, as we previously indicated, it would be unrealistic to assume that each exposure event would involve a different animal; some animals might be exposed once during a seismic or drilling operation while other animals may be exposed more than once. The data we would need to estimate the number of times individual whales are likely to be exposed are unavailable. By focusing on "instances of exposure" rather than "number of individuals exposed," we do not need to make any assumptions about the number of times an individual whale might be exposed.

Exposure Estimates Including Turnover Assumptions

The exposure estimates in Table 20 above are considered conservative. Assumptions included upward scaling of source levels for all sound sources, assuming no avoidance of activities/sounds by individual marine mammals, and assuming 100% turnover of individuals in ensonified areas every 24 hours.

The following section presents instances of exposure for bowhead whales and ringed seals, based on an evaluation of the best available science and a reconsideration of the assumptions surrounding avoidance behavior and the frequency of turnover (information was not available to do similar analyses with the other listed species).

Individual marine mammals move into or out of exposed areas and new individuals move through subsequently. It is possible that this turnover of marine mammals within the ensonified area would be greater during the fall season than the summer season since many of the species present in the fall are migrating through the Chukchi Sea. However, wide ranging foraging patterns of some species may result in a similar amount of turnover within the ensonified area during the summer period as during migratory movements in the fall period. In either case, it is likely an overestimate to assume that the entire group of marine mammals within the ensonified area around each drill site or seismic operation would turnover every day (i.e. a completely new set of individual marine mammals is present on a daily basis). Regardless, that is the assumption that has been made in calculating the estimates shown above in Table 20, which result from multiplying the 'Total Area Potentially Ensonified' for each activity scenario shown in Table 17 by the density estimates for each season. For the reasons explained, the estimates of instances of exposure to marine mammals to sounds above 120dB and 160dB re 1 µPa (rms) thresholds shown in Table 20 are best interpreted as a very high estimate and one that is unlikely.

The following section presents estimates of instances of exposure for bowhead whales and ringed seals, based on an evaluation of the best available scientific information and provides a reconsideration of the assumptions surrounding avoidance behavior and the frequency of turnover (information was not available to do similar analyses with the other listed species).

Bowhead Whales

There are several methods for generating bowhead whales exposure estimates based on assumptions regarding bowhead whale avoidance and the frequency of turnover. We considered 5 alternatives: (1) 24 hour turnover, zero avoidance (most conservative method; see Table 20); (2) 24 hour turnover, 50% avoidance at no energetic cost; (3) 48 hour turnover, zero avoidance; (4) 48 hour turnover, 50% avoidance at an energetic cost; and (5) 48 hour turnover, 50% avoidance at no energetic cost (least conservative).

We have already described Method 1 in detail, so we will focus the remainder of this analysis on the other four methods described above.

Method 2

If bowhead whales avoid drilling and related support activities at distances of approximately 20 km (consistent with avoidance distances presented in (Koski and Johnson 1987, LGL and Greenridge 1987, Schick and Urban 2000), this would preclude exposure to the vast majority of individuals to continuous sounds ≥120 dB re 1 µPa rms or impulsive noise sources ≥160 dB re 1 µPa rms. Only icebreaking is expected to result in the lateral propagation of continuous sound levels ≥120 dB re 1 µPa rms to distances of 20 km or greater from the source (Austin et al. 2015).

If we assume half of the individual bowhead whales avoid areas greater than 20 km of drilling operations, or at received levels ≥120 dB re 1 µPa rms for continuous noise sources, and avoid received levels ≥160 dB re 1 µPa rms for impulsive noise sources, and that these avoidance behaviors do not result in an energetic cost, then the exposure estimate would be reduced by 50% even if 100% turnover of migrating whales is assumed to take place every 24 hours. However, we do not have enough information to determine which if any of those avoidance behaviors could come at an energetic cost or to develop a robust dose-response model to help characterize this avoidance. In addition, a 24-hour turnover rate for bowhead whales is unrealistically conservative (as described in more detail below in Methods 3-5). For these reasons we did not feel that method 2 represented the most scientifically defensible approach.

Method 3

Alternatively, we could assume that zero bowhead whales avoid sound levels above harassment thresholds. However, instead of assuming a 24-hour turnover rate, we would assume a 48-hour turnover rate to account for bowhead whales moving in pulses of one to several days due to feeding opportunities.

It is difficult to determine an appropriate average turnover time for individual bowhead whales in a particular area of the Chukchi Sea. Reasons for this include differences in residency time between migratory and non-migratory periods, changes in distribution of food and other factors such as behavior that influence animal movement, variation among individuals, etc. Complete turnover of individual bowhead whales in the project area each 24-hour period is possible during distinct periods within the fall migration when bowheads are traveling through the area. Even during the fall migration, however, bowheads often move in pulses with one to several days between major pulses of whales (Miller et al. 2002). Gaps between groups of traveling whales during fall migration result in days when no bowhead whales would be expected to be present in the activity area. The absence of bowhead whales during periods of the fall migration can likely be attributed to individuals stopping to feed opportunistically when food is encountered, which is known to occur annually in an area north of Barrow (Citta et al. 2014). The extent of feeding by bowhead whales during fall migration across other areas of the Chukchi Sea varies greatly from year to year based on the location and abundance of prey (Shelden and Mocklin 2013).

During the summer, relatively few bowhead are present in the Chukchi Sea and in most cases, given that the lease sale area is not known to be a critical feeding area (Allen and Angliss 2014, Citta et al. 2014, Clarke et al. 2015), whales would be likely to simply avoid the area of operations (Schick and Urban 2000; Richardson et al. 1995a).

In short, while Method 3 provides pertinent information on alternative turnover rates, it is not consistent with available information on bowhead whale avoidance associated with anthropogenic noise sources (see *Response Analysis*).

Method 4

Under this method, we assume half of the individual bowhead whales would avoid the area with sound levels above harassment thresholds, and assume this avoidance may come at an energetic cost that could rise to the level of take. While the take estimates under Method 4 (i.e. take is occurring either due to exposure to noise, or take is occurring due to the animals moving around the noise at an energetic cost), effectively remain the same as take estimates under Method 3 (i.e. all animals are taken due to noise exposure), they rely on very different assumptions regarding avoidance behavior.

As we discussed above, few bowhead whales are anticipated to be in the area during the summer, and gaps are anticipated between groups of traveling whales during fall migration. Many whales would likely travel around the project area (i.e., avoid it) as the areas in Lease Sale 193 are not known to contain important feeding habitat for bowheads during any portion of the year (Allen and Angliss 2014, Citta et al. 2014, Clarke et al. 2015). There is a large body of evidence indicating that bowhead whales avoid anthropogenic activities and associated underwater sounds depending on the context in which these activities are encountered (Koski and Johnson 1987, LGL and Greenridge 1987, Schick and Urban 2000, Moore et al. 2002, Treacy et al. 2006, Koski and Miller 2009, LGL Alaska Research Associates Inc. et al. 2014). Increasing evidence suggests that proximity to an activity or sound source, coupled with an individual's behavioral state (e.g., feeding vs traveling) among other contextual variables, as opposed to received sound level alone, strongly influences the degree to which an individual whale demonstrates aversion or other behaviors (reviewed in (Richardson et al. 1995, Gordon et al. 2003). For these reasons, we selected an assumed turnover rate of 48 hours to account for intermittent periods of migrating and feeding bowhead whales.

Method 5

Finally, we considered 48-hour turnover rate with 50% avoidance at no energetic cost. The assumptions behind a 48-hour turnover rate are described in Methods 3-4. This turnover rate incorporates intermittent periods of migrating and feeding pulses of bowhead whales. However, as described in Method 2, we do not have enough information to determine if avoidance behaviors would come at an energetic cost that would rise to the level of take or develop a robust dose-response model to help characterize this avoidance. Considering that Method 5 is the least conservative of all of the methods presented, the lack of information to develop a dose-response model, and the amount of uncertainty regarding future Lease Sale 193 exploration activities, we did not feel that we had enough information to currently justify this method.

Ultimately, we selected *Method* 4, with an assumed turnover rate of 48 hours (to account for intermittent periods of migrating and feeding individuals) and up to 50% avoidance that may come at an energetic cost, resulting in the reduction of instances of exposure to bowhead whales by 50% (see Table 21). We did not apply a 48-hour turnover rate and assumptions regarding avoidance for fin and humpback whales because of the low densities of these species in the action area and the paucity of information on their movements in the action area. Instead, we used the 24-hour turnover rate for fin and humpback whales even though we recognize this may result in an overestimate of exposure to fin and humpback whales. However, we do not have enough information to further refine our estimates for these other baleen whales.

Table 21. Instances of Exposure Incorporating Turnover Rate Assumptions for Bowhead Whale and Ringed Seal. The range of exposures represents the Rea vs. Rmax ensonified areas.

Species	Total Instances of Exposure/Year/ Activity Scenario to Cont. Sounds ≥120 dB or Impulsive Sounds 160 dB re 1 µPa rms	Total Instances of Exposure for Duration of Proposed Action (9yrs)/Activity Scenario to Cont. Sounds ≥120 dB or Impulsive Sounds 160 dB
	Rea-Rmax	Rea-Rmax
Annual Scenario 1 – Impulsive Noise Sources (3D + Geohazard Site)		
Bowhead Whale	12-14	12-14
Fin Whale	0	0
Humpback Whale	0	0
Ringed Seal	1,559-1,720	1,559-1,720
Bearded Seal	1,245-1,431	1,245-1,431
Annual Scenario 2 - Impulsive Noise Sources (Geohazard Site)		
Bowhead Whale	2	2
Fin Whale	0	0
Humpback Whale	0	0
Ringed Seal	248-266	248-266
Bearded Seal	198-213	198-213
Triannual Scenario 3 -Continuous and Impulsive Noise Sources (2 Drilling Rigs + 4 VSP)[*]		
Bowhead Whale	930-1054	2,790-3,162
Fin Whale	16-18	48-54
Humpback Whale	16-18	48-54
Ringed Seal	125,356-142,729	376,067-428,186
Bearded Seal	100,161-114,062	300,483-342,186

Annual Scenario 4 - Continuous and Impulsive Noise Sources (Geohazard Pipeline + 2 Drilling Rigs + 4 VSP)		
Bowhead Whale	956-1,082	956-1,082
Fin Whale	17-19	17-19
Humpback Whale	17-19	17-19
Ringed Seal	128,841-146,534	128,841-146,534
Bearded Seal	102,945-117,102	102,945-117,102
Biannual Scenario 5 - Continuous and Impulsive Noise Sources (Geohazard Site + 2 Drilling Rigs + 4 VSP)		
Bowhead Whale	932-1,056	1,864-2,111
Fin Whale	16-18	32-36
Humpback Whale	16-18	32-36
Ringed Seal	125,604-142,995	251,207-285,989
Bearded Seal	100,359-114,274	200,718-228,548
Scenario 6 - Continuous and Impulsive Noise Sources (2D + Icebreaker+2 Drilling Rigs + 4 VSP)		
Bowhead Whale	1,220-2,063	1,220-2,063
Fin Whale	20-24	20-24
Humpback Whale	20-24	20-24
Ringed Seal	154,736-183,290	154,736-183,290
Bearded Seal	120,785-142,533	120,785-142,533

Ringed Seals

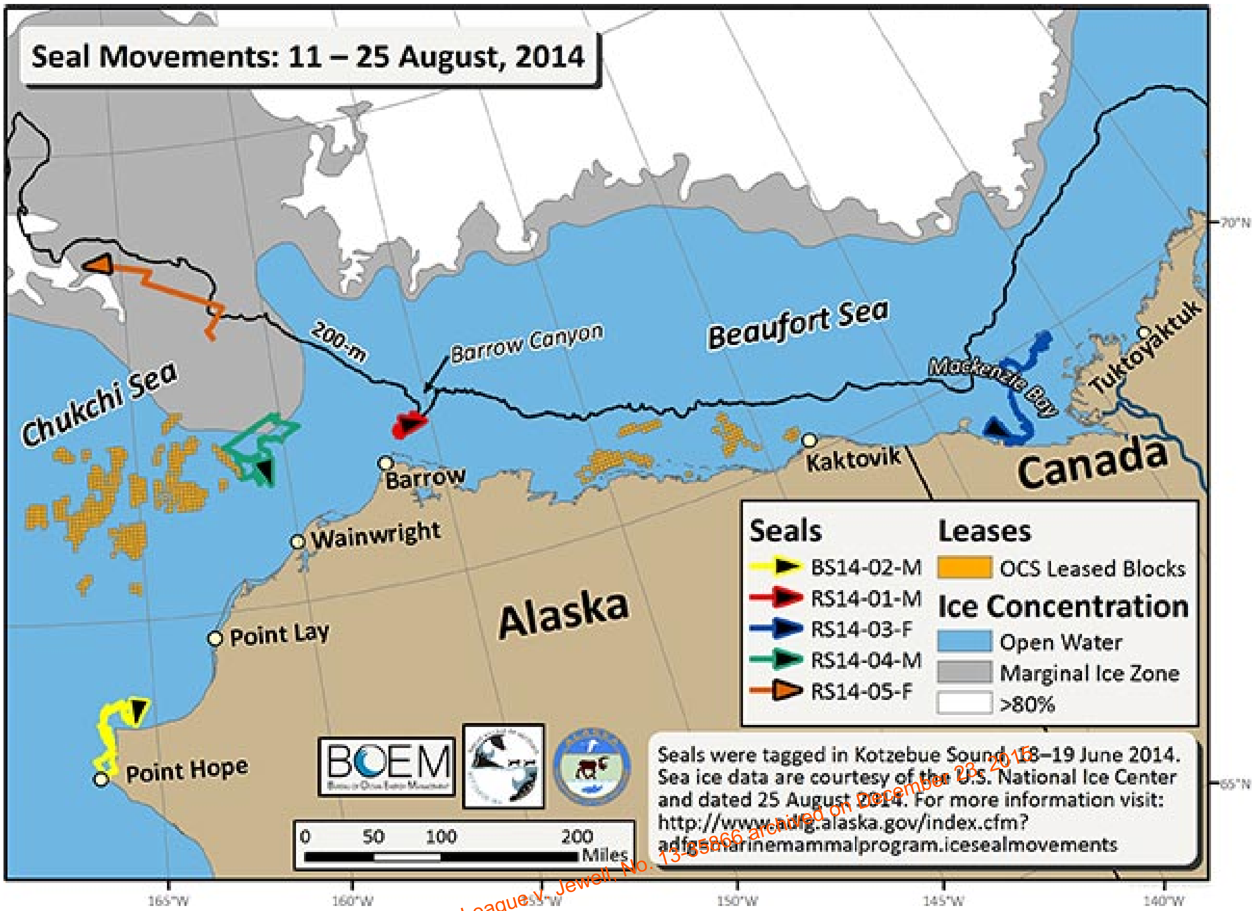
Data for some seal species suggest they may not avoid offshore exploration activities and associated sounds to the degree demonstrated by many cetaceans. Recent evidence suggests little change in the distribution of seals around offshore drilling operations. Moulton et al. (2005) reported that ringed seal densities in spring did not appear to be affected by proximity to construction, drilling, and oil production activities at a man-made island in the Beaufort Sea. There was no apparent difference in the detection distances and distributions of seals around Shell's two drilling units in 2012 when comparing periods of active drilling to non-drilling periods (LGL Alaska Research Associates Inc. et al. 2014).

Ringed seals frequently do not avoid the area within a few hundred meters of operating airgun arrays (Harris et al. 2001, Moulton and Lawson 2002, Miller et al. 2005). Some evidence, however, suggests that avoidance of active airguns by phocid seals in the Arctic may occur at slightly greater distances. Reiser et al. (2010) reported a tendency for localized avoidance of areas immediately around the seismic source vessel along with coincident increased sighting rates at support vessels operating 1–2 km away.

Following the methods described above for bowhead whale turnover, we considered various exposure estimates for ringed seals based on assumptions regarding avoidance and the frequency of turnover.

The turnover of individual seals in operational areas may not be as frequent as it is for cetaceans, at least for much of the operational period. Recent evidence from monitoring conducted in support of Shell's 2012 exploration drilling program is informative for assessing turnover rates of seals around an active drilling unit (Bisson et al. 2013). PSOs conducted detailed visual monitoring of seals in the Beaufort Sea from the *Kulluk* while it was drilling a pilot hole and excavating a mudline cellar in 2012. PSOs were able to identify individual ringed and bearded seals through unique markings on their pelage that were then documented and catalogued using high definition photographs. In total, 15 distinct, individual seals were identified; 12 ringed and 3 bearded (Patterson et al. 2014). Observations of these seals indicated numerous individuals were spending extended periods in the vicinity of the drilling unit. The time periods from when each of these seals was first identified as a unique individual to the last sighting of each respective individual ranged from 6 to 24 days (Patterson et al. 2014). These results suggest that assuming 100% turnover of all individual seals around an offshore drilling operation on a daily basis is unreasonable, and a period closer to a week may be more appropriate and yet still conservative for other individuals that remained in the area for longer periods.

ADFG has conducted satellite tagging and tracking of ringed seals in the Arctic. During the 2014 tagging season, four ringed seals were tagged (two males and two females) in Kotezebue Sound. Some of these seals spent time in the lease area. Figure 19 presents one of their weekly tagging map archives from the 2014 open water season, indicating that seals may occupy a relatively small area (particularly when actively foraging), as well as travel long distances to other foraging locations.



Seals were tagged in Kotzebue Sound, 18–19 June 2014. Sea ice data are courtesy of the U.S. National Ice Center and dated 25 August 2014. For more information visit: http://www.adfg.alaska.gov/index.cfm?adfg=marinemammalprogram.icesealmovements

Figure 19. **Ringed seal satellite tracking map archive August 11-25 2014, indicates that seals can occupy a relatively small area over a 2 week period, as well as traveling long distances. Male RS14-04 remained on or near lease blocks in the Chukchi Sea (ADFG 2014).**

We consider a 24-hr turnover rate and zero avoidance to be an overestimate of instances of exposure to ringed seals (Method 1). Although evidence exists to indicate a turnover period of a week or more for individual seals near a drilling operation in the Alaskan Arctic (Patterson et al. 2014), more data and analysis are necessary to determine an accurate extended turnover rate for seal populations in the activity area. Similarly, studies have investigated potential avoidance of anthropogenic activities and associated underwater sounds by ice seals. However, these studies have not yielded a clear understanding of how ice seals react to underwater sound (Harris et al. 2001, Moulton and Lawson 2002, Blackwell et al. 2004b, Miller et al. 2005, Moulton et al. 2005, Bain and Williams 2006, Reiser et al. 2010). We selected Method 3, which assumes a 48-hour turnover rate and zero avoidance based on repeated seal re-sights during previous drilling operations, tagging data, and tolerance to anthropogenic noise. While this method also results in a 50% reduction in exposure estimates to ringed seals, it is based on different assumptions (i.e., resight data indacting ringed seals remain in the area for prolonged periods of time) than what was presented for bowhead whales (i.e., pulses of migration and feeding) which relied on Method 4 (see Table 21).

NMFS did not apply a 48-hour turnover rate for bearded seals because sufficient information on their movements, time spent foraging at one location and satellite tagging information on bearded seals in the lease area were not available. Instead, NMFS used the 24-hour turnover rate for bearded seals. Although this assumption may be overly conservative (i.e., it assumes a high turnover rate in the vicinity of the planned drilling and seismic activities), it is difficult to scale variables more precisely without additional data.

The first column in Table 21 represents the total annual potential instances of exposure to marine mammals from impulsive and continuous noise associated with exploration activities incorporating 48-hour turnover rates for bowhead whales and ringed seals. The final column in Table 21 represents the total potential instances of exposure for the duration of the first incremental step (1-9 years). In the *Response Analysis* (Section 6.1.4) we apply the best science and commercial data available to describe the species' expected responses to these exposures and discuss what (if any) instances of exposure are assumed to constitute take under the ESA.

Marine seismic surveys, ancillary geohazard surveys, VSP surveys, and drilling operations conducted during the first incremental step of the proposed action all produce noise that could affect proposed ring seal critical habitat mainly through the essential feature of primary prey resources. In addition, ice management and icebreaking vessels, which may be used for in-ice seismic or to manage ice near exploratory drilling operations, have the potential to affect Arctic ringed seals and their habitat through both acoustic effects and physical alteration of the sea ice (Richardson et al. 1995). In the *Response Analysis* (Section 6.1.4) we try to determine whether and how the quantity, quality, or availability of one or more of the physical or biological features that led us to conclude that the area was essential for the conservation of a listed species are likely to change in response to the exposure.

6.1.3.2 Exposure to Other Noise Sources

6.1.3.2.1 Exposure to Other Impulsive Noise Sources

Non-airgun geohazard acoustic sources include single and multibeam echosounders, sub-bottom profilers, side scan sonars, and HiPaP positioning systems. These sources tend to be smaller and emit sounds at higher frequencies than airguns. The source levels of these devices range from 180 dB re 1 μPa at 1 m to 250 dB re 1 μPa at 1 m and have frequency ranges from 0.2 kHz to 1,600 kHz.

Mitigation Measures to Minimize the Likelihood of Exposure to Other Impulsive Noise Sources

Mitigation measures are described in detail in Sections 2.1.5 and 2.1.6. The following mitigation measure will be required through the MMPA permitting process to reduce the adverse effects of exposure to other impulsive noise sources on marine mammals from the proposed oil and gas exploration activities.

1. PSOs are required on all vessels engaged in activities that may result incidental take through acoustic exposure.

Approach to Estimating Exposures to Other Impulsive Noise Sources

In addition to the major noise sources described in section 6.1.3.1, we also analyzed other impulsive non-airgun noise sources associated with geohazard surveys including: single and multibeam echosounders, subbottom profilers, side-scan sonar, and HiPaP positioning systems. Section 2.1.3.7 describes each of these sound sources, with source levels and frequency ranges, in more detail.

We relied on the measured radii for the non-airgun geohazard survey sources from Statoil's 2011 geohazard survey in the Chukchi Sea (Warner and McCrodan 2011). We used these radii to estimate the ensonified area for each source (see Table 22). Similar to the approach we used to estimate the potential instances of exposure to marine mammals associated with major noise sources, the instances of exposure for each listed species to received levels of impulsive sound associated with other non-airgun geohazard impulsive sources ≥160 dB rms were estimated by multiplying the anticipated area to be ensonified to the specified levels (see Table 22) by the expected species density (see Table 18 and Table 19).

Table 22. **Ensonified area estimates associated with various received sound levels for non-airgun geohazard survey sources (ensonified area provided in km^2) (Warner and McCrodan 2011, Austin et al. 2015).**

Sound Source		190 dB	180 dB	160 dB	120 dB
Subbottom profiler	Ensonified Area (km^2)	--	--	.003	.636
Side scan sonar	Ensonified Area (km^2)	0.001	0.008	0.166	81.671
Single beam echosounder	Ensonified Area (km^2)	--	--	0.005	3.140
Multibeam echosounder	Ensonified Area (km^2)	--	--	--	0.342
HiPap (22/23 kHz)	Ensonified Area (km^2)	--	--	0.005	3.140

Results of Exposure Analysis (Other Impulsive Noise Sources)

We estimated potential instances of exposure for listed species at received levels ≥160 dB (rms) by multiplying the ensonified area by the densities of animals just one time per season (see Table 18 and Table 19). We determined that this approach was appropriate because vessels are moving throughout the survey area, animals are not anticipated to parallel the movements of the source vessel, and thus repeat exposures are unlikely.

Since these are projections for future BOEM authorizations, the specific models of each device and exact frequency and source levels are unknown at this point, but we anticipate that underwater sound propagation would drop to 160 dB within 40 m (or less) based on source measurements during Statoil's 2011 geohazard survey in the Chukchi Sea (Warner and McCrodan 2011). Marine mammals are unlikely to be subjected to repeated pings because of the narrow fore-aft width of the beam and will receive only limited amounts of energy because of the short pings. The beam is narrowest closest to the source, further reducing the likelihood of exposure to marine mammals.

Based on the small ensonified area estimates (Table 22), no exposures are anticipated to occur at received levels ≥160 dB. In addition, if marine mammals are exposed, they are not likely to respond to that exposure as described in Section 6.1.4.2 (*Responses to Other Impulsive Noise Sources*).

Given the directionality, short pulse duration, and small beam widths for these acoustic sources, only a few exposures at low received levels are anticipated for listed species. If exposed, whales and seals would not be anticipated to be in the direct sound field for more than one to two pulses (NMFS 2013c). Based on the information provided, most of the energy created by these potential sources is outside the estimated hearing range of baleen whales, and pinnipeds generally (Southall et al. 2007), and the energy that is within hearing range is high frequency, and as such is only expected to be audible in very close proximity to the mobile source. We do not anticipate these sources to be operating in isolation, and expect co-occurrence with other acoustic sources including airguns. Many whales and seals would move away in response to the approaching airgun noise or the vessel noise before they would be in close enough range for there to be exposure to the non-airgun related sources. In the case of whales and seals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of seismic sources (see Sections 2.1.5 and 2.1.6) would further reduce or eliminate any potential effect from non-airgun acoustic sources.

All of these factors reduce the probability of bowhead whales, fin whales, humpback whales, ringed seals, and bearded seals being exposed to sound fields associated with single and multibeam echosounders, sub-bottom profilers, side scan sonars, and HiPaP positioning sources to levels that we would consider insignificant.[23]

6.1.3.2.2 Exposure to Vessel Transit Noise

Mitigation Measures to Minimize the Likelihood of Exposure to Vessel Noise

Mitigation measures are described in detail in Sections 2.1.5 and 2.1.6. The following mitigation measures will be required through the MMPA permitting process to reduce the adverse effects of vessel noise exposure on marine mammals from the proposed oil and gas exploration activities.

1. PSOs are required on seismic source vessels, ice management vessels, drilling vessels, and other vessels engaged in activities that may result in an incidental take through acoustic exposures;
2. Avoid concentrations or groups of three or more whales by all vessels;
3. Maintain a vigilant watch for listed whales and pinnipeds, avoid multiple changes in direction, and observe the 5 knots speed restriction when within 274m of whales or pinnipeds; and

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[23] Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. In this situation, exposures may occur to a few whales and pinnipeds at ≥120 dB, but at received levels far below what would be considered "take" for impulsive sounds (≥160 dB).

4. Lessee and/or operator will avoid transits within designated North Pacific right whale critical habitat. If transit within North Pacific right whale critical habitat cannot be avoided, vessel operators are requested to exercise extreme caution and observe the 10 knot vessel speed restriction while within North Pacific right whale critical habitat, and maintain an avoidance distance of 800m from any observed North Pacific right whale while within their designated critical habitat consistent with vessel safety.

Approach to Estimating Exposures to Vessel Noise

Our previous analysis (Section 6.1.3.1) focused on the loudest anticipated vessel sound sources (DP, anchor handling, icebreaking and ice management). This section will focus on the remaining noise component of vessel transit.

Numerous measurements of underwater vessel sound have been performed in support of recent industry activity in the Chukchi and Beaufort Seas. Results of these measurements were reported in various 90-day and comprehensive reports since 2007. Like other industry-generated sound, underwater sound from vessels is generally at relatively low frequencies. During 2012, underwater sound from 10 vessels in transit, and in two instances towing or providing a tow-assist, were recorded by JASCO in the Chukchi Sea as a function of the Sound Source Characterization (SSC) study required in the Shell 2012 Chukchi Sea drilling IHA. SSC transit and tow results from 2012 include ice management vessels, an anchor handler, OSR vessels, the OST, support tugs, and OSVs (Shell 2015). The recorded sound pressure levels to 120 dB re 1 µPa rms for vessels in transit primarily range from ~ 1.3 – 6.9 km (0.8 mi – 4.3 mi), whereas the measured 120 dB re 1 µPa rms for the drilling unit *Kulluk* under tow by the *Aiviq* in the Chukchi Sea was ~ 11.8 mi (19 km) while traveling to the Beaufort Sea (O’Neill and McCrodan 2012b, a).

A vessel noise detector was run on the AMAR data from the Chukchi Sea (Delarue et al. 2013) to study the influence of vessel noise in the soundscapes. Figure 20 shows the difference between the median sound level from all data in which vessels were detected and the median sound level in the absence of vessels, over the entire summer 2012 deployment in the Chukchi Sea (Delarue et al. 2013). This plot shows that throughout the summer of 2012 median vessel sound levels were 10–19 dB above ambient sound levels at the Burger drill site and approximately 56 km (35 mi) offshore from Wainwright. These locations reflect areas of concentrated vessel presence during the drilling program (LGL et al. 2013).

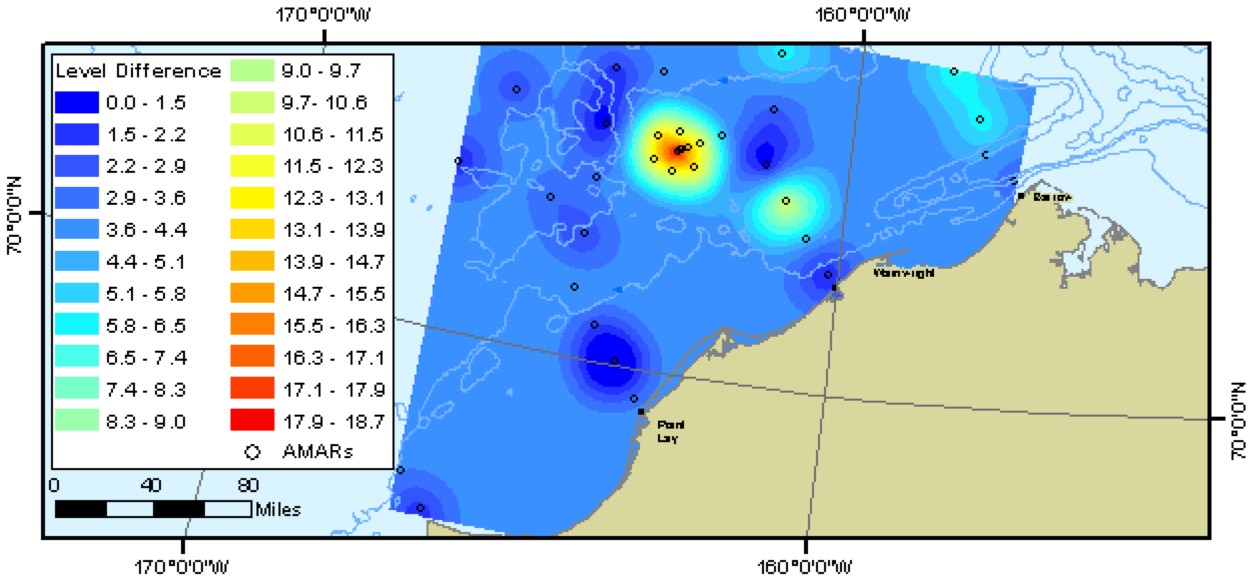

Figure 20. **Difference between the median of vessel and ambient noise levels throughout the Chukchi Sea, summer 2012 (LGL et al. 2013).**

Listed cetaceans and pinnipeds have the potential to overlap with vessel noise associated with the proposed oil and gas exploration activities. We will discuss potential responses of listed species to vessel noise in Section 6.1.4.2.

Vessel noise during the first incremental step would also have the potential to affect the proposed critical habitat for Arctic ringed seals (see Section 6.1.4.2).

6.1.3.2.3 Exposure to Aircraft Noise

Mitigation Measures to Minimize the Likelihood of Exposure to Aircraft

Mitigation measures are described in detail in Sections 2.1.5 and 2.1.6. The following mitigation measures will be implemented through the MMPA permitting process to reduce the adverse effects of aircraft traffic on marine mammals from the proposed action.

1. Aircraft shall not fly within 1,000 ft (305 m) of marine mammals or below 1,500 ft (457 m) altitude (except for take-off, landing, emergency situations, and inclement weather) while over land or sea.
2. Helicopters may not hover or circle above marine mammals.
3. Support aircraft must avoid extended flights over the coastline to minimize effects on marine mammals in nearshore waters or the coastline.

Approach to Estimating Exposure to Aircraft Noise

Exploration surveys, drilling operations, search and rescue efforts, and onshore construction may be supported by fixed-wing and rotary aircraft. Little aircraft traffic is anticipated in association with marine surveys during the first incremental step. During exploratory drilling and onshore construction, up to six round-trip flights (primarily using helicopters) could occur each day, to transport crew, small equipment, and supplies from Wainwright or Barrow to operation sites (BOEM 2015a).

Drilling operations are anticipated to occur over a 120 day period (30 days/well) with up to six round-trip flights per day (BOEM 2015a). This would result in a maximum of 720 round trips per year, and 5,040 round trips over the duration of the first incremental step.

Fixed-wing monitoring surveys are typically conducted with aircraft flying 1,500 ft (AGL) unless safety due to weather or other factors becomes an issue (see mitigation measures). Greene and Moore (1995) determined that fixed wing aircraft typically used in offshore activities were capable of producing tones mostly in the 68 to 102 Hz range and at noise levels up to 162 dB re 1 μPa m at the source.

Helicopters used to support drilling activities are anticipated to complete one round-trip daily between the drilling rig and the onshore support base. Rotary aircraft operations are conducted 1,500 feet AGL/ASL unless safety due to weather or other factors becomes an issue (see mitigation measures). Greene and Moore (1995) explained helicopters commonly used in offshore activities radiate more sound forward than backwards, and are capable of producing tones mostly in the 68 to 102 Hz range and at noise levels up to 151 dB re 1 μPa m at the source. By radiating more noise forward of the helicopter, noise levels will be audible at greater distances ahead of the aircraft than to the rear.

Low-flying aircraft produce sounds that marine mammals can hear when they occur at or near the ocean's surface. Helicopters generally tend to produce sounds that can be heard at or below the ocean's surface more than fixed-wing aircraft of similar size and larger aircraft tend to be louder than smaller aircraft. Underwater sounds from aircraft are strongest just below the surface and directly under the aircraft. Aircraft noise is typically present for shorter periods of time and moves at a greater speed due to the higher travel speed of aircraft as oppose to vessel noise (Luksenberg and Parsons 2009). Sounds from aircraft would not have physical effects on marine mammals but represent acoustic stimuli (primarily low-frequency sounds from engines and rotors) that have been reported to affect the behavior of some marine mammals.

There are studies of the responses of marine animals to air traffic and the few that are available have produced mixed results. The nature of sounds produced by aircraft above the surface of the water does not pose a direct threat to the hearing of marine mammals that are in the water; however, minor and short-term behavioral responses of cetaceans to helicopters have been documented in several locations, including the Arctic (Richardson et al. 1985a, Richardson et al. 1985c, Patenaude et al. 2002). Richardson et al. (1995) reported that there is no evidence that single or occasional aircraft flying above large whales in water cause long-term displacement of these mammals.

Richardson et al. (1985a) reported that bowhead whales (*Balaena mysticetus*) responded behaviorally to fixed-wing aircraft that were used in their surveys and research studies when the aircraft were less than 457 meters above sea level; their reactions were uncommon at 457 m and were undetectable above 610 m. They also reported that bowhead whales did not respond behaviorally to helicopter overflights at about 153 m above sea level.

Patenaude *et al.* (2002) found that most reactions by bowhead whales to a Bell 212 helicopter occurred when the helicopter was at altitudes of 150 m or less and lateral distances of 250 m or less. The most common reactions were abrupt dives and shortened surface time and most, if not all, reactions seemed brief. However, the majority of bowhead whales showed no obvious reaction to single passes, even at those distances.

In a review of aircraft noise effects on marine mammals, Luksenburg and Parsons (2009) determined that the sensitivity of whales and dolphins to aircraft noise may depend on the animals' behavioral state at the time of exposure (e.g. resting, socializing, foraging or traveling) as well as the altitude and lateral distance of the aircraft to the animals. While resting animals seemed to be disturbed the most, low flying aircraft with close lateral distances over shallow water elicited stronger disturbance responses than higher flying aircraft with greater lateral distances over deeper water (Luksenberg and Parsons 2009).

Considering that the proposed mitigation would require aircraft not to operate within 305 m (1,000 ft) of marine mammals or below 457 m (1,500 ft) altitude, we would not expect marine mammals to be adversely affect by the noise or presence of aircraft. In addition, there is a low number of aircraft overflight anticipated during the first incremental step. We conclude that if any responses of marine mammals associated with aircraft were to occur, they are likely to be short-lived and would not rise to the level of harassment and are considered insignificant.

6.1.3.2.4 Exposure to Onshore Construction Noise

In conjunction with the beginning of the first incremental step, up to three onshore facilities may be constructed in the vicinity of Barrow or Wainwright over a two-year period. Construction is anticipated to occur in the winter from January through December. These onshore facilities would provide air support, search and rescue capabilities, and personnel housing/equipment storage (BOEM 2015a).

Mitigation Measures to Minimize the Likelihood of Exposure to Construction Noise

Mitigation measures that may be issued by NMFS or BOEM/BSEE are described in detail in Sections 2.1.5 and 2.1.6. Onshore activities would also be subject to permits, authorizations, stipulations, required operating procedures (ROPs), and best management practices (BMPs) as recommended or required by the appropriate land-based resource and management agencies. The U.S. Bureau of Land Management's 2013 Record of Decision for the National Petroleum Reserve– Alaska Integrated Activities Plan (USDOI, BLM, 2013) presents stipulations and BMPs that are typical of the types of mitigation BOEM/BSEE anticipates for onshore oil and gas activities described in the proposed action if located on federal lands. These mitigation measures provide operators with guidance in minimizing impacts to wildlife, vegetation, and subsistence resources, including requirements for water and mineral withdrawals, waste disposal, construction footprints, and contaminant and spill handling. Of particular applicability to ESA-listed species are the following BMPs:

1. All pipelines shall be designed, constructed, and operated under an authorized officer-approved QAQC plan that is specific to the product transported and shall be constructed to detect and prevent corrosion or mechanical defects during routine structural integrity inspections;
2. Facilities shall be designed and located to minimize the development footprint;
3. Minimize the impact of mineral material mining activities on air, land, water, fish, and wildlife resources;
4. Minimize the take of species, particularly those listed under the ESA and BLM Special Status Species, from direct or indirect interaction with oil and gas facilities;
5. Minimize the effects of low-flying aircraft on wildlife, subsistence activities, and other local communities:
    - Aircraft used as part of a BLM-authorized activity along the coast and shorefast ice zone shall maintain minimum altitude of 3,000 feet when within 1 mile from aggregations of seals, unless doing so would endanger human life or violate safe flying practices;
6. Protect fish and wildlife habitat (including, but not limited to, marine mammals), preserve air and water quality, and minimize impacts to subsistence activities and historic travel routes on the major coastal waterbodies.
7. With the exception of linear features such as pipelines, no permanent oil and gas facilities are permitted on or under the water within ¾ mile seaward of the shoreline of the major coastal waterbodies or natural coastal islands (including Wainwright Inlet/Kuk River). Permanent facilities within major coastal waterbodies will only be permitted on or under the water if they meet all the following criteria:
    - Design and construction of facilities shall minimize impacts to subsistence uses, travel corridors, seasonally concentrated fish and wildlife resources;
    - Daily operational activities, including use of support vehicles, watercraft, and aircraft traffic, alone or in combination with other past, present, and reasonably foreseeable activities, shall be conducted to minimize impacts to subsistence uses, travel corridors, and seasonally concentrated fish and wildlife resources;
    - The location of oil and gas facilities, including artificial islands, platforms, associated pipelines, ice or other roads, bridges or causeways, shall be sited and constructed so as to not pose a hazard to navigation by the public using traditional high-use subsistence related travel routes into and through the major coastal waterbodies as identified by the North Slope Borough;
    - Demonstrated year-round oil spill response capability, including the capability of adequate response during periods of broken ice or open water, or the availability of alternative methods to prevent well blowouts during periods when adequate response capability cannot be demonstrated. Such alternative methods may include seasonal drilling restrictions, improvements in blowout prevention technology, equipment and/or changes in operational procedures, and “top-setting” of hydrocarbon-bearing zones;
    - Reasonable efforts will be made to avoid or minimize impacts related to oil spill

response activities, including vessel, aircraft, and pedestrian traffic that add to impacts or further compound "direct spill" related impacts on area resources and subsistence uses;
- Before conducting open water activities, the permittee shall consult with the Alaska Eskimo Whaling Commission and the North Slope Borough to minimize impacts to the fall and spring subsistence whaling activities of the communities of the North Slope;

8. Protect coastal waters and their value as fish and wildlife habitat (including but not limited to, marine mammals), protect shoreline habitat for seals, and prevent impacts to subsistence resources and activities.
  - In cases where BLM authorizes a permanent oil and gas facility within a Coastal Area, the lessee/permittee shall develop and implement a monitoring plan to assess the effects of the facility and its use on coastal habitat and use.
  - Marine vessels used as part of a BLM-authorized activity shall maintain a 1-mile buffer from the shore when transiting past an aggregation of seals using a terrestrial haulout unless doing so would endanger human life or violate safe boating practices. Marine vessels shall not conduct ballast transfers or discharge any matter into the marine environment within 3 miles of the coast except when necessary for the safe operation of the vessel.

Approach to Estimating Exposures to Onshore Construction Noise

The first incremental step of the proposed action includes construction of up to three onshore facilities at a location near Wainwright or Barrow (see Section 2.1.3.5 for details). Most construction would occur during the winter months when listed whales are largely absent from the area, and construction is limited to land so effects will be minimal. Construction would produce low energy localized noise from equipment operation, generators, etc. Noise from on-land pile driving would be the loudest source of noise and is only anticipated to expose ringed and bearded seals and proposed ringed seal critical habitat (BOEM 2015a).

The hearing range of phocids is anticipated to be between 75 Hz – 100 kHz (NOAA 2013), and overlaps with the anticipated 100 Hz – 2 kHz frequency of pile driving activities. Furthermore it is generally assumed that seals, would refrain from approaching noises loud enough to produce a PTS or TTS since mammals instinctively avoid injury under most situations. With audible noise levels slightly above those of ambient noise within a kilometer of pile-driving activity, the effects of pile driving should include behavioral responses such as slight avoidance, and nothing more. No PTS, TTS, or other physiological responses should occur because of pile-driving or other construction activities (BOEM 2015a).

Noise and disturbance from on-shore facility construction may affect nearby ringed and bearded seals. Ringed seals near Northstar in 2000 and 2001 established lairs and breathing holes in the landfast ice within a few meters of Northstar, before and during the onset of winter oil activity. Seal use of the habitat continued despite low-frequency noise and vibration, construction, and use of an ice road (Williams et al. 2006). Blackwell et al. (2003) determined ringed seal densities were significantly higher around offshore industrial facilities. Another study by Frost and Lowry

(1988) found ringed seal densities between 1985 and 1986 were higher in industrialized areas than in the controls in the Central Beaufort Sea. These activities will not affect food availability as construction is all onshore.

Excavation and construction are slow moving operations and a relatively stationary sound source around a small noise footprint. The location, timing, and specific actions have not been determined and would be evaluated as plans are submitted. Companies would have to work with landowners (i.e., BLM, North Slope Borough, ANSCA Corporations) to obtain any required construction permits.

Vessel (during the open-water season) and aircraft traffic would be associated with the construction of an on-shore facility and potential effects from these sources have been addressed above (see Sections 6.1.3.2.1 and 6.1.3.2.2).

Construction activities would be subject to standard mitigation measures that would help avoid disturbance to ringed and bearded seals, primary prey resources, sea ice habitats that would otherwise be suitable for formation and maintenance of ringed seal birth lairs, and sea ice that would otherwise be suitable for basking and molting platforms. For example, vehicles must avoid pressure ridges, ice ridges, and ice deformation areas where seal structures are likely to be present. If it is not possible to avoid these features, NMFS may require the use of trained dogs to determine that no seal lairs are present before to the onset of activities within 150 m (500 ft) of any of these features. In addition, there could be shutdown zones associated with pile driving activities if seals get within a certain distance of the source, or activities could be restricted during the pupping season and when shorefast ice is present. Thus, because of the small footprint of the onshore facilities and associated construction activities, the standard mitigation measures to avoid adverse impacts to ringed and bearded seals and proposed critical habitat, and the small amount of habitat that would be exposed to onshore construction noise, these construction activities are not anticipated to create more than a minor level of effect to ringed and bearded seals, and are not likely to adversely modify proposed critical habitat and are considered insignificant (BOEM 2015a).

6.1.3.3 Exposure to Oil and Gas Spill

As previously mentioned in the *Environmental Baseline* section of this opinion, NMFS analyzed the potential impacts associated with authorized discharge of contaminants under the issuance of new NPDES permits in the Chukchi Sea (EPA 2015) through informal consultation, and EPA issued a Vessel General Permit for discharges under NPDES (EPA 2013). The remainder of this analysis will thus be focused on the probability of an unauthorized discharge of oil and gas, and the potential impacts associated with exposure of ESA-listed marine mammals under NMFS's authority to small, large, and VLOS events during exploration activities in the action area.

A portion of the Bering Sea is included in the action area due to transit of marine vessels associated with exploration. However, the potential effects of oil spills in the Bering Sea due to this transiting activity is discountable due to the small number of vessels and low amounts of oil onboard the vessels. The transit route is well offshore and any accidental spills will be relatively minor and quickly dispersed, therefore oil spills in the Bering Sea will not be discussed further in this analysis. This analysis will focus on the risk of spills in the Chukchi Sea.

Mitigation Measures to Minimize the Likelihood of Exposure Oil and Gas Spill

At the lease sale stage mitigation measures take the form of lease stipulations; post-lease activities may have mitigation imposed through conditions for approval of plans, permit conditions, or other mechanisms. As specific projects are proposed in this multi-stage oil and gas program, more precise information about the nature and extent of the activities – including the scale and location of the activities and a description of the particular technologies to be employed – will be considered and evaluated in additional ESA consultations and other analyses (such as NEPA) as appropriate. Additional mitigation measures and protections may be developed at any stage based on the specific details of the particular projects.

Regulations/Requirements
In light of the 2010 Deepwater Horizon explosion, loss of life, oil spill, and response, the federal government, along with industry, adopted new rules and safety measures related to oil-spill prevention, containment, and response.

BOEM and BSEE instituted regulatory reforms in response to many of the recommendations expressed in the various reports prepared following the Deepwater Horizon event, including both prescriptive and performance-based regulation and guidance, as well as OCS safety and environmental protection requirements. The reforms strengthen the requirements for all aspects of OCS operations. Ongoing reform and research endeavors of BSEE to improve workplace safety and to strengthen oil-spill prevention, planning, containment, and response are described in the 2012-2017 Programmatic EIS (BOEM 2012).

Oil and Gas and Sulphur Operations on the Outer Continental Shelf–Increased Safety Measures for Energy Development on the Outer Continental Shelf. BSEE published its Final Drilling Safety Rule in August 2012 (77 FR 50856). The Final Rule:

- Establishes new casing installation requirements
- Establishes new cementing requirements
- Requires independent third party verification of blind-shear ram capability
- Requires independent third party verification of subsea BOP stack compatibility
- Requires new casing and cementing integrity tests
- Establishes new requirements for subsea secondary BOP intervention
- Requires function testing for subsea secondary BOP intervention
- Requires documentation for BOP inspections and maintenance
- Requires a Registered Professional Engineer to certify casing and cementing requirements; and
- Establishes new requirements for specific well control training to include deepwater operations

Oil and Gas and Sulphur Operations in the Outer Continental Shelf—Revisions to Safety and Environmental Management Systems" (SEMS II). BSEE issued a Final Rule effective in June 2013. This Final Rule, also known as the Workplace Safety Rule, includes refinements to the existing SEMS program. The SEMS II Final Rule amends the existing regulations to require operations to develop and implement additional provisions involving stop work authority and ultimate work authority, establishes requirements for reporting unsafe working conditions, and requires employee participation in the development and implementation of their SEMS programs. In addition, the Final Rule requires the use of independent third parties to perform the audits of the operators’ programs.

The SEMS II Final Rule provides greater protection by supplementing operators’ SEMS programs with employee training, empowering field level personnel with safety management decisions, and strengthening auditing procedures by requiring them to be environmental management systems. The SEMS is a nontraditional, performance-focused tool for integrating and managing offshore operations. The purpose of SEMS is to enhance the safety and operations by reducing the frequency and severity of accidents. The four principal SEMS objectives are:

- Focus attention on the influences that human error and poor organization have on accidents
- Continuous improvement in the offshore industry’s safety and environmental records
- Encourage the use of performance-based operating practices
- Collaborate with industry in efforts that promote the public interests of offshore worker safety and environmental protection.

<u>NTL (Notice to Lessees) 2010-N06</u>. Effective November 8, 2010, NTL No. 2010-NO6 requires that blowout intervention information be submitted with future Exploration or Development and Production Plans. The blowout scenarios required by 30 CFR 250.213(g) and 250.243(h) provide for a potential blowout of the proposed well expected to have the highest volume of hydrocarbons, and must include supporting information for any assertion that well bridging will constrain or terminate the flow or that surface intervention will stop the blowout. The availability of a rig to drill a relief well and rig package constraints must also be addressed. These scenarios must also specify as accurately as possible the time it would take to contract for a rig, move it on site, and drill a relief well, including the possibility of drilling a relief well from a neighboring platform or an onshore location.

<u>NTL (Notice to Lessees) 2010-N10</u>. Also released on November 8, 2010, was NTL 2010-N10. This NTL explains that applications for well permits must include a statement that all authorized activities will be conducted in compliance with all applicable regulations, to include the new measures discussed above. For operations using subsea blowout preventers (BOPs) or surface BOPs on floating facilities, BOEM will evaluate whether each operator has submitted adequate information demonstrating that it has access to and can deploy subsea containment resources that can adequately and promptly respond to a blowout or other loss of well control. BOEM will also evaluate whether each operator has adequately described the types and quantities of surface and subsea containment equipment that the operator can access in the event of a spill or threat of a spill.

Intervention and Response

Potential intervention and response methods are listed below, and may be included in individual exploration plans. These tools and actions could substantially reduce the duration, volume, and effects of an oil spill. These methods are not mutually exclusive; several techniques could be employed concurrently if necessary. The availability and effectiveness of these techniques may vary depending on the nature of the blowout, as well as environmental conditions, such as the seasonal presence of ice.

Well Intervention. If a blowout occurred, the original drilling vessel would initiate well control procedures. The procedures would vary based on the blowout situation, but could include:

- Activating the blowout preventer equipment
- Pumping kill weight fluids into the well to control pressures
- Replacing any failed equipment to remedy mechanical failures that may have contributed to the loss of well control
- Activating manual and automated valves to prevent flows from coming up the drill string

These four procedures remedy loss-of-well-control events the vast majority of the time without any oil being spilled. Natural bridging or plugging could also occur. These terms refer to circumstances where a dramatic loss of pressure within the well bore (as could occur in the event of a blowout) causes the surrounding formation to cave in, thereby bridging over or plugging the well.

Containment Domes. In the event that well intervention is unsuccessful and the flow of oil continues, a marine well containment system (MWCS) could be deployed with associated support vessels. One design for a MWCS specific to Arctic operations is completed. The MWCS is anticipated to provide containment domes, well intervention connections, remotely operated vehicle capabilities, barge with heavy lift operations, separation equipment, and oil and gas flaring capabilities.

Relief Wells. If the above techniques are unavailable or unsuccessful, a relief well could be drilled. The relief well is a second well, directionally drilled, that intersects the original well at, near, or below the source of the blowout. Once the relief well is established, the operator pumps kill weight fluids into the blowout well to stop the flow and kill the well. Both wells are then permanently plugged and abandoned.

Some exploratory drilling vessels are capable of drilling their own relief well. Mobile Offshore Drilling Units can disconnect from the original well, move upwind and up current from the blowout location, and commence the drilling of a relief well.

Second Vessel. Should the original drilling vessel sustain damage or prove otherwise incapable of stopping the blowout, a second vessel could be brought in to terminate or otherwise contain the blowout. A second vessel, with support from additional vessels as needed, could employ similar techniques to those described above. The time required by a second vessel to successfully stop the flow of oil must factor in the time needed for travel to the site of the blowout. The location of a second vessel is thus critical when considering a scenario in which same vessel intervention or response is unavailable. The availability of a second vessel within the Chukchi Sea or possibly the Beaufort Sea, or on site would substantially reduce transport time and, therefore, the time needed for successful intervention. This could equate to shorter spill duration and smaller overall spill volume.

Mechanical Recovery. The primary method of response to oil spilled in the water is mechanical recovery, which physically removes oil from the ocean. Mechanical recovery is accomplished through the use of devices such as containment booms and skimmers. A containment boom is deployed on the water and positioned within an oil slick to contain and concentrate into a pool thick enough to allow collection by a skimmer. The skimmer collects the oil and transfers it to a storage vessel (storage barges or oil tankers) where it will eventually be transferred to shore for appropriate recycling or disposal.

Dispersants. Chemical dispersants are applied to oil spilled in the marine environment in order to distribute the oil particles more widely in the water column to allow for increased natural biodegradation of the oil. Dispersant application can be accomplished by means of injection at the source or through aerial or vessel based application. There are dispersant stockpiles located in Prudhoe Bay, Anchorage, and the Lower 48 states (dispersants can be flown to Alaska from the Lower 48). Dispersant use is limited to surface ocean application in waters deeper than 10 meters; this depth restriction is used to avoid or reduce potential toxicity concerns to nearshore organisms.

In situ Burning. *In situ* burning (or burning the oil where it has spilled) is also a viable response method in the Chukchi Sea. Any *in situ* burning would be conducted in accordance with the Alaska Unified Plan *In situ* Burn Guidelines. *In situ* burning is a method that can be used in open ocean, broken ice, nearshore, and shoreline cleanup operations. In broken ice conditions, the ice can act as a natural containment boom, limiting the spread of oil and concentrating it into thicker slicks, which aids in starting and maintaining combustion. *In situ* burning has the potential to remove in excess of 90 percent of the volume of oil involved in the burn.

Depending on the timing and location of the spill, the above efforts could be affected by seasonal conditions. In the event that response efforts continue into the winter season, small vessel traffic would come to a halt once the forming ice begins to cover the ocean surface. Larger skimming vessels could continue until conditions prevent oil from flowing into the skimmers. Operations could shift to *in situ* burning if sufficient oil thicknesses are encountered. The lack of daylight during winter months would increase the difficulties of response.

As ice formation progresses, the focus of the response would shift to placing tracking devices in the forming ice sheet to follow the oil as it is encapsulated into the ice sheet. Once the ice sheet becomes solid and stable enough, recovery operations could resume by trenching through the ice to recover the oil using heavy equipment. This would most likely occur in areas closer to shore because the ice will be more stable. In late spring and early summer, as the ice sheet rots, larger ice-class vessels could move into the area and begin recovery or *in situ* burning operations as the oil is released from the ice sheet. As the ice sheet decays, oil encapsulated in the ice would begin surfacing in melt pools at which time responders will have additional opportunities to conduct in-situ burn operations. Smaller vessels could eventually recommence skimming operations in open leads and among ice flows, most likely in a free skimming mode (without boom) along the ice edge. Effectiveness of intervention, response, and cleanup efforts depend on the spatial location of the blowout, trajectory of the oil, and amount of ice in the area.

Based on clean-up activities with the Exxon Valdez oil spill where only about 14% was recovered or disposed (Wolfe et al. 1994), spill response may be largely unsuccessful in remote open water conditions, and spill response drills have had various levels of success in the cleanup of oil in broken-ice conditions (Dickins 2011). When sea ice is present, many of the processes that affect oil behavior in open water (e.g., evaporation, emulsification, and natural dispersion) are slowed down or halted for extended periods of time (Payne et al. 1991, NRC 2014). Overall, recovery efforts in open water tend to have limited effectiveness; recovery rates can range from 1 to 30% (MMS 2010). Booms and skimmers recovery oil less effectively with increased concentrations of sea ice (NRC 2014). Sea ice interferes with boom operation and reduces flow to the skimmer head (Potter et al. 2012, NRC 2014). It is difficult to say how effective cleanup efforts would be at reducing the volume of oil in the environment if a large oil spill occurred. Oil spill response activities are not a component of the proposed action and have been previously consulted on by NMFS as part of the *Alaska Federal/State Preparedness Plan for Response to Oil & Hazardous Substance Discharges/Releases (Unified Plan)* consultation (AKR 2014-9361).

Behavior and Fate of Crude Oil

Effects of oil are based on its chemical composition. Likewise, the composition of crude oil determines its behavior in the marine environment (Geraci and St. Aubin 1990). Weathering (spreading, evaporating, dispersing, emulsifying, degrading, oxidizing, dissolution: Figure 21) and aging processes can alter the chemical and physical characteristics of crude oil. The environment in which a spill occurs, such as the water surface or subsurface, spring ice overflow, summer open-water, winter under ice, winter on ice, or winter broken ice, will affect how the spill behaves. In ice-covered waters many of the same weathering processes occur; however, the sea ice and cold temperatures change the rates and relative importance of these processes (Payne et al. 1991, NRC 2014).

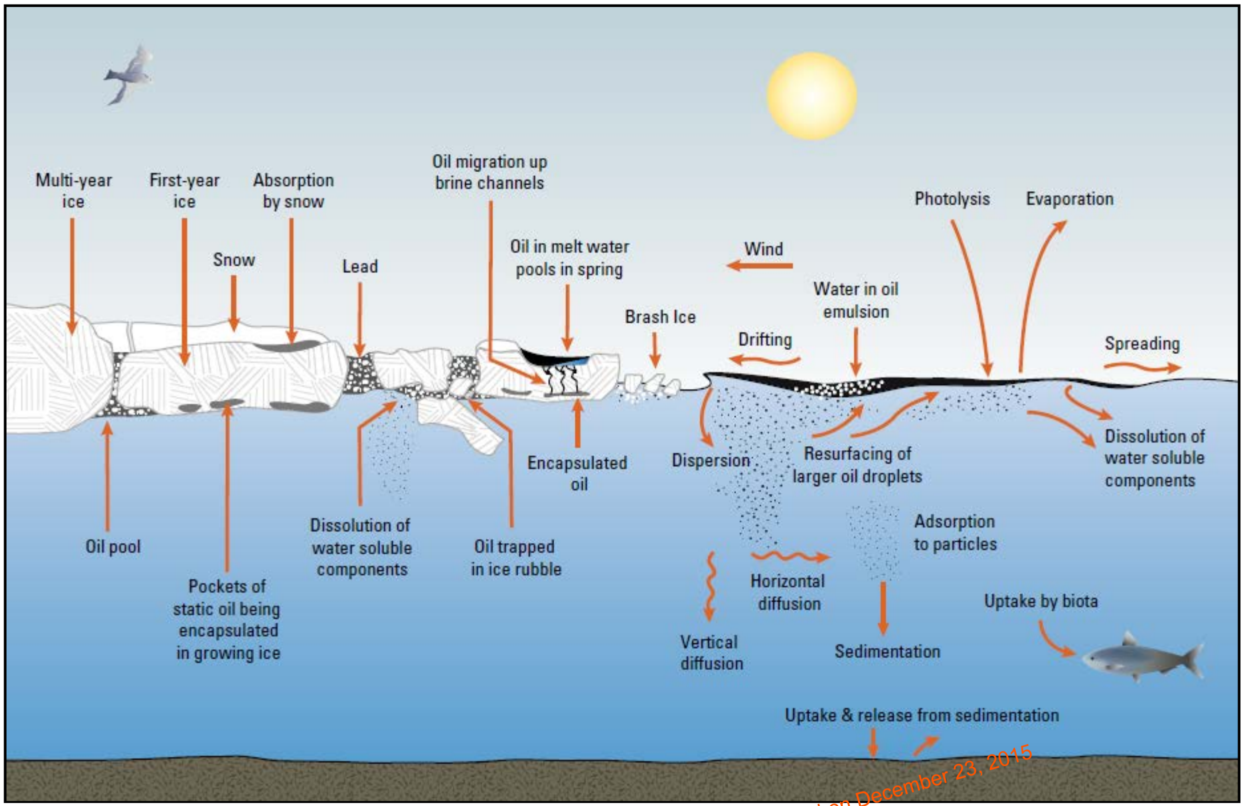

Figure 21. **Diagram of some of the weathering processes that occur to oil spilled into the marine environment (NRC 2014).**

Oil released at or near the surface will immediately begin to spread, or drift, horizontally in an elongated shape driven by wind and surface water currents (Elliott et al. 1986). If released below the water, oil will travel through the water column before it forms an oil slick at the surface. The rate of spreading is positively associated with increased temperature and wave action (Geraci and St. Aubin 1990). Oil spills in the cooler waters of the Arctic are expected to spread less and remain thicker than in temperate waters due to increased viscosity of oil in colder temperatures (NRC 2014). The leading edge of the slick is typically thicker than the interior (Fannelop and Waldman 1972). The thicker oil tends to form patches that move downwind faster than the thinner part of the slick, eventually leaving it behind (Geraci and St. Aubin 1990).

In increasing ice conditions spilled oil would be bound up in the ice, pumped to the surface by wind/wave action, or encapsulated in pack ice. In late spring or summer the unweathered oil would melt out of the ice at different rates, depending on whether it was encapsulated in multiyear or first-year ice, and when the oil was frozen into the ice. In approximately mid-July, the oil pools on first-year ice would drain into the water among the floes of the opening pack ice. Oil could be pooled on first-year ice for up to 30 days before being discharged back into marine waters.

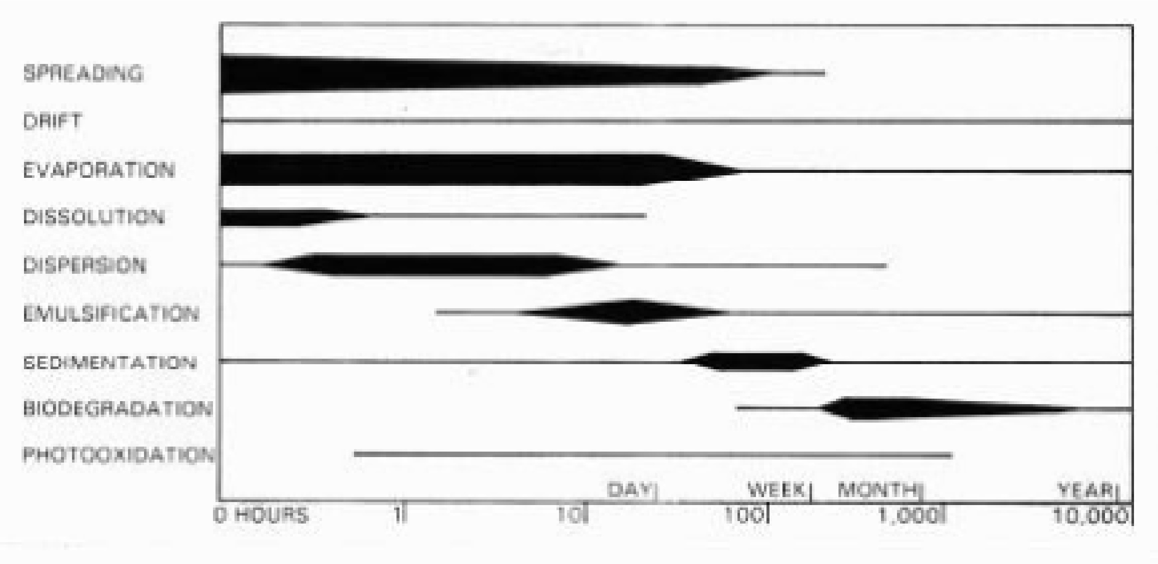

Figure 22. **Schematic showing the relative importance of weathering processes of an oil slick over time (Hayes et al. 1992). The width of the line shows the relative magnitude of the process in relation to other contemporary processes.**

In the first few days following a spill, evaporation is the most significant weathering process affecting the volume and chemical composition of oil (Geraci and St. Aubin 1990) (Figure 22). The lighter, more volatile hydrocarbons evaporate most quickly, increasing the density and viscosity, and decreasing the toxicity and vapors of the oil (Mackay 1985). About 30-40% of spilled crude consists of volatile hydrocarbons that evaporate, with approximately 25% of the evaporation occurring in the first 24 hours (Fingas et al. 1979, NRC (National Research Council) 1985). Initial evaporation rate increases with increased wind speed, temperature, and sea state. Evaporation rates decrease when oil spills in broken ice conditions, and stops altogether if the oil is under or encapsulated in ice (Payne et al. 1987, Payne et al. 1991). In the spring, oil that has been trapped in ice will be released to the surface and evaporation will occur.

Approximately 2-5% of spilled crude oil is dissolved into the water column (Payne et al. 1987). Although this appears to be a small proportion of the crude oil, this dissolution process is significant because it brings the most toxic hydrocarbons into contact with marine organisms in a form that is biologically available to them (Geraci and St. Aubin 1990). Dissolved hydrocarbon components appear to be transported through brine channels in first-year ice (Faksness and Brandvik 2008). Field studies showed that high air temperature led to more porous ice, thereby allowing the dissolved water-soluble components to rapidly leak out, but under cold air temperatures and less porous ice, the water-soluble components were released more slowly and had potentially toxic concentrations (Faksness and Brandvik 2008).

Dispersion is the most significant weathering process in the breakdown of an oil slick already reduced by evaporation (Geraci and St. Aubin 1990), and results in the transport of small oil particles into the water column (NRC (National Research Council) 1985). Increased wave action and water turbulence are directly associated with an increased rate of dispersion (Mackay 1985).

Small oil droplets break away from the main oil slick and become dispersed in the water column. If the droplets become smaller than 0.1 mm in size they rise so slowly as to remain indefinitely dispersed (Payne and McNabb 1985). More viscous and/or weathered crude oil may adhere to porous icefloes, concentrating oil within areas of broken ice and limiting oil dispersion. However, the presence of a small amount of ice is thought to promote dispersion (Payne et al. 1987).

After weathering, some oils will accumulate and retain water droplets within the oil phase. This process is called emulsification, and the emulsified oil is typically referred to as 'mousse' (Mackay 1985). Mousse can form more quickly under certain conditions; with sufficient gas, turbulence, and precursors in the oils, oil spilled subsurface can form mousse by the time it reaches the surface (Payne 1982). The formation of mousse slows the subsequent weathering of oil by inhibiting evaporation, dissolution, and degradation (Geraci and St. Aubin 1990). The presence of ice and turbulence increases emulsification (Payne et al. 1987).

Most oil droplets suspended in the water column will eventually be degraded by bacteria in the water column, or deposited to the seafloor. This deposition, or sedimentation, depends on many factors; suspended load in the water column, water depth, turbulence, oil density, and processing by zooplankton. Weathered oil can become heavier than seawater and sink (Boehm 1987). This process is enhanced when the density of water is lowered by input of fresh water from runoff or melting ice. In areas of significant downwelling (e.g., in a polynya or at the edge of an ice sheet) sinking water may carry oil droplets to the ocean bottom (Geraci and St. Aubin 1990).

Biodegradation, or natural degradation by marine fungi and bacteria (microbial organisms), begins 1-2 days following a spill and continues as long as hydrocarbons remain in the water and sediments (Lee and Ryan 1983). All components of hydrocarbons spilled into the marine environment are degraded by microbial organisms in the water and sediments simultaneously, but at very different rates (Atlas et al. 1981, Bartha and Atlas 1987). The rate of biodegradation is influenced by oxygen concentration, temperature, nutrients (especially nitrogen and phosphorous), salinity, physical state and chemical composition of the oil, and history of previous oil spills at the site (Atlas 1981, Bartha and Atlas 1987). Biodegradation is a very slow process. In Arctic environments, degradation by microbial organisms is slowed even further by a lack of nutrients (Atlas 1986) and low temperatures (Cundell and Traxler 1973).

Solar radiation acting on oil on the water results in photo oxidation, or photolysis, of hydrocarbons. The molecular compounds in oil vary in their sensitivities to photolysis and are subject to photolysis at different rates. In general, photolysis decreases with decreasing water depths as light intensity decreases. In addition, photolysis is slower at higher latitudes where and when there is less sunlight, especially during the winter (Geraci and St. Aubin 1990). At 60° N latitude, there is approximately a tenfold decrease in the photolysis rate of benzo(a)pyrene between June and December (Zepp and Baughman 1978).

Persistence of oil from a spill in the marine environment can vary depending on the size of the spill, the environmental conditions at the time of the spill, the substrate of the shoreline, and whether the shoreline is eroding. The oil weathering models conducted by BOEM estimate that approximately 30% of oil from a slick would remain from a 60,000 bbl per day summer spill after 30 days, and 48% would remain from a winter (meltout) spill after 30 days (BOEM 2015e). These estimates assume that wind speeds remain consistent with typical measurements for the action area (approximately 4 m/s) (BOEM 2015e). At higher wind speeds, the oil slick would be dispersed and evaporate more quickly. Consequently, at least half of the oil in any of the leads or polynyas would quickly weathered out of the slick (BOEM 2015a).

Offshore petroleum exploration activities have been conducted in State of Alaska waters and the OCS of the Beaufort and Chukchi Sea Planning Areas since the late 1960s. However, historical data on offshore oil spills for the Alaska Arctic OCS regions consists only of small spills and cannot be used to create a meaningful distribution for statistical analysis (NMFS 2013c). For this reason, agencies use a fault tree model to represent expected frequency of oil spills in the Beaufort Sea (Bercha Group 2008, 2014).

Approach to Estimating Exposures to Oil and Gas Spill

Estimating oil spill occurrence and potential effects on marine mammals is an exercise in probability. Uncertainty exists regarding the location, number, and size of small, large, and very large oil spills, and the wind, ice, and current conditions that could occur at the time of a spill.

The following sections will go into the probabilities of various sized oil spills occurring in the area of LS 193 during the first 9 years of authorizations, and the assumptions behind those analyses.

Based on BOEM/BSEE’s oil and gas spill analyses, the only sized spills that are reasonably likely to occur during the first incremental step, are small spills (<1000 bbl) (BOEM 2015a).

Small Oil Spills

Small oil spills have occurred with routine frequency and are considered likely to occur during the first incremental step as well as subsequent steps (BOEM 2015e). Small spills during exploration activities are expected to consist of refined oils because crude and condensate oil would not be produced during exploration (BOEM 2015a).

Based on a review of potential discharges and on the historical oil spill occurrence data for the Alaska OCS and adjacent State of Alaska waters, several spills from refueling operations (primarily at West Dock) have been reported to the National Response Center in the Beaufort and Chukchi Seas and all the spills were small (BOEM 2015e).

From 1971-2010 industry drilled 84 exploration wells in the entire Alaska OCS (BOEM 2011). Within the Beaufort and Chukchi OCS, the oil industry drilled 35 exploratory wells. During the time of this drilling, industry has had 35 small spills totaling 26.7 bbl or 1,120 gallons (gal). Of the 26.7 bbl spilled, approximately 24 bbl were recovered or cleaned up (BOEM 2011).

Refined oil is used in exploratory drilling activity for equipment and refueling. Any small refined oil spills during seismic and geophysical and geotechnical surveys and exploratory drilling activities is likely occur during July through early November.

The estimated total and annual numbers and volumes of small refined oil spills during the first incremental step activities are presented in Table 23. G&G activities[24] may result in 0-6 small spills in total (0–3 annually), and 0–14 small spills total (0–2 annually) could occur during exploration and delineation drilling activities during the first incremental step.[25] Small fuel spills associated with the vessels used for geological and geophysical activities could occur, especially during fuel transfer. For purposes of this analysis, a seismic vessel transfer spill was estimated to range from <1–13 bbl. The < 1 bbl volume considers dry quick disconnect and positive pressure hoses function properly. The 13 bbl spill volume considers failure of spill prevention measures or rupture of fuel lines. BOEM and BSEE anticipate that most spills from the proposed action's G&G survey activities would be <1 bbl, one would be up to 13 bbl, for a total of <18 bbl during the first incremental step (BOEM 2015e). There are no reported historical fuel spills from geological or geophysical operations in the Chukchi Sea OCS.

Small spills could also occur during exploration drilling operations. BOEM and BSEE anticipate that most spills originating from the proposed action's exploration and delineation drilling activities would ≤5 bbl; some would be up to 50 bbl, for a total of <115 bbl during the first incremental step (BOEM 2014a, 2015b, e). For the purpose of the analysis, BOEM and BSEE assume that 13 spills would be ≤5 bbl, and one spill would be up to 50 bbl, for a total of <115 bbl during the first incremental step (BOEM 2015b).

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[24] G&G activities include marine seismic surveys, geohazard surveys, and geotechnical surveys which total 12 surveys during the first incremental step (BOEM 2015e). BOEM assumes that every other G&G activity may have an offshore transfer fuel spill (which is very conservative as no offshore fuel transfer spills have been reported from G&G activities in the Alaska Region to date) (BOEM 2015b).

[25] The combination of G&G and exploratory drilling activities during the first incremental step could total 0-20 small spills with 0-5 spills occurring annually and ranging in size from <1bbl up to 50 bbl per spill (BOEM 2015e).

Table 23. **Estimated number, volume, and risk of small refined oil spills during the first incremental step (BOEM 2014a, 2015b, e).**

Activity Phase	Estimated Total Number of Small Spills	Estimated Total Volume of Small Spills (bbl)	Chance of Occurrence
Small Refined Oil Spills			
Exploration G&G Activities	0 - 6	0 - < 18	> 99.5% chance of a spill
Exploration and Delineation Drilling	0 - 14	0 - < 115	> 99.5% chance of a spill
Total # of Spills during First Incremental Step	0-20	0-<133	> 99.5% chance of a spill
Large Oil Spills			
Exploration and Delineation Drilling	None	N/A	0.074 per 1,000 Years[*]
Very Large Oil Spills			
Exploration and Delineation Drilling	None	N/A	$10^{-4} – 10^{-5}$ per well[**]

[*] See Table 6.3 (Bercha Group 2008, 2014)

[**] See Table 4.3.3-3(BOEM 2012)

Large Oil Spills

BOEM and BSEE analyzed historical data on oil spills over the U.S. OCS from 1971-2010, and determined that no crude oil spills ≥1,000 bbl have occurred during exploration, other than the Deepwater Horizon (DWH) incident (BOEM 2015a). No large or very large oil spills have occurred historically in the action area.

BOEM and BSEE estimated the rate of large oil spills occurring as 0.074 spill per 1,000 years (see Table 23) (BOEM 2015a). Since the first incremental step is only over nine years, BOEM/BSEE predict that no large spills (>1,000–150,000 bbl) would occur over this time period. This estimate is based historical data about oil spills. Of over 15,000 exploration wells drilled on the OCS from 1971–2010, no crude oil spills ≥1,000 bbl have occurred during exploration, other than the DWH incident (BOEM 2015a).

Any authorized exploration drilling program as part of the proposed action would include oil spill response and cleanup vessels and equipment, which may be staged near the drilling area or in more protected nearshore areas, such as Goodhope Bay in Kotzebue Sound (BOEM 2015a).

Very Large Oil Spills

The DWH oil spill event falls within the category of VLOS, which is defined as spills greater than 150,000 bbl, and is considered a low-probability, high-impact event. In other words, a spill of this volume is highly unlikely to occur during any activity phase, but if one did occur, the impacts would be substantial (BOEM 2015e). VLOS are analyzed separately from large oil spills, as they present an even lower likelihood of occurrence.

It is highly unlikely but cannot be entirely ruled out that a VLOS could occur from a well control incident followed by a long duration flow during exploratory drilling in the first incremental step, or during drilling for production in future incremental steps. A VLOS is extremely unlikely to occur because the frequency of such a spill from a loss of well control incident is extremely low, and the number of wells anticipated to be drilled during the first incremental step is low. BOEM anticipates that the VLOS chance of occurrence during the first incremental step would be between 10^{-4} and 10^{-5} per well (BOEM 2015a) (see Table 23). Thus, the probability of a VLOS occurring as part of the proposed action is low, but if one were to occur the potential effects would be substantial (such effects were analyzed in the Second SEIS for the purpose of evaluating a low-probability, high impact event) (BOEM 2014a, 2015a, e). We analyze potential responses of listed marine mammals to VLOS exposure below in Sections 6.2.6 and 6.1.4.5.

Severity of Exposure

The severity of exposure that can result in impacts to listed marine mammals and their habitats depends on a number of factors:

- size of a spill (the flow rate and duration);
- volume of oil available to be released (reservoir size);
- type of oil;
- location;
- time of year;
- species, life history, or migratory stage; and
- manner of exposure (external only or ingestion, inhalation, or aspiration).

While marine mammals may show irritation, annoyance, or distress from oil, for the most part, an animal’s need to remain in an area for food, shelter, or other biological requirements overrides any avoidance behaviors to oil (Vos et al. 2003). In addition, depending on the location of a spill, highly populated areas would be more susceptible than sparsely populated areas. Animals can be affected outside of a main spill area through oil transported by currents and oiled prey (Figure 23). The exposure to oil needs to be in sufficient quantity to produce adverse effects from either external oiling, internal absorption from ingestion of oil and prey, aspiration of oil, inhalation of volatile vapors in the air, and/or a combination of the above.

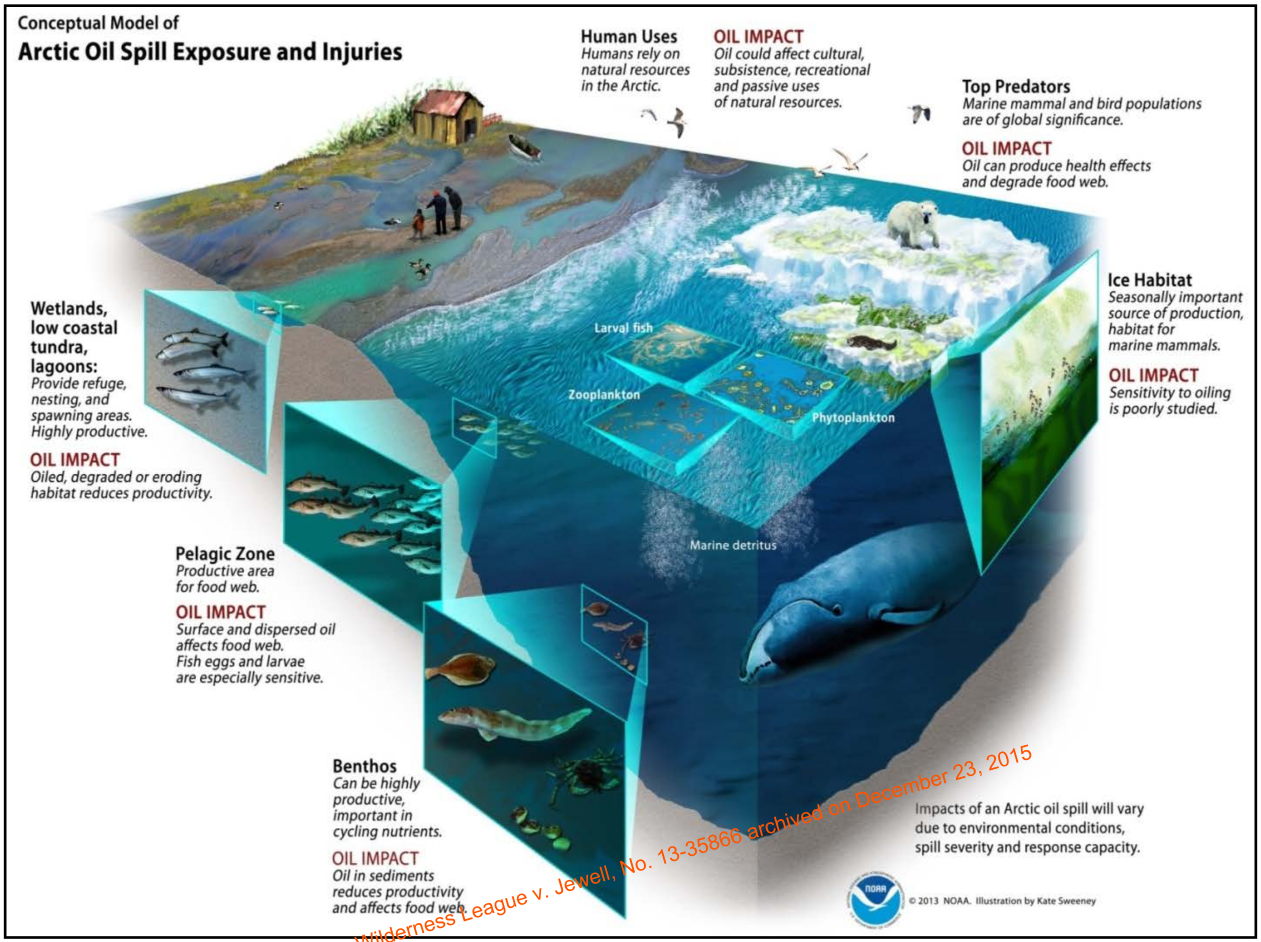

Figure 23. **Conceptual model of the various pathways by which marine predators and their prey can be exposed to spilled oil.**

In the following sections on anticipated oil spill exposures to listed species we qualitatively describe the potential for exposure. This is due to the fact that we have estimates of likelihood of the various sized oil spills occurring, but we do not have estimates on the potential for overlap between spills and listed species.

Baleen Whale (bowhead, fin, and humpback) Exposure

Some small spills could be in or close to areas used by bowhead, humpback, and fin whales. However, small refined oil spills rapidly dissipate volatile toxic compounds within hours to a few days through evaporation, and residual components rapidly disperse in open waters. If individual bowhead, humpback, or fin whales were exposed to small spills, the spills would likely have minimal effects on their health due to small spills sizes, weathering, and rapid spill dispersal. Humpback and fin whales occur in very low densities in the Chukchi Sea during the summer months. Their low numbers further reduce the potential for exposure and response to oil spills (BOEM 2015a).

A small fuel spill would be localized and would not permanently affect whale prey populations (e.g., forage fish and zooplankton). The amount of zooplankton and other prey lost in such a spill likely would be undetectable compared to what is available on the whales’ summer feeding grounds. NMFS does not expect small spills of refined fuels at the rates predicted by BOEM to expose whales or their prey to a measureable level.

Based on the localized nature of small oil spills, the relatively rapid weathering expected for <1,000 bbl of refined oil, the small number of refueling activities in the proposed action, and the safeguards in place to avoid and minimize oil spills, the likelihood of a small spill affecting bowhead, fin, or humpback whales during the first incremental step in the Chukchi Sea is low. However, due to the uncertainty associated with potential exposure to whales, we analyze potential responses to oil spill below in Section 6.1.4.5.

Large or very large spills are not reasonably foreseeable during the first incremental step. If the stressor and species are not anticipated to overlap in time and space, then we would not anticipate that whales would be exposed to large or very large oil spills during the first incremental step. However, potential exposure and response of whales to large and VLOS are described below for future incremental steps (see Section 6.2.6).

Pinniped (ringed and bearded seals) Exposure

Ringed and bearded seals are commonly observed in the Chukchi Sea year-round. It is possible that some small spills may occur in, or close to, areas used by ringed and bearded seals in the Chukchi Sea. Based on the localized nature of small spills and the relatively rapid attenuation and dispersion of < 1,000 bbl of refined oil, the small number of predicted spills, the safeguards in place to avoid and minimize oil spills, and the small number of past Arctic spills, the likelihood of a small spill affecting ringed and bearded seals during the first incremental step of LS 193 in the Chukchi Sea is low. A small oil spill would be localized and would not permanently affect fish and invertebrate populations that are ringed and bearded seal prey. The amount of fish and other prey lost in such a spill likely would be undetectable compared to what is available throughout the range of the two seal species.

We conclude that the probability of a BOEM/BSEE authorized activity within the action area causing a small oil spill and exposing ringed or bearded seals during the first incremental step is sufficiently small as to be considered discountable, i.e., extremely unlikely to occur.

Large or very large spills are not reasonably foreseeable during the first incremental step. If the stressor and species are not anticipated to overlap in time and space, then we would not anticipate that seals would be exposed to large or very large oil spills during the first incremental step. However, potential exposure and response of seals to large and VLOS are described below for future incremental steps (see Section 6.2.6).

Proposed Ringed Seal Critical Habitat Exposure

Any accidental discharges that occur as part of the LS 193 proposed action would occur within the area proposed for designation as ringed seal critical habitat (see Figure 9).

Sea ice is represented in two of three essential features identified in the critical habitat proposal (sea ice suitable for birth lairs and basking/molting platforms). Ice edges, whether associated with shorefast ice or pack ice, generally act as a barrier to the spread of oil (McLaren 1990). Therefore, unless oil is released directly under ice, swept under by strong currents, otherwise dispersed in water, or tracked in by oiled animals, it would not likely spread into lairs, or on the adjacent subsurface of ice. Instead, oil would accumulate in leads and cracks that are connected to the spill source through open water. This would confine oil to the spaces between ice floes and tide-cracked landfast ice sheets that have a direct connection with the spill source (BOEM 2015a).

The third essential feature for proposed ringed seal critical habitat, primary prey resources, may also be adversely affected by oil spills. A spill in the Chukchi Sea could affect fish through many pathways, including adsorption to outer body, respiration through gills, ingestion, and absorption of dissolved fractions into cells through direct contact (BOEM 2015a).

Although small spills will likely occur within ringed seal critical habitat, the spills are expected to be localized and temporary in nature. We determine whether and how the quantity, quality, or availability of one or more of the physical or biological features of proposed ringed seal critical habitat are likely to change in response to the exposure of small oil spills in Section 6.1.4.5.

6.1.3.4 Exposure to Other Stressors

6.1.3.4.1 Exposure to Vessel Strike

Mitigation Measures to Minimize the Likelihood of Exposure to Vessel Strike

Mitigation measures are described in detail in Sections 2.1.5 and 2.1.6. The following mitigation measures will be implemented through the MMPA permitting process to reduce the potential for vessel strike on marine mammals from the proposed action.

1. PSOs are required on all seismic source vessels, ice management vessels, and other vessels engaged in activities that may result in an incidental take through acoustic exposure;
2. Check waters immediately adjacent to vessels with propellers to ensure that no marine mammals will be injured;
3. Avoid concentrations of 3 or more whales and not operating vessels in a way that separates members of a group;
4. Maintain a vigilant watch for listed whales and pinnipeds, avoid multiple changes in direction, and observe the 5 knots speed restriction when within 274m of whales or pinnipeds;

5. Lessee and/or operator will avoid transits within designated North Pacific right whale critical habitat. If transit within North Pacific right whale critical habitat cannot be avoided, vessel operators are requested to exercise extreme caution and observe the 10 knot vessel speed restriction while within North Pacific right whale critical habitat, and maintain an avoidance distance of 800m from any observed North Pacific right whale while within their designated critical habitat consistent with vessel safety;

6. Lessee and/or operators transiting through North Pacific right whale critical habitat will have PSOs actively engaged in sighting marine mammals. PSOs would increase vigilance and allow for reasonable and practicable actions to avoid collisions with North Pacific right whales; and

7. Vessels should take reasonable steps to alert other vessels in the vicinity of whale(s), and, report any dead or injured listed whales or pinnipeds.

Approach to Estimating Exposures to Vessel Strike

As discussed in the *Proposed Action* section of this opinion, the activities BOEM and BSEE propose to authorize would increase the number of vessels transiting the area. Additional vessel traffic could increase the risk of exposure between vessels and marine mammals.

Assumptions of increased vessel traffic related to exploration activities in the Chukchi Sea LS 193 are as follows:

- Mobilization and demobilization are primarily planned to occur at Dutch Harbor with resupply potentially occurring out of Kotzebue, Barrow, or Wainwright.

- At the start of a program, vessels may transit from Dutch Harbor through the Bering Strait and into the Chukchi Sea in order to reach the lease area. The reverse is anticipated to occur at the conclusion of the season.

- The maximum number of vessels associated with marine seismic survey activities is anticipated to be 3 vessels used for Towed-Streamer 2D/3D seismic surveys in the Chukchi Sea during the open water season (July-Oct), and 2 vessels for in-ice Towed Streamer 2/D in the winter (Nov-Dec). A support vessel may make up to 3 round-trips per survey.

- The maximum number of vessels associated with geohazard high-resolution activities is 3 vessels potentially used for airgun surveys during the open water season (July-Oct).

- The maximum number of vessels associated with geotechnical activities is 1 vessel during the open water season (July-Oct).

- The maximum number of vessels associated with exploratory drilling activities would involve drilling from a drillship. If BOEM and BSEE authorize two exploratory drilling programs per year for a total of seven years, there is the potential that all of these authorizations may involve drilling from a drillship. NMFS anticipates that the maximum number of vessels associated with exploratory drilling activities would be 33 per year. Support vessels may make up to 154 round-trips per drilling season.[26]

- The maximum number of vessels associated with onshore facility construction is anticipated to be 2.

- Drilling operations would commence on or after approximately July 1 and end by early November, depending on weather.

Based on the proposed action, the maximum number of vessels that would be associated with authorized activities per year would be 33 vessels[27] and a total of 154 round-trip transits associated with support vessels per year in the Chukchi Sea 193 lease area.

Evidence suggests that a greater rate of mortality and serious injury to marine mammals correlates with greater vessel speed at the time of a ship strike (Laist et al. 2001, Vanderlaan and Taggart 2007) as cited in (Aerts and Richardson 2008). Vessels transiting at speeds >10 knots present the greatest potential hazard of collisions (Jensen and Silber 2004a, Silber et al. 2009). Vanderlann and Taggart (2007) demonstrated that the greatest rate of change in the probability of a lethal injury to a large whale occurs between vessel speeds of 8.6 and 15 knots.

While most seismic survey operations occur at relatively low speeds (1-5 knots), large vessels are capable of transiting at up to 16.5 knots and operate in periods of darkness and poor visibility (BOEM 2015a). In addition, large vessels when traveling cannot perform abrupt turns and cannot slow speeds over short distances to react to encounters with marine mammals (BOEM 2015a). All of these factors increase the risk of collisions with marine mammals. However, BOEM/BSEE propose to include vessel strike mitigation measures as described in Section 2.1.5 and highlighted above. Operators are also required to abide by NMFS's standard mitigation measures through MMPA authorization. PSOs on survey ships to alert vessel operators to the presence of marine animals are also expected to help vessels avoid marine mammal strikes.

Cetacean Exposure

Available information indicates that the rate of vessel strikes of whales in the region is low and there is no indication that strikes will become a major source of injury or mortality in the action area (BOEM 2011).

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[26] BOEM anticipates support vessels may make 1-3 round-trips per week per week. Exploratory drilling operations are anticipated to take 120 days, which equals approximately 51 round-trips per support vessel. BOEM anticipates that drilling operations may have as many as 3 offshore supply vessels, so we anticipate a total of 153 round-trips per drilling season.

[27] This is based on BOEM's scenario that one geohazard survey (3 vessels), one geotechnical survey (1 vessel), 2 drilling operations (27 vessels), and onshore facility construction (2 vessels) may occur within one year during the first incremental step of nine years totaling 33 vessels.

Vessels will primarily transit during the open-water period (July-Nov) and bowhead, fin, and humpback whales are known to migrate and feed in the Chukchi during open-water periods. Vessels transiting to the Chukchi Sea from Dutch Harbor at the start of the open water season, or returning at the end of the season, transiting between sites, or for resupply in and out of coastal communities along the Chukchi Sea have the highest chance of encountering migrating bowheads or aggregations feeding in more coastal regions of the northeast Chukchi (Clarke et al. 2011c, Clarke et al. 2012, 2013b).

Several behavioral factors of bowhead whales help determine whether transiting vessels may be able to detect the species or whether bowhead would be at depths to avoid potential collision. Bowhead whales typically spend a high proportion of time on or near the ocean floor when feeding. Even when traveling, bowhead whales visit the bottom on a regular basis (Quakenbush et al. 2010a). Bowhead foraging dives are twice as long as most fin and humpback whales, and even at equivalent depths, their dives are followed by shorter recovery times at the surface (Krutzikowsky and Mate 2000). This behavior may make bowhead whales less likely to encounter a vessel transiting in the action area, and lowers the likelihood of vessels colliding with whales. However, calves have shorter dive duration, surface duration, and blow intervals than their mothers (BOEM 2011), which put them at a higher risk of ship strike. Bowhead whale neonates have been reported in the Arctic as early as March and as late as early August (BOEM 2011). Most bowhead whales show strong avoidance reactions to approaching ships which may help them avoid collisions with vessels (NMFS 2013c). However, Alaska Native hunters report that bowheads are less sensitive to approaching boats when they are feeding (George et al. 1994), leaving them more vulnerable to vessel collisions. In addition, bowhead whales are also among the slowest moving whales, which may make them particularly susceptible to ship strikes if they happen to be on the surface when a vessel is transiting. The low number of observed ship-strike injuries suggests that bowhead whales either do not often encounter vessels or they avoid interactions with vessels.

NMFS is not aware of any records for bowhead whales killed by ship strike in the Arctic. However, George *et al.* (1994) reported propeller scars on 2 of the 236 (0.8%) bowhead whales landed by Alaska Native whalers between 1976 and 1992. Even if vessel-related deaths were several times greater than observed levels of propeller scars, it would still be a small fraction of the total bowhead population (Laist et al. 2001). Bowhead whales are long lived and scars could have been from decades prior to the whale being harvested.

Around the world, fin whales are killed and injured in collisions with vessels more frequently than any other whale (Laist et al. 2001, Jensen and Silber 2004a, Douglas et al. 2008a). Differences in frequency of injury types among species may be related to morphology. The long, sleek, fin whale tends to be caught on the bows of ships and carried into port where they are likely found and recorded in stranding databases (Laist et al. 2001). There have been 108 reports of whale-vessel collisions in Alaska waters between 1978 and 2011. Of these, 3 involved fin whale (Neilson et al. 2012). None of the reported fin whale ship strikes occurred in Arctic waters. Even if vessel-related deaths of fin whales in the waters south of the action area where strike of fin whales has been known to occur were several times greater than observed levels, it would still be a small fraction of the total fin whale population (Laist et al. 2001).

Some of the unique feeding habits of fin whales may also put them at a higher risk of collision with vessels than other baleen whales. Fin whales lunge feed instead of skim feeding (BOEM 2011). These lunges are quick movements which may put them in the path of an oncoming vessel, and give the captain of a vessel little time to react. In addition, despite their large body size, fin whales appear to be limited to short dive durations (Goldbogen et al. 2007) which may make them more susceptible to ship strikes when they are near the surface. Based on ship-strike records, immature fin whales appear to be particularly susceptible to strike (Douglas et al. 2008a).

The number of humpback whales killed worldwide by ship strikes is exceeded only by fin whales (Jensen and Silber 2004a). On the Pacific coast, a humpback whale is killed about every other year by ship strikes (Barlow et al. 1997). There were 108 reports of whale-vessel collisions in Alaska waters between 1978 and 2011. Of these, 93 involved humpback whales (Neilson et al. 2012). Between 2007 and 2011 the mean minimum annual human-caused mortality and serious injury rate for humpback whales based on vessel collisions in Alaska was (0.36) reported in the NMFS Alaska Regional Office stranding database (Allen and Angliss 2014). However, even if vessel-related deaths of humpback whales in the waters south of the action area where strike of humpback whales has been known to occur were several times greater than observed levels, it would still be a small fraction of the total humpback whale population (Laist et al. 2001). No vessel collisions or prop strikes involving humpback whales have been documented in the Chukchi Sea or Bering Sea (BOEM 2011).

The high proportion of calves and juveniles among stranded ship-struck right whales and humpback whales indicates that young animals may be more vulnerable to being hit by ships (Laist et al. 2001). This could be caused by the relatively large amount of time that calves and juveniles spend at the surface or in shallow coastal areas where they are vulnerable to being hit (Laist et al. 2001). Considering that at least one humpback cow/calf pair has been sighted in the action area, we can assume that this life stage may be present and susceptible to ship strike.

Vessels associated with BOEM-authorized activities would have a transitory presence in any specific location, except for drilling sites. NMFS is not able to quantify existing traffic conditions across the entire action area to provide context for the addition of 33 vessels and 154 round-trip transits as a maximum per year. However, the rarity of collisions involving vessels and listed marine mammals in the Arctic despite decades of spatial and temporal overlap suggests that the probability of collision is low.

Based on the small number of vessels associated with the proposed action, the small number of activities being authorized by BOEM and BSEE, the limited number of sightings of fin and humpback whales in the Chukchi Sea, and the decades of spatial and temporal overlap that have not resulted in a known marine mammal vessel strike or mortality from vessel strike in the Chukchi or Bering Seas, and the mitigation measures in place to minimize exposure of cetaceans to vessel activities, we conclude that the probability of a BOEM/BSEE authorized vessel striking an endangered cetacean in the Bering Sea or Chukchi Sea is sufficiently small as to be discountable.

Pinniped Exposure (ringed and bearded seals)

Ringed seals and bearded seals have been the most commonly encountered species of any marine mammals in past exploration activities and their reactions have been recorded by PSOs on board source vessels and monitoring vessels (Reiser et al. 2011, Aerts et al. 2012, Funk et al. 2013, Reider et al. 2013, Cate et al. 2014). These data indicate that seals tend to avoid on-coming vessels and active seismic arrays (NMFS 2013c). Available information indicates that the rate of vessel strikes of seals in the region is low and there is no indication that strikes will become a significant source of injury or mortality (BOEM 2011).

During the open water foraging period for ringed seals there is a possibility that vessels could strike seals (BOEM 2015a). Seals that closely approach larger vessels also have some potential to be drawn into bow-thrusters or ducted propellers (BOEM 2015a). In recent years gray and harbor seal carcasses have been found on beaches in eastern North America and Europe with injuries indicating the seals may have been drawn through ducted propellers (BOEM 2015a). To date, few incidents such as these have been documented in Alaska, though Sternfield (2004) documented a single spotted seal stranding in Bristol Bay, Alaska that may have resulted from a propeller strike (BOEM 2015a). There have been no incidents of ship strike with bearded or ringed seals documented in Alaska (BOEM 2015a) despite the fact that PSOs routinely sight bearded and ringed seals during oil and gas exploration activities.

Ringed seals molt from around mid-May to mid-July when they spend quite a bit of time hauled out on ice at the edge of the permanent pack, or on remnant land-fast ice along coastlines (Reeves 1998b). While ringed seals do not cease foraging entirely during their molting period, the higher proportion of time spent hauled out (Kelly and Quakenbush 1990, Kelly et al. 2010b) may make them less likely to encounter a transiting vessel during the early seismic survey and drilling periods. During the open-water period ringed seals are anticipated to be more widely distributed. This dispersed distribution may help mitigate the risks of localized shipping disturbance since the impacts from such events would be less likely to affect a large number of seals (Kelly et al. 2010a). However, ringed seals may be at the greatest risk from shipping threats in areas of the Arctic where geographic constriction concentrates seals and vessel activity into confined areas, such as the Bering Strait (Arctic Council 2009).

From mid-April to June as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer they are found near the widely fragmented margin of sea ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea. Since bearded seals are benthic feeders, they generally associate with seasonal sea ice over shallow water of less than 200m (656 ft) (Burns 1981). However, they can also feed on ice-associated organisms when they are present, which allows a few bearded seals to live in areas where water depth is considerable greater than 200m (Cameron and Boveng 2009). Bearded seals are likely to be encountered during exploration activities, and greater numbers are likely to be encountered if the ice edge occurs nearby.

NMFS does not anticipate much overlap between ice-breaking activities and the subnivean period (early winter through spring) for ringed seals. Ice-breaking activities typically occur in late fall-early winter, a time period when ice seals are often on top of sea ice and in the water but not in subnivean structures (NMFS 2013c). Ringed seals give birth in lairs beginning in mid-

March (Smith and Stirling 1975), months after the latest time icebreakers are anticipated to operate in the Arctic. However, if there were overlap between ice-breaking activities and the period when ringed seals are in subnivean lairs on the ice, icebreakers may pose a special risk. Icebreakers are capable of operating year-round in all but the heaviest ice conditions and are often used to escort other types of vessels (*e.g.,* seismic source vessels) through ice-covered areas (Kelly et al. 2010a). Reeves (1998b) noted that some ringed seals have been killed by icebreakers moving through fast-ice breeding areas.

Vessels associated with BOEM-authorized activities would have a transitory presence in any specific location, except for drilling sites. NMFS is not able to quantify existing traffic conditions across the entire action area to provide context for the addition of 33 vessels and 154 round-trip transits as a maximum per year. However, the absence of collisions involving vessels and ice seals in the Arctic despite decades of spatial and temporal overlap suggests that the probability of collision is low.

Standard mitigation measures require advance scouting of routes and survey lines to minimize impacts to seals by avoiding areas more likely to have lairs (pressure ridges and deep snow accumulations). These mitigation measures also require use of various methods to detect and avoid seal lairs, thereby reducing the chance of destroying an active lair from ice road construction or on-ice survey activities. However, if an active lair is not detected and is incidentally impacted by heavy survey equipment, the adult female could likely escape into the water but the pup could be killed by crushing or premature exposure to the water (NMFS 2013c). Timing restrictions would likely avoid adverse effects to newborn ringed seal pups, particularly when nursing and molting (NMFS 2013c). In addition, standard mitigation measures require vessel speed and course alternations if a marine mammal is detected within 300 yards of a vessel.

Based on the small number of vessels associated with the proposed activities in the Chukchi Sea, the small number of activities being authorized by BOEM and BSEE, the decades of spatial and temporal overlap that have not resulted in a known vessel strike or mortality from vessel strike in the Chukchi or Bering Seas for ice seals, and the mitigation measures in place to minimize exposure of pinnipeds to vessel activities, we conclude that the probability of a BOEM/BSEE authorized vessel striking a threatened ringed or bearded seal in the action area sufficiently small as to be discountable.

6.1.3.4.2 Exposure to Seafloor Disturbance

Arctic marine mammal species exploit prey resources close to the sea ice, in the water column, and at the sea floor, including lipid-rich pelagic and benthic crustaceans and pelagic and ice-associated schooling fishes such as capelin and Arctic cod (Bluhm and Gradinger 2008). Aspects of the proposed action have the potential to cause seafloor disturbance, turbidity, and discharge that may impact marine mammal benthic prey species.

Seafloor disturbance can occur from sediment sampling, placement and removal of equipment on the seafloor, and discharge of drilling waste during geotechnical surveys and exploratory drilling activities. Sampling includes gravity/piston coring, shallow coring, gravity or vibracores, rotary cores, and grab sampling and individual sampling events lasts three days or less. Seafloor disturbance and scour can also occur from bottom founded anchors associated with exploratory drilling operations (BOEM 2015a).

Geotechnical Surveys

Sampling for geotechnical surveys would occur at specific sites (consisting of one or more OCS blocks) in water depths less than 200 m, and along potential cable routes to shore. LS 193 has 10,541 km^2 of active lease blocks where geotechnical surveys could occur from July to October. Over the nine years of the proposed action, only 5 geotechnical surveys will be authorized (BOEM 2015a).

Bottom sampling activities would primarily take place in soft bottom areas as most bottom sampling equipment cannot penetrate hard bottom substrate. Piston and gravity cores are approximately 8-cm (3-in) diameter holes in the seafloor and, depending upon the firmness of the seafloor, the core or probe weight stand (30-45 cm [12-18 in] diameter footprint) may also impact the seafloor. Grab sampling is performed to identify the benthic fauna and penetrates from a few inches to a few feet below the seafloor and typically involves 30-40 grabs within an area of interest. A vibracore survey generally uses a 7 cm (2.8 in) diameter core barrel mounted on a 2 to 4 m^2 platform and that can penetrate sediments between 6 -15 m (20-50 ft) below the seafloor. Fifteen to twenty five cores would be obtained in a 1 mi^2 (259 ha) area of interest.

BOEM anticipates that geotechnical surveys involving coring have the potential to impact a small amount of habitat. Each rotary bore hole would affect roughly 233m^3 of soil below the seabed (BOEM 2015e).

Although several hundred cores may be collected under the proposed action, sampling in soft bottom areas would produce only minor, localized turbidity which is expected dissipate when sampling ends.

Exploratory Drilling

Drilling operations are expected to range between 30 and 90 days at different well sites and may occur from June through October. BOEM/BSEE are only authorizing two drilling operations per year with a total of four wells drilled per year, and drilling operations must occur on the 10,541 km^2 of active lease blocks.

Exploratory drilling will disturb an area of the seafloor. The area of disturbance would vary based on the type of drill rig used, ocean currents, and other environmental factors, but in general includes disturbance from the mud cellar (MLC), the anchoring system for the MODU (e.g., legs of the jack up rig or footprint of the drillship anchors), displacement of sediments, and discharge of drilling waste (BOEM 2015a).

Mooring of the drilling units and construction of MLCs will result in some seafloor disturbance and temporary increases in water column turbidity. The drilling units would be held in place during operations with systems of eight anchors for each unit. Anchor laying is anticipated to be short-term lasting 2-5 days (BOEM 2015a). The embedment type anchors designed to embed into the seafloor thereby providing the required resistance. The anchors will penetrate the seafloor on contact and may drag 2-3 or more times their length while being set. Both the anchor and anchor chain will disturb sediments in this process creating a trench or depression with surrounding berms where the displaced sediment is mounded. Some sediments will be suspended in the water column during the setting and subsequent removal of the anchors. The depression with associated berm, collectively known as an anchor scar, remains when the anchor is removed (Shell 2015).

The anchoring area of disturbance per well associated with a drill ship would range to 2,755m^2 – 5,510m^2 (roughly 30,000 ft^2 – 60,000 ft^2) per well (BOEM 2015e). Considering that BOEM may authorize up to two MODUs per year and each MODU may drill up to two wells, we anticipate the disturbance area may range from 11,020 m^2 –22,040m^2 (roughly 120,000 ft^2 – 240,000 ft^2) per year. The nine year duration and total of 28 well during the first incremental step would result in a disturbance area of 77,140 m^2 – 154,280m^2 (roughly 840,000ft^2 –1,680,000ft^2) (BOEM 2015e). The surface area of disturbance from a drill ship would be about 95 m^2 (roughly 1,000 ft^2). The depth at which the anchors would sink would vary depending upon the substrate (BOEM 2015e).

Once the drilling units end operation, the anchors may be retrieved or left on site for wet storage. Over time the anchor scars will be filled through natural movement of sediment. The duration of the scars depends upon the energy of the system, water depth, ice scour, and sediment type. Anchor scars were visible under low energy conditions in the North Sea for five to ten years after retrieval. Scars typically do not form or persist in sandy mud or sand sediments but may last for nine years in hard clays (Centaur Associates Inc. 1984). Surficial sediments in Shell's Burger Prospect consist of soft sandy mud (silt and clay) with lesser amounts of gravel (Shell 2015). The energy regime, plus possible effects of ice gouge in the Chukchi Sea suggests that anchor scars would be refilled faster than in the North Sea (Shell 2015).

Excavation of each MLC by the drilling units using a large diameter drill bit may directly disturb approximately 14,957 – 35,953m^2 (161,000-387,000 ft^2) of seafloor. Annually this would result in 59,830 – 143,814 m^2 (644,000-1,548,000 ft^2) (BOEM 2015e). Some of the excavated sediments will be displaced to adjacent seafloor areas and some will be pumped and discharged on the seafloor away from the MLC. These excavated materials will also have some indirect effects as they are suspended in the water and deposited on the seafloor in the vicinity of the MLCs (Shell 2015).

Cuttings from the MLC excavation would be deposited on the seafloor below the temperature and salinity stratification layer. It is estimated that the maximum thickness of the sediment deposition onto the seafloor would be 3.2 m (10.4 ft) and the deposition would continue out to a horizontal distance of 137 m (449 ft) from the excavation site, where it would be 1 cm (0.4 in) thick (BOEM 2015a).

Drilling associated with delineation/exploration wells during exploration is anticipated to use a 6m to 12 m diameter drill that would result in disturbance of 933 m^3 – 3,700 m^3 (roughly 33,000 ft^3 – 130,600 ft^3). If a jack-up rig or drillship was used for drilling, BOEM anticipates the 28 wells during the first incremental step would disturb approximately 1,330m^2 of seabed at a maximum (BOEM 2015e).[28]

There was no indication from benthic biomass or density that previous drilling activities at the Hammerhead Prospect have had a measurable impact on the ecology of the immediate local area. To the contrary, the abundance of benthic communities in the Sivulliq area would suggest that the benthos were actually thriving there (Dunton et al. 2009). No appreciable adverse impacts on benthic populations would be expected due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations. Any mortalities or impacts that might occur as a result of the proposed action is immaterial compared to the naturally occurring high reproductive and mortality rates. In addition, disturbed areas, depending on substrate types, community composition, and ocean current speed and direction, would begin the process of recolonization after deposition has completed following the benthic disturbance (Conlan and Kvitek 2005, BOEM 2015a). Invertebrate species important to large mammalian benthic foragers, such as bivalves, would likely reach sizes readily utilized by foraging mammals at approximately 7-9 or more years depending upon substrate classification, depth, and water temperature (BOEM 2015a). Other benthic foragers such as crabs, fish, and pelagic bird species typically utilize smaller organisms such as amphipods, copepods, shrimp, nematodes, and polychaetes. These are among the first to recolonize taking generally less than a year for establishment in new locations (Trannum et al. 2011).

Only localized turbidity is expected to occur as a result of the proposed bottom sampling activities. This turbidity is expected to dissipate after sampling activities have ceased. Seafloor disturbance from anchor handling activities is anticipated to fill in through natural movement of sediment over time. Disturbance associated with MLC excavation or exploration/delineation wells is anticipated to temporarily impact a small area of habitat which would soon be re-colonized by benthic organisms. Based on the above, we would not expect adverse effects to listed species from bottom sampling activities and would consider this stressor insignificant. We will not consider bottom disturbance further in this opinion.

6.1.3.4.3 Exposure to Trash and Debris

Mitigation Measures to Minimize the Likelihood of Exposure to Trash and Debris

Mitigation measures are described in detail in Sections 2.1.5 and 2.1.6. The following mitigation measure is considered part of the proposed action to reduce the potential for marine mammal entanglement and ingestion of debris.

1. All vessel operators, employees and contractors actively engaged in exploration surveys or drilling operations must be briefed on marine trash and debris awareness elimination.

Approach to Estimating Exposure to Trash and Debris

Operations under the proposed action generate trash comprised of paper, plastic, wood, glass, and metal mostly from galley and offshore food service operations. A substantial amount of waste products could be generated from seismic and drilling activities over the duration of the

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[28] BOEM anticipates that approximately 47.5 m^2 would be disturbed per well, and anticipate a total of 28 wells may be drilled during the first incremental step = 1,330 m^2 of disturbed habitat (BOEM 2015e).

proposed action. The possibility exists that trash and debris could be released into the marine environment.

Entanglement in marine debris is a threat to marine mammals worldwide. A 2014 global study found that ingestion of debris has been documented in 56% of cetacean species, with rates of ingestion as high as 31% in some populations (Baulch and Perry 2014). In Alaska, many species of cetaceans and pinnipeds are known to become entangled in or ingest marine debris. Manufactured packing bands are a particular problem for pinnipeds and should always be cut before disposal to prevent neck entanglements.

All survey vessels performing work within U.S. jurisdictional waters are expected to comply with federal regulations that implement the International Convention for the Prevention of Pollution from Ships (MARPOL) as amended by the 1978 Protocol (MARPOL 73/78). Within MARPOL Annex V, Regulations for the Control of Pollution by Garbage from Ships, as implemented by 33 CFR 151, are requirements designed to protect the marine environment from various types of garbage generated on board vessels. These requirements include, a prohibition on the deliberate discharge of containers and other similar materials (i.e., trash and debris) into the marine environment unless it is passed through a comminutor that breaks up solids and can pass through a 25-mm mesh screen; a prohibition on the discharge of plastic regardless of size; markings on equipment, tools and containers (especially drums), and other material as well as recording and reporting of items lost overboard, and; precautions for handling and disposing of small items and packaging materials.

In addition to MARPOL requirements, all vessel operators, employees and contractors actively engaged in exploration surveys or drilling operations must be briefed on marine trash and debris awareness elimination. BOEM will not require operators, employees and contractors to undergo formal training or to post placards. However, the operator will be required to ensure that its employees and contractors are made aware of the environmental and socioeconomic impacts associated with marine trash and debris and their responsibilities for ensuring that trash and debris are not intentionally or accidentally discharged into the marine environment.

Because operators must comply with federal regulations and BOEM's trash and debris guidance, the amount of trash and debris occurring within the action area is expected to be minimal and distributed over a wide area resulting in a discountable effect. As such we do not expect exposure of listed species to trash and debris and will not consider this further in this opinion.

6.1.4 Response Analysis

As discussed in the *Approach to the Assessment* section of this opinion, response analyses determine how listed species are likely to respond after being exposed to an action's effects on the environment or directly on listed species themselves. Our assessments try to detect the probability of lethal responses, physical damage, physiological responses (particular stress responses), behavioral responses, and social responses that might result in reducing the fitness of listed individuals. Our response analyses consider and weigh evidence of adverse consequences, beneficial consequences, or the absence of such consequences.

In addition, we try and determine whether and how the quantity, quality, or availability of one or more of the physical or biological features that led us to conclude that the area was essential for the conservation of a listed species are likely to change in response to the exposure.

6.1.4.1 Responses to Seismic Noise

Of all of the stressors we consider in this opinion, the potential responses of marine mammals upon being exposed to low-frequency seismic noise from airgun pulses have received the greatest amount of attention and study. Nevertheless, despite decades of study, empirical evidence on the responses of free-ranging marine animals to seismic noise is very limited. We examine multiple sources of seismic noise from the proposed action (2D, 3D, geohazard, and VSP) and the potential responses of listed species to these sources in this section, and also consider effects on proposed ringed seal critical habitat.

Baleen Whales (bowhead, fin, and humpback)

While cetaceans are a diverse group with varied life histories and migratory patterns (see Section 4.3), they share many important traits and exhibit similar physiological and behavioral responses. In this section, whales' responses are analyzed collectively where appropriate, as the species share many similar characteristics. Where sufficient information exists for species-specific analysis, or unique effects or susceptibilities exist, individual species are discussed separately. The majority of the information provided below focuses on bowhead whales as they are the most commonly occurring listed baleen whale in the action area, and a large amount of research has been done on this species. We anticipate responses from fin and humpback whales to be similar to the bowhead whale.

The maximum annual instances of exposure to seismic activities of bowhead whales range from 1-93, and fin and humpback whale instances of exposure range from 0-1 for each species depending on the activity scenario authorized (Table 21 provides annual instances of exposure for which seismic operations are a subset). All instances of exposure are anticipated to occur at received levels ≥ 160 dB. These instances of exposure combine all potential seismic sources (2D, 3D, geohazard, and VSP) that could co-occur annually. As an example, for BOEM/BSEE's Scenario 6, four VSP surveys may occur during the open-water season, and one 2D survey may occur in the in-ice season. This scenario is anticipated to result in the greatest annual instances of exposure to baleen whales (95 total instances of exposure for all three species).

These instances of exposure are likely to be overestimates because they assume a uniform distribution of animals, do not account for avoidance, assume all of the tracklines will be shot during the season, and result from summing the ensonified area associated with the concurrent sources (see Section 6.1.3.1 for full list). We used the Rea and Rmax ensonified areas and average densities in estimating a range of instances of exposure in order to account for variability over the next nine years and to be conservative.

During the first incremental step we anticipate 126-157 instances in which bowhead whales, and 1-2 instances in which fin and humpback whales might be exposed to sounds produced by seismic airguns at received levels ≥160 dB during seismic surveys using ~40-4500 cui airgun arrays (see Table 21).

Given the large size of baleen whales, and their pronounced vertical blow, it is likely that PSOs would be able to detect bowhead, fin, and humpback whales at the surface. The implementation of mitigation measures to reduce exposure to high levels of seismic sound, and the short duration and intermittent exposure to seismic airgun pulses, reduces the likelihood that exposure to seismic sound would cause a behavioral response that may affect vital functions (reproduction or survival), or result in temporary threshold shift (TTS) or permanent threshold shift (PTS). However, despite observer effort to mitigate exposure to sounds ≥180 dB re 1 μPa rms, evidence exists that some whales may be exposed to these higher received levels of noise. For example, during seismic survey activities in the Chukchi Sea in 2006 and 2008, 13 cetaceans were sighted within the ≥180 dB re 1 μPa rms radius and exposed to noise levels above that range before appropriate mitigation measures could be implemented (Haley et al. 2010).[29] The majority of cetaceans exhibited no reaction to vessels regardless of received sound levels (~96% of sightings). An increase in speed and splash were the next commonly observed reactions (Haley et al. 2010). Similarly, during ION's 2013 in-ice seismic survey in the Chukchi Sea, 10 bowhead whales were sighted within the ≥180 dB re 1 μPa rms radius. The whales exhibited no overt reaction and either continued swimming alongside or in a direction away from the seismic vessel (Beland et al. 2013).

As discussed in the *Status of the Species* section, we have no data on baleen whale hearing so we assume that baleen whale vocalizations are partially representative of their hearing sensitivities. While there is no direct data on hearing in low-frequency cetaceans, the functional hearing range is anticipated to be between 7 Hz to 30 kHz (Watkins 1986b, Au et al. 2006, Southall et al. 2007, Ciminello et al. 2012, NOAA 2013).

Bowhead whales are among the more vocal of the baleen whales (Clark and Johnson 1984). Vocalization is made up of moans of varying pitch, intensity and duration, and occasionally higher-frequency screeches. Bowhead calls have been distinguished by Würsig and Clark (1993): pulsed tonal calls, pulsive calls, high frequency calls, low-frequency FM calls (upsweeps, inflected, downsweeps, and constant frequency calls). Inferring from their vocalizations, bowhead whales should be most sensitive to frequencies between 20 Hz-5 kHz, with maximum sensitivity between 100-500 Hz (Erbe 2002a). As previously mentioned, Cumming and Holliday (1987) calculated source level measures for bowhead whales songs to be between 158 and 189 dB.

The sounds fin whales produce underwater are one of the most studied *Balaenoptera* sounds. Fin whales produce a variety of low-frequency sounds in the 10-200 Hz band (Watkins 1981, Watkins et al. 1987, Edds 1988, Thompson et al. 1992). The most typical signals are long, patterned sequences of short duration (0.5-2s) infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton 1964). Estimated source levels for fin whales are 140-200 dB re 1 μPa m

(Patterson and Hamilton 1964, Watkins et al. 1987, Thompson et al. 1992, McDonald et al. 1995, Clark and Gagnon 2004). In temperate waters intense bouts of long patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Short sequences of rapid pulses in the 20-70 Hz band are associated with animals in social groups (McDonald et al. 1995). Each pulse lasts on the

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[29] These are considered minimum estimates since they are based on direct observation.

order of one second and contains twenty cycles (Tyack 1999).

Humpback whales produce a wide variety of sounds. During the breeding season males sing long, complex songs, with frequencies in the 20-5000 Hz range and intensities as high as 181 dB (Payne 1970, Winn et al. 1970, Thompson et al. 1986). Source levels average 155 dB and range from 144 to 174 dB (Thompson et al. 1979). Social sounds in breeding areas associated with aggressive behavior in male humpback whales are very different than songs and extend from 50 Hz to 10 kHz (or higher), with most energy in components below 3 kHz (Tyack and Whitehead 1983, Silber 1986a). These sounds appear to have an effective range of up to 9 km (Tyack and Whitehead 1983). Humpback whales produce sounds less frequently in their summer feeding areas. Feeding groups produce distinctive sounds ranging from 20 Hz to 2 kHz, with median durations of 0.2-0.8 seconds and source levels of 175-192 dB (Thompson et al. 1986). These sounds are attractive and appear to rally animals to the feeding activity (D'Vincent et al. 1985, Sharpe and Dill 1997).

This information leads us to conclude that bowhead, fin, and humpback whales exposed to sounds produced by seismic airguns are likely to respond if they are exposed to low-frequency (7 Hz – 30 kHz) sounds. However, because whales are not likely to communicate at source levels that would damage the tissues of other members of their species, this evidence suggests that received levels of up to 189 dB are not likely to damage the tissues of bowhead, fin, or humpback whales (Thompson et al. 1986, Cummings and Holliday 1987, Clark and Gagnon 2004).

During the open water season (July-Oct) when the majority of proposed seismic activities would occur (for about 30 days), bowhead whales are anticipated to spend half of that time feeding in the Beaufort Sea and then migrating back through the Chukchi in the fall with some whales starting as early as end of August (Allen and Angliss 2014). While fall densities in the Chukchi Sea are anticipated to be higher than summer densities, some bowhead whales may be present in the action area during the summer (Ireland et al. 2009, Clarke et al. 2011b). Humpback and fin whales are anticipated to occur in the action area in the summer to early fall (July-Oct), but in low densities (Aerts et al. 2012, Clarke et al. 2013b, Delarue et al. 2013b).

Seismic activity on LS 193 would likely impact bowhead, fin, and humpback whales, although the level of disturbance depends on whether the whales are feeding or migrating, as well as other factors such as the age of the animal, whether it tolerates the sound, etc. In addition to targeted studies in marine mammals indicating that frequency (beyond just differing sensitivities at different frequencies) can affect the likelihood of auditory impairment incurred, there is increasing evidence that contextual factors other than received sound level, including activity states of exposed animals, the nature and newness of the sound, and the relative spatial positions of sound and receiver, can strongly affect the probability of behavioral response (Ellison et al. 2012).

Tolerance, Habituation, and Sensitization

While numerous studies have shown that underwater sounds from industry activities are often readily detectable by marine mammals in the water at distances of many kilometers, few studies have attempted to address habituation, sensitization, or tolerance (Nowacek et al. 2007).

Tolerance is defined as ‘the intensity of disturbance that an individual tolerates without responding in a defined way’ (Nisbet 2000). Tolerance levels can be measured instantaneously and are, therefore, more readily demonstrated than the longer-term processes of habituation or sensitization. In fact, habituation and sensitization are identified, and distinguished from each other, by the direction of change indicated by repeated measures of tolerance taken over time. Thus, over the course of a habituation process, individual tolerance levels will increase, whereas tolerance levels will conversely decrease as individuals become sensitized to specific stimuli (Bejder et al. 2009).

Despite industry activities occurring at distances of only a few kilometers away, often times marine mammals show no apparent response or tolerance to industry activities of various types (Miller et al. 2005, Bain and Williams 2006). This is often true even in cases when the sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Weir (2008) observed marine mammal responses to seismic pulses from a 24 airgun array firing a total volume of either 5,085 in^3 or 3,147 in^3 in Angolan waters between August 2004 and May 2005. Weir recorded a total of 207 sightings of humpback whales (n = 66), sperm whales (n = 124), and Atlantic spotted dolphins (n = 17) and reported that there were no significant differences in encounter rates (sightings/hr) for humpback and sperm whales according to the airgun array’s operational status (i.e., active versus silent). The airgun arrays used in the Weir (2008) study were larger than the array anticipated for use on LS 193 (total discharge volumes of 40 to 4,500 in^3). Based on this information regarding marine mammal tolerance of underwater sounds, we anticipate that some baleen whales exposed to low frequency underwater sounds from exploration activities may tolerate seismic noise and show no apparent response. More information is needed in order to determine if the learned processes of habituation or sensitization are occurring over time as animals experience repeated exposures.

Masking

Masking occurs when anthropogenic sounds and marine mammal signals overlap at both spectral and temporal scales. For the airgun sound generated from the proposed seismic surveys, sound will consist of low frequency pulses with extremely short durations (less than one second). Lower frequency anthropogenic sounds are more likely to affect detection of communication calls and other potentially important natural sounds such as surf and prey noise. There is little concern regarding masking near the sound source due to the brief duration of these pulses and relatively longer silence between airgun shots (approximately 5-6 seconds). However, at long distances (over tens of kilometers away), due to multipath propagation and reverberation, the durations of airgun pulses can be “stretched” to seconds with long decays (Madsen et al. 2006), although the intensity of the sound is greatly reduced. This could affect communication signals used by low frequency mysticetes when they occur near the noise band and thus reduce the communication space of animals (e.g., (Clark et al. 2009) and cause increased stress levels (e.g., (Foote et al. 2004, Holt et al. 2009). However, marine mammals are thought to be able to compensate for masking by adjusting their acoustic behavior by shifting call frequencies, and/or increasing call volume and vocalization rates. For example, blue whales are found to increase call rates when exposed to seismic survey noise in the St. Lawrence Estuary (Di Lorio and Clark. 2010). In addition, the sound localization abilities of marine mammals suggest that, if signal and noise come from different directions, masking would not be as severe as the usual types of masking studies might suggest (Richardson et al. 1995).

Responses While Feeding

Feeding bowheads tend to show less avoidance of sound sources than do migrating bowheads (BOEM 2015a). Bowhead whales feeding in the Canadian Beaufort Sea in the 1980s showed no obvious behavioral changes in response to airgun pulses from seismic vessels 6 to 99 km (3.7 to 61.5 mi) away, with received sound levels of 107 to 158 dB rms (Richardson et al. 1986). They did, however, exhibit subtle changes in surfacing–respiration–dive cycles. Seismic vessels approaching within approximately 3 to 7 km (2 to 4 mi), with received levels of airgun sounds of 152 to 178 dB, elicited avoidance (Richardson et al. 1986, Ljungblad et al. 1988, Richardson et al. 1995, Miller et al. 2005). Richardson *et al.* (Richardson et al. 1986) observed feeding bowheads start to turn away from a 30-airgun array with a source level of 248 dB re 1 μPa at a distance of 7.5 km (4.7 mi) and swim away when the vessel was within about 2 km (1.2 mi); other whales in the area continued feeding until the seismic vessel was within 3 km (1.9 mi).

While the ranges at which bowhead whales respond to approaching seismic vessels varied, the responses that have been reported point to a general pattern. First, the responses of bowhead whales appear to be influenced by their pre-existing behavior: bowhead whales are more tolerant of higher sound levels when they are feeding than during migration (Miller et al. 2005, Harris et al. 2007). Data from an aerial monitoring program in the Alaskan Beaufort Sea during 2006 to 2008 also indicate that bowheads feeding during late summer and autumn did not exhibit large-scale distribution changes in relation to seismic operations (Funk et al. 2011). Feeding bowheads may be so highly motivated to stay in a productive feeding area that they remain in an area with noise levels that could, with long term exposure, cause adverse effects (NMFS 2010a).

The absence of changes in the behavior of foraging bowhead whales should not be interpreted to mean that the whales were not affected by the noise. Animals that are faced with human disturbance must evaluate the costs and benefits of relocating to alternative locations; those decisions would be influenced by the availability of alternative locations, the distance to the alternative locations, the quality of the resources at the alternative locations, the conditions of the animals faced with the decision, and their ability to cope with or “escape” the disturbance (Lima and Dill 1990a, Gill and Sutherland 2001, Frid and Dill. 2002, Beale and Monaghan 2004a, b, Bejder et al. 2006, Bejder et al. 2009). Specifically, animals delay their decision to flee from predatory stimuli they detect until they decide that the benefits of abandoning a location are greater than the costs of remaining at the location or, conversely, until the costs of remaining at a location are greater than the benefits of fleeing (Ydenberg and Dills 1986). Ydenberg and Dill (1986) and Blumstein (2003) presented an economic model that recognized that animals will almost always choose to flee a site over some short distance to a predator; at a greater distance, animals will make an economic decision that weighs the costs and benefits of fleeing or remaining; and at an even greater distance, animals will almost always choose not to flee. For example, in a review of observations of the behavioral responses of 122 minke whales, 2,259 fin whales, 833 right whales, and 603 humpback whales to various sources of human disturbance, Watkins (1986a) reported that fin, humpback, minke, and North Atlantic right whales tolerated sounds that occurred at relatively low received levels, had most of their energy at frequencies below or above the hearing capacities of these species, or were from distant human activities and received levels were below ambient levels. Most of the negative reactions that were observed occurred within 100 m of a sound source or when sudden increases in received sound levels were judged to be in excess of 12 dB, relative to previous ambient sounds.

As a result of using this kind of economic model to consider whales' behavioral decisions, we would expect whales to continue foraging in the face of moderate levels of disturbance. For example, bowhead, fin, and humpback whales, which only feed during part of the year and must satisfy their annual energetic needs during the foraging season, may continue foraging in the face of disturbance. Similarly, a bowhead cow accompanied by her calf is less likely to flee or abandon an area at the cost of her calf's survival. By extension, we assume that animals that choose to continue their pre-disturbance behavior would have to cope with the costs of doing so, which will usually involve physiological stress responses and the energetic costs of stress physiology (Frid and Dill 2002b, MMS 2008).

Responses While Migrating

As we discussed previously, migrating bowhead whales respond more strongly to seismic noise pulses than do feeding whales. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn showed avoidance out to 20 to 30 km (12.4 to 18.6 mi) from a medium-sized airgun source at received sound levels of around 120 to 130 dB re 1 μPa rms (Miller et al. 1999, Richardson 1999). Avoidance of the area did not last more than 12 to 24 hours after seismic shooting stopped. Deflection might start as far as 35 km (21.7 mi) away and may persist 25 to 40 km (15.6 to 24.9 mi) to as much as 40 to 50 km (24.9 to 31.1 mi) after passing seismic-survey operations (Miller et al. 1999). Preliminary analyses of recent data on traveling bowheads in the Alaskan Beaufort Sea also showed a stronger tendency to avoid operating airguns than was evident for feeding bowheads (Christie et al. 2009, Koski et al. 2009). Most bowheads would be expected to avoid an active source vessel at received levels of as low as 116 to 135 dB re 1 μPa rms when migrating (MMS 2008). Richardson et al. (1999) suggests that migrating bowheads start to show significant behavioral disturbance from multiple pulses at received levels around 120 dB re 1 μPa.

Avoidance responses of migrating humpback whales to airgun noise appear consistent with bowhead and gray whale avoidance at received levels between 150-180 dB (Richardson et al. 1995). Migrating humpbacks showed localized avoidance of operating airguns in the range of received levels 157-164 dB. In addition, humpback whales seemed more sensitive to seismic airgun noise while exhibiting resting behavior (McCauley et al. 2000). For resting humpback pods that contained cow-calf pairs, the mean airgun noise level for avoidance was 140 dB re 1 μPa rms, and a startle response was observed at 112 dB re 1μ Pa rms (McCauley et al. 2000). When calves are small, comparatively weak and possibly vulnerable to predation and exhaustion, the potential continual dislocation of these animals in a confined area would interrupt this resting and feeding stage, with potentially more serious consequences than any localized avoidance response to an operating seismic vessel as seen during their migratory swimming behavior (McCauley et al. 2000).

In 9 of the 16 trials (McCauley et al. 2000), mostly single, large mature humpbacks approached the operating airgun within 100-400m to investigate before swimming off. These whales would have received maximum air gun signals at 100m of 179 dB re 1 μPa rms (or 195 dB re 1 μPa peak–peak). This level is equivalent to the high peak to peak 192 dB re 1μPa humpback whale sounds recorded in Alaska (Thompson et al. 1986). The underwater signals produced by humpback whale breaching were audibly similar to air gun signals. McCauley *et al.* (2000) speculate that given the similarities between airgun and breaching signals, male humpback whales may identify airgun signals as a “competitor.” Humpback whales on feeding grounds did not alter short-term behavior or distribution in response to explosions with received levels of about 150dB re 1µ Pa/Hz at 350Hz (Lien et al. 1993, Todd et al. 1996). However, at least two individuals were probably killed by the high-intensity, impulse blasts and had extensive mechanical injuries in their ears (Ketten et al. 1993, Todd et al. 1996). Frankel and Clark (1998) showed that breeding humpbacks showed only a slight statistical reaction to playbacks of 60 - 90 Hz sounds with a received level of up to 190 dB. Although these studies demonstrated that humpback whales may exhibit short-term behavioral reactions to playbacks of industrial noise, the long-term effects of these disturbances on the individuals exposed to them are not known.

Studies of bowhead, gray, and humpback whales have determined that received levels of pulses in the 160-170 dB re 1 µPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. Fin whales are anticipated to respond in a similar manner.

Avoidance is one of many behavioral responses whales may exhibit when exposed to seismic noise. Other behavioral responses include evasive behavior to escape exposure or continued exposure to a sound that is painful, noxious, or that they perceive as threatening, which we would assume would be accompanied by acute stress physiology; increased vigilance of an acoustic stimulus, which would alter their time budget (that is, during the time they are vigilant, they are not engaged in other behavior); and continued pre-disturbance behavior with the physiological consequences of continued exposure.

In addition to these behavioral responses, whales alter their vocal communications when exposed to anthropogenic sounds. Communication is an important component of the daily activity of animals and ultimately contributes to their survival and reproductive success. Animals communicate to find food (Marler et al. 1986, Elowson et al. 1991), acquire mates (Ryan 1985), assess other members of their species (Parker 1974, Owings et al. 2002), evade predators (Greig-smith 1980), and defend resources (Zuberbuhler et al. 1997). Human activities that impair an animal’s ability to communicate effectively might have significant effects on the survival and reproductive performance of animals experiencing the impairment.

At the same time, most animals that vocalize have evolved with an ability to make adjustments to their vocalizations to increase the signal-to-noise ratio, active space, and recognizability of their vocalizations in the face of temporary changes in background noise (Cody and Brown 1969, Brumm 2004, Patricelli and Blickley 2006). A few studies have demonstrated that marine mammals make the same kind of vocal adjustments in the face of high levels of background noise. For example, two studies reported that some mysticete whales stopped vocalizing – that is, adjust the temporal delivery of their vocalizations – when exposed to active sonar (Miller et al. 2000, Melcon et al. 2012). Melcón *et al.* (2012) reported that during 110 of the 395 d-calls (associated with foraging behavior) they recorded during mid-frequency active sonar transmissions, blue whales stopped vocalizing at received levels ranging from 85 to 145 dB, presumably in response to the sonar transmissions. These d-calls are believed to attract other individuals to feeding grounds or maintain cohesion within foraging groups (Oleson et al. 2007). It should also be noted that mid-frequency sonar is not in the frequency range of most baleen whale calls, and a response by blue whales to mid-frequency sonar suggests that they have the ability to perceive and respond to these sounds (Erbe 2002a, Southall et al. 2007, Melcon et al. 2012).

Another study by Pirotta et al. (2014) showed that the probability of recording a harbor porpoise “buzz” (inter-click interval associated with attempted prey captures or social communication) declined by 15% in the ensonified area of a 2D seismic operation. The probability of occurrence of buzzes increased significantly with distance from the seismic source. This suggests that the likelihood of buzzing was dependent upon received noise intensity. Observed changes in buzzing occurrence could reflect disruption of either foraging or social activities. These effects may result from prey reactions to noise, leading to reduced porpoise foraging rates. Alternatively, foraging effort may change if porpoises adjust time budgets or diving behavior to avoid noise (Pirotta et al. 2014).

The effect of seismic airgun pulses on bowhead whale calling behavior has been extensively studied in the Beaufort Sea and is similar to the patterns reported in other whales. During the autumn in 2007 and 2008, calling rates decreased significantly in the presence (<30 km [<18.6 mi]) of airgun pulses (Blackwell et al. 2010). There was no observed effect when seismic operations were distant (>100 km [>62 mi]). Call detection rates dropped rapidly when cumulative sound exposure levels (CSELs) were greater than 125 dB re 1 µPa2·s over 15 minutes. The decrease was likely caused by a combination of less calling by individual whales and by avoidance of the area by some whales in response to the seismic activity. Calls resumed near the seismic operations area shortly after operations ended. Aerial surveys showed high sighting rates of feeding, rather than migrating, whales near seismic operations (Miller et al. 2005, Blackwell et al. 2010). In contrast, reduced calling rates during a similar study in 1996 to 1998 were largely attributed to avoidance of the area by whales that were predominantly migrating, not feeding (Miller et al. 1999, Richardson 1999). Greene et al. (1999) concluded that the patterns seen were consistent with the hypothesis that exposure of bowhead whales to airgun sound resulted in diversion away from airguns, a reduction in calling rate, or a combination of both. Funk et al. (2010b) findings are generally consistent with Greene et al. (1999), i.e., seismic surveys lead to a significant decrease in the call detection rates of bowhead whales. Blackwell *et al.* (2013) found a statistically significant drop in bowhead call localization rates with the onset of airgun operations nearby. This effect was evident for whales that were “near” the seismic operation (median distance 41-45 km) and exposed to median received levels (SPL) of at least 116 dB re 1 µPa. In these whales, call localization rates dropped from an average of 10.2 calls/h before the onset of seismic operations to 1.5 call/h during and after airgun use (Blackwell et al. 2013).

In birds, song diversity is an important index for population viability, and is influenced by anthropogenic noise (Laiolo et al. 2008, Slabbekorn and Ripmeester 2008), and in bowhead whales song diversity and complexity may serve as a barometer of the impact of encroaching Arctic oil and gas development (Johnson et al. 2014).

It is anticipated that for the marine seismic airgun array (3,200 cui) that will be used for the one planned on-lease 3D seismic survey in the Chukchi Sea during the open water season, the distances to the 160 dB isopleth range from 7.6-9.11 km depending on the geoacoustic environment and sound speed profile. The one on-lease 2D marine seismic survey (4,500 cui) during in-ice season is anticipated to reach the 160 dB isopleth at a range of 11.6-15.4 km depending on the geoacoustic environment and sound speed profile (Austin et al. 2015).

Based on this information, we would not anticipate migrating bowhead to devote attention to a seismic stimulus beyond the 120 dB isopleth, which may be more than 113 kilometers from the source (Austin et al. 2015). At these distances, a whale that perceived a signal is likely to ignore such a signal and devote its attention to stimuli in its local environment (that is, they would filter the sound out as background noise or ignore it) (MMS Miller et al. 1999, Richardson 1999, 2008). Because of their distance from the seismic source, we would also not anticipate bowhead whales would change their behavior or experience physiological stress responses at received levels ≤ 120 dB; these animals may exhibit slight deflection from the noise source, but this behavior is not likely to result in adverse consequences for the animals exhibiting that behavior.

Feeding bowhead, however, may cease calling or alter vocalization at significantly lower received levels. While calling rates may change for feeding bowhead in response to seismic noise at low received levels (85 dB-145 dB), LS 193 is not known to be a biologically important area for feeding (Clarke et al. 2015).

Those animals that are closer to the source and not engaged in activities that would compete for their attentional resources (for example, mating or foraging) might engage in low-level avoidance behavior (changing the direction or their movement to take them away from or tangential to the source of the disturbance) possibly accompanied by short-term vigilance behavior, but they are not likely to change their behavioral state (that is, animals that are foraging or migrating would continue to do so). We do not anticipate that low-level avoidance or short-term vigilance would occur until noise levels are >150 dB (Richardson et al. 1995). Again, neither low level avoidance nor short-term vigilance is likely to result in adverse consequences for the animals exhibiting the behavior.

Similarly, we would not anticipate that fin or humpback whales would devote attentional resources to a seismic stimulus beyond the 140 dB isopleth (McCauley et al. 2000). We would not anticipate startle responses with ramp-up procedures in place. Females and females with calves may avoid sound sources ≥ 140 dB. However, we would not anticipate the majority of individuals to show low-level avoidance until noise levels are ≥ 150 dB (Lien et al. 1993, Richardson et al. 1995, Todd et al. 1996).

At some distance that is closer still, these species are likely to engage in more active avoidance behavior. Of the bowhead, fin, and humpback whales that may be exposed to received levels ≥160 dB during the maximum 95 annual instances of exposure from the proposed action (Scenario 6: 4,500 cui in-ice survey + 4 open-water VSP), some whales are likely to reduce the amount of time they spend at the ocean's surface, increase their swimming speed, change their swimming direction to avoid seismic operations, change their respiration rates, increase dive times, reduce feeding behavior, or alter vocalizations and social interactions (Richardson et al. 1986, Ljungblad et al. 1988, Richardson and Malme 1993, Greene et al. 1999, Frid and Dill. 2002, Christie et al. 2009, Koski et al. 2009, Blackwell et al. 2010, Funk et al. 2010b, Melcon et al. 2012). Based on the proposed action, we would expect these kind of responses at distances between 0 and 15.4 km for the largest 4,500 cui seismic array, and 4 km for the 500 cui VSP (Austin et al. 2015). We assume that these responses are more likely to occur when whales are aware of multiple vessels in their surrounding area. However, while these exposures may all occur within the same year, they are anticipated to be separated in time and space considering that the VSP would occur during the open-water season, and the seismic survey would occur during the in-ice period.[30]

Some whales may be less likely to respond because they are feeding. The whales that are exposed to these sounds probably would have prior experience with similar seismic stressors resulting from their exposure during previous years considering that seismic operations have been occurring in the Arctic since the 1960s and baleen whales are long lived animals; that experience will make some whales more likely to avoid the seismic activities while other whales would be less likely to avoid those activities. In addition, standard mitigation measures (seismic array ramp ups, delayed ramp ups, power downs, and shut downs) will be in place along with monitoring measures. Some whales might experience physiological stress (but not distress) responses if they attempt to avoid one seismic vessel and encounter another seismic vessel while they are engaged in avoidance behavior.

Prey Resources

Zooplankton are food sources for bowhead, fin, and humpback whales. Sound energy generated from seismic operations is not anticipated to negatively impact the diversity and abundance of zooplankton.

Studies on euphausiids and copepods, which are some of the more abundant and biologically important groups of zooplankton in the Chukchi Sea, have documented the use of hearing receptors to maintain schooling structures (Wiese 1996) and detection of predators (Chu et al. 1996) respectively, and therefore have some sensitivity to sound; however any effects of airguns on zooplankton would be expected to be restricted to the area within a few feet or meters of the airgun array and would likely be sub-lethal.

No appreciable adverse impact on zooplankton populations will occur due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations. Any mortality or impacts on zooplankton as a result of seismic operations is immaterial as compared to the naturally-occurring reproductive and mortality rates of these species. This is consistent with previous conclusions that crustaceans (such as zooplankton) are not particularly sensitive to sound produced by seismic sounds (Wiese 1996).

Fish are not considered a primary prey resource for whales in the Arctic (Lowry et al. 2004), but if fish were exposed to seismic we would anticipate the responses as described below under pinniped prey resources.

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[30] VSP and the 2D seismic survey may overlap temporally in the fall, but they would not overlap for summer or winter seasons. Even during the fall season they are anticipated to occur in separate locations for data integrity purposes. BOEM requires minimum of ~ 24 km [15 mi] spacing between each independent survey operation.

Pinnipeds (ringed and bearded seals)

We estimated a maximum of 2,907 possible annual instances where ringed seals might be exposed to seismic activities during the proposed action, and 2,056 possible instances for bearded seals (Scenario 6: 4 VSP open-water + 4,500 cui 2D survey in-ice seasons). All instances of exposure are anticipated to occur at received levels ≥ 160 dB (Table 21 provides annual instances of exposure for which seismic operations are a subset). These instances of exposure are likely to be overestimates because they assume a uniform distribution of animals and do not account for avoidance (see Section 6.1.3.1 for full list). We used the Rea and Rmax ensonified areas and average densities in estimating a range of instances of exposure for our exposure analysis in order to account for variability over the next nine years and to be conservative.

While a single individual may be exposed multiple times, the short duration and intermittent transmission of seismic airgun pulses, combined with a moving vessel, and implementation of mitigation measures to reduce exposure to high levels of seismic sound, reduce the likelihood that exposure to seismic sound would cause a behavioral response that may affect vital functions, or cause TTS or PTS.

Ringed and bearded seals traveling across a broad area may encounter more than one seismic exploration activity in a season and may therefore be disturbed repeatedly by the presence of vessels or seismic survey sound or both. However, seismic operations are required to be at least 24 km from each other which would reduce multiple disturbances. It is not known if multiple disturbances within a certain timeframe add to the stress of an animal and, if so, what frequency and intensity may result in biologically important effects. There is likely to be a wide range of individual sensitivities to multiple disturbances, with some animals being more sensitive than others.

Ringed and bearded seals vocalize underwater in association with territorial and mating behaviors. Underwater audiograms for phocids suggest that they have very little hearing sensitivity below 1 kHz, though they can hear underwater sounds at frequencies up to 60 kHz and make calls between 90 Hz and 16 kHz (Richardson et al. 1995). A more recent review suggests that the functional hearing range of phocids should be considered to be 75 Hz to 100 kHz (Hemila et al. 2006, Kastelein et al. 2009, NOAA 2013). The airgun sound sources proposed for LS 193 are anticipated to be below 1 kHz, and should be within the auditory bandwidth for ringed and bearded seals.

Ringed seals are known to make barks, clicks and yelps with a frequency range between 0.4-16 kHz, and have dominant frequencies <5 kHz (Cummings et al. 1986), as cited in (Stirling 1973, Richardson et al. 1995). Ringed seal sounds are less complex and much lower in source level than bearded seal sounds (Richardson et al. 1995). Ringed seal sounds include 4 kHz clicks, rub sound with peak energy at 0.5-2 kHz and durations of 0.08-0.3 s, squeaks that are shorter in duration and higher in frequency; quaking barks at 0.4-1.5 kHz and durations of 0.03-0.12 s; yelps; and growls (Schevill et al. 1963, Stirling 1973, Cummings et al. 1986). Ringed seals may produce sounds at higher frequencies, given their most sensitive band of hearing extends up to 45kHz (Terhune and Ronald 1976) and most equipment used in studies is unsuitable for frequencies >15 kHz (Richardson et al. 1995). Ringed seals are known to vocalize at source levels of up to 130 dB (Stirling 1973, Cummings et al. 1986, Richardson et al. 1995).

Male bearded seals rely on underwater vocalizations to find mates. As background noise increases, underwater sounds are increasingly masked and uni-directional, deteriorate faster, and are detectable only at shorter ranges (Cameron et al. 2010). Underwater audiograms for phocids suggest that they have very little hearing sensitivity below 1 kHz (Richardson et al. 1995), and seismic operations are anticipated to operate as frequencies <1 kHz. The frequency range of the predominant “trill” and “moan” calls (130 Hz-10.6 kHz and 130 Hz-1.3 kHz, respectively) that are broadcast during the mating season overlaps the range (10 Hz-1kHz) of proposed airgun sources.

Bearded seals are a dominant component of the ambient noise in many Arctic areas during the spring (Thiele 1988). The song is thought to be a territorial advertisement call or mating call by the male (Ray et al. 1969a, Budelsky 1992). Cummings et al. (1983) estimated source levels of up to 178 dB re 1µ Pa m. Parts of some calls may be detected 25+ km away (Cleator et al. 1989). Because bearded seals are not likely to communicate at source levels that would damage the tissues of other members of their species, this evidence suggests that received levels of up to 178 dB are not likely to damage tissues of this species.

Information on behavioral reactions of pinnipeds in water to multiple pulses involves exposures to small explosives used in fisheries interactions, impact pile driving, and seismic surveys. Several studies lacked matched data on acoustic exposures and behavioral responses by individuals. As a result, the quantitative information on reactions of pinnipeds in water to multiple pulses is very limited (Southall et al. 2007). However, based on the available information on pinnipeds in water exposed to multiple noise pulses, exposures in the ~150-180 dB re 1µ Pa range (rms values over the pulse duration) generally have limited potential to induce avoidance behavior in pinnipeds (Southall et al. 2007). We anticipate this would also apply to bearded seals since they are known to make calls with source levels up to 178 dB (Cummings et al. 1983). Received levels exceeding 190 dB re 1µ Pa are likely to elicit avoidance responses, at least in some ringed seals (Harris et al. 2001, Blackwell et al. 2004b, Miller et al. 2005). Harris *et al.* (2001) reported 112 instances when seals were sighted within or near the exclusion zone based on the 190 dB radius (150-250m of the seismic vessel).[31] The results suggest that seals tended to avoid the zone closest to the boat (<150m) (or noise levels greater than 190 dB).

However, overall, seals did not react dramatically to seismic operations. Only a fraction of the seals swam away, and even this avoidance appeared quite localized (Harris et al. 2001). In the case of ringed seals exposed to sequences of airgun pulses from an approaching seismic vessel, most animals showed little avoidance unless the received level was high enough for mild TTS to be likely (Southall et al. 2007). We assume that bearded seals will behave in a similar manner to ringed seals when exposed to seismic sounds.

Seals have been noted to tolerate high levels of sounds from airguns (Arnold 1996, Harris et al. 2001, Moulton and Lawson 2002). In any case, the observable behavior of seals to passing active source vessels is often to just watch them go by or swim in a neutral way relative to the ship

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[31] It should be noted that visual observations from the seismic vessel were limited to the area within a few hundred meters, and 79% of the seals observed were within 250m of the vessel (Harris et al. 2001).

rather than swimming away. Seals at the surface of the water would experience less powerful sounds than if they were the same distance away but in the water below the seismic source. This may also account for the apparent lack of strong reactions in ice seals (NMFS 2013c).

During the open water season (July-Oct) when the majority of proposed activities would occur (for about 30 days), ringed seals are anticipated to be making short and long distance foraging trips (Smith 1973, 1976, Smith and Stirling 1978, Teilmann et al. 1999, Gjertz et al. 2000a, Harwood and Smith 2003). Bearded seals are anticipated to occur at the southern edge of the Chukchi and Beaufort Sea pack ice and at the wide, fragmented margin of multi-year ice (Burns 1981, Nelson et al. 1984). Bearded seals are less likely to encounter seismic surveys during the open water season than ringed seals because of the bearded seals preference for sea ice habitat (BOEM 2015a). However, bearded seals are often spotted by PSOs during surveys so there is still the potential for exposure.

While the potential instances of exposure suggest a high number of exposure events, the majority of these are anticipated to occur at received levels between ≥ 160 dB and ≤189 dB re 1 μPa rms where previous studies have shown limited potential to induce avoidance behavior in pinnipeds (Southall et al. 2007). Even if exposure occurred at higher received levels, the tendency of pinnipeds such as ringed and bearded seals to raise their heads above water, or haul out (during the in-ice period) to avoid exposure to sound fields, as well as mitigation measures, reduce the potential for harassment of these species. Ringed and bearded seals that avoid these sound fields or exhibit vigilance are not likely to experience significant disruptions of their normal behavior patterns because the vessels are transiting and the ensonified area is temporary, and seals seem rather tolerant of low frequency noise.

Based on this information, we would not expect ringed and bearded seals that are more than 14 kilometers from the seismic sound source to devote attention to that stimulus, even though received levels might be as high as 160 dB.[32] Similarly, we would not expect ringed and bearded seals that find themselves more than 2 km (Austin et al. 2015) from seismic surveys to change their behavioral state, despite being exposed to received levels ranging up to 180 dB (Cummings et al. 1983, Southall et al. 2007); these seals might engage in low-level avoidance behavior or short-term vigilance behavior. Ringed and bearded seals that occur within 0.8 km at received levels ranging up to 190 dB during seismic surveys are likely to change their behavioral state to avoid slight TTS, although this avoidance is anticipated to be localized and temporary as the seismic operations are moving (Harris et al. 2001, Blackwell et al. 2004b, Miller et al. 2005). In addition, if ringed or bearded seals are spotted within the 190 dB isopleth a power down/shutdown of seismic operations would occur.[33]

Proposed Ringed Seal Critical Habitat

Marine seismic surveys, ancillary geohazard surveys, and VSP surveys conducted during the first

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[32] Rmax radii of rms SPL contours for average sound speed profile and high-reflectivity geoacoustics for the largest seismic array 4,500 cui reaches the 160 dB isopleth at ~14km (Austin et al. 2015).

[33] The distances to received levels presented here are all based on the maximum distances anticipated from the 4500 cui airgun array even though the other seismic sources (3200, 500, and 40 cui arrays) are anticipated to have far smaller threshold distances (Austin et al. 2015).

incremental step of the proposed action all produce noise that could affect proposed ringed seal critical habitat mainly through the essential feature of primary prey resources. In-depth information, including supporting references, on the potential effects of the proposed action to fish is found in the Final Second SEIS for LS 193 (BOEM 2015e), and is briefly summarized here.

The types of noises produced by seismic surveys in the proposed action could cause hearing impairment and physical, physiological, and behavioral effects on fish and fish prey. Typical behavioral responses of fish to introduced sound, such as sound from seismic surveys, include: balance disturbance (i.e., staying in normal orientation); disoriented swimming behavior; increased swimming speed; disruption or tightening of schools; disruption of hearing; interruption of important biological behaviors (e.g., feeding, reproduction); shifts in the vertical distribution (either up or down); and occurrence of alarm and startle behaviors (BOEM 2015a).

Fish sensitivity to impulse sound such as that generated by seismic operations varies depending on the species of fish. Cod, herring and other species of fish with swim bladders have been found to be relatively sensitive to sound, while mackerel, flatfish, and many other species that lack swim bladders have been found to have poor hearing (Hawkins 1981, Hastings and Popper 2005). Arctic cod in particular is a hearing specialist and is known to be acoustically sensitive (Normandeau Associates Inc. 2012).

An alarm response in these fish is elicited when the sound signal intensity rises rapidly compared to sound rising more slowly to the same level (Blaxter and Hoss 1981). A recent study of feeding herring schools off of Northern Norway demonstrated no observed reaction in swimming speed, swimming direction, or school size that could be attributed to an approach by an active seismic vessel shooting a 3D seismic survey (Pena et al. 2013). They attributed the unanticipated lack of response to the strong motivation for feeding combined with the slow approach of a distant seismic stimulus (Pena et al. 2013). Any such effects on fish are anticipate to be minimal and temporary and would not be expected to diminish a marine mammal species' or stock's foraging success.

In their detailed review of studies on the effects of airguns on fish and fisheries, Dalen et al. (1996) concluded that airguns can have deleterious effects on fish eggs and larvae out to a distance of 16 ft. (5.0 m), but that the most frequent and serious injuries are restricted to the area within 5.0 ft. (1.5 m) of the airguns. Most investigators and reviewers (Gausland 2003, Thomson and Davis 2001, Dalen et al. 1996) have concluded that even seismic surveys with much larger airgun arrays than are used for shallow hazards and site clearance surveys have no impact to fish eggs and larvae discernible at the population or fisheries level.

Koshleva (1992) reported no detectable effects on the amphipod (*Gammarus locusta*) at distances as close as 0.5 m from an airgun with a source level of 223 dB re 1 μPa rms. A recent Canadian government review of the impacts of seismic sound on invertebrates and other organisms included similar findings; this review noted "there are no documented cases of invertebrate mortality upon exposure to seismic sound under field operating conditions" (CDFO 2004). Some sub-lethal effects (e.g., reduced growth, behavioral changes) were noted (CDFO

2004). Studies on brown shrimp in the Wadden Sea (Webb and Kempf 1998) revealed no particular sensitivity to sounds generated by airguns used in with sound levels of 190 dB re 1 µPa rms at 3.3 ft. (1.0 m) in water depths of 6.6 ft. (2.0 m).

Seismic surveys would not alter the physical characteristics of either of the two sea ice related essential features identified in the critical habitat proposal (i.e., lairs for whelping and nursing, and platforms for basking and molting). Noise from seismic surveys conducted in close proximity to these features could make them less attractive to ringed seals, or cause seals to temporarily abandon the features. However, all seismic surveys would occur outside of the whelping and nursing seasons, and only overlap with molting during one month of the year (July), which we discussed above (BOEM 2015a).

6.1.4.2 Responses to Other Impulsive Noise Sources

No exposures to listed marine mammals are anticipated at received levels ≥160 dB re 1 µPa m (rms) from non-airgun impulsive noise sources including: single and multibeam echosounders, sub-bottom profilers, side scan sonars, and HiPaP positioning systems during the first incremental step. If exposures were to occur, they are anticipated to be at low received levels.

Baleen Whales (bowhead, fin, and humpback)

As described in the *Exposure to Other Impulsive Noise Sources* Section 6.1.3.2.1, NMFS does not anticipate that marine mammals will be exposed to single and multi-beam echosounders, sub-bottom profilers, side scan sonars, or HiPaP positioning systems due to the directionality and small beam widths of these sources, and short pulse duration. However, since the specifics for these sources are not available at this time, we will analyze the potential responses that may be exhibited if exposure to a few pulses were to occur.

Given the directionality, short pulse duration, and small beam widths for the non-airgun impulsive sources, it is not anticipated that baleen whales would be exposed to these sources. If exposed, whales are not anticipated to be in the direct sound field for more than one to two pulses (NMFS 2013c). Based on the information provided, most of the energy created by these potential sources is outside the estimated hearing range of baleen whales generally (Watkins 1986b, Au et al. 2006, Southall et al. 2007, Ciminello et al. 2012, NOAA 2013), and the energy that is within hearing range is high frequency, and as such is only expected to be audible in very close proximity to the mobile source. As previously mentioned, we do not anticipate these sources to be operating in isolation, and expect co-occurrence with other acoustic sources including airguns. Many whales would move away in response to the approaching airgun noise or the vessel noise before they would be in close enough range for there to be exposure to the non-airgun related impulsive sources. However, if a whale did not move away from the other noise sources and was exposed, we would anticipate the potential responses discussed below.

Masking

Marine mammal communications are not anticipated to be masked appreciably by side scan sonar, single-beam or multi-beam sonar, echosounders, or for the sub-bottom profiler signals given their relatively low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. Some level of masking could result for whales in close proximity to the survey vessel during brief periods of exposure to the sound if signals were within the hearing range of the species. However masking is unlikely to be an issue because whales are likely to avoid survey vessels. In the case of marine mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of the higher-power airgun sources would further reduce or eliminate any minor effects of the non-airgun impulsive noise sources.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Marine mammal behavioral reactions to pulsed sound sources from an active airgun array are discussed above, and responses to the pulsed noise associated with pinger and transponder signals are likely to be similar to those for other pulsed sources if received at the same levels. During exposure to a 21–25 kHz whale-finding sonar with a source level of 215 dB re 1 μPa m, gray whales showed slight avoidance (~200 m) behavior (Frankel 2005). However, these sources are anticipated to operate in brief pulses which are concentrated in a downward beam, with noise sources that are typically outside the hearing range of baleen whales. For these species a disturbance reaction is highly unlikely to occur from non-airgun impulsive noise sources associated with this consultation.

Pinnipeds (ringed and bearded seals)

As described in the *Exposure to Other Impulsive Noise Sources* Section 6.1.3.2.1, NMFS does not anticipate that ice seals will be exposed to single and multi-beam echosounders, sub-bottom profilers, side scan sonars, or HiPaP positioning systems due to the directionality and small beam widths of these sources, and short pulse duration. However, since ice seals are the most commonly observed marine mammal in the Chukchi Sea, and the specifics for these sources are not available at this time, we will analyze the potential responses that may be exhibited if exposure to a few pulses were to occur.

We are not aware of any data on the reactions of pinnipeds to single-beam echosounders, sub-bottom profilers, side scan sonars, or HiPaP positioning systems. However, based on observed pinniped responses to other types of impulsive sounds, and the likely brevity of exposure to non-airgun impulsive sources, pinniped reactions are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Jacobs and Terhune (2000) observed the behavioral responses of harbor seals exposed to acoustic harassment devices with source levels of 172 dB re 1 μPa m deployed around aquaculture sites. The seals in their study generally did not respond to sounds from the harassment devices and in two trials, seals approached to within 43 and 44 m of active harassment devices and did not appear to exhibit any measurable behavioral responses to the exposure.

Costa et al. (2003) placed acoustic data loggers on translocated elephant seals and exposed them to an active ATOC source off northern California (source was located at a depth of 939 meters with the following source characteristics: 75 Hz signal with 37.5 Hz bandwidth; 195 dB re: 1

μPa m max. source level, ramped up from 165 dB re: 1 μPa m over 20 min). Seven control seals were instrumented similarly and released when the ATOC source was not active. Received exposure levels of the ATOC source for experimental subjects averaged 128 dB re: 1 μPa (range 118 to 137 dB) in the 60 to 90 Hz band. None of the animals in the study terminated dives or radically altered behavior when they were exposed to the ATOC source, but nine individuals exhibited changes in their dive patterns that were statistically significant.

Gotz and Janik (2011a) presented evidence of spatial avoidance behavior in captive grey seals to a "startle pulse" at received levels of ~ 170 dB re 1 μPa m (rms). Further trials determined mean startle thresholds of 159 dB re 1 μPa m from pure tone signals.

Hastie et al. (2014) conducted a series of behavioral response tests on two captive gray seals to determine their reactions to underwater operation of a 200 kHz and 375 kHz multibeam imaging echosounder that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the signal by significantly increasing their dive durations. However, because of the brevity of exposure of pinnipeds to such sound sources, pinniped reactions are anticipated to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Based on this information, we would not anticipate ringed or bearded seals to devote attentional resources to single and multi-beam echosounders, sub-bottom profilers, side scan sonars, or HiPaP positioning systems at low received levels.

6.1.4.3 Responses to Vessel Noise (Transit, Anchor Handling, Dynamic Positioning, Icebreaking and Management)

As described in the *Exposure to Major Noise Sources* Section 6.1.3.1, bowhead, humpback, and fin whales, ringed and bearded seals are all anticipated to occur in the action area and are anticipated to overlap with noise associated with vessel transit, anchor handling, dynamic positioning, icebreaking, and ice management activities. We assume that some individuals are likely to be exposed and respond to these continuous noise sources. In addition, vessel operations will overlap with proposed ringed seal critical habitat.

Baleen Whales (bowhead, fin, and humpback whales)

While cetaceans are a diverse group with varied life histories and migratory patterns (see Section 4.3), they share many important traits and exhibit similar physiological and behavioral responses. In this section whales' responses are analyzed collectively where appropriate, as the species share many similar characteristics. The majority of the information provided below focuses on bowhead whales as they are the most commonly occurring listed baleen whale in the action area, and a large amount of research has been done on this species. We anticipate responses from fin and humpback whales to be similar to the bowhead whale.

Transiting Vessels

Reactions of marine mammals 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 (NMFS 2013c). Past experiences of the animals with vessels are important in determining the degree and type of response elicited from an animal-vessel encounter. Whale reactions to slow-moving vessels are less dramatic than their reactions to faster and/or erratic vessel movements. 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 (Wartzok et al. 1989b, Richardson et al. 1995, Heide-Jorgensen et al. 2003).

Bowhead whales react to approaching vessels at greater distances than they react to most other activities. Vessel-disturbance experiments in the Canadian Beaufort Sea by Richardson and Malme (1993) showed that most bowheads begin to swim rapidly away when fast moving vessels approach directly. Avoidance usually begins when a rapidly approaching vessel is 1 to 4 km (0.62 to 2.5 mi) away. Whales move away more quickly when approached closer than 2 km (1.2 mi) (Richardson and Malme 1993). A few whales reacted at distances of 5 to 7 km (3.1 to 4.3 mi), while others did not react until the vessel was <1 km (<0.62 mi) away. Received noise levels as low as 84 dB re 1 μPa, or 6 dB above ambient, elicited strong avoidance reactions from bowhead from an approaching vessel 4 km (2.5 mi) away. During the experiments, vessel disturbance temporarily disrupted activities, and socializing whales moved apart from one another. Fleeing from a vessel usually stopped soon after the vessel passed, but scattering lasted for a longer time period. Some bowheads returned to their original locations after the vessel disturbance (Richardson and Malme 1993). However, it is not known whether they would return after repeated disturbance (Richardson et al. 1995). Boat disturbance also tended to cause unusually brief surfacing with few respirations per surfacing (Richardson et al. 1985b). Bowheads showed clear reactions to approaching vessels as much as 4 km away, based on measurements of whale headings, speeds, surface times, and number of respirations per surfacing (Richardson and Malme 1993). Bowheads react less dramatically to and appear more tolerant of slow-moving vessels, especially if they do not approach directly.

Confirming assertions made by native bowhead hunters, low levels of underwater noise can elicit flight reactions in bowhead whales (Richardson and Malme 1993). In one test, received noise levels from an approaching fishing boat were only ~6-13 dB above the background noise and cause flight reactions in bowhead (Miles et al. 1987a, Richardson and Malme 1993). Mothers

traveling with calves can be particularly sensitive to vessel traffic, and showed strong evasive behaviors when vessels were over 15 km away (Richardson and Malme 1993). In contrast, animals that are actively feeding may be less responsive to boats (Wartzok et al. 1989b).

Humpback whale reactions to approaching boats are variable, ranging from approach to avoidance (Payne 1978, Salden 1993). On rare occasions humpbacks “charge” towards a boat and “scream” underwater, apparently as a threat (Payne 1978). Baker *et al.* (1983) reported that humpbacks in Hawai’i responded to vessels at distances of 2 to 4 km. Bauer and Herman (1986) concluded that reactions to vessels are probably stressful to humpbacks, but that the biological significance of that stress is unknown. Similar to bowhead whales, humpbacks seem less likely to react to vessels when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984). Mothers with newborn calves seem most sensitive to vessel disturbance (Clapham and Mattila 1993). Marine mammals that have been disturbed by anthropogenic noise and vessel approaches are commonly reported to shift from resting behavioral states to active behavioral states, which would imply that the incur an energy cost. Morete *et al.* (2007) reported that undisturbed humpback whale cows that were accompanied by their calves were frequently observed resting while their calves circled them (milling) and rolling interspersed with dives. When vessels approached, the amount of time cows and calves spent resting and milling respectively declined significantly. Considering that one cow calf pair was observed in the Beaufort Sea (Hashagen et al. 2009), there is the potential for interactions between vessels and cow calf pairs in the Arctic.

Fin whales responded to vessels at distances of about 1 km (Edds and Macfarlane 1987). Watkins (1981) found that fin and humpback whales appeared startled and increased their swimming speed to avoid approaching vessels. Jahoda et al. (2003) studied responses of fin whales in feeding areas when they were closely approached by inflatable vessels. The study concluded that close vessel approaches caused the fin whales to swim away from the approaching vessel and to stop feeding. These animals also had increases in blow rates and spent less time at the surface (Jahoda et al. 2003). This suggests increases in metabolic rates, which may indicate a stress response. All these responses can manifest as a stress response in which the mammal undergoes physiological changes with chronic exposure to stressors, it can interrupt essential behavioral and physiological events, alter time budget, or a combination of all these stressors (Sapolsky 2000, Frid and Dill 2002b).

In general, baleen whales react strongly and rather consistently to approaching vessels of a wide variety of types and sizes. Whales are anticipated to interrupt their normal behavior and swim rapidly away if approached by a vessel. Surfacing, respiration, and diving cycles can be affected. The flight response often subsides by the time the vessel has moved a few kilometers away. After single disturbance incidents, at least some whales are expected to return to their original locations. Vessels moving slowly and in directions not toward the whales usually do not elicit such strong reactions (Richardson and Malme 1993).

Marine seismic vessels are typically transiting at slower speeds of 4.5 knots, but seismic and other vessels may transit at speeds up to 16.5 knots. Vessel operations are typically confined to the open water period (BOEM 2015a).

We anticipate that noise associated with transiting vessels would drop to 120 dB within 7 km (or less) of the most vessels associated with oil and gas activities, and within 19 km of vessels towing drilling units (O’Neill and McCrodan 2012b, a). At these distances, a whale that perceived the vessel noise is likely to ignore such a signal and devote its attentional resources to stimuli in its local environment. If animals do respond, they may exhibit slight deflection from the noise source, engage in low-level avoidance behavior, short-term vigilance behavior, or short-term masking behavior, but these behaviors are not likely to result in adverse consequences for the animals.

In addition, with mitigation measures in place which specify procedures for changing vessel speed and/or direction to avoid groups of whales, avoid potential for collision, and PSOs on board to spot nearby whales, the impact of vessel transit on bowhead, humpback, and fin whales is anticipated to be minor, and considered insignificant.

Anchor Handling, Dynamic Positioning, Icebreaking, and Ice Management

The maximum annual instances of exposure to anchor handling, dynamic positioning, icebreaking, and ice management activities of bowhead whales range from 1,150-1,970, and fin and humpback whale instances of exposure range from 20-23 for each species depending on the activity scenario authorized (Table 21 provides annual instances of exposure for which these activities are a subset). These instances of exposure combine all potential seismic sources (anchor handling, DP, ice management and ice breaking) that could co-occur annually. As an example, for BOEM/BSEE’s Scenario 6: two drilling operations may occur during the open-water season, and one ice breaker may occur in the in-ice season. This scenario is anticipated to result in the greatest annual instances of exposure to baleen whales (1,993 total instances of exposure for all three species).

These instances of exposure assume a uniform distribution of animals, do not account for avoidance, and summed the ensonified area associated with the multiple concurrently operating vessels (see Section 6.1.3.1 for full list). We used the Rea and Rmax ensonified areas and average densities in estimating a range of instances of exposure in order to account for variability over the next nine years and to be conservative.

The primary sources of sounds from all vessel classes are propeller cavitation, propeller singing, and propulsion or other machinery. Propeller cavitation is usually the dominant noise source for vessels (Ross 1976). Propeller cavitation and singing are produced outside the hull, whereas propulsion or other machinery noise originates inside the hull. There are additional sounds produced by vessel activity, such as pumps, generators, flow noise from water passing over the hull, and bubbles breaking in the wake. Considering that icebreaking activities are anticipated to produce the loudest ensonified area in comparison to the other vessel activities, we will focus on potential responses of marine mammals to this stressor. Icebreakers contribute greater sound levels during ice-breaking activities than ships of similar size during normal operation in open water (Richardson et al. 1995). This higher sound production results from the greater amount of power and propeller cavitation required when operating in thick ice.

Baleen whale response distances to ice management vessels are expected to vary, depending on icebreaker activities and sound-propagation conditions. Miles, Malme, and Richardson (1987b) modeled icebreaker noise and predicted that roughly half of the bowhead whales would show an avoidance response to an icebreaker underway in open water at a range of 5–34 km (3–21 mi) when the noise associated with the source is at least 30 dB greater than ambient noise levels.

Reactions of baleen whales to icebreaking activities are largely unknown. In the Beaufort Sea, migrating bowheads apparently avoided an icebreaker-supported drillsite by 25+ km during the autumn of 1992 where there was intensive icebreaking around the drillsite almost daily (Brewer et al. 1993). However, migrating bowheads also avoided a nearby drillsite in another autumn with little icebreaking (LGL and Greenridge Sciences Inc 1987). Thus, the relative roles of icebreaker noise, drilling noise, and the ice itself in diverting bowheads around these drillsites are uncertain (Richardson et al. 1995). An icebreaker playback study in the spring lead system indicated the predicted response distances for bowhead whales around an actual icebreaker would be highly variable; however, for typical traveling bowhead whales, detectable effects on movements and behavior are predicted to extend commonly out to radii of 10–30 km (6.2–18.6 mi).

BOEM concluded that icebreaker activity, should it occur, in the spring could potentially disturb bowhead whales during calving, breeding and migrating activities in and adjacent to the spring polynya system in the Chukchi Sea. Bowhead whales could occur in the area and these individuals could be affected by icebreaker activity and respond by avoidance, displacement from habitat, or alter migratory or other movements (BOEM 2015a).

Since dynamic positioning, icebreaking, and ice management will be continuous noise sources, it is not anticipated that marine mammals would enter into an area where they would suffer from TTS or PTS. In addition, vessel mitigation measures will also avoid separation of whales within groups, slow down during periods of low visibility, and avoid close approaches.

Of the whales that might be exposed to received levels ≥120 dB during the maximum annual 1,993 exposure events from Scenario 6 of the proposed action, some whales are likely to reduce the amount of time they spend at the ocean's surface, increase their swimming speed, change their swimming direction to avoid vessel operations, change their respiration rates, increase dive times, reduce feeding behavior, or alter vocalizations and social interactions (Richardson et al. 1986, Ljungblad et al. 1988, Richardson and Malme 1993, Greene et al. 1999, Frid and Dill. 2002, Christie et al. 2009, Koski et al. 2009, Blackwell et al. 2010, Funk et al. 2010b, Melcon et al. 2012). We assume that these responses are more likely to occur when multiple vessels are operating in the surrounding area.

Some whales may be less likely to respond because they are feeding. The whales that are exposed to these sounds probably would have prior experience with similar vessel stressors resulting from their exposure during previous years considering that oil and gas operations have been occurring in the Arctic since the 1960s and baleen whales are long lived animals; that experience will make some whales more likely to avoid the vessel icebreaking activities while other whales would be less likely to avoid those activities. Some whales might experience physiological stress (but not distress) responses if they attempt to avoid one vessel and encounter another vessel while they are engaged in avoidance behavior.

Prey Resources

No appreciable adverse impact on zooplankton populations will occur due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations. Any mortality or impacts on zooplankton as a result of vessel operations is immaterial as compared to the naturally-occurring reproductive and mortality rates of these species.

Ringed and Bearded Seals and Proposed Ringed Seal Critical Habitat

Vessel Transit

Few authors have specifically described the responses of pinnipeds to boats, and most of the available information on reactions to boats concerns pinnipeds hauled out on land or ice. However, the mere presence and movements of ships in the vicinity of seals can cause disturbance to their normal behaviors (Henry and Hammill 2001, Ferland and Decker 2005, Shaughnessy et al. 2008, Jansen et al. 2010), and could potentially cause ringed seals and bearded seals to abandon their preferred breeding habitats in areas with high traffic (Smiley and Milne 1979, Mansfield 1983a, Reeves 1998b). Surveys and studies in the Arctic have observed mixed reactions of seals to vessels at different times of the year. Disturbances from vessels may motivate seals to leave haulout locations and enter the water (Richardson et al. 1995). Due to the relationship between ice seals and sea ice, the reactions of seals to vessel activity is likely to vary seasonally with seals hauled out on ice reacting more strongly to vessels than seals during the open water conditions (BOEM 2015a).

Ringed seals hauled out on ice pans often showed short-term escape reactions when a ship came within 250-500m (Brueggeman et al. 1992). Jansen *et al.* (2006) reported that harbor seals approached by vessels to 100m (0.06 mi) were 25 times more likely to enter the water than were seals approached at 500m (0.3 mi). However, in places where boat traffic is heavy, there have been cases where seals have tolerated vessel disturbance (e.g. (Bonner 1982, Jansen et al. 2006).

During the open water season in the Chukchi Sea, bearded and ringed seals are commonly observed close to vessels where received sound levels are low (e.g., (Harris et al. 2001, Moulton and Lawson 2002, Blees et al. 2010, Funk et al. 2010b). Funk et al. (2010a) noted among vessels operating in the Chukchi Sea where received sound levels were <120 dB, 40% of observed seals showed no response to a vessel's presence, slightly more than 40% swam away from the vessel, 5% swam towards the vessel, and the movements of 13% of the seals were unidentifiable. More recently, Bisson et al. (2013) reported a total of 938 seals observed during vessel-based monitoring of exploratory drilling activities by Shell in the Chukchi Sea during the 2012 open-water season. This total includes animals sighted outside of the leased area during transits to and from the drill site. The majority of seals (42%) responded to moving vessels by looking at the vessel, while the second most noted behavior was no observable reaction (38%). The majority of seals (58%) showed no reaction to stationary vessels, while looking at the vessel was the second most common behavioral response (38%). Other common reactions to both moving and stationary vessels included splashing and changing direction.

Adult ringed and bearded seals are agile and easily avoid vessels in open water conditions. Pups have a greater potential for heat loss than adults and so would be more prone to incur energetic costs of increased time in the water if vessel disturbance became a more frequent event (Cameron et al. 2010). If a vessel disturbs young ice seals, some might become energetically and behaviorally stressed, leading to lower overall fitness of those individuals. The potential for ship traffic to cause a mother to abandon her pup may be lower in bearded seals than in ringed seals (Smiley and Milne 1979), as bearded seal mothers appear to exhibit a high degree of tolerance when approached by small boats.

We anticipate that noise associated with transiting vessels would drop to 120 dB within 7 km (or less) of most vessels associated with oil and gas activities, and within 19 km of vessels towing drilling units (O'Neill and McCrodan 2012b, a). At these distances we would not anticipate that ice seals would devote attention to these stressors. If animals do respond, they may exhibit slight deflection from the noise source, engage in low-level avoidance behavior, short-term vigilance behavior, or short-term masking behavior, but these behaviors are not likely to result in adverse consequences for the animals. Overall, vessel noise does not seem to strongly affect pinnipeds that are in the water (Richardson et al. 1995), which is where ringed and bearded seals are anticipated to be during the open-water season.

In addition, with mitigation measures in place restricting vessel speed and approach, and PSOs on board to spot nearby seals, the impact of vessel transit on ringed and bearded seals is anticipated to be minor, and considered insignificant.

Anchor Handling, Dynamic Positioning, Icebreaking, and Ice Management

The maximum annual instances of exposure to anchor handling, dynamic positioning, icebreaking, and ice management activities of ringed seals range from 151,829-179,467, and bearded seal instances of exposure range from 118,729-139,833, dependent on the activity scenario authorized (Table 21 provides annual instances of exposure for which these activities are a subset). These instances of exposure combine major vessel noise (e.g. anchor handling, DP, ice management, and icebreaking) that could co-occur annually. As an example, for BOEM/BSEE's Scenario 6, anchor handling, dynamic positioning, and ice management may occur during the open-water season, and one icebreaker may occur in the in-ice season. This scenario is anticipated to result in the greatest annual instances of exposure to ringed and bearded seals (319,300 total instances of exposure for both species).

These instances of exposure are likely to be overestimates because they assume a uniform distribution of animals, do not account for avoidance or mitigation measures, and derive from summing the ensonified area associated with the multiple concurrently operating vessels (see Section 6.1.3.1. for full list). In addition, these exposure estimates are significantly higher than what has previously been reported in 90 day reports from previous drilling operations in the Arctic (ex: during Shell's 2012 drilling operations only seven ringed and seven bearded seals were directly observed to be taken due to anchor handling activities, and 466 ringed seals and 16 bearded seals were estimated to be taken based on density; see Bisson et al. 2013). We used the Rea and Rmax ensonified areas and average densities in estimating a range of instances of exposure in order to account for variability over the next nine years and to be conservative.

Considering that icebreaking activities are anticipated to produce the loudest ensonified area in comparison to the other vessel activities, we will focus on potential responses of ice seals to this stressor. Icebreakers contribute greater sound levels during ice-breaking activities than ships of similar size during normal operation in open water (Richardson et al. 1995). This higher sound production results from the greater amount of power and propeller cavitation required when operating in thick ice.

All vessels produce sounds during operation, which when propagated at certain frequencies and intensities can alter the normal behavior of marine mammals, mask their underwater communications and other uses of sound, and cause them to avoid noisy areas (Arctic Council 2009, Götz and Janik 2011b). All ice-breeding pinniped species are known to produce underwater vocalizations (Richardson et al. 1995). Male bearded seals rely on underwater vocalizations to find mates. As background noise increases, underwater sounds are increasingly masked and uni-directional, deteriorate faster, and are detectable only at shorter ranges. Effects of vessel noise on bearded seal vocalizations have not been studied, though the frequency range of the predominant “trill” and “moan” calls (130-10590 Hz and 130-1280 Hz, respectively) that are broadcast during the mating season partially overlaps the range (20-300 Hz) over which ship noise dominates ambient noise in the oceans (Urick 1983, Cleator et al. 1989, Ross 1993, Risch et al. 2007, Tyack 2008). Vocalizations of the sympatric harp seal were shown to be completely masked by stationary ship noise at a distance of 2 km (Terhune et al. 1979), a finding supported by communication-range models for this species which predicted call masking and a significant loss of communication distances in noisy environments (Rossong and Terhune. 2009).

Studies show that animals adapt acoustic signals to compensate for environmental modifications to sound (Wilczynski and Ryan 1999). Indeed, background noise has been suggested to account for geographical differences in the range and quality of bearded seal calls (Rogers 2003, Risch et al. 2007). However, compensating for sound degradation – such as by delaying calling, shifting frequencies, moving to a quieter area, or calling louder, longer, and more frequently – incurs a cost (Tyack 2008). The cost of these adaptations, or that of missing signals, is inherently difficult to study in free-ranging seals and to date has not been measured in any phocid seal. Because bearded seals broadcast over distances of at least 30-45 km (Cleator et al. 1989), perhaps over 100s of kilometers (Stirling 1983, Rossong and Terhune. 2009), their calls are increasingly susceptible to background interference. Though in some areas male bearded seals may “practice” calling throughout the year, the period of peak vocalization is during the breeding season (April to mid-June). While ice-breaking vessels have the potential of disrupting bearded seal communication and thus mating because they produce louder (174-200 dB), higher frequency (> 5000 Hz), and more variable sounds (Arctic Council 2009), these activies are not anticipated to overlap with the breeding season, minimzing the effects of masking. Overall, the noise generated from ice breaking could have a similar masking effect on seals as ambient noise such as proximity to a vocalizing marine mammal or noise from strong wind and rain or ice movement (Gales 1982).

Most oil and gas activities in the Chukchi Sea are not anticipated to start until late June to early July, minimizing the potential overlap with the bearded seal breeding season. The extent to which these louder vessel operations are localized near areas where bearded seals are mating, and the acoustic characteristics of the area, will determine the level that communication is disrupted. Considering that vessels largely avoid areas of pack ice, where communication and mating occurs, or transit these areas outside the breeding season, effects are not expected to be significant.

Vessel sounds from the ice-breaking cargo vessel MV *Arctic* were estimated to be detectable by seals under fast ice at distances up to 20-35 km (Davis and Malme 1997). Mansfield (1983) reasoned that an icebreaker approaching a ringed seal at full power while breaking ice could be heard by ringed seals from 40 km (about 25 mi) away in Lancaster Sound, Canada. For the proposed action, JASCO estimated that noise associated with icebreaking may reach the 120 isopleth at a distance of ~45 km in reflective environments (Austin et al. 2015).

Data on how close seals allow icebreakers to approach are limited, but ringed and bearded seals on pack ice typically dove into the water within 0.93 km (0.58 mi) of the vessel (Brueggeman et al. 1992), and remained on the ice when the icebreaker was 1-2 km away (Kanik et al. 1980). Because of their habitat preferences in polynyas, and the ice front, icebreakers could elicit brief startle or escape reactions by a proportion of bearded seals encountered on ice.

Icebreakers are unlikely to be a threat to bearded seals because of their habitat preferences and the fast growth and development of their pups. Unlike ringed seals, bearded seals rest on top of the ice where they would be visible to approaching icebreakers and less likely to be crushed (BOEM 2015a). We will discuss icebreaker effects on ringed seals in more detail below under proposed critical habitat. Recent research suggests that bearded seals may exhibit fidelity to distinct areas and habitats during the March to June breeding season (Van Parijs and Clark 2006). Vessel traffic that occurs during this period could disturb bearded seals in the pack ice; however, vessels without icebreaker support are expected to avoid these areas by a large margin due to the risks associated with navigating large amounts of sea ice.

Ice seals are adapted to moving frequently to accommodate changing ice conditions so displacement due to a passing icebreaker is likely to be temporary and well within the normal range of ability for ice seals at this time of year.

Of the seals that might be exposed to received levels ≥120 dB during the maximum 319,300 annual exposure events from Scenario 6 of the proposed action, some seals may change their behavior, alter their vocalizations, mask received noises, increase vigilance, and avoid noisy areas (Richardson and Malme 1993, Richardson et al. 1995, Rogers 2003, Blackwell et al. 2004b, Rossong and Terhune. 2009). We assume that these responses are more likely to occur when seals are aware of multiple vessels in their surrounding area.

Since anchor handling, dynamic positioning, icebreaking, and ice management will be continuous noise sources, it is not anticipated that marine mammals would enter into an area where they would suffer from TTS or PTS. Mitigation measures restricting vessel speed and approach, and requiring PSOs on board to spot nearby seals will minimize the impacts of the potential exposures, and timing of operations will minimize potential masking effects on bearded seals during the breeding season. Thus, despite the fact that there may be large instances of exposure to continuous sounds ≥120 dB, the impact of anchor handling, dynamic positioning, icebreaking, and ice management on ringed and bearded seals is anticipated to be minor.

Proposed Ringed Seal Critical Habitat

Proposed critical habitat for the Arctic subspecies of ringed seal includes three features essential to the conservation of the species: sea ice habitat suitable for the formation and maintenance of subnivean birth lairs; sea ice habitat suitable as a platform for basking and molting; and primary prey resources to support Arctic ringed seals. The proposed area encompasses the EEZ in the Chukchi, Beaufort, and northern Bering Seas, with a southern boundary north of Bristol Bay. The shoreward boundary is the coastline of Alaska (see Figure 9).

NMFS identified vessel traffic as a potential threat that may affect each of the features identified as essential to the conservation of Arctic ringed seals (79 FR 73010). Both physical and acoustic effects could alter the quality of the essential features of Arctic ringed seal critical habitat, or render it temporarily unsuitable.

While noise is not anticipated to directly affect the two sea ice related essential features of proposed critical habitat, noise could temporarily make the sea ice features near the vessel less suitable to ringed seals (BOEM 2015a). The noise effects could last as long as the vessels are present. Icebreakers are anticipated to create more noise than other vessels due to the sound associated with cracking ice, friction against the snow, and cavitation, and cause physical alteration of sea ice habitat (BOEM 2015a).

Icebreaking may be used for both exploratory drilling ice management and in-ice seismic associated with the proposed action. However, only icebreaking during drilling operations (June-Nov) has the potential to temporally overlap with ringed seal use of birth lairs or molting platforms (March-July), and only by a few months. In-ice seismic activity would occur October through December, which is outside of the timeframe for whelping, nursing, basking, and molting (BOEM 2015a).

Vessel sounds from the ice-breaking cargo vessel MV *Arctic* were estimated to be detectable by seals under fast ice at distances up to 20-35 km (Davis and Malme 1997). Mansfield (1983) reasoned that an icebreaker approaching a ringed seal at full power while breaking ice could be heard by ringed seals from 40 km (about 25 mi) away in Lancaster Sound, Canada. For the proposed action, JASCO estimated that noise associated with icebreaking may reach the 120 dB isopleth at a distance of ~45 km in reflective environments (Austin et al. 2015).

The noise in a ringed seal den is buffered by snow (Holliday et al. 1983) and tolerances to vessel presence and sound could be higher for ringed seal pups in their winter dens. While ice breaking activity has the potential to fracture, collapse, or otherwise alter lairs (BOEM 2015a), and has been known to kill ringed seals when icebreakers moved through fast-ice in breeding areas (April-May) (Reeves 1998a), there is no anticipated overlap between ice breaking activities associated with the proposed action and the whelping or breeding seasons. It is also anticipated that ringed seal pups would be weaned by mid-June, prior to icebreaking activities commencing in late June.

Icebreaking vessels would be less likely to affect the formation (compared to maintenance) of sea ice habitat suitable for birth lairs, due primarily to the spatial extent and timing of icebreaker activity. Ice breaking would create narrow linear strips that are a very small fraction of the total sea ice present, and ice breaking would not occur from February through May. Any leads created during drilling operations or in-ice seismic activities would have adequate time to refreeze prior to March when birth lairs would start to be created (BOEM 2015a).

Sea ice suitable for basking and molting platforms (used April-July) could be fractured by ice breaking activities. However, because ringed seals haul out on ice of many shapes and sizes, fractured ice would probably remain suitable as platforms (BOEM 2015a). The amount of basking and molting platform ice habitat that could be fractured due to a maximum of three icebreaking/ice management operations a year is anticipated to be insignificant in comparison to the total amount of habitat available. In addition, fractured ice can refreeze, meaning that habitat would only be impacted for a short amount of time.

Both physical and acoustic effects could alter the quality of the essential features of Arctic ringed seal critical habitat, or render small portions of it temporarily unsuitable. However, due to the low number of vessels being authorized, the limited use of ice breakers, the limited overlap with ice habitat, the size and quality of the remaining habitat, the high tolerance of ice seals to vessel operations, and the application of standard mitigation measures to avoid adverse impacts, we anticipate that anchor handling, dynamic positioning, icebreaking and ice management vessel operations will have minor effects on ringed and bearded seals and proposed ringed seal critical habitat.

Vessel traffic is anticipated to have negligible impact on the primary prey resource identified as an essential feature in the proposed critical habitat for ringed seals. Response of fish and invertebrates to vessels is anticipated to be temporary, localized, and minor (BOEM 2015a), and considered insignificant.

6.1.4.4 Responses to Drilling Operations

As described in the *Exposure to Major Noise Sources* Section 6.1.3.1, bowhead, humpback, and fin whales, ringed and bearded seals are all anticipated to occur in the action area and are anticipated to overlap with noise associated with drilling operations. We assume that some individuals are likely to be exposed and respond to these continuous noise sources. In addition, drilling operations will overlap with proposed ringed seal critical habitat.

Baleen Whales (bowhead, fin, and humpback)

The majority of the information provided below focuses on bowhead whales as they are the most commonly occurring listed baleen whale in the action area, and a large amount of research has been done on this species. We anticipate responses from fin and humpback whales to be similar to the bowhead whale.

The maximum annual instances of exposure to drilling activities was encompassed in our previous discussion on exposure to anchor handling, dynamic positioning, icebreaking and ice management as they are the loudest sources of noise associated with drilling operations (see Section 6.1.4.3) However, we will discuss specific responses of baleen whales to drilling operations below.

Bowhead reaction to drillship-operation noise is variable. Richardson and Malme (1993) point out that the data, although limited, suggest that stationary industrial activities producing continuous noise, such as stationary drillships, result in less dramatic reactions by whales than do moving sources, particularly ships. It also appears that bowhead avoidance is less around an unattended structure than one attended by support vessels. Most observations of bowhead whales tolerating noise from stationary operations are based on opportunistic sightings of whales near ongoing oil-industry operations, and it is not known whether more whales would have been present in the absence of those operations. Other cetaceans seem to tolerate continuous or repeated noise exposure when the noise is not associated with a harmful event (BOEM 2015a). However, in order to determine if whales are habituating over time to these exposure event, long-term sequential measurements of responses by individuals to controlled stimuli are needed (Nisbet 2000, Bejder et al. 2009). Additionally, it is not known what components of the population were observed around the drillship (e.g., adult or juvenile males, adult females, etc.) (BOEM 2015a).

Several authors noted that migrating whales are likely to avoid stationary sound sources by deflecting their course slightly as they approached a source (LGL and Greenridge 1987, Richardson et al. 1995). McDonald et al. (2006) reported subtle offshore displacement of the southern edge of the bowhead whale migratory corridor offshore from the drilling on Northstar island.

Malme et al. (1983, 1984, 1986) studied the behavioral responses of gray whales (*Eschrictius robustus*) that were migrating along the California coast to various sound sources located in their migration corridor. The whales they studied showed statistically significant responses to four different underwater playbacks of continuous sound at received levels of approximately 120 dB. The sources of the playbacks were typical of a drillship, semisubmersible, drilling platform, and production platform. Up to 50 percent of migrating gray whales deflected from their course when the received level of industrial noise reached 116-124 dB re 1 µPa, and disturbance of feeding activity may occur at sound levels as low as 110 dB re 1 µPa (Malme et al. 1986).

Some bowheads likely avoid closely approaching drilling operations by changing their migration speed and direction, making distances at which reactions to drillships occur difficult to determine. LGL and Greenridge (1987) and Schick and Urban (2000) indicate that few whales approached within ~18 km of an offshore drilling operation in the Beaufort Sea. Results in Schick and Urban (2000) indicated that whales within hearing range of the drillship (<50 km [<31.1 mi]) were distributed farther from the rig than they would be under a random scenario. They concluded that spatial distribution was strongly influenced by the presence of the drillship but lacked data to assess noise levels. Other factors that could influence distribution relative to the drillship were support vessels and icebreakers operating in the vicinity, as well as ice thickness (Schick and Urban 2000). In a study by Koski and Johnson (1987), one whale appeared to alter course to stay 23 to 27 km (14.3 to 16.8 mi) from the center of the drilling operation. The study detected no bowhead whales within 9.5 km of the drillship, and few within 15 km. They concluded that westward migrating bowheads appeared to avoid the offshore drilling operation during the fall of 1986, and some may avoid noise from drillships at 20 km (12.4 mi) or more.

During the 2012 drilling season, bowhead whales lingered within the Chukchi Sea lease sale area, co-occurring with drilling operations by Shell at the Burger Prospect (Quakenbush et al. 2013). During fall migration, 97.6% of tagged bowhead whales entered the LS 193 area (Quakenbush et al. 2013). There were a total of 107 cetaceans observed by PSOs aboard vessels in the Chukchi Sea during the 2012 while the *Discoverer* was conducting drilling operations. However, all but two of these individuals were recorded from distant support vessels in areas where received levels from drilling activities was <120 dB (rms) (Bisson et al. 2013). The remaining two unidentified mysticetes were anticipated to have been exposed to sounds between 130-140 dB from MLC construction operations at approximately 1.6-2 km from the vessel (Bisson et al. 2013).

Although bowheads have been observed well within the ensonified zones around active drill ships, playbacks of drillship noise to a small number of bowheads demonstrated some avoidance. Playbacks of *Explorer II* drillship noise (excluding components below 50 Hz) showed that some bowheads reacted to broadband received levels near 94-118 dB re 1 µPa – no higher than the levels tolerated by bowheads seen a few kilometers from actual drillships (Richardson et al.

1985a, Richardson et al. 1985c, Richardson et al. 1990). The playback results of Wartzok et al. (1989a) seem consistent: the one observed case of strong avoidance of *Kulluk* drilling noise was at a broadband received level ≥ 120 dB.

Two explanations may account for the seemingly different reactions of summering bowhead to playbacks versus actual drilling: tolerance and variable sensitivity. Bowheads may react to the onset of industrial noise (over several minutes) during a brief playback, but show tolerance when that sound level continues for a long period near an actual drillship. However, playback also showed that responsiveness varies among individuals and days. Thus, whales near actual drillships may have been some of the less responsive individuals- those remaining after the more responsive animals had moved out of the area. Both tolerance and variable sensitivity may have been involved (Richardson et al. 1995).

Taken together, results of drilling noise playbacks indicated that a typical summering bowhead does not react overtly unless broadband received sound levels are ~115 dB re 1 µPa, or ~20 dB above the ambient level (Richardson et al. 1995). Based on noise within the dominant 1/3 octave band, the reaction criteria are ~110 dB re 1 µPa or ~30 dB above ambient in that band (Richardson et al. 1990). Received industrial noise levels diminish to 20-30 dB above ambient noise level (radius of responsiveness) well before they diminish to the ambient level (radius of presumed audibility). Hence, the radius of responsiveness around a drillsite is apparently much smaller than the radius of audibility (Richardson et al. 1995).

If bowhead whales, fin whales, and humpback whales avoid drilling and related support activities at distances of approximately 20 km (consistent with avoidance distances presented in (Koski and Johnson 1987, LGL and Greenridge 1987, Schick and Urban 2000), this would preclude exposure of the vast majority of individuals to continuous sounds ≥120 dB re 1 µPa rms.

While PSOs are expected to monitor for listed species during drilling operations, there are no power- or shut-down mechanisms in place if marine mammals enter this zone. However, since drilling will be a continuous noise source, it is not anticipated that marine mammals would enter into an area where they would suffer from acoustic harassment.

Drilling operations typically do not begin in the Chukchi Sea until July, when most of the spring migration for bowhead is complete. Few bowheads are expected to be encountered during the early drilling operations in the summer, further minimizing noise effects. Drilling operations occurring in the fall could potentially disturb and displace bowheads migrating through and across the Chukchi Sea.

We anticipate that the majority of whales would avoid areas within 9.5-20 km of the vessel and should be outside the 120 dB isopleth in (Koski and Johnson 1987, LGL and Greenridge 1987, Schick and Urban 2000). However, a few, less responsive individuals may be exposed within the 120 dB isopleth. These exposures may result in tolerance, slight avoidance, or displacement around drilling operations.

Prey Resources

Sound energy generated from drilling operations is not anticipated to negatively impact the diversity and abundance of zooplankton, and will therefore have no effect on prey for whales.

Pinnipeds (ringed and bearded seals)

We estimated a maximum total of 2,306 possible annual instances where ringed seals might be exposed to drilling operations (drilling and MLC construction) during the first incremental step, and 1,842 possible instances for bearded seals (see Section 6.1.3.1, *Exposure to Major Noise Sources*, Table 21). All instances of exposure are anticipated to occur at received levels ≥ 120 dB. These instances of exposure are a subset of the total annual exposures anticipated for Scenario 6. These instances of exposure are likely to be overestimates because they assume a uniform distribution of animals and do not account for avoidance, and assume all drilling operations and MLC construction will be completed.

Ringed and bearded seals traveling across a broad area may encounter more than one drilling operation in a season and may therefore be disturbed repeatedly by the presence of vessels or seismic survey sound or both. It is not known if multiple disturbances within a certain timeframe add to the stress of an animal and, if so, what frequency and intensity may result in biologically important effects. There is likely to be a wide range of individual sensitivities to multiple disturbances, with some animals being more sensitive than others.

Ringed and bearded seals vocalize underwater in association with territorial and mating behaviors. Underwater audiograms for phocids suggest that they have very little hearing sensitivity below 1 kHz, though they can hear underwater sounds at frequencies up to 60 kHz and make calls between 90 Hz and 16 kHz (Richardson et al. 1995). A more recent review suggests that the function hearing range phocids should be considered to be 75 Hz to 100 kHz (Hemila et al. 2006, Kastelein et al. 2009, NOAA 2013). Drilling operations are anticipated to be below 10 kHz, and should be within the auditory bandwidth for ringed and bearded seals. All ice-breeding pinniped species are known to produce underwater vocalizations (reviewed by (Richardson et al. 1995, Van Opzeeland et al. 2008) which may be masked by continuous noise sources such as drilling and MLC construction.

During the open water season (July-Oct) when the drilling activities would occur (for up to 120 days), ringed seals are anticipated to be making short and long distance foraging trips (Smith 1973, 1976, Smith and Stirling 1978, Teilmann et al. 1999, Gjertz et al. 2000a, Harwood and Smith 2003). Bearded seals are anticipated to occur at the southern edge of the Chukchi and Beaufort Sea pack ice and at the wide, fragmented margin of multi-year ice (Burns 1981, Nelson et al. 1984). Bearded seals are less likely to encounter drilling operations during the open water season than ringed seals because of the bearded seals preference for sea ice habitat (BOEM 2015a). However, bearded seals are often spotted by PSOs during surveys so there is still the potential for exposure.

The effects of offshore drilling on ice seals in the Beaufort Sea have been investigated in the past (Frost et al. 1988, Moulton et al. 2003). Frost and Lowry (1988) concluded that local seal populations were less dense within a 2 nmi buffer of man-made islands and offshore wells that were being constructed in 1985-1987, and acoustic exposure was at least a contributing factor in that reduced density. Moulton et al. (2003) found seal densities on the same locations to be higher in years 2000 and 2001 after initial exposure. Thus, ringed seals were briefly disturbed by drilling activities, until the drilling and post-construction activity was concluded, then they adjusted to the environmental changes for the remainder of the activity. Seals may be disturbed by drilling activities temporarily, until the drilling and post-construction activity has been completed. The same type of reaction is anticipated for MLC construction. Seals may be disturbed during the maximum ~120 days of drilling activities, but then are anticipated to resume normal behavior.

Richardson et al. (1990, 1991), reported that ringed and bearded seals appeared to tolerate playbacks of underwater drilling sounds and dove within 50 m if these projected broadcasts. At that distance, the received sound level at depths greater than a few meters was ~130 dB re 1 μPa.

Moulton et al. (2003) reported no indication drilling activities at BP's Northstar oil development affected ringed seal numbers and distribution although drilling and production sounds from Northstar could have been audible to ringed seals, out to about 1.5 km in water and 5 km in air (Blackwell et al. 2004a). Richardson and Williams (2004) found underwater noise from drilling reached background values at 2-4 km and underwater sound from vessels were sometimes detectable out to 30 km offshore. They concluded that the low-frequency industrial sounds emanating from the Northstar facility during the open-water season resulted in brief, minor localized effects on ringed seals with no consequences to ice seal populations. Adult ringed seals seem to tolerate drilling activities. Brewer et al. (1993) noted ringed seals were the most common marine mammal sighted and did not seem to be disturbed by drilling operations at the Kuvlum #1 project in the Beaufort Sea.

Harwood et al. (2007) evaluated the potential impacts of offshore exploratory drilling on ringed seals in the near shore Canadian Beaufort Sea during February to June 2003-2006. The first 3 years of the study (2003-2005) were conducted prior to industry activity in the area, while a fourth year of study (2006) was conducted during the latter part of a single exploratory drilling season. Seal presence was not significantly different in distance from industrial activities during the non-industry (2003 and 2004) and industry (2006) years. Further, the movements, behavior, and home range size of 10 seals tagged in 2006 also did not vary statistically between the 19 days when industry was active (20 March to 8 April) and the following 19 days after industry operations had been completed. The density of basking seals was not significantly different among the different study years and was comparable to densities found in this same area during surveys conducted in 1974-1979, and no detectable effect on ringed seals was observed during the single season of drilling in the study area (Harwood et al. 2007).

Southall et al. (2007) reviewed literature describing responses of pinnipeds to continuous sound and reported that the limited data suggest exposures between ~90 and 140 dB re 1 μPa generally do not appear to induce strong behavioral responses in pinnipeds exposed to nonpulsed sounds in water; no data exist regarding exposures at higher levels. It is important to note that among these studies of pinnipeds responding to continuous noise exposures in water, there are some apparent differences in responses between field and laboratory conditions. In contrast to the mid-frequency odontocetes, captive pinnipeds responded more strongly at lower levels than did animals in the field. Again, contextual issues are the likely cause of this difference.

During Shell's 2012 drilling operations in the Chukchi Sea, a total of 396 seals were observed by PSOs. It was impossible to determine how many seals represented sightings of new individuals or if they were re-sightings of seals that already had been observed and recorded in the area. Most (93%) of the seal sightings were recorded during periods when the pilot hole was being drilled. The remaining 26 seals were observed during MLC construction. The estimated radius to received levels ≥120 dB (rms) during MLC excavation was 8.1 km compared to the 1.5 km during the pilot hole drilling (Bisson et al. 2013). They estimates that 97% of the observed pinnipeds were exposed to received levels ≤120 dB (rms). No seals were observed at distances where received levels were estimated to be ≥160 dB (rms) (Bisson et al. 2013).

While PSOs are expected to monitor the presence of marine mammals near drilling and MLC operations, there are no power- or shut-down mechanisms in place if marine mammals enter this zone. However, since both drilling and MLC construction will be a continuous noise source, it is not anticipated that marine mammals would enter into an area where they would suffer from acoustic harassment.

While a large number of potential instances of exposure derive from ringed and bearded seal density multiplied by the ensonified area of each source associated with drilling operations, the majority of these are anticipated to occur at low received levels ≥ 120 dB. Even if exposure occurred at higher received levels, the tendency of pinnipeds such as ringed and bearded seals to raise their heads above water, or haul out (during the in-ice period) to avoid exposure to sound fields, reduces the potential for harassment of these species. Ringed and bearded seals that avoid these sound fields or exhibit vigilance are not likely to experience significant disruptions of their normal behavior patterns.

Based on this information, we would not expect ringed and bearded seals that are more than 9 kilometers from drilling operations to devote attention to that stimulus, even though received levels might be as high as 120 dB (Austin et al. 2015). If ringed and bearded seals respond in a similar manner to drilling and MLC construction as they have with previous drilling activities and playback simulations, we would anticipate slight behavioral changes from ringed and bearded seals at received levels between 120 and 140 dB. These exposures may result in tolerance, slight avoidance, masking, or temporary displacement around drilling operations.

Proposed Ringed Seal Critical Habitat

Drilling operations during the first incremental step could potentially affect primary prey resources identified as an essential features of the proposed ringed seal critical habitat (BOEM 2015a).

Due to Arctic cod acoustic sensitivity (Normandeau Associates Inc. 2012), drilling operations may cause behavioral effects on fish and fish prey. If cod and other prey resources avoid drilling areas, this could reduce ringed seals ability to find food and displace seals from the area in which drilling is occurring (BOEM 2015a).

However, all drilling operations would occur outside of the whelping season and only partially overlap with nursing and molting (BOEM 2015a).

6.1.4.5 Responses to Oil and Gas Spills

The empirical evidence available did not allow us to estimate the number of listed marine mammals that are likely to be exposed to oil spills associated with BOEM and BSEE's authorized activities during the first incremental step (years 1-9). Nevertheless, we assume that any individuals that overlap in time and space with a potential spill may be exposed.

There are different probabilities of potential occurrence between the various sized oil spills (small, large, and VLOS). It is more likely that a small oil spill could occur on LS 193 in association with oil exploration activities than a VLOS. However, the general responses of individual animals to exposure to oil do not differ with the size of a spill. The size of the spill determines the number of individuals that will be exposed and duration of exposure.

Toxic substances can impact animals in two major ways. First, the acute toxicity caused by a major point source of a pollutant (such as an oil spill or hazardous waste) can lead to acute mortality or moribund animals with a variety of neurological, digestive and reproductive problems. Second, toxic substances can impair animal populations through complex biochemical pathways that suppress immune functions and disrupt the endocrine balance of the body, causing poor growth, development, reproduction and reduced fitness. Toxic substances come in numerous forms, with the most-recognized being the organochlorines (OCs; mainly PCBs and DDTs), heavy metals and polycyclic aromatic hydrocarbons (PAHs). There are also a number of "emerging" contaminants, e.g., flame retardant polybrominated diphenyl ethers (PBDEs), which could also be impacting marine mammals.

If an oil spill were to occur, marine mammals and their habitats may be adversely impacted. Marine mammals could experience adverse effects from contact with hydrocarbons, including:

- Inhalation of liquid and gaseous toxic components of crude oil and gas;
- Ingestion of oil and/or contaminated prey;
- Fouling of baleen (bowhead, fin, and humpback whales);
- Oiling of skin, eyes, and conjunctive membranes causing corneal ulcers, conjunctivitis, swollen nictitating membranes and abrasions.

Available evidence suggests that mammalian species vary in their vulnerability to short-term damage from surface contact with oil and ingestion. While vulnerability to oil contamination exists due to ecological and physiological reasons, species also vary greatly in the amount of information that has been collected about them and about their potential oil vulnerability.

Ingestion of hydrocarbons can irritate and destroy epithelial cells in the stomach and intestine of marine mammals, affecting motility, digestion, and absorption, which may result in death or reproductive failure (Geraci and St. Aubin 1990). Direct ingestion of oil, ingestion of contaminated prey, or inhalation of volatile hydrocarbons transfers toxins to body fluids and tissues causing effects that may lead to death, as suspected in dead gray and harbor seals found with oil in their stomachs (Engelhardt 1982, Geraci and St. Aubin 1990, Frost et al. 1994, Spraker et al. 1994, Jenssen 1996). Additionally, harbor seals observed immediately after oiling appeared lethargic and disoriented, which may be attributed to lesions observed in the thalamus of the brain (Spraker et al. 1994).

All accidental discharges occurring as part of the LS 193 proposed action will occur within proposed ringed seal critical habitat (see Figure 9). An accidental discharge could render areas containing the identified essential features for Arctic ringed seals unsuitable for use. In such an event, sea ice habitat suitable for whelping, nursing, or molting could be oiled. Primary prey species could become contaminated, experience mortality, or be otherwise adversely affected by spilled oil.

Baleen Whales (bowhead, fin, and humpback)

Depending on the timing of the spill, bowhead, fin, and humpback whales could briefly be exposed to small spills of refined oil during the first incremental step. The rapid dissipation of toxic fumes into the atmosphere from rapid aging of fresh refined oil and disturbance from response related noise and activity limits potential exposure of whales to prolonged inhalation of toxic fumes. Surface feeding whales could ingest surface and near surface oil fractions with their prey, which may be contaminated with oil components. Ingestion of oil may result in temporary and permanent damage to whale endocrine function and reproductive system function, but is not likely for small oil spills.

Exposure of bowheads could occur in the spring lead system during the spring calving and migration period. Calves could be more vulnerable than adults to vapors from a spill, because they take more breaths than do their mothers and spend more time at the surface (BOEM 2015a).

Research has shown that while cetaceans are capable of detecting oil, they do not seem to be able to avoid it. For example, during the spill of Bunker C and No. 2 fuel oil from the *Regal Sword*, researchers saw humpback and fin whales, and a whale tentatively identified as a right whale, surfacing and even feeding in or near an oil slick off Cape Cod, Massachusetts (Geraci and St. Aubin 1990).

The greatest threat to cetaceans is likely from the inhalation of the volatile toxic hydrocarbon fractions of fresh oil which can damage the respiratory system (Hansen 1985, Neff 1990), cause neurological disorders or liver damage (Geraci and St. Aubin 1990), have anaesthetic effects (Neff 1990), and cause death (Geraci and St. Aubin 1990). However, for small spills there is anticipated to be a rapid dissipation of toxic fumes into the atmosphere from rapid aging of fresh refined oil which limits potential exposure of whales to prolonged inhalation of toxic fumes.

Whales could be exposed to a multitude of short and longer term additional human activity associated with initial spill response, cleanup and post event human activities that include primarily increased and localized vessel and aircraft traffic associated with reconnaissance and monitoring. These activities would be expected to be intense during the spill cleanup operations and continue at reduced levels for potentially decades post-event. Specific cetacean mitigation would be employed as the situation requires and would be modified as needed to meet the needs of the response effort. The response contractor would be expected to work with NMFS and state officials on wildlife management activities in the event of a spill. We will not evaluate the potential effects associated with spill response and cleanup as part of this consultation. However, oil spill response activities have been previously consulted on by NMFS as part of the *Unified Plan* (AKR-2014-9361).

Based on the localized nature of small oil spills, the relatively rapid weathering expected for <1,000 bbl of oil, the small number of refueling activities in the proposed action, and the safeguards in place to avoid and minimize oil spills, we conclude that the probability of a BOEM/BSEE authorized activity within the first incremental step causing a small oil spill and exposing bowhead, fin, or humpback whales is sufficiently small as to be considered discountable. If exposure were to occur, due to the ephemeral nature of small, refined oil spills, NMFS does not expect detectable responses from whales and would consider exposure insignificant.

Pinnipeds (ringed and bearded seals)

In the event of a small oil spill, ice seals could be briefly exposed depending on habitat use, densities, season, and various spill characteristics. Oil tends to concentrate in ice leads and in breathing holes, and will be held closer to the surface against ice edges where seals tend to travel (Engelhardt 1987). Floating sea ice also reduces wave action and surface exchange thus delaying the weathering and dispersion of oil and increasing the level and duration of exposure to seals. It also reduces evaporation of volatile hydrocarbons, lessening the acute levels of toxins in the air but lengthening the period of exposure (Engelhardt 1987).

Both bearded and ringed seals closely associate with sea ice throughout the year. Both species prefer to forage in proximity to the southern ice edge during the summer months, although some may be found in the open ocean away from areas of sea ice. Bearded seals feed on benthic organisms on the relatively shallow Chukchi continental shelf, while ringed seals forage for fishes and some invertebrates in the water column. These differences in food selection and foraging behavior help determine the presence or absence of each of these species in an area. Bearded seals are essentially restricted to areas over the continental shelf and the ice front where they can reach the seafloor to feed on benthic organisms. Ringed seals may be found under areas of solid ice as well as in the ice front where they prey upon fishes such as Arctic and saffron cod.

Surface contact with petroleum hydrocarbons, particularly the low-molecular-weight fractions, to seals can cause temporary damage of the mucous membranes and eyes (Davis et al. 1960) or epidermis (Walsh et al. 1974, Hansbrough et al. 1985, St. Aubin 1988). Researchers have suggested that pups of ice-associated seals may be particularly vulnerable to fouling of their dense lanugo coat (Geraci and St. Aubin 1990, Jenssen 1996). Though bearded seal pups exhibit some prenatal molting, they are generally not fully molted at birth, and thus would be particularly prone to physical impacts of contacting oil. Adults, juveniles, and weaned young of the year rely on blubber for insulation, so effects on their thermoregulation are expected to be minimal. Other acute effects of oil exposure which have been shown to reduce seal health and possibly survival include skin irritation, disorientation, lethargy, conjunctivitis, corneal ulcers, and liver lesions. Direct ingestion of oil, ingestion of contaminated prey, or inhalation of hydrocarbon vapors can cause serious health effects including death (Geraci and Smith 1976b, Geraci and St. Aubin 1990). However, for small spills there is anticipated to be a rapid dissipation of toxic fumes into the atmosphere from rapid aging of fresh refined oil which limits potential exposure of seals to prolonged inhalation of toxic fumes

Based on the localized nature of small oil spills, the relatively rapid weathering expected for <1,000 bbl of oil, the small number of refueling activities in the proposed action, and the safe guards in place to avoid and minimize oil spills, we conclude that the probability of a BOEM/BSEE authorized activity within the first incremental step causing a small oil spill and exposing ringed and bearded seals is sufficiently small as to be considered discountable. If exposure were to occur, due to the ephemeral nature of small, refined oil spills, NMFS does not expect detectable responses from seals and would consider exposure insignificant.

Proposed Ringed Seal Critical Habitat

Sea ice is represented in two of three essential features characterizing proposed critical habitat for ringed seals (sea ice suitable for birth lairs and basking/molting platforms). Oil that is released directly under ice, swept under by strong currents, otherwise dispersed in water, or tracked in by oiled animals, could spread into lairs, or on the adjacent subsurface of ice. Oil would also accumulate in leads and cracks that are connected to the spill source through open water (BOEM 2015a).

The third essential feature of proposed ringed seal critical habitat, primary prey resources, may also be adversely affected by oil spills. A spill in the Chukchi Sea could affect fish through many pathways, including adsorption to outer body, respiration through gills, ingestion, and absorption of dissolved fractions into cells through direct contact. The severity of effects to fish would depend on several factors including the type of oil/gas mixture, the thickness of the oil, the duration of exposure, the season of year, and the life stage of the fish (BOEM 2015a).

An oil spill can also affect the habitat of ringed seal primary prey resources. Arctic cod are associated with ice in in various seasons and life stages for shelter. Arctic cod spawn under the ice during winter, and they feed on microorganisms on the underside of ice, such as amphipods, which are also a primary prey resource of ringed seals (BOEM 2015a).

A small crude oil spill or condensate spill during open water would introduce hydrocarbon contaminants of various weights into the surface water, causing temporary decreases in water quality and conditions for toxicity for fish at the surface. Early life stages that occur at the surface, such as Arctic cod eggs and larvae in later winter, spring and early summer, would be particularly affected. Lighter weight hydrocarbon fractions (such as condensates) would volatilize more rapidly than heavier hydrocarbon fractions. Lighter weight fractions, however, would cause greater acute toxicity conditions for early life stages of fish that occur on the surface. During ice season, small crude oil and condensate spills could occur and cause fish to disperse from an area of ice used for feeding and shelter, or cause acute toxicity to weak-swimming or non-swimming early life stages at the surface (BOEM 2015e).

However, due to the ephemeral nature of small, refined oil spills, NMFS does not expect detectable effects to proposed ringed seal critical habitat associated with accidental discharges that may occur during the first incremental step of the proposed action.

6.2 Anticipated Effects of Future Incremental Steps

While the proposed action is focused on exploration activities, this consultation also considers potential effects of future incremental steps through the endpoint of decommissioning. Future incremental steps consider the hypothetical scenarios of production and development of an anchor field and, if successful, the exploration, development and production of a satellite field, followed by the decommissioning of all of these activities covering years 10-77(see Table 4).

Development and production logically follow if a leaseholder finds an economically-developable field. During future incremental steps, BOEM anticipates that a large prospect, Anchor A, and a smaller satellite prospect, A-2, are discovered, developed, and produced from sale 193 leases. Their combined potential oil and condensate are 4.3 Bbbl. Producing this volume of oil and its associated natural gas would require eight platforms of a new Arctic-class design and drilling an additional 561 wells (exploration, delineation, production, and service) (BOEM 2015a).[34]

Development activities include the construction or installation of a production facility and necessary pipelines that would convey oil or gas to existing infrastructure (BOEM 2015a). Many of the stressors associated with future incremental steps have been discussed above including: vessel and aircraft traffic, seismic surveys, drilling activities, and discharges (see Sections 6.1 and 6.1.4). Production activities are those that make use of the developments: the drilling of production wells, operation of pump stations, and operation of other facilities that move the oil/gas to existing infrastructure. The new activities anticipated during development and production includes facility construction and operation. Decommissioning is considered the end-point of production and could include the removal of platforms and other infrastructure (BOEM 2015a).

Development and production are not considered reasonably certain to occur and a DPP would be submitted, evaluated consistent with NEPA, and require additional consultation under the ESA. The purpose of this section is to describe the potential effects of a "single and complete project" that could arise from the leases issued under the LS 193 program as it is currently understood. Subsequent evaluations would be based on site-specific information and additional details provided through the DPP process (BOEM 2015a).

6.2.1 Anticipated Effects from Marine Seismic, Geohazard, and Geotechnical Surveys

During future incremental steps, six additional marine seismic surveys may occur between years 10 and 29 (see Table B-7 in BOEM 2015e). Deep penetration marine seismic surveys may be conducted to assess reservoir status. An additional eight geohazard high resolution low energy surveys (including airgun supported surveys) for site clearance and shallow hazards could occur in localized areas near prospective platform sites (see Table B-7 in BOEM 2015e). There could also be additional noise associated with highly localized ancillary activities such as sonar, coring, echosounders, etc. (BOEM 2015a). BOEM and BSEE anticipate that eight geotechnical surveys (with no more than two surveys per year) could occur between years 11 and 28 (see Table B-7 in BOEM 2015e).

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[34] 12 wells during exploration of satellite prospect A-2 (future consultation), 459 production wells (future consultation), and 90 service wells (future consultation) = 561 total wells.

6.2.1.1 Effects to Listed Species

The effects to baleen whales and pinnipeds associated with seismic, geohazard, and geotechnical operations during future incremental steps (years 10-29) are anticipated to be similar to those effects described during the first incremental step of exploration (see Section 6.1.3.1), but would be limited to the area over the satellite field (BOEM 2015a).

Marine seismic surveys should affect very few bowhead whales in the leased area until mid to late September when large migration pulses of bowhead begin leaving the Beaufort Sea, traveling through the leased area to feeding ground off the northern coast of Chukotka.

The small scale of the geohazard and geotechnical surveys, the equipment used, and the few deep penetration marine seismic surveys would not interact to produce anything beyond temporary, brief avoidance behavior by whales and pinnipeds (BOEM 2015e).

In addition, seismic surveys would be subject to mitigation measures that would help avoid adverse effects on baleen whales and pinnipeds. When seismic surveys are being conducted around the satellite field, PSOs could monitor for the presence of whales and seals as during exploration. Overall, no more than a minor level of effect to listed species from seismic survey activity during future incremental steps is anticipated (BOEM 2015e).

6.2.2 Anticipated Effects from Vessel and Aircraft Traffic

Vessel and aircraft traffic could be elevated from the exploration phase levels in order to access and support construction of production facilities in the action area, which could occur simultaneous to exploration of a satellite field (BOEM 2015a). In addition, the duration and frequency of these activities may substantially increase as a production facility may be in operation year round for decades versus the relatively short duration and short season of exploration activities. However, once exploration and development activities are complete, aircraft and vessel traffic are expected to decrease (BOEM 2015a).

6.2.2.1 Effects to Listed Species and Proposed Critical Habitat

While the range of effects to baleen whales, pinnipeds, and proposed critical habitat associated with vessel and aircraft are anticipated to be similar to those described during the exploration phase (see Sections 6.1.3.2.2-6.1.3.2.3, and 6.1.4.3), the intensity of those activities is anticipated to increase during the development and production phases. The duration and intensity of such activities likely would be years longer than exploration activities and may occur year round (as opposed to just the open-water period).

There may be an increased risk of vessel strike due to the increased traffic (BOEM 2015a). Vessel collisions with whales often lead to the death of the whale that was struck. However, most bowhead whales would be in the Beaufort Sea during the majority of vessel operations in the summer, lowering their chances of encounter. If the intensity and frequency of icebreaking activities increases during production and development phases, ice seals and proposed critical habitat could be disturbed, and ringed seal pups may inadvertently be killed during ice breaking activities during the mid-March to mid-June period. In addition ice seals may be startled by vessel or aircraft noise and abandon sea ice habitat for the ocean. Over time seals may habituate to these continuous noise sources. However, in order to determine if habituation is occurring over time, long-term sequential measurements of responses by individuals to controlled stimuli are needed (Nisbet 2000, Bejder et al. 2009). Vessel and aircraft traffic is anticipated to decrease once exploration and development activities are complete (BOEM 2015a).

Standard mitigation measures would help avoid or minimize adverse effects to listed species. Timing stipulations would likely avoid adverse effects to newborn ringed seal pups, particularly when nursing and molting. BOEM anticipates a minor level of effect to listed species and proposed ringed seal critical habitat from vessel and aircraft activity during development and production phases (BOEM 2015e).

6.2.3 Anticipated Effects from Exploration, Development, and Production Drilling Operations

The drilling of exploration and delineation wells is anticipated to continue during future incremental steps with a total of 12 wells being drilled during the exploration of satellite prospect A-2 (see Table 4).

Production well and service well drilling would be conducted both from new Arctic-class design production platforms and from MODUs. An estimated annual maximum of eight wells could be drilled by each production platform rig (e.g., 16 wells total per platform per year). A total of 459 production and service wells would be drilled from production platforms. Subsea wells would be drilled by MODUs. With efficiencies gained by repeated operations, BOEM assumes that a single drillship could drill up to three subsea wells in a single season. BOEM estimates that 6 to 9 subsea wells would be drilled per open water season, requiring two to four MODUs each summer over approximately 12 years. A total of 90 sub-sea production wells would be drilled over the life of the project (BOEM 2015e).

During future incremental steps a total of 561 wells may be drilled in the action area.[35]

6.2.3.1 Effects to Listed Species and Proposed Ringed Seal Critical Habitat

Drilling operations generate continuous underwater sounds that could affect listed species and proposed critical habitat in the same ways as previously discussed for exploration drilling (Section 6.1.4.4). However drilling activities likely would occur year round until production wells are completed, which could increase the duration and intensity of effects associated with drilling operations in the future. As an example, instead of a maximum of 4 wells being drilled per year during the exploration phase of the proposed action, a maximum of 35 wells may be drilled per year during future incremental steps (4 exploration wells, 25 production wells, and 6 subsea wells). Drilling from a fixed platform could have less sound transmission than from exploration drilling using MODUs. However, subsea wells would be drilled by MODUs, and the effects of such activity would be similar to the effects of drilling exploration wells. Specific development proposals would be further assessed and consulted upon incrementally for development as specific actions and action areas become known (BOEM 2015a).

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[35] 12 wells during exploration of satellite prospect A-2 (subsequent consultation), 459 production wells (subsequent consultation), and 90 service wells (subsequent consultation) = 561 total wells during future incremental steps (see Table 4).

A total of eight production platforms would be installed in the anchor and satellite fields, and a maximum of 32 production and service wells, 9 subsea wells, and 4 explorations wells would be drilled in a single season (but not necessarily during the same season). The Molikpaq is a mobile Arctic drilling platform, similar in many ways to what would be expected for production platforms in the lease area. Thomson and Johnson (1996) documented decibel levels of 112 dB at 1.4 km from the Molikpaq, with most of the energy occurring below 20 Hz. Assuming the decibel and frequency levels between the Chukchi Sea and Sea of Okhotsk are similar, and since 112 dB is approximately at or below ambient noise levels for the Chukchi Sea, the radii for effects should extend to 1.4 km (0.87 mi) or less from each production platform (BOEM 2015a). Not all platforms would be drilling simultaneously; however, the noise production from drilling 32 wells from 8 platforms would average 4 wells per platform during the peak of drilling activity (~ year 25). The noise footprint from this level of drilling would amount to a 1.4 km zone surrounding each production platform where manmade noise might exceed the ambient noise levels for the ocean, mostly at 20 Hz which is within the bottom range of the auditory bandwidth for baleen whales (7 Hz–30 kHz) and below the bottom range for seals (75 Hz – 100 kHz) (Ciminello et al. 2012, NOAA 2013, BOEM 2015a). However, the noise footprint associated with drilling from two MODUs is anticipated reach the 120 dB isopleth at ~13 km from the MODUs with maximum over depth broadband (10 Hz- 3kHz) (Austin et al. 2015), and would be well within the hearing range for baleen whales and seals. It is anticipated that whales would continue moving and migrating across the Chukchi Sea as needed, diverting around locations where drilling is occurring by 1-13 km. Drilling from production platforms produces much less noise than drilling from drillships, so noise effects on listed species would be reduced and restricted to the immediate vicinity of the platform (BOEM 2015a). Once drilling is completed, listed species should tolerate the presence of production wells potentially passing near areas of active production platforms with minimal response (McDonald et al. 2006, Aerts and Richardson 2008). However, in order to determine if habituation is occurring over time, long-term sequential measurements of responses by individuals to controlled stimuli are needed (Nisbet 2000, Bejder et al. 2009).

Drilling operations are likely to displace some primary prey resources and compromise the suitability of sea ice habitats otherwise suitable as birth lairs or platforms to ringed seals. The zone of avoidance by ringed seals or their primary prey resources is not fully known; however, ringed seals have been seen as close as 10 m from an active drilling platform (Brewer et al. 1993).

The location, timing, and specific actions have not been determined and would be evaluated as development and production plans are submitted to BOEM and BSEE. Individual whales and seals likely would avoid activities that bothered them; the distances vary according to the individual and site-specific conditions (activity type, duration, and timing, etc.). These activities, however, would be subject to mitigation measures that would help avoid adverse effects on whales, seals, and proposed critical habitat (BOEM 2015a).

Overall the effects to listed species are anticipated to be minor with short-term and localized impacts (BOEM 2015e).

6.2.4 Anticipated Effects from Seafloor Disturbance

Habitat alteration and seafloor disturbance may occur from drilling operations, pipeline installation, and geotechnical surveys during future incremental steps. The effects to listed species and proposed ringed seal critical habitat are anticipated to be similar to those discussed for the first incremental step (Section 6.1.3.4.2). However the intensity and duration of drilling activities are anticipated to be much higher during future incremental steps, and pipeline installation would be a new source of seafloor disturbance.

As described above, BOEM anticipates 561 wells may be drilled in the action area during future incremental steps (see Table 4). These drilling operations would release drill cuttings, drilling fluids, and well cellar sediment discharge into the water and on the seafloor (BOEM 2015e).

Offshore pipeline installation would occur during the open-water season. All pipelines would be trenched in the seafloor as a protective measure against damage by floating ice masses. BOEM and BSEE anticipate that the depth and width of subsea pipeline trenches would be similar to those dug for Northstar (7–11 ft deep and 8–52 ft wide), with pipelines at greater depths requiring deeper and wider trenches. Approximately 6–9 ft of backfill would cover trenched pipelines. An estimated 160 mi of trunk oil pipelines would connect the anchor field hub platform (first installed platform) to the onshore processing facility (discussed below). An additional estimated 20 mi of oil pipeline would connect the satellite field hub platform to the anchor field hub. Subsea gas pipelines would be installed approximately 20 years after the oil pipelines and along the same routes (BOEM 2015a).

To comply with BSEE regulations (30 CFR 250.1710—wellheads/casings and 30 CFR 250.1725— platforms and other facilities), lessees are required to remove all seafloor obstructions from their leases within one year of lease termination or relinquishment. Decommissioning is anticipated to begin after approximately 30 years of production (BOEM 2015a). Post-decommissioning surveys would be required to confirm that no debris remains following decommissioning and that pipelines were abandoned properly.

6.2.4.1 Effects to Listed Species and Proposed Ringed Seal Critical Habitat

Habitat alterations can occur due to disturbance of the benthic surface resulting from the volume and physical nature of materials (mud, sand, cobblestone, etc.) that are displaced by the actions of oil and gas discovery, development, and decommissioning activities. These activities would include anchoring of vessels and platforms, construction of infrastructure such as pipelines and subsea platforms, well drilling activities, and any similar activities that would disturb benthic surfaces. The disturbance of these surfaces and their effects are further defined by dispersal of materials through the water column (density of particles and residence time in the water column), and subsequent deposition on the benthic surface (area and depth of coverage of the benthic surface by displaced materials). Effects would include the temporary disruption of pelagic habitat by way of turbidity caused by suspended material. Disruption of habitat by way of covering benthic communities with sediment through deposition of suspended material downstream of disturbance sites would cause temporary loss of local benthic communities lasting from one year to 4-8 years, depending on amount of material suspended and dispersal by way of local current patterns (BOEM 2015e).

Indirect effects to listed species and proposed ringed seal critical habitat are primarily related to prey. Bowhead whales and seals may forage on benthic invertebrates which may be buried resulting in prey mortality during operations that disturb the seafloor. Turbidity could affect the prey species and possibly the ability of marine mammals to locate prey in the immediate area of the drilling (BOEM 2015e). However, the discharge of drilling muds and cutting during drilling activities is unlikely to have measurable effects on listed marine mammals, either directly through contact or indirectly by affecting prey because the effects would be restricted primarily to the immediate area around the drill site. The potential benthic habitat affected would be insignificant relative to the total benthic habitat in the leased area (BOEM 2015e).

There was no indication from benthic biomass or density that previous drilling activities at the Hammerhead Prospect have had a measurable impact on the ecology of the immediate local area. To the contrary, the abundance of benthic communities in the Sivulliq area would suggest that the benthos were actually thriving there (Dunton et al. 2009). No appreciable adverse impacts on benthic populations would be expected due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations. Any mortalities or impacts that might occur as a result of the proposed action is immaterial compared to the naturally occurring high reproductive and mortality rates. In addition, disturbed areas, depending on substrate types, community composition, and ocean current speed and direction, would begin the process of recolonization after deposition has completed following the benthic disturbance (Conlan and Kvitek 2005, BOEM 2015a). Invertebrate species important to large mammalian benthic foragers, such as bivalves, would likely reach sizes readily utilized by foraging mammals at approximately 7-9 or more years depending upon substrate classification, depth, and water temperature (BOEM 2015a). Other benthic foragers such as crabs, fish, and pelagic bird species typically utilize smaller organisms such as amphipods, copepods, shrimp, nematodes, and polychaetes. These are among the first to recolonize taking generally less than a year for establishment in new locations (Trannum et al. 2011).

Based on the above, we would not expect any population level effects to marine mammals, either directly through contact or indirectly by affecting prey species from substrate alteration. Any effects would be localized primarily around the drilling unit or pipeline because of the rapid dilution/deposition of materials, and the recolonization of prey species (BOEM 2015e).

6.2.5 Anticipated Effects from Trash and Debris

Operations that may occur under future incremental steps will generate trash comprised of paper, plastic, wood, glass, and metal mostly from galley and offshore food service operations. A substantial amount of waste products could be generated from seismic and drilling activities over the duration exploration, development, production and decommissioning activities. The possibility exists that trash and debris could be released into the marine environment, and the intensity and duration of this release may be increased in the future due to the increase in activities in general. While, this type of trash and debris discharge is illegal, it can pose significant risks to marine mammals, and is anticipated to be more common and widespread than accidental or illegal oil discharges.

The effects to baleen whales and pinnipeds associated with trash and debris during future incremental steps (years 10-65) are anticipated to be similar to those described for the first incremental step of exploration (see Section 6.1.3.4.3) (BOEM 2015a).

In addition to MARPOL requirements, all vessel operators, employees and contractors actively engaged in oil and gas operations must be briefed on marine trash and debris awareness elimination as described in Section 2.1.5. BOEM will not require operators, employees and contractors to undergo formal training or to post placards. However, the operator will be required to ensure that its employees and contractors are made aware of the environmental and socioeconomic impacts associated with marine trash and debris and their responsibilities for ensuring that trash and debris are not intentionally or accidentally discharged into the marine environment

Because operators must comply with federal regulations and BOEM's trash and debris guidance, the amount of trash and debris occurring within the action area is expected to be minimal and distributed over a wide area resulting in a discountable effect. As such we do not expect substantial exposure of listed species to trash and debris and will not consider this further in this opinion.

6.2.6 Anticipated Effects from Oil and Gas Spills

This analysis is focused on the probability of an unauthorized discharge of oil and gas, and the potential impacts associated with exposure of ESA-listed marine mammals under NMFS's authority to small, large, and VLOS events during exploration, development, production, and decommissioning activities associated with future incremental steps in the action area.

The effects to listed species and proposed ringed seal critical habitat are anticipated to be similar to those discussed for the first incremental step (see Sections 6.1.3.3 and 6.1.4.5). However the intensity and duration of drilling activities is anticipated to be much higher during future incremental steps, and pipeline installation, facilities, and tankers would be new sources of potential spills.

Approach to Estimating Exposures to Oil and Gas Spill

Estimating oil spill occurrence and potential effects on marine mammals is an exercise in probability. Uncertainty exists regarding the location, number, and size of small, large, and very large oil spills, and the wind, ice, and other environmental conditions that could occur at the time of a spill. Additional uncertainty exists because it is difficult to predict conditions and events up to 77 years into the future. The following sections will go into the probabilities of various sized oil spills occurring in the area of LS 193 during years 10-77 of future incremental steps, and the assumptions behind those analyses.

Small Oil Spills

For the purposes of analysis, BOEM and BSEE estimate that approximately 757 small spills (<1,000 bbl) could occur during future incremental steps (years 10-77).

Small spills of both refined oils and crude or condensate oils could occur both onshore and offshore during future incremental steps. The estimated total and volumes of small refined oil spills resulting from future incremental step activities are presented in Table 24. BOEM and BSEE estimate that approximately 537 spills of refined oil and 222 spills of crude or condensate oil or liquid natural gas could occur during future incremental steps. BOEM and BSEE anticipate that these spills would be <1–5 bbl each but assume that one of the on-shore spills would be a roughly 700 bbl spill occurring along the 300–320 miles of onshore pipeline (BOEM 2015a).

Table 24. **BOEM's estimated total number of refined and crude or liquid gas condensate oil spills during the Future Incremental Steps of the Proposed Action (years 10-77) (BOEM 2015a, b).**

Activity Phase	Estimated Total Number of Small Spills	Estimated Total Volume of Small Spills (bbl)	Percent Chance or Frequency
Small Refined Oil Spills			
Exploration G&G Activities[*]	0 - 11	0 - < 11	>99.5% chance of spill
Exploration and Delineation Drilling	0 - 6	0 - < 30	>99.5% chance of spill
Development and Production	0 - 520	0 - 1,600	>99.5% chance of spill
Small Crude or Liquid Gas Condensate Oil Spills			
Development and Production	0 - 222	0 - 2,000	>99.5% chance of spill
Large Oil Spills			
Development and Production	2[**]	1,700 or 5,100 bbl[**]	75% chance of one or more large spills[**]
Very Large Oil Spills			
Exploration, Delineation, or Development Drilling or Production Wells	None	N/A	$10^{-4} – 10^{-5}$ per well[***]

[*] BOEM anticipates a total of 22 G&G activities may be authorized during future incremental steps with small spills potentially occurring with every other activity or 11 times (BOEM 2015b).

[**] Analysis from BOEM's Biological Assessment (BOEM 2015a), volume of spill is based on median size of a crude oil spill from a pipeline and the median size of a platform spill respectively (Anderson et al. 2012).

[***] Analysis from BOEM's Final Programmatic EIS (BOEM 2012).

Large Oil Spills

BOEM and BSEE's estimate of the likelihood of one or more large spills occurring during future incremental steps assumes there is a 100% chance that development(s) will occur and 4.3 Bbbl of crude oil and natural gas liquid condensate will be produced. A large spill could potentially come from four sources associated with OCS exploration or development operations: (1) pipelines (2) facilities (3) tankers or (4) support vessels. BOEM and BSEE reviewed those four sources and determined well-control incidents have the potential for the largest spill volumes, assuming all primary and secondary safeguards fail and the well does not bridge (collapse in on itself) (BOEM 2015e).

At this time, pipelines are the preferred mode of petroleum transport (over tankers) in the Chukchi OCS, therefore, BOEM and BSEE did not consider the loss of a fully loaded tanker reasonably foreseeable. The loss of the entire volume in an offshore pipeline would be less than a long duration well control incident with high flow rates. Sizes of spills from support vessels were considered based on foundering and the loss of entire fuel tanks, and determined to be lower in volume than a well control incident where all primary and secondary safeguards failed (BOEM 2015a).

To estimate the effects of a large oil spill resulting from future incremental steps, BOEM and BSEE estimated information regarding the general source(s) of a large oil spill (such as a pipeline, platform, or well), the location and size of the spill, the type and chemistry of the oil, how the oil will weather (naturally degrade in the environment), how long it will remain prior to naturally degrading, and where it may go. BOEM and BSEE also estimated the mean number of large spills and the chance of one or more large spills occurring over the full 77 years (BOEM 2015a).

The large spill-size assumptions BOEM and BSEE used are based on the reported spills in the Gulf of Mexico and Pacific OCS because no large spills have occurred on the Alaska OCS from oil and gas activities. BOEM used the median OCS spill size as the likely large spill size (Anderson et al. 2012) because it is the most probable size for that spill size category. The Gulf of Mexico and Pacific OCS data show that a large spill most likely would be from a pipeline or a platform. The median size of a crude oil spill ≥1,000 bbl from a pipeline on the OCS over the last 15 years in these other locations is 1,720 bbl, and the average is 2,771 bbl (Anderson et al. 2012). The median spill size for a platform on the OCS over the entire record from 1964-2010 is 5,066 bbl, and the average is 395,500 bbl (Anderson et al. 2012). Outliers, such as the DWH spill volume, skew the average and the average is not a useful statistical measure. For purposes of analysis for the second SEIS, BOEM/BSEE used the median spill size (rounded to the nearest hundred) as the likely large spill sizes (see Table 24) (BOEM 2015e).

BOEM and BSEE estimate that there is a 75% chance of one or more large spills (>1,000 bbl) occurring from platforms or pipelines during future incremental steps (years 10-77). For the oil spill risk analysis in the second SEIS, BOEM/BSEE assume that two large spills would occur during the lifetime of the project: one of these large spills would be from a production platform and the other from large offshore pipeline (see Table 24). No large spills are assumed to occur onshore (BOEM 2015a).

Large condensate and diesel fuel spills would evaporate and disperse generally within 1–13 days. A large crude oil spill, however, is estimated to persist much longer: after 30 days 28–40% would evaporate, 3–16% would disperse, and 44–62% would remain. A large crude oil spill from a platform (5,100 bbl) into open-water would cover an estimated discontinuous area of 54 km^2 after 3 days and 1,063 km^2 after 30 days. A large crude oil spill from a platform on to the ice surface during November through May would cover an estimated discontinuous area of 18 km^2 after 3 days and 351 km^2 after 30 days. A large crude oil spill from an offshore pipeline (1,700 bbl) during open-water would cover an estimated discontinuous area of 31 km^2 after 3 days and 615 km^2 after 30 days. A large offshore pipeline crude oil spill onto the ice surface during November through May would cover an estimated discontinuous area of 10 km^2 after 3 days, and

200 km^2 after 30 days. Oiled ice that drifts and subsequently melts during open water would introduce oil into surface waters in new areas (BOEM 2015a).

Very Large Oil Spills

Although unexpected, very large spills may result from OCS exploration, development and production operations involving facilities, tankers, pipelines, and/or support vessels. Incidents with the greatest potential for catastrophic consequences are losses of well control with uncontrolled releases of large volumes of oil, where primary and secondary barriers fail, the well does not bridge (bridging occurs when the wellbore collapses and seals the flow path), and the flow is of long duration.

VLOS are defined by BOEM to be > 150,000 bbl. In general, historical data show that loss of well control events resulting in oil spills are infrequent and that those resulting in very large oil spills are even rarer events (Anderson and LaBelle 2000, Bercha Group 2006, Anderson et al. 2012). The Norwegian SINTEF Offshore Blowout Database, which tracks worldwide offshore oil and gas blowouts, where risk-comparable drilling operations are analyzed, supports the same conclusion. Blowout frequency analyses of the SINTEF database suggest that the highest risk operations are associated with exploration drilling in high–pressure, high-temperature conditions. As the 2010 DWH event illustrated, there is a risk for very large spills to occur and result in unacceptable impacts, some of which have the potential to be catastrophic.

A fundamental challenge is to accurately describe this risk, especially since there have been relatively few large to very large oil spills that can serve as benchmarks. Prior to the DWH event, the three largest blowout spills on the OCS were 80,000 bbl, 65,000 bbl, and 53,000 bbl, and all occurred before 1971 (Anderson et al. 2012). From 1964 to 2010 there were 283 well control incidents, 61 of which resulted in crude or condensate spills (drilling mud or gas releases not included) (Table 25). Excluding the DWH event, less than 2,000 bbl of crude or condensate were spilled from fewer than 50 well control incidents after 1971. During the 1971–2010 period, more than 41,800 wells were drilled on the OCS and almost 16 Bbbl of oil produced (BOEM 2012).

Table 25. Loss of well control by region during OSC activities from 1964-2010 (BOEM 2012).

Region	Exploration Wells	Development Wells	Loss of Well Control Events	Loss of Well Control with Oil Pollution Events
Alaska	84	6	0	0
Atlantic	51	0	0	0
Gulf of Mexico	16,889	29,733	278	59
Pacific	324	1372	5	2
Total	17,348	31,111	283	61

At the present time, there is a not an ideal, standardized approach to characterizing the risk of spill occurrence and consequence. Historically, BOEM has characterized oil-spill risk using the Oil Spill Risk Analysis (OSRA) model to identify the risk of oil released from numerous locations on the OCS occurring and contacting environmental, social and economic resources. BOEM performs OSRA modeling in the evaluation of individual lease sales and certain exploration/development plans. BOEM or BSEE also consider risk during the review of an operator's Exploration Plan, Development and Production Plan (or Development Operations Coordination Document), and/or Application for Permit to Drill.

BOEM and BSEE analyzed the potential impacts of a VLOS scenario in the second SEIS for the purposes of evaluating a low-probability, high-impact event in the LS 193 area (BOEM 2015e). VLOS are analyzed separately from large oil spills due to their lower level of probability. VLOS is a highly unlikely event and is not reasonably likely to occur, based on the probability analysis provided by BOEM. BOEM analyzed the impacts of a hypothetical catastrophic discharge scenario (e.g., VLOS) that consisted of a 1.4-2.2 Mbbl spill that lasted 45-75 days. BOEM estimates that the risk of such an event occurring in the Chukchi Sea is between > 10^{-4} and > 10^{-5} per well drilled (see Table 24) (BOEM 2012). Although the risk of a VLOS is estimated to be very small, we analyze the potential effects of BOEM's hypothetical VLOS scenario in the sections below to consider the effects of this low-risk, high-impact event.

6.2.6.1 Effects to Baleen Whales (bowhead, fin, and humpback whales)

The primary potential effects to marine mammals from accidental oil spills include: 1) fouling of individuals (including fur and baleen), 2) ingestion/inhalation of oil, 3) habitat/prey degradation, and 4) disruption of migration (see Figure 24) (BOEM 2012). Disruption of other essential behaviors, such as breeding, communication, and feeding may also occur.

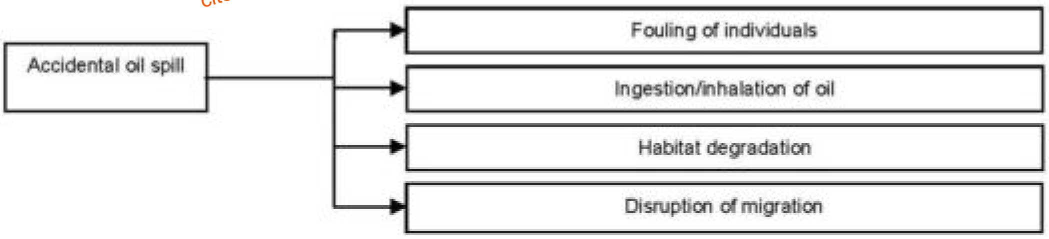

Figure 24. **A conceptual model of potential effects of accidental oil spills on marine mammals (BOEM 2012).**

The risk of exposure and response of baleen whales to small spills occurring in future incremental steps will be similar to descriptions for the first incremental step (see Sections 6.1.3.3 and 6.1.4.5). This section will focus on expected effects to baleen whales should a large or a VLOS occur.

Depending on the timing, size, and duration of the spill, bowhead, fin, and humpback whales could experience contact with fresh oil during summer and/or fall feeding events and migration in the Chukchi Sea. Skin and eye contact with oil could cause irritation and various skin disorders. Toxic aromatic hydrocarbon vapors are associated with fresh oil. The rapid dissipation of toxic fumes into the atmosphere from rapid aging of fresh oil and disturbance from response related noise and activity could limit the potential exposure of whales to prolonged inhalation of toxic fumes. Exposure of whales to toxic vapors, especially if calves are present, could result in mortality. Surface feeding whales could ingest surface and near surface oil fractions with their prey, which may also be contaminated with oil components. Incidental ingestion of oil factions that may be incorporated into benthic sediments can also occur during near-bottom feeding. To the extent that ingestion of crude oil affected the weight or condition of the mother, the dependent young could also be affected. Decreased food assimilation could be particularly important in very young animals, those that seasonally feed, and those that need to accumulate high levels of fat to survive their environment. Ingestion of oil may result in temporary and permanent damage to whale endocrine function and reproductive system function; and if sufficient amounts of oil are ingested mortality of individuals may also occur (BOEM 2015a).

Bowhead whales are most vulnerable to oil spills in the Chukchi Sea while feeding during late summer and fall and during the westward migration throughout the fall. A winter spill, or if oil persists in ice over winter, could impact bowheads migrating through the lead system during the spring. Exposure of bowheads could occur in the spring lead system during the spring calving and migration period. Exposure to aged winter spill oil (which has had a portion or all of the toxic aromatic compounds dissipated into the atmosphere through the dynamic open water and ice activity in the polynya) presents a much reduced toxic inhalation hazard. It is possible that a winter spill would result in a situation where toxic aromatic hydrocarbons would be trapped in ice for the winter period and released in toxic amounts in the spring polynya system when bowheads are migrating through in large numbers. Calves could be more vulnerable than adults to vapors from a spill, because they take more breaths than do their mothers and spend more time at the surface. If a VLOS were to occur during a time when many bowhead whale calves were present, calves could die and recovery from the loss of a substantial portion of an age class cohort and its contribution to recruitment and species population growth could take decades (BOEM 2015a).

Injury and mortality to whales are most likely during the initial spill event. Contact through the skin, eyes, or through inhalation and ingestion of fresh oil could result in temporary irritation or long-term endocrine or reproductive impacts, depending on the duration of exposure. We anticipate that if a VLOS were to occur, the magnitude of the resulting impact could be high because a large number of whales could be impacted. The duration of impacts could range from temporary (such as skin irritations or short-term displacement) to permanent (e.g. endocrine impairment or reduced reproduction) and would depend on the length of exposure and means of exposure, such as whether oil was directly ingested, the quantity ingested, and whether ingestion was indirect through prey consumption. Displacement from areas impacted by the spill due to the presence of oil and increased vessel activity is likely. If the area is an important feeding area, such as off Barrow, or along a migratory corridor, especially in the spring lead system, the impacts may be higher magnitude (BOEM 2015a).

Humpback and fin whales are only present during the open water season and occur in very low numbers in the lease area, and therefore would be at lower risk of exposure and be impacted less by a large or very large oil spill than bowhead whales. A large or very large oil spill could result in some individual humpback or fin whales coming into contact with oil (potentially resulting in inhalation of hydrocarbon vapors, baleen fouling, and ingestion of contaminated prey).

Temporary and/or permanent injury and non-lethal effects could occur, but mortality is not likely. Temporary displacement from feeding and resting areas could also occur. Fin and humpback whale prey (schooling forage fish and zooplankton) could be reduced or contaminated, leading to modified distribution of these whales (BOEM 2015a).

If an oil spill were to cause extensive mortality within a high latitude amphipod population with low fecundity and long generation times, a marked decrease in secondary production could ensue in some areas (Highsmith and Coyle 1992), which could impact all three whale species. Exposure to contaminated prey multiple times over the long lifetime of these whales could increase contamination of whale tissues through accumulation. Because the statistical probability of large oil spills occurring is very small, any consumption of contaminated prey is unlikely to accumulate to levels that would harm individual whales.

A low probability, high impact circumstance where large numbers of whales experience prolonged exposure to toxic fumes, and/or ingest large amounts of oil, could result in injury and mortality that exceeds PBR. However, due to the low likelihood of multiple large oil spills, and even lower predicted likelihood of a VLOS, the risk of significant exposures of whales to such discharges of oil is low.

6.2.6.2 Effects to Pinnipeds and Proposed Ringed Seal Critical Habitat

Pinnipeds (Ringed and Bearded seals)

In the event of an oil spill, ice seals could be adversely affected to varying degrees depending on habitat use, densities, season, and various spill characteristics. The risk of exposure and response of ringed and bearded seals to small spills occurring in future incremental steps will be similar to descriptions for the first incremental step (see Section 6.1.3.3 and 6.1.4.5). This section will focus on expected effects to ringed and bearded seals should a large or a VLOS occur.

Oil tends to concentrate in ice leads and in breathing holes, and will be held closer to the surface against ice edges where seals tend to travel (Engelhardt 1987). Floating sea ice also reduces wave action and surface exchange thus delaying the weathering and dispersion of oil and increasing the level and duration of exposure to seals. Low temperatures make oil more viscous and thus increases the hazards associated with fouling of animals. It also reduces evaporation of volatile hydrocarbons, lessening the acute levels of toxins in the air but lengthening the period of exposure (Engelhardt 1987).

Surface contact with petroleum hydrocarbons, particularly the low-molecular-weight fractions, to seals can cause temporary damage of the mucous membranes and eyes (Davis et al. 1960) or epidermis (Walsh et al. 1974, Hansbrough et al. 1985, St. Aubin 1988). Contact with crude oil can damage eyes (Davis et al. 1960), resulting in corneal ulcers and abrasions, conjunctivitis, and swollen nictitating membranes (Geraci and Smith 1976a, b). Crude oil immersion studies resulted in 100% mortality in captive ringed seals (Geraci and Smith 1976a). Unlike the animals in the immersion study, seals in the wild would have ice as a resting/escape platform or, during the open water period, water depth and distance for escape routes from an oil spill, which they might detect and avoid (Geraci and St. Aubin 1990). Researchers have suggested that pups of ice-associated seals may be particularly vulnerable to fouling of their dense lanugo coat (Geraci and St. Aubin 1990, Jenssen 1996). Though bearded seal pups exhibit some prenatal molting, they are generally not fully molted at birth, and thus would be particularly prone to physical impacts of contacting oil. Adults, juveniles, and weaned young of the year rely on blubber for insulation, so effects on their thermoregulation are expected to be minimal. Other acute effects of oil exposure which have been shown to reduce seal health and possibly survival include skin irritation, disorientation, lethargy, conjunctivitis, corneal ulcers, and liver lesions. Direct ingestion of oil, ingestion of contaminated prey, or inhalation of hydrocarbon vapors can cause serious health effects including death (Geraci and Smith 1976a, Geraci and St. Aubin 1990).

A VLOS reaching a polynya or lead system could have serious effects on local ringed and bearded seal sub-populations, potentially oiling or even killing a number of bearded and/or ringed seals (BOEM 2012). PBR for ringed and bearded seals is unknown because there currently are no accurate estimates of minimum abundance (Allen and Angliss 2014). It is important to evaluate the effects of anthropogenic perturbations, such as oil spills, in the context of historical data. Without historical data on distribution and population size, it is difficult to predict the impacts of an oil spill on ringed seals or bearded seals (Cameron et al. 2010, Kelly et al. 2010b). Based on the documented exposures of ringed seals and other phocid species to oil, however, significant effects on health and survival would be expected for seals immersed or coated in oil during the days and weeks following a spill (Geraci and St. Aubin 1990).

Reduction or contamination of food sources would be localized relative to the area of the spill. Exposure to contaminated prey multiple times over the long lifetime of these seals could increase contamination of bearded seal tissues through accumulation. A VLOS could affect large numbers of seals, because they would be exposed to contaminated prey in a large area for a sustained amount of time. Because the statistical probability of large and especially very large oil spills occurring is very small, any consumption of contaminated prey is unlikely to accumulate to levels that would harm individual seals.

A low probability, high impact circumstance where large numbers of ice seals experience prolonged exposure to toxic fumes, and/or ingest large amounts of oil, could result in injury and mortality of a substantial number of seals. However, due to the low likelihood of multiple large oil spills, and even lower predicted likelihood of a VLOS, the risk of significant exposures of seals to such discharges of oil is low.

Proposed Ringed Seal Critical Habitat

Several factors have to be taken into consideration when assessing the risk of a large or very large spill to proposed critical habitat for ringed seal. First, while still unlikely, a large or very large oil spill is more associated with oil production than exploration, and the probability of a successful commercial find in the Chukchi Sea Planning Area is low (BOEM 2015a). Secondly, the location of the oil or gas find and subsequent development platform could influence the chance that a spill would occur. Finally, the presence of sea ice suitable for lairs and platforms, and the duration and type of oil exposure influences the potential effects.

Should a large or very large oil spill occur, oil contact could modify all three essential features of proposed ringed seal critical habitat, rendering areas unsuitable or detrimental for use until cleanup or weathering could occur. Depending on the size and scale of the spill, it could require multiple seasons to return the essential features to their original quality given the capacity of ice to lock and release ice with freeze and thaw cycles. Areas within the pathway of the spill would be most impaired while areas outside of the pathway would be affected less. The essential feature of primary prey resources would likely take longer to recover from a large or very large spill than the two sea ice essential features, due to potential effects on prey populations and reproduction (BOEM 2015a).

Oil that gets under ice may heat ice and melt it (BOEM 2015a). A given volume of oil will melt roughly 1/200 of that volume of ice for each degree the oil is above freezing. In stationary or very slow moving ice over a blowout, melting may weaken the ice and make it more probable that trapped gas bubbles will fracture the ice and escape into the atmosphere. However, during much of the ice season in the Chukchi Sea region, the air is so cold that it would cause oil to behave more like a solid than a liquid. The oil would therefore be limited to a relatively smaller area on the surface until it pooled deep enough to begin spreading beneath the ice (BOEM 2015a).

When oil gets underneath an ice sheet, several factors control the concentration and spatial extent of the oil spread. The primary factors include the bottom roughness of the ice, the presence of gas under the ice, the magnitude and direction of ocean currents, and the movement of ice cover (BOEM 2015a). If oil alone is present, or if accompanying gas is vented, the oil would begin filling under-ice voids (such as lairs) near the blowout. As a void fills and oil is pressed downward, the oil eventually reaches a depth where it can progress along the underside of ice to the next void. If the ice is moving over the site of the blow-out, the voids may not be completely filled, and only that ice passing directly over the blowout plume collects oil (BOEM 2015a).

Oil contacting ice can be frozen and incorporated into the ice, eventually being released when the ice melts. In this way, oil can be temporarily sequestered from sea ice features essential to the conservation of ringed seals, and released again later in time. This would change the duration, spatial extent, and intensity of the effects on the essential features, but it is not clear how it would impacts the overall effects on critical habitat.

One large oil spill in the Chukchi Sea between years 10-77 of future incremental steps as predicted by BOEM (BOEM 2015a) would significantly impact proposed ringed seal critical habitat at any time of the year, either (or both) by contaminating/destroying ice characteristics that are essential features of the habitat, or by contaminating/destroying food resources, another essential feature. However, proposed ringed seal habitat is extensive and a large oil spill would still be localized to a portion of the overall habitat. One large oil spill will not likely adversely modify proposed ringed seal critical habitat due to the relatively small proportion of the habitat that would be impacted, and the temporary nature of oil in water or ice.

A very large oil spill in the Chukchi Sea has the potential to adversely modify proposed ringed seal critical habitat. A VLOS could affect an area extending across a major portion of the Chukchi Sea and into the Beaufort Sea. A VLOS is not expected to extend south into proposed ringed seal critical habitat in the Bering Sea (BOEM 2015a). The impacts to the proposed ringed seal critical habitat in the Chukchi Beaufort Seas could be at a level that destroys the value of the habitat for multiple years to a degree that a significant proportion of the stock is not able to successfully reproduce or survive; risking the recovery or stability of the subspecies. However, BOEM estimates that the chance of a VLOS occurrence is so low in the Arctic as to be discountable due to a number of factors, including historical occurrence, and differences in Arctic drilling conditions that make a catastrophic discharge even less likely than the Deepwater Horizon event (BOEM 2012, 2015a). Based on likelihood, NMFS concludes that predicted oil spills resulting from the proposed action may adversely affect proposed ringed seal critical habitat in the first incremental step, but has the potential to cause more serious adverse effect to proposed ringed seal critical habitat in future incremental steps. However, due to their low predicted likelihood, oil spills resulting from future incremental steps are not likely to adversely modify proposed ringed seal critical habitat.

6.2.7 Anticipated Effects from Offshore Facility Construction

A production facility and new subsea pipelines are the largest components that would need to be constructed to support getting product to existing infrastructure. BOEM anticipates this would include eight platforms, multiple subsea templates, pipeline, and a boat dock/barge terminal (see Section 2.1.4.1). Construction could occur year round.

Subsea pipeline construction would be between a location near Wainwright or Barrow and the site of the first production platform. BOEM and BSEE estimate that 160 mi of subsea oil pipeline, 160 miles of subsea gas pipeline, and 30 miles of flowline connecting subsea templates to host platforms would ultimately be laid for development and production. Construction of the first platform should take approximately a year to complete. Between years 10 and 30, approximately eight platforms would be constructed in the anchor field, approximately 5-mi apart, with a 20-mi distance from the anchor field to the satellite field where three more platforms would be built using similar 5-mi spacing.

Noise from activities such as pile-driving, dredging, or equipment operation, would add to the existing noise level at the construction locations. Excavation and pipeline placement are slow moving operations and a relatively stationary sound source around a small noise footprint. Platform construction would produce lower energy localized noise from equipment operation, generators, etc. The sounds from these activities would not be likely to travel as far as sound from 2D/3D or geohazard site clearance seismic surveys. Similarly, pipeline construction would involve a slow-moving sound source that would have a localized, low energy noise footprint that is smaller than 2D/3D or geohazard site clearance seismic surveys (BOEM 2015a).

The loudest noise associated with production platform construction would be pile-driving, and Greene et al. (1995) described pile-driving noise levels of 131–135 dB re 1 μPa (rms) (40–100 Hz) at 1 km from the source. Due to ice characteristics, production platforms in the Chukchi Sea may require larger, or more, pilings to anchor each platform to the sea floor. In either situation pile-driving sound propagation characteristics could change (BOEM 2015a).

The location, timing, and specific actions have not been determined and would be evaluated as development plans are submitted.

6.2.7.1 Effects to Baleen Whales (bowhead, fin, and humpback whales)

Listed whales would be expected to display variable responses to construction activity (ranging from no response to avoidance). Some whales may alter their movements away from or around a source of noise that bothered them. Bowhead whales do not seem to travel more than a few kilometers in response to a single disturbance, and behavioral changes are temporary. Similarly, whales could exhibit the same behaviors if they saw or smelled emissions from a construction activity, and move away (BOEM 2015a).

The audibility range for baleen whales is anticipated to occur within a 7 Hz–30 kHz range (Ciminello et al. 2012, NOAA 2013), overlapping the 100 Hz–2 kHz frequency noise range produced by pile driving. Noise associated with pile driving is anticipated to rapidly attenuate within 1 km of the source (BOEM 2015a). However, sound source verification would most likely be required to confirm source levels and sound propagation distances to the various isopleths in the Chukchi Sea. Though there is overlap in the noise frequencies affected by pile driving and the hearing range of baleen whales, the overlap occurs at the bottom of the audibility spectrum (BOEM 2015a).

Pile-driving could occur during the open water season and may overlap with listed whales. With audible noise levels slightly above those of ambient noise within a kilometer of pile-driving activity, the effects of pile driving may include behavioral responses such as slight shifts in individual migration trajectories to avoid approaching the noises and activity. No PTS, TTS, or other physiological responses should occur because of pile-driving or other construction activities, dredging, or pipeline construction (BOEM 2015a).

Construction of production facilities would likely take place year round (until complete). Some activities could be scheduled to take place during the winter when listed whales are largely absent from the Chukchi Sea lease areas. Individual and groups of bowhead whales engaged in migration during the fall-early winter period would be expected to defer migration route up to several kilometers in an avoidance response to encountering sufficient levels of construction noise (BOEM 2015a).

6.2.7.2 Effects to Pinnipeds and Proposed Ringed Seal Critical Habitat

Noise and disturbance from production facility and pipeline construction may affect nearby ringed and bearded seals. Ringed seals near Northstar in 2000 and 2001 established lairs and breathing holes in the landfast ice within a few meters of Northstar, before and during the onset of winter oil activity (BOEM 2015a). Seal use of the habitat continued despite low-frequency noise and vibration, construction, and use of an ice road (Williams et al. 2006). Blackwell *et* (2004b) determined ringed seal densities were significantly higher around offshore industrial facilities. Another study by Frost and Lowry (1989) found ringed seal densities between 1985 and 1986 were higher in industrialized areas than in the controls in the central Beaufort Sea.

Construction activities have the potential to affect proposed ringed seal critical habitat through the placement of the platform, installation of pipelines, and other facilities. Noise from activities such as pile driving may make sea ice habitats temporarily unsuitable. Excavation and pipeline placement are slow moving operations, provide a relatively stationary sound source, and small noise footprint, and are only anticipated to temporarily impact prey resources and habitat suitability. However, mitigation measures could be put in place to help avoid disturbance to primary prey resources, and sea ice habitats that would otherwise be suitable for the formation and maintenance of birth lairs, and basking and molting platforms. As an example, activities could be restricted during the pupping season when shorefast ice is present.

The placement of bottom-founded structures may reduce the amount of habitat available to ice seals by a very small amount. Existing production facilities in the Beaufort Sea as a result of past oil and gas development may have altered a few km^2 of benthic habitat (BOEM 2015a). This is anticipated to be similar in the Chukchi Sea. Trenching and pipeline burial could affect benthic prey resources, but these prey are already subject to periodic scour by ice keels and recovery is a slow but natural cycle in these disturbed areas (BOEM 2015a).

Offshore facility construction could temporarily cause sediment suspension or turbidity in the marine environment that would disappear over time. These activities are not expected to affect food availability over the long term because, for example, prey species such as Arctic cod have a very broad distribution and ice seals appear are able to forage over large areas of the Chukchi Sea and do not exclusively rely on local prey abundance in open water conditions. In other instances, submerged structure may provide habitat for some prey species (BOEM 2015a)

BOEM does not anticipate more than a minor level of effects to ringed and bearded seals or proposed ringed seal critical habitat from construction activities during the development phase (BOEM 2015e).

6.2.8 Anticipated Effects from Offshore Facility Operations

Once a development facility is constructed, routine production operations would begin. The location, timing, and specific actions have not been determined and would be evaluated as development plans are submitted. The specific potential effects would depend on the type of facility being proposed, its location, and the equipment being used (pumps, motors, etc.) (BOEM 2015a).

6.2.8.1 Effects to Listed Species and Proposed Ringed Seal Critical Habitat

Listed whales would be expected to display variable responses to routine operations (ranging from no response to limited avoidance around active drilling). Some whales may alter their movements away from or around a source of noise that bothered them. Bowhead whales do not seem to travel more than a few kilometers in response to a single disturbance, and behavioral changes are temporary. Similarly, whales could exhibit the same behaviors if they saw or smelled emissions from a routine operation, and move away from it (BOEM 2015a). Considering that fin and humpback whales have low densities in the LS 193 area, we do not anticipate much overlap with drilling noise and these listed species.

Monitoring at the offshore Northstar facility noted changes in the calling behavior of bowhead whales around the island; however, an expert panel interpreting these data was unable to determine if differences were due to changes in calling behavior or deflection (BOEM 2015a).

BOEM and BSEE anticipate that some whales could experience noise exposure and adjust their path around active drilling operations. The degree of this alteration would depend on the timing and location of the drilling operation (BOEM 2015e). BOEM anticipated that these adjustments in migration would be temporary, non-lethal, and minor (BOEM 2015e).

Bottom-founded drilling units can cover areas of benthic habitat that support benthic invertebrates used for food by marine mammals, and placement of fill material might result in habitat loss. This construction would temporarily cause sediment suspension or turbidity in the marine environment that would disappear over time. Alterations from trench dredging and pipeline burial are not expected to affect food availability over the long term because, for example, prey species such as Arctic cod have a very broad distribution and ringed seals are able to forage over large areas of the Chukchi Sea and are not reliant exclusively on the abundance of local prey in open water conditions. In other instances, fill may provide habitat for some prey species.

Drilling operations are likely to displace some bearded and ringed seals due to noise exposure to drilling operations. The degree of adjustment would depend on the timing and location of drilling operations. However, these small adjustments are anticipated to be temporary and non-lethal (BOEM 2015a).

Facility operations are likely to displace some primary prey resources, and compromise the suitability of sea ice habitats otherwise suitable as birth lairs or platforms to ringed seals. The zone of avoidance by ringed seals or their primary prey resources is not fully known. The zone of avoidance would depend on the timing, location, sound level, and other particulars of the operation. Given the spatial extent of proposed critical habitat, and the small number of facilities expected over the life of the action, a negligible impact is anticipated to proposed critical habitat for ringed seals (BOEM 2015a).

6.2.9 Anticipated Effects from Decommissioning Operations

Decommissioning would commence after both oil and gas resources are depleted, and income from production no longer pays operating expenses. MODUs (two to three per open-water season over an estimated 12 years) would be used to plug wells with cement permanently. Wellhead equipment would be removed and processing modules would be moved off the platforms. Subsea pipelines and flowlines would be decommissioned by cleaning the line, plugging both ends, and leaving it in place buried in the seabed. The overland oil and gas pipelines would remain in operation and are likely to be used by other fields in the NPR-A. Lastly, the platform would be disassembled and removed from the area and the seafloor site would be cleared of all obstructions. Post-decommissioning surveys would be required to confirm that no debris remains following decommissioning and that pipelines were abandoned properly (BOEM 2015a).

During decommissioning there would be a surge of heavy equipment and vehicle activity engaged in disassembling pipeline sections and transporting them from the area, and performing any reclamation activities deemed necessary. There would also be a corresponding increase in the number of aircraft flying personnel and supplies to camps engaged in decommissioning. These activities are a potential source of noise, disturbance, or injury (BOEM 2015e).

6.2.9.1 Effects to Listed Species and Proposed Ringed Seal Critical Habitat

The effects associated with decommissioning activities are anticipated to be similar to those described under construction activities (see Section 6.2.7). However, the use of explosives would be a new stressor that could result in noise disturbance and possible injury and death to marine mammals that are present in the area at the time of detonations (BOEM 2015e). Impacts to whales from well-decommissioning activities may be avoided if activities are conducted after whales have completed their migration through the area. Mitigation measures would reduce impacts to listed species and critical habitat (BOEM 2015a).

Production equipment would be partly disassembled and moved off the platform during the summer open-water season. This could affect listed species, but the effects are anticipated to be similar to construction activities and are anticipated to cause temporary avoidance (BOEM 2015e).

After decommissioning, the area would be re-colonized by benthic invertebrates and fishes. The period of time it would take for re-colonization to occur would depend upon the size of the disturbed area and other factors (BOEM 2015a).

7. CUMULATIVE EFFECTS

“Cumulative effects” are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area (50 CFR 402.02). Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

NMFS reviewed recent environmental reports, NEPA compliance documents, BOEM’s biological assessment, and other source documents to evaluate and identify actions that are anticipated to occur within the analytical timeframe of this opinion (i.e., the first incremental step, June 2015-June 2024). Reasonably foreseeable future state, tribal, local or private actions include: oil and gas exploration, development, and production activities; military training exercises; air and marine transportation; and tourism.

7.1 Oil and Gas Projects

State of Alaska: The State of Alaska has a Five–Year Oil and Gas Leasing Program (submitted to the Alaska State Legislature each January). The program outlines a stable and predictable schedule of proposed lease sales, which could result in the further development of Alaska's petroleum resources. The State of Alaska has no scheduled lease sale in the Chukchi Sea nearshore areas in the most recent program (BOEM 2015a).

Activities related to natural gas development are only reasonably foreseeable if there is oil production and if there is a market found for the gas and a gas pipeline is constructed to transport the gas. Such activities may include the construction and installation of a gas pipeline to shore from OCS production facilities in the Chukchi Sea (BOEM 2015a).

Russia: Oil and gas exploration has also occurred in offshore areas of the Russian Arctic and in areas around Sakhalin Island to the south of the Bering Strait. These activities are anticipated to continue into the future. There is little information on specific plans, but the effects are expected to be similar to those resulting from activities occurring in the U.S Arctic (BOEM 2015a).

7.2 Mining

While the majority of mining activities take place onshore, marine and air transportation could contribute to potential cumulative effects through the disturbance of marine mammals. The world’s largest known zinc resources are located in the western Brooks Range. As much as 25 million tons of high-grade zinc is estimated to be present near Red Dog Mine, approximately 40 mi from the southwest corner of the NPR-A (Schoen and Senner 2002). In 2012 Red Dog produced approximately 958,000 tons of zinc concentrate and 175,000 tons of lead concentrate (AK DNR 2013). All concentrates are exported to world markets via the DeLong Mountain Transportation System that connects the mine to port facilities on the Chukchi Sea.

7.3 Transportation

Reductions in sea ice cover will likely lead to increased activity from shipping and resource extraction industries, with associated increased threat of marine accidents and pollution discharge. It is also reasonable to assume that trends associated with transportation to facilitate the maintenance and development of coastal communities and Red Dog Mine will continue. In some specific cases, described below, transportation and associated infrastructure in the action area may increase as a result of increased industrial and commercial activity in the area (BOEM 2015a).

Aircraft Traffic: Existing air travel and freight hauling for local residents is likely to continue at approximately the same levels. Air traffic to support mining is expected to continue to be related to exploration because there are no new large mining projects in the permitting process. Tourism air traffic will not likely change much because there are no reasonably foreseeable events that would draw large numbers of visitors to travel to or from the area using aircraft. Sport hunting and fishing demand for air travel will likely continue at approximately the same levels. Use of aircraft for scientific and search and rescue operations is likely to continue at present levels.

Vehicle Traffic: None of the anticipated future activities propose to construct permanent roads to the communities in the area. Construction of ice roads could allow industry vehicles access to community roads, and likewise allow residents vehicular access to the highway system (BOEM 2015a).

Vessel Traffic: Vessel traffic through the Bering Strait has risen steadily over recent years according to USCG estimates, and Russian efforts to promote a Northern Seas Route for shipping may lead to continued increases in vessel traffic adjacent to the western portion of the action area. Between 2008 and 2012, vessel activity in the U.S. Arctic went from 120 vessels to 250, an increase of 108 percent (ICCT 2015). This includes only the northern Bering Sea, the Bering Strait, Chukchi Sea and Beaufort Sea to the Canadian border. The increase in vessel traffic on the outer continental shelf of the Chukchi Sea and the near-shore Prudhoe Bay from oil and gas exploration activity is particularly pronounced (ICCT 2015).

A site-specific analysis done by Shell Oil as part of a Revised Outer Continental Shelf Lease Exploration Plan for the Chukchi Sea indicated that barge traffic passing through the Chukchi Sea during July through October increased from roughly 2000 miles of non-seismic vessel traffic in 2006 to roughly 11,500 miles of non-seismic vessel traffic in 2010. In comparison, the same analysis estimated that vessel miles associated with seismic surveys in 2006 were roughly 70,000 miles, compared to roughly 30,000 miles in 2010 (BOEM 2015a).

Vessel traffic within the action area can currently be characterized as traffic to support oil and gas industries, barges or cargo vessels used to supply coastal villages, smaller vessels used for hunting and local transportation during the open water period, military vessel traffic, and recreational vessels such as cruise ships and a limited number of ocean-going sailboats. Barges and small cargo vessels are used to transport machinery, fuel, building materials and other commodities to coastal villages and industrial sites during the open water period. Additional vessel traffic supports the Arctic oil and gas industry, and some activity is the result of emergency-response drills in marine areas.

In addition, research vessels, including NSF and USCG icebreakers, also operate in the project area. USCG anticipates a continued increase in vessel traffic in the Arctic. Cruise ships and private sailboats sometimes transit through the proposed action area. Changes in the distribution of sea ice, longer open water periods, and increasing interest in studying and viewing Arctic wildlife and habitats may support an increase in research and recreational vessel traffic in the proposed action area regardless of oil and gas activity.

Spill records indicate most accidental petroleum spills in Alaska occur in harbors and from groundings. Vessel-related spills on the high seas are considered infrequent. Vessels transiting the Chukchi seas during ice periods are more prone to accidents. The ADEC (ADEC 2014) reports the highest probability of spills of refined petroleum products occurs during bulk-fuel transfer operations at remote North Slope villages.

7.4 Community Development

Community development projects in Arctic communities involve both major infrastructure projects such as construction of airports and response centers, as well as smaller projects. These projects could result in construction noise in coastal areas, and could generate additional amounts of marine and aircraft traffic to support construction activities. Marine and air transportation could contribute to potential cumulative effects through the disturbance of marine mammals. No Major community development projects are foreseeable at the present time (BOEM 2015a).

7.5 Recreation and Tourism

Marine and coastal vessel and air traffic could contribute to potential cumulative effects through the disturbance of marine mammals. With the exception of adventure cruise ships that transit the Chukchi Sea coasts in small numbers, much of the air sightseeing traffic is concentrated in the Arctic National Wildlife Refuge and should not impact species in the action area. In addition, future sport hunting and fishing, or other recreation or tourism-related activities are anticipated to continue at current levels and in similar areas in the project area (BOEM 2015a).

7.6 Subsistence Hunting

The take of ice seals by Alaska Native hunters represents the largest known human-related cause of mortality and is likely to remain so for the foreseeable future. The subsistence take is small and ringed and bearded seal populations are likely to have the capacity to absorb it. Subsistence hunting of bowhead whales is covered by ESA consultations due to required federal actions to set harvest quotas.

7.7 Research Activities

International and domestic entities are devoting more and more attention towards studying the Arctic. While generally authorized under scientific permits and MMPA authorizations, these studies are not without impact. Aircraft surveys often drop below levels specified to minimize disturbance effects and circle groups of marine mammals in order to count and photograph them. Incidental and direct take associated with research permitting was discussed in the Environmental Baseline section. While federal projects undergo consultation under the ESA, there are often similar State or local governmental projects that contribute to vessel or aircraft traffic in the action area.

Oil and gas exploration is not the only source of seismic surveying in the action area. For example, the University of Alaska Fairbanks conducted a 2D survey in the fall of 2011 in the Chukchi borderland region using the NFS-owned R/V *Marcus G. Langseth*, a 235 ft, 3,834 gross ton research vessel. This vessel can tow up to four seismic hydrophone cables. The UAF team surveyed a grid of 2D seismic lines over the Chukchi borderland, to obtain images of the stratification of the rocks in the borderland continental shelf, then, ran seismic lines south into the northern Chukchi Sea.

8. INTEGRATION AND SYNTHESIS

The Integration and Synthesis section is the final step of NMFS's assessment of the risk posed to listed species by the proposed action. In this section, we add the effects of the action (Section 6) to the environmental baseline (Section 5) and the cumulative effects (Section 7) in full consideration of the status of the species (Section 4).

As we discussed in the *Approach to the Assessment* section of this opinion, we begin our risk analyses by asking whether the probable physical, physiological, behavioral, or social responses of endangered or threatened species are likely to reduce the fitness of endangered or threatened individuals or the growth, annual survival or reproductive success, or lifetime reproductive success of those individuals. If we would not expect individuals of the listed species exposed to an action's effects to experience reductions in the current or expected future survivability or reproductive success (that is, their fitness), we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (Stearns 1977, Brandon 1978, Mills and Beatty 1979, Stearns 1992b, Anderson 2000). Therefore, if we conclude that individuals of the listed species are not likely to experience reductions in their fitness, we would conclude our assessment because we would not expect the effects of the action to affect the performance of the populations those individuals represent or the species those population comprise. If, however, we conclude that individuals of the listed species are likely to experience reductions in their fitness as a result of their exposure to an action, we then determine whether those reductions would reduce the viability of the population or populations the individuals represent and the "species" those populations comprise (species, subspecies, or distinct populations segments of vertebrate taxa).

As part of our risk analyses, we consider the consequences of exposing endangered or threatened species to the stressors associated with the proposed action, individually and cumulatively, given that the individuals in the action area for this consultation are also exposed to other stressors in the action area and elsewhere in their geographic range.

In addition to considering the effects of stressors associated with the activities proposed in the first incremental step, we analyzed the effects of the future incremental steps, including exploration, development, production, and decommissioning activities on LS 193, to determine if there is reasonable likelihood that the entire proposed action could violate section 7(a)(2) of the ESA. However, considerable uncertainty remains concerning future activities. If future activities exceed the amount of incidental take estimated and authorized here for any given year, or if the project-specific effects on the listed species or designated critical habitat will occur in a manner or to an extent not considered in this opinion, reinitiation of this consultation would be required.

8.1 Cetacean Risk Analysis (bowhead, fin, and humpback whales)

Based on the results of the exposure analysis, during the first incremental step we expect bowhead, fin, and humpback whales may be exposed to low-frequency seismic noise, ice breaking activities, drilling activities, and other noise sources associated with exploration drilling operations based on annual authorization scenarios provided by BOEM/BSEE. Exposure to vessel noise from transit, aircraft noise, construction noise from shore bases, noise from non-seismic geohazard surveys, seafloor disturbance, and small oil spills may occur but are considered insignificant and would not rise to the level of take. As discussed below, exposure to vessel strike and marine debris is extremely unlikely to occur and therefore considered discountable, and because large and very large oil spills are considered extremely unlikely to occur, effects from those events are also considered discountable.

Our consideration of probable exposures and responses of listed whales to oil and gas exploration activities associated with the proposed action is designed to help us assess whether those activities are likely to increase the extinction risks or jeopardize the continued existence of listed whales.

The effects to bowhead, fin, and humpback whales associated with marine seismic, geohazard, geotechnical, pile driving, aircraft traffic, drilling operations, and small oil spills during future incremental steps (exploration, development, production, and decommissioning) are anticipated to be similar those effects described for whales during the first incremental step, but with increased sound exposures and risk of spill due to increased seismic surveys, vessel and aircraft traffic, and drilling operations. However, ancillary activities are anticipated to be low energy and localized in areas near prospective drill sites (BOEM 2015a). Mitigation measures required for seismic and pile driving would further reduce the impacts to listed whales (BOEM 2015a). In addition, the risk associated with large oil spills is anticipated to increase during future incremental steps. BOEM estimates a 75% likelihood of one or more large oil spills if the assumed 4.3 Bbbl of oil were developed and produced between years 10-77. No VLOS is expected. The effects of a large oil spill would be significantly greater than small spills. A low probability, high impact circumstance where large numbers of whales experience prolonged exposure to toxic fumes, and/or ingest large amounts of oil, could result in injury and mortality that exceeds PBR. However, due to the low likelihood of multiple large oil spills, and even lower predicated likelihood of a VLOS, the risk of significant long term exposures of whales to accidental discharges of oil is low. In addition, a number of regulatory changes have been put in place since Deepwater Horizon in an effort to reduce the risk of spills associated with oil and gas exploration and development activities.

The primary mechanism by which the behavioral changes we have discussed affect the fitness of individual animals is through the animal’s energy budget, time budget, or both (the two are related because foraging requires time). Whales have an ability to store substantial amounts of energy, which allows them to survive for months on stored energy during migration and while in wintering areas, and their feeding patterns allow them to acquire energy at high rates. The individual and cumulative energy costs of the behavioral responses we have discussed are not likely to reduce the overall energy budgets of listed whales. As a result, the whales’ probable responses to close approaches by seismic vessels (i.e., reduce the amount of time they spend at the ocean’s surface, increase their swimming speed, change their swimming direction to avoid seismic operations, change their respiration rates, increase dive times, reduce feeding behavior, or alter vocalizations and social interactions) and their probable exposure to active seismic and drilling noise are not likely to reduce the fitness or current or expected future reproductive success of listed whales or reduce the rates at which they grow, mature, or become reproductively active. Therefore, these exposures are not likely to reduce the abundance, reproduction rates, and growth rates (or increase variance in one or more of these rates) of the populations those individuals represent.

Based on the annual activity scenarios provided by BOEM/BSEE (BOEM 2015e) (see Table 17), NMFS estimated that maximum annual instances of exposure to bowhead whales (1,220-2,063), fin whales (20-24) and humpback whales (20-24) would result from Scenario 6: 2 Drilling operations and 4 VSP during the open-water season + 4,500 cui 2D survey and icebreaker during the in-ice season (see Table 21), at received levels sufficiently high (or distances sufficiently close) that might result in behavioral harassment (see Section 6.1.4, *Response Analysis*). No whales are anticipated to be exposed to sound levels that could result in TTS or PTS.

In total, the proposed action (the first incremental step) is anticipated to result in 6,844-8,434 instances of exposure to bowhead whales, 117-133 instances of exposure to fin whales, and 117-133 instances of exposure to humpback whales at received sound levels ≥120 dB re 1 μPa rms for continuous noise sources, or ≥160 dB e 1 μPa rms for impulsive noise sources depending on the Rea or Rmax ensonified areas (see Table 26).

These estimates represent the total number of takes that could potentially occur, not necessarily the number of individuals taken, as a single individual may be taken multiple times over the course of the proposed action (the first incremental steps, years 1-9). These exposure estimates are likely to be overestimates because they assume a uniform distribution of animals, do not account for avoidance or mitigation measures, and assume all of the tracklines will be shot, and all wells drilled.

Exposure to vessel noise from transit, aircraft noise, construction noise from shore bases, noise from non-seismic geohazard surveys, seafloor disturbance, and small oil spill discharge may occur as part of the proposed action, but are considered insignificant and would not rise to the level of take. Exposure to vessel strike, marine debris, large and very large oil spills are considered extremely unlikely during the first incremental step (years 1-9) (see Sections 6.1.3.2 through 6.1.3.4).

Based on the localized nature of small oil spills, the relatively rapid weathering expected for <1,000 bbl of oil, the small number of refueling activities in the proposed action, and the safeguards in place to avoid and minimize oil spills, we conclude that the probability of a BOEM/BSEE authorized activity within the first incremental step causing a small oil spill and exposing bowhead, fin, or humpback whales on LS 193 in the Chukchi Sea sufficiently small as to be considered discountable. If exposure were to occur, due to the ephemeral nature of small, refined oil spills, NMFS does not expect detectable responses from whales, and we would consider the effects during the first incremental step of the proposed action to be insignificant.

While individual whales may be exposed multiple times to seismic noise over the course the open water and in-ice seasons, the short duration and intermittent transmission of seismic airgun pulses, combined with a moving vessel, and implementation of mitigation measures to reduce exposure to high levels of seismic sound, reduce the likelihood that exposure to seismic sound would cause a behavioral response that may affect vital functions, or cause TTS or PTS.

For drilling operations, PSOs are required. However, the drilling unit does not have the ability to power- or shut-down if marine mammals enter this zone. While this will not mitigate the potential impacts associated with drilling noise, PSOs will keep track of the potential take (if any) that could occur. Considering that this will be a continuous source of underwater noise, it is not anticipated that marine mammals would enter into an area where they would suffer from acoustic harassment.

Although the oil and gas exploration activities are likely to cause some individual whales to experience changes in their behavioral states that might have adverse consequences (Frid and Dill. 2002), these responses are not likely to alter the physiology, behavioral ecology, and social dynamics of individual whales in ways or to a degree that would reduce their fitness because the whales are actively foraging in waters around the seismic or drilling operations or migrating through these operations.

As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual whales would not be likely to reduce the viability of the populations those individual whales represent (that is, we would not expect reductions in the reproduction, numbers, or distribution of such populations). For the same reasons, an action that is not likely to reduce the viability of those populations is not likely to increase the extinction probability of the species those populations comprise; in this case, the bowhead, fin, or humpback whale. As a result, the exploration activities BOEM and BSEE plan to authorize during the first incremental step on LS 193 in the Chukchi from June 2015 through June 2024 are not likely to appreciably reduce the bowhead, fin, or humpback whales' likelihood of surviving or recovering in the wild.

The strongest evidence supporting the conclusion that exploration activities will likely have minimal impact on bowhead, fin, and humpback whales is the estimated growth rate of the whale populations in the Arctic and sub-Arctic. The Western Arctic stock of bowhead whales has been increasing at approximately 3.2-3.4 percent per year (George et al. 2004b, Schweder and Sadykova. 2009). The maximum theoretical net productivity rate is 4% for the Western Arctic stock of bowhead (Wade and Angliss 1997). The time series of abundance estimates indicates an approximate 50% increase in total abundance of bowhead whales during the last ten years, and a doubling in abundance since the early 1990s (LGL Alaska Research Associates Inc. et al. 2014). The Northeast Pacific fin whale stock has been increasing at approximately 4% (Wade and Angliss 1997, Allen and Angliss 2014). Zerbini et al.(2006) estimated the rate of increase for fin whales in coastal waters south of the Alaska Peninsula to be around 4.8% (95% CI: 4.1-5.4%) for the period 1987-2003. While there is no accurate estimate of the maximum productivity rate for humpback whale WNP stock is assumed to be 7% (Wade and Angliss 1997, Allen and Angliss 2014). Recent passive acoustic detections (Delarue et al. 2010, Crance et al. 2011, Hannay et al. 2011, Delarue et al. 2013b) and direct observations from monitoring and research projects of fin and humpback whales from industry (Ireland et al. 2008, Hashagen et al. 2009, Ireland et al. 2009, Funk et al. 2010b, Aerts et al. 2012, Aerts et al. 2013a, Bisson et al. 2013, Funk et al. 2013, Hartin et al. 2013) and government (Clarke et al. 2011b, Clarke et al. 2013a, Clarke et al. 2013b) indicate that fin and humpback whales are considered to be in low densities, but regular visitors to the Alaska Chukchi Sea. Despite exposure to oil and gas exploration activities in the Beaufort and Chukchi Seas since the late 1960s (BOEM 2015a), a small number of humpback and fin whale entanglements in fishing gear, and a single subsistence take of one humpback whale in 2006, this increase in the number of listed whales suggests that the stress regime these whales are exposed to in the action area has not prevented them from increasing their numbers and humpback and fin whales expanding their range in the action area. Given the life history of bowhead whales and gestational constraints on minimum calving intervals (e.g., (Reese et al. 2001b), and assuming that adult survival rates based on aerial photo-ID data (Zeh et al. 2002, Schweder et al. 2010a) and age-at-maturity have remained stable, the trend in abundance implies that the population has been experiencing relatively high annual calf and juvenile survival rates. This is consistent with documented observations of native whalers around St. Lawrence Island, who have reported not only catching more pregnant females but also seeing more young whales than during earlier decades (Noongwook et al. 2007a). While the sample size was small, the pregnancy rate from the 2012 Alaskan harvest data indicate that 2013 calf production could be higher than average (George et al. 2004b, George et al. 2011, Suydam et al. 2013).

As discussed in the *Environmental Baseline* section of this opinion, bowhead, fin, and humpback whales have been exposed to active seismic and drilling activities in the Arctic, including vessel traffic, aircraft traffic, and seismic and drilling noise, for generations. Although we do not know if more bowhead, fin, or humpback whales might have used the action area or the reproductive success of bowhead, fin, or humpback whales in the Arctic would be higher absent their exposure to these activities, the rate at which these whales occur in the Arctic and sub-Arctic, and the increasing number of sightings of fin and humpback whales in the action area suggests that bowhead, fin, and humpback whale numbers have increased substantially in these important migration and feeding areas despite exposure to oil and gas exploration activities. BOEM and BSEE are not proposing to increase the frequency of these activities, and we do not believe the proposed activities are likely to affect the rate at which bowhead, fin, or humpback whale counts in the action area are increasing.

During future incremental steps, a low probability, high impact event involving an unauthorized large oil spill where large numbers of whales might experience prolonged exposure to toxic fumes, and/or ingest large amounts of oil, could result in injury and mortality that exceeds PBR (103 bowhead, 2.6 WNP humpback, and unknown for fin whale). The hypothetical exploration and development scenario estimates a 75% likelihood of 1-2 large oil spills if the assumed 4.3 Bbbl of oil were developed and produced between years 10-77 (BOEM 2015a). No VLOS is expected (the estimated probability is 10^{-4} – 10^{-5} per well; see BOEM 2012) based on historical occurrence, and differences in Arctic drilling conditions that make a catastrophic discharge even less likely than the DWH event. BOEM anticipates that the most likely outcome of LS 193 is zero production (BOEM 2015a). Based on these factors, the risk of significant long term exposures of whales to accidental discharges of oil is low. The other stressors associated with future incremental steps are anticipated to have similar effects to those discussed during the first incremental step. The effects of future incremental steps, including exploration, development, production, and decommissioning activities on LS 193 in the Chukchi Sea are not reasonably likely to jeopardize the continued existence or appreciably reduce the likelihood of recovery of bowhead, fin, or humpback whales.

A change in either bowhead whale calf production or survival rates (or age-at-sexual maturation) of young whales in the future could be indicative of a population level response to anthropogenic stressors, or alternatively, a signal of the seemingly inevitable event that this population approaches the carrying capacity of its environment (Eberhardt 1977). Since the late 1970s and the initiation of surveys for abundance, however, the estimates of population size do not indicate that either anthropogenic (e.g., offshore oil and gas activities, subsistence whaling catch quotas, etc.) or natural factors (e.g., prey availability) have resulted in any negative influence on the bowhead whale trend in abundance (LGL Alaska Research Associates Inc. et al. 2014).

8.2 Pinniped Risk Analysis (ringed seal and bearded seal)

Based on the results of the exposure analysis, during the first incremental step we expect ringed and bearded seals may be exposed to low-frequency seismic noise, ice breaking activities, drilling activities, and other noise sources associated with exploration drilling operations based on annual authorization scenarios provided by BOEM/BSEE. Exposure to vessel noise from transit, aircraft noise, construction noise from shore bases, noise from non-seismic geohazard surveys, seafloor disturbance, and small oil spills may occur but are considered insignificant and would not rise to the level of take. Exposure to vessel strike, marine debris, large and very large oil spills are considered extremely unlikely and therefore discountable (see Sections 6.1.3.2 through 6.1.3.4).

The effects to ringed and bearded seals associated with marine seismic, geohazard, geotechnical, pile driving, aircraft traffic, drilling operations, and small oil spills during future incremental steps (exploration, development, production, and decommissioning) are anticipated to be similar to those effects described for seals during the first incremental step, but with increased sound exposures and risk of spill due to increase seismic surveys, vessel and aircraft traffic, and drilling operations. However, ancillary activities are anticipated to be low energy and localized in areas near prospective drill sites (BOEM 2015a). Mitigation measures required for seismic and pile driving would further reduce the impacts to listed seals (BOEM 2015a). The risk of spill associated with large oil spills is anticipated to significantly increase during future incremental steps due to the increase of activities. BOEM estimates a 75% likelihood of one or more large spills between years 10-77 (assuming maximum production and development), but no VLOS is expected. A low probability, high impact circumstance where large numbers of ice seals experience prolonged exposure to toxic fumes, and/or ingest large amounts of oil, could result in injury and mortality of a substantial number of seals. However, due to the low likelihood of multiple large oil spills, and even lower predicated likelihood of a VLOS, the risk of significant long term exposures of seals to accidental discharges of oil is low. In addition, a number of regulatory changes have been put in place since Deepwater Horizon in an effort to reduce the risk of unauthorized discharges associated with oil and gas exploration and development activities.

The primary mechanism by which the behavioral changes we have discussed affect the fitness of individual animals is through the animal's energy budget, time budget, or both (the two are related because foraging requires time). Fall and early winter periods, prior to the occupation of breeding sites, are important in allowing female ringed seals to accumulate enough fat stores to support estrus and lactation (Kelly et al. 2010b). This fall and early winter time period overlaps with late season seismic and the end of the drilling season. However, the individual and cumulative energy costs of the behavioral responses we have discussed are not likely to reduce the energy budgets of ringed and bearded seals. As a result, the ringed and bearded seal's probable responses (i.e., tolerance, avoidance, short-term masking, and short-term vigilance behavior) to close approaches by seismic vessels and their probable exposure to seismic airgun pulses are not likely to reduce the fitness or current or expected future reproductive success or reduce the rates at which they grow, mature, or become reproductively active. Therefore, these exposures are not likely to reduce the abundance, reproduction rates, and growth rates (or increase variance in one or more of these rates) of the populations those individuals represent.

Based on the annual activity scenarios provided by BOEM/BSEE (BOEM 2015e) (see Table 17), NMFS estimated that maximum annual instances of exposure to ringed seals (154,736-183,290), and bearded seals (120,785-142,533) would result from Scenario 6: 2 Drilling operations and 4 VSP during the open-water season + 4,500 cui 2D survey and icebreaker during the in-ice season (see Table 21), at received levels sufficiently high (or distances sufficiently close) that might result in behavioral harassment (see Section 6.1.4, *Response Analysis*). No ringed or bearded seals are anticipated to be exposed to sound levels that could result in TTS or PTS.

In total, the proposed action is anticipated to result in 912,658-1,045,985 instances of exposure to ringed seals, and 726,374-832,013 instances of exposure to bearded seals at received sound levels ≥120 dB re 1 µPa rms for continuous noise sources, or ≥160 dB e 1 µPa rms for impulsive noise sources depending on the Rea or Rmax ensonified areas (see Table 26).

These estimates represent the total number of takes that could potentially occur, not necessarily the number of individuals taken, as a single individual may be "taken" multiple times over the course of the proposed action (first incremental step, years 1-9). These exposure estimates are likely to be overestimates because they assume a uniform distribution of animals, do not account for avoidance or mitigation measures, and assume all of the tracklines will be shot, and all wells drilled.

Exposure to vessel noise from transit, aircraft noise, construction noise from shore bases, noise from non-seismic geohazard surveys, seafloor disturbance, and small oil spill discharge may occur as part of the proposed action, but are considered insignificant and would not rise to the level of take. Exposure to vessel strike, marine debris, large and very large oil spills are considered extremely unlikely (see Sections 6.1.3.2 through 6.1.3.4).

Based on the localized nature of small oil spills, the relatively rapid weathering expected for <1,000 bbl of oil, the small number of refueling activities in the proposed action, and the safe guards in place to avoid and minimize oil spills, we conclude that the probability of a BOEM/BSEE authorized activity within the first incremental step causing a small oil spill and exposing ringed or bearded seals on LS 193 in the Chukchi Sea sufficiently small as to be considered discountable. If exposure were to occur, due to the ephemeral nature of small, refined oil spills, NMFS does not expect detectable responses from whales from small oil spills and we would consider exposure insignificant during the first incremental step of the proposed action.

For drilling operations, PSOs are required. However, the drilling unit does not have the ability to power- or shut-down if marine mammals enter this zone. While this will not mitigate the potential impacts associated with drilling noise, PSOs will keep track of the potential take (if any) that could occur. Considering that this will be a continuous source of underwater noise, it is not anticipated that marine mammals would enter into an area where they would suffer from acoustic harassment.

Although these oil and gas exploration activities are likely to cause some individual ringed and bearded seals to experience changes in their behavioral states that might have adverse consequences (Frid and Dill. 2002), these responses are not likely to alter the physiology, behavioral ecology, and social dynamics of individual ringed or bearded seals in ways or to a degree that would reduce their fitness because the seals are actively foraging in waters around the seismic and drilling operations, have their heads above water, or hauled out. While a single individual may be exposed multiple times over the course the proposed action, the short duration and intermittent transmission of seismic airgun pulses, combined with a moving vessel, and implementation of mitigation measures to reduce exposure to high levels of seismic sound, reduce the likelihood that exposure to seismic sound would cause a behavioral response that may affect vital functions, or cause TTS or PTS. In most circumstances, ringed and bearded seals are likely to avoid certain ensonified areas that may cause TTS. Ringed and bearded seals that avoid these sound fields or exhibit vigilance are not likely to experience significant disruptions of their normal behavior patterns because the vessels are transiting and the ensonified area is temporary, and ringed seals seem rather tolerant of low frequency noise. Drilling operations at Northstar facility during the open-water season resulted in brief, minor localized effects on ringed seals with no consequences to ice seal populations (Richardson and Williams 2004). Adult ringed seals seem to tolerate drilling activities. Brewer et al. (1993) noted ringed seals were the most common marine mammal sighted and did not seem to be disturbed by drilling operations at the Kuvlum #1 project in the Beaufort Sea. Southall et al. (2007) reviewed literature describing responses of pinnipeds to continuous sound and reported that the limited data suggest exposures between ~90 and 140 dB re 1 μPa generally do not appear to induce strong behavioral responses in pinnipeds exposed to continuous sounds in water.

As we discussed in the *Approach to the Assessment* section of this opinion, an action that is not likely to reduce the fitness of individual seals would not be likely to reduce the viability of the populations those individual seals represent (that is, we would not expect reductions in the reproduction, numbers, or distribution of such populations). For the same reasons, an action that is not likely to reduce the viability of those populations is not likely to increase the extinction probability of the species those populations comprise; in this case, the ringed and bearded seal. As a result, the exploration activities BOEM and BSEE plan to authorize during the first incremental step on LS 193 from June 2015 through June 2024 are not likely to appreciably reduce the ringed or bearded seals' likelihood of surviving or recovering in the wild.

During future incremental steps, a low probability, high impact circumstance where large numbers of seals experience prolonged exposure to toxic fumes, and/or ingest large amounts of oil, could result in injury and mortality that of a substantial number of individuals. However, due to the low likelihood of multiple large oil spills, and even lower predicated likelihood of a VLOS, the risk of significant long term exposures of seals to accidental discharges of oil is low. The other stressors associated with future incremental steps are anticipated to have similar effects to those discussed during the first incremental step. The effects of future incremental steps, including exploration, development, production, and decommissioning activities on LS 193 in the Chukchi Sea are not reasonably likely to jeopardize the continued existence or appreciably reduce the likelihood of recovery in ringed or bearded seals.

8.3 Proposed Ringed Seal Critical Habitat Risk Analysis

As described in the *Status of Proposed Critical Habitat* section (Section 4.4), proposed critical habitat for the Arctic subspecies of ringed seal includes three features essential to the conservation of the species: sea ice habitat suitable for the formation and maintenance of subnivean birth lairs; sea ice habitat suitable as a platform for basking and molting; and primary prey resources to support Arctic ringed seals. The primary threats that could affect the features identified as essential to conservation of the species include: greenhouse gas emissions; oil and gas exploration activities; shipping and transportation; and commercial fishing. Despite the overlap of these stressors in the action area, the preexisting stress regime for proposed ringed critical habitat in the area seems relatively low, and the overall functioning of essential habitat features in the action area appears to be high.

The proposed action may cause physical and acoustic effects which could alter the quality of the essential features of Arctic ringed seal critical habitat, or render it temporarily unsuitable.

While noise is not anticipated to directly affect the two sea ice related essential features of proposed critical habitat, noise could temporarily make the sea ice features (between June and July) near the seismic and drilling operations less suitable to ringed seals (BOEM 2015a). The noise effects could last as long as the operations are occurring (~30-120 days for seismic and drilling). Icebreakers are anticipated to create more noise than other vessels due to the sound associated with cracking ice, friction against the snow, and cavitation, and cause physical alteration of sea ice habitat (BOEM 2015a).

Icebreaking may be used for both exploratory drilling ice management, and in-ice seismic associated with the proposed action. However, only icebreaking during drilling operations (June-Nov) has the potential to temporally overlap with ringed seal use of birth lairs or molting platforms (March-July), and only by a few months. In addition, there is no anticipated overlap between ice breaking activities associated with the proposed action and the whelping or breeding seasons. It is also anticipated that ringed seal pups would be weaned by mid-June, prior to icebreaking activities commencing in late-June. In-ice seismic activity would occur October through December, which is outside of the timeframe for whelping, nursing, basking, and molting (BOEM 2015a).

Sea ice suitable for basking and molting platforms (used April-July) could be fractured by ice breaking activities. However, because ringed seals haul out on ice of many shapes and sizes, fractured ice would probably remain suitable as platforms (BOEM 2015a). The amount of basking and molting platform ice habitat that could be fractured due to a maximum of three icebreaking/ice management operations a year is anticipated to be insignificant in comparison to the total amount of habitat available. In addition, fractured ice can refreeze, meaning that habitat would only be impacted for a short amount of time.

We anticipate that anchor handling, dynamic positioning, icebreaking and ice management vessel operations will have minor effects on proposed ringed seal critical habitat. Vessel traffic, seismic, and drilling operations are anticipated to have negligible impact on the primary prey resource identified as an essential feature.

BOEM estimates a 75% likelihood of one or more large spills between years 10-77 (assuming maximum production and development), but no VLOS (BOEM 2015a). If a large spill were to occur it could significantly impact proposed ringed seal critical habitat at any time of the year, either (or both) by contaminating/destroying ice characteristics that are essential features of the habitat, or by contaminating/destroying food resources, another essential feature. However, a large oil spill would still be localized to a portion of the overall habitat. One large oil spill will not likely adversely modify proposed ringed seal critical habitat due to the relatively small proportion of the habitat that would be impacted, and the temporary nature of oil in water or ice.

Should a large or very large oil spill occur, oil contact could modify all three essential features of proposed ringed seal critical habitat, rendering them unsuitable or detrimental for use until cleanup or weathering could occur. Depending on the size and scale of the spill, it could require multiple seasons to return the essential features to their original quality given the capacity of ice to lock and release ice with freeze and thaw cycles. Areas within the pathway of the spill would be most impaired while areas outside of the pathway would be affected less. The essential feature of primary prey resources would likely take longer to recover from a large or very large spill than the two sea ice essential features, due to potential effects on prey populations and reproduction (BOEM 2015a).

A very large oil spill in the Chukchi Sea has the potential to adversely modify proposed ringed seal critical habitat. A VLOS could affect an area extending across a major portion of the Chukchi Sea and into the Beaufort Sea. A VLOS is not expected to extend south into proposed ringed seal critical habitat in the Bering Sea (BOEM 2015a). The impacts to the proposed ringed seal critical habitat in the Chukchi and Beaufort Seas could be at a level that destroys the value of the habitat for multiple years to a degree that a significant proportion of the stock is not able to successfully reproduce or survive, risking the recovery or stability of the subspecies. However, BOEM estimates that the chance of a VLOS occurrence is extremely low in the Arctic due to a number of factors, including historical occurrence, and differences in Arctic drilling conditions that make a catastrophic discharge even less likely than the Deepwater Horizon event (BOEM 2012, 2015a). Based on likelihood, NMFS concludes that predicted oil spills resulting from the proposed action may adversely affect proposed ringed seal critical habitat in the first incremental step, but has the potential to cause more serious adverse effect to proposed ringed seal critical habitat in future incremental steps. However, due to their low predicted likelihood, oil spills resulting from future incremental steps are not likely to adversely modify proposed ringed seal critical habitat.

Based on our analyses of the evidence available, the quantity or availability of the essential features of critical habitat are not likely to decline as a result of being exposed to oil and gas exploration activities during the first incremental step, or activities associated with future incremental steps. Disturbance consisting of both physical and acoustic effects could temporarily alter the quality of the essential features of Arctic ringed seal critical habitat. However, due to the low number of vessels being authorized, the limited use of ice breakers, the limited overlap with ice habitat, the low probability of spill, the size and quality of the remaining habitat, the high tolerance of ice seals to drilling and seismic operations, the minor impact to prey resources, and the application of standard mitigation measures to avoid adverse impacts, we conclude that the proposed action is not likely to destroy or adversely modify the proposed critical habitat for the Arctic subspecies of ringed seal.

9. Conclusion

After reviewing the current status of the listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS's biological opinion that the proposed action is not likely to jeopardize the continued existence of the endangered bowhead whale (*Balaena mysticetus*), endangered fin whale (*Balaenoptera physalus*), endangered humpback whale (*Megaptera novaeangliae*), threatened Arctic subspecies of ringed seal (*Phoca hispida hispida*), or the Beringia DPS of bearded seal (*Erignathus barbatus nauticus*), or destroy or adversely modify the Arctic subspecies of ringed seal's proposed critical habitat.

In addition, the proposed action is not likely to adversely affect the endangered North Pacific right whale (*Eubalaena japonica*), the endangered Western DPS of gray whale (*Eschrichtius robustus*), the endangered sperm whale (*Physeter macroephalus*), the endangered Western DPS of Steller sea lion (*Eumetopias jubatus*), or their designated critical habitats.

10. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA prohibits the "take" of endangered species without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. The ESA, however, does not define harassment. Under the MMPA, there is a definition of what is referred to as Level B harassment: "any act of pursuit, torment, or annoyance which . . . has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" 16 U.S.C. §1362(18)(A)(ii).

In this opinion and incidental take statement we have considered the stressors associated with the proposed oil and gas exploration activities occurring during years the first incremental step of activities associated with LS 193 (years 1-9), including potential exposures of listed species to certain sound sources and the effects these sources may have (see Table 26). We are not authorizing take for future incremental steps, as they would require additional consultation.

For any given exposure, it is impossible to predict the exact impact to the individual marine mammal(s) because an individual's reaction depends on a variety of factors (the individual's sex, reproductive status, age, activity engaged in at the time, etc.). Therefore, we estimate potential instances of exposure and assume these exposures constitute takes. We find this approach conservative for evaluating jeopardy under the ESA since the exposure estimates are likely over-estimates, and since an instance of exposure may not actually result in any measurable or adverse effect. Notwithstanding that fact, the exposure estimates reflect the best scientific and commercial data available.

Under the terms of section 7(b)(4) and section 7(o)(2) of the ESA, taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA, provided that such taking is in compliance with the terms and conditions of an Incidental Take Statement (ITS).

Section 7(b)(4)(C) of the ESA provides that if an endangered or threatened marine mammal is involved, the taking must first be authorized by section 101(a)(5) of the MMPA. Accordingly, **the terms of this incidental take statement and the exemption from Section 9 of the ESA (which does not apply to threatened ringed seals or bearded seals) become effective only upon the issuance of MMPA authorization to take the marine mammals identified here**. The permittee or lessee will need MMPA authorization each year for this take statement to become effective. Absent such authorization, this statement is inoperative.

Prior to the occurrence of any take, BOEM's permittees and lessees will need to request authorization under the MMPA for incidental take of small numbers of marine mammals from the National Marine Fisheries Service's Permits Division (PR1). These authorizations are either in the form of a Letter of Authorization (LOA) or an Incidental Harassment Authorization

(IHA).[36] The issuance of an LOA or IHA constitutes an action for the purposes of section 7(a)(2) of the ESA; therefore, NMFS may complete separate section 7 consultations on the issuance of those LOAs or IHAs. NMFS will compare the effects of project-specific actions and associated take levels to the effects and take levels that were anticipated under this overarching LS 193 opinion. If the amount or extent of incidental take that is proposed to be authorized through individual LOAs or IHAs exceeds the levels estimated and analyzed here for any given year, or if the project-specific effects on the listed species or designated critical habitat will occur in a manner or to an extent not considered in this opinion, reinitiation of consultation on the LS 193 opinion will be required.

The terms and conditions described below are nondiscretionary. BOEM and BSEE have a continuing duty to regulate the activities covered by this incidental take statement. In order to monitor the impact of incidental take, BOEM and BSEE must monitor the progress of the action and its impact on the species as specified in the incidental take statement (50 CFR 402.14(i)(3)). If BOEM and BSEE (1) fail to require their permittees and lessees to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to the permit or grant document, and/or (2) fail to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

10.1 Amount or Extent of Take

The section 7 regulations require NMFS to estimate the number of individuals that may be taken by proposed actions or the extent of land or marine area that may be affected by an action, if we cannot assign numerical limits for animals that could be incidentally taken during the course of an action (50 CFR § 402.14 (i); see also 51 FR 19926, 19953-54 (June 3, 1986)). This biological opinion analyzes and this incidental take statement covers the take associated with BOEM and BSEE's authorization of on-lease oil and gas exploration activities (seismic, geohazard, and geotechnical surveys, and exploratory drilling) associated with the 460 active leases issued through LS 193 in the Chukchi Sea between June 2015 and June 2024.

As discussed in the *Approach to the Assessment* section of this opinion, we used the best scientific and commercial information available to determine whether and how listed individuals in the exposed populations might respond given their exposure to the proposed action. To estimate the number of animals that might be "taken" in this opinion, we classified the suite of responses as one or more forms of "take" and estimated the number of animals that might be "taken" by (1) reviewing the best scientific and commercial information available to determine the likely suite of responses given exposure of listed marine mammals to the proposed action at various received levels; (2) classifying particular responses as one or more form of "take;" and (3) adding the number of exposure events that could produce responses that we would consider "take." These estimates include whales and pinnipeds that are likely to be exposed and respond to low-frequency seismic airgun pulses, vessel noise, and drilling operations at received levels sufficiently high (or distances sufficiently close) that are likely to result in behavioral changes that we would classify as "harassment."

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[36] The activities included in the proposed action and this consultation involve only takes by harassment. Commonly, these takes are authorized through the IHAs. It is also possilbe that an applicant will seek incidental take regulations, after which specific takes would be authorized through LOAs. Regardless, those LOAs could cover only takes by harassment.

No mortalities are anticipated during the first incremental step. The results of our estimates are presented in Table 26.

For bowhead, fin, and humpback whales and ringed and bearded seals, based on the best scientific and commercial information available, we would not anticipate responses to impulsive seismic noise at received levels between 120-159 dB re 1 μPa rms would rise to the level of "take" as defined under the ESA. For this reason, the total instances of harassment for baleen whales and pinnipeds only considered exposures at received levels ≥ 160 dB e 1 μPa rms. For continuous noise sources, we only considered exposures at received levels ≥120 dB re 1 μPa rms.

Based on the annual activity scenarios provided by BOEM/BSEE (BOEM 2015e) (see Table 17), NMFS estimated a range of annual instances of exposure to bowhead whales depending on Rea and Rmax ensonified areas (Table 26).

For purposes of this opinion, the endangered bowhead, fin and humpback whale are the only species for which the section 9 take prohibition applies. This incidental take statement, however, includes limits on taking of ringed and bearded seals since those numbers were analyzed in the jeopardy analysis and to provide guidance to the action agency on its requirement to re-initiate consultation if the take limit for any species covered by this opinion is exceeded.

Table 26. **Summary of potential instances of exposure of listed marine mammals to received sound levels ≥120 dB re 1 µPa (rms) for continuous noise or ≥160 dB re 1 µPa (rms) for impulsive noise associated with BOEM/BSEE oil and gas exploration authorizations under the first incremental step. The range of exposures represents the Rea vs. Rmax ensonified areas. Take estimates incorporate turnover rate assumptions for bowhead whale and ringed seal (the only species for which sufficient information was available).**

Species	Instances of Exposure/Year/ Activity Scenario to Cont. Sounds ≥120 dB or Impulsive Sounds 160 dB re 1 µPa rms		Anticipated Temporal Extent of Take
	Annual Rea-Rmax	Full Scenario Rea-Rmax	
Annual Scenario 1 – Impulsive Noise Sources (3D + Geohazard Site)			
Bowhead Whale	12-14	12-14	**June 1, 2015 Through June 1, 2024**
Fin Whale	0	0	
Humpback Whale	0	0	
Ringed Seal	1,559-1,720	1,559-1,720	
Bearded Seal	1,245-1,431	1,245-1,431	
Annual Scenario 2 - Impulsive Noise Sources (Geohazard Site)			
Bowhead Whale	2	2	
Fin Whale	0	0	
Humpback Whale	0	0	
Ringed Seal	248-266	248-266	
Bearded Seal	198-213	198-213	
Triannual Scenario 3 -Continuous and Impulsive Noise Sources (2 Drilling Rigs + 4 VSP)			
Bowhead Whale	930-1,054	2,790-3,162	
Fin Whale	16-18	48-54	

Humpback Whale	16-18	48-54
Ringed Seal	125,356-142,729	376,067-428,186
Bearded Seal	100,161-114,062	300,483-342,186
Annual Scenario 4 - Continuous and Impulsive Noise Sources (Geohazard Pipeline + 2 Drilling Rigs + 4 VSP)		
Bowhead Whale	956-1,082	956-1,082
Fin Whale	17-19	17-19
Humpback Whale	17-19	17-19
Ringed Seal	128,841-146,534	128,841-146,534
Bearded Seal	102,945-117,102	102,945-117,102
Biannual Scenario 5 - Continuous and Impulsive Noise Sources (Geohazard Site + 2 Drilling Rigs + 4 VSP)		
Bowhead Whale	932-1,056	1,864-2,111
Fin Whale	16-18	32-36
Humpback Whale	16-18	32-36
Ringed Seal	125,604-142,995	251,207-285,989
Bearded Seal	100,359-114,274	200,718-228,548
Scenario 6 - Continuous and Impulsive Noise Sources (2D + Icebreaker+2 Drilling Rigs + 4 VSP)		
Bowhead Whale	1,220-2,063	1,220-2,063
Fin Whale	20-24	20-24
Humpback Whale	20-24	20-24
Ringed Seal	154,736-183,290	154,736-183,290
Bearded Seal	120,785-142,533	120,785-142,533

Total Instances of Exposure for Duration of Proposed Action (9yrs) for Combined Scenarios to Cont. Sounds ≥120 dB or Impulsive Sounds ≥160 dB re 1 μPa rms		
	Rea	**Rmax**
Bowhead Whale	**6,844**	**8,434**
Fin Whale	**117**	**133**
Humpback Whale	**117**	**133**
Ringed Seal	**912,658**	**1,045,985**
Bearded Seal	**726,374**	**832,013**

The instances of harassment identified in Table 26 would generally represent changes from foraging, resting, milling, and other behavioral states that require lower energy expenditures shifting to traveling, avoidance, and behavioral states that require higher energy expenditures and, therefore, would represent disruptions of the normal behavioral patterns of the animals that have been exposed. We assume animals would respond to a suite of environmental cues that include sound fields produced by seismic airguns, sounds produced during drilling operations, sounds produced by the engines of icebreaking and ice management vessels, and other sounds associated with the proposed activities.

10.2 Effect of the Take

Studies of marine mammals and responses to seismic transmissions and drilling operations have shown that bowhead, fin, and humpback whales, as well as ringed and bearded seals are likely to respond behaviorally upon hearing low-frequency seismic transmissions and drilling noise. The only takes authorized during the first incremental step are takes by acoustic harassment. No serious injury or mortalities are anticipated or authorized as part of this proposed action. Although the biological significance of those behavioral responses remains unknown, this consultation has assumed that exposure to major noise sources might disrupt one or more behavioral patterns that are essential to an individual animal’s life history. However, any behavioral responses of these whales and pinnipeds to major noise sources and any associated disruptions are not expected to affect the reproduction, survival, or recovery of these species.

10.3 Reasonable and Prudent Measures (RPMs)

“Reasonable and prudent measures” are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02).

The RPMs included below, along with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action.

NMFS concludes that the following RPMs are necessary and appropriate to minimize or to monitor the incidental take of bowhead, fin, and humpback whales and ringed and bearded seals resulting from the proposed action.

1. This ITS is valid only for the activities described in this biological opinion, and which have been authorized under section 101(a)(5) of the MMPA.

2. The taking of bowhead whales, fin whales, humpback whales, ringed seals, and bearded seals shall be by incidental harassment only. The taking of endangered whales by serious injury or death is prohibited under the ESA, and such taking of endangered whales or threatened seals may result in the modification, suspension or revocation of the ITS.

3. BOEM/BSEE must implement measures to reduce the probability of exposing bowhead whales, humpback whales, fin whales, ringed seals, and bearded seals to seismic transmissions and drilling operations that will occur during the proposed activities.

4. BOEM/BSEE must implement a monitoring program that allows NMFS AKR to evaluate the take estimates contained in this biological opinion and that underlie this incidental take statement.

5. BOEM/BSEE must submit reports to NMFS AKR that evaluate its mitigation measures and the results of its annual monitoring program.

6. BOEM/BSEE must identify which programmatic consultation (LS 193 Biological Opinion or Arctic Regional Biological Opinion) authorized oil and gas exploration activities in the Chukchi Sea fall under for the purposes of tracking take.

10.4 Terms and Conditions

"Terms and conditions" implement the reasonable and prudent measures (50 CFR 402.14). These must be carried out for the exemption in section 7(o)(2) to apply.

In order to be exempt from the prohibitions of section 9 of the ESA, BOEM/BSEE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and the mitigation measures set forth in Sections 2.1.5 and 2.1.6 of this opinion.

Partial compliance with these terms and conditions may result in more take than anticipated, and may invalidate this take exemption. These terms and conditions constitute no more than a minor change to the proposed action because they are consistent with the basic design of the proposed action.

To carry out RPM #1, BOEM and BSEE or their lessees or permittees must undertake the following:

A. BOEM and BSEE shall require all parties requesting on-lease geophysical and geological permits, ancillary notices, or application for permit to drill authorized by BOEM/BSEE under the provisions of the OCSLA, that involve the take of threatened or endangered marine mammals, to apply for and receive the appropriate authorizations under section 101(a)(5) of the MMPA.

B. At all times when conducting seismic- or drilling-related activities, BOEM/BSEE shall require their authorized operators to possess on board the seismic source vessel or drilling vessel a current and valid Incidental Harassment Authorization issued by NMFS under section 101(a)(5) of the MMPA. Any take must be authorized by a valid, current, IHA issued by NMFS under section 101(a)(5) of the MMPA, and such take must occur in compliance with all terms, conditions, and requirements included in such authorizations.

To carry out RPM #2, BOEM and BSEE or their lessees or permittees must undertake the following:

A. The taking of any marine mammal in a manner other than that described in this ITS must be reported within 24 hours to NMFS AKR, Protected Resources Division at 907-586-7638.

B. In the event that the proposed action causes a take of a marine mammal that results in a serious injury or mortality (e.g. ship-strike, stranding, and/or entanglement), lessees or permittees shall immediately cease operations and immediately report the incident to NMFS AKR, Protected Resources Division at 907-586-7638 and/or by email to Jon.Kurland@noaa.gov, Alicia.Bishop@noaa.gov, the Alaska Regional Stranding Coordinator at 907-586-7248 (Aleria.Jensen@noaa.gov), and PR1 Shane Guan 301-427-8418 for any MMPA authorization issues. The report must include the following information: (i) Time, date, and location (latitude/longitude) of the incident; (ii) the name and type of vessel involved; (iii) the vessel's speed during and leading up to the incident; (iv) description of the incident; (v) status of all sound source use in the 24 hours preceding the incident; (vi) water depth; (vii) environmental conditions (*e.g.*, wind speed and direction, Beaufort sea state, cloud cover, and visibility); (viii) description of marine mammal observations in the 24 hours preceding the incident; (ix) species identification or description of the animal(s) involved; (x) the fate of the animal(s); (xi) and photographs or video footage of the animal (if equipment is available).

Activities shall not resume until NMFS is able to review the circumstances of the prohibited take. NMFS shall work with the lessee/permittee to determine what is necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. The lessee/permittee may not resume their activities until notified by NMFS via letter, email, or telephone.

C. In the event that an oiled marine mammal is spotted, the lessees or permittees shall report the incident within 24 hours to NMFS AKR, Protected Resources Division at 907-586-7638 and/or by email to Jon.Kurland@noaa.gov, Alicia.Bishop@noaa.gov, the Alaska Regional Stranding Coordinator at 907-586-7248 (Aleria.Jensen@noaa.gov), and PR1 Shane Guan 301-427-8418 for any MMPA authorization issues.

To carry out RPM #3, BOEM and BSEE or their lessees or permittees must undertake the following:

A. All mitigation measures as outlined in Section 2.1.5 and 2.1.6 of this biological opinion, or better or equivalent measures, must be implemented, based on the type of activity to which they apply (e.g., mitigation measures for seismic surveys do not apply to drilling projects).

B. Require sound source verification (SSV) tests for sound sources and vessels at the start of the season when an operation is occurring in an area that has not previously had SSV, or is using a new technology or new sized airgun array that has not previously had on-site SSV. Before conducting BOEM/BSEE authorized activities, the operators shall conduct SSV tests to verify the radii of the exclusion and monitoring zones within real-time conditions in the field, thus providing for more accurate radii to be used. When moving an operation into a new area (i.e. moved activities to a location where they have not yet measured those sound sources if that new location has different depth, bathymetry, or other characteristics from the previously measured location), the operator shall re-verify the new radii of the exclusion zones. The purpose of this testing is to establish and monitor more accurate safety zones based on empirical measurements, as compared to the zones based on modeling and extrapolation from different datasets. Using a hydrophone system, the vessel operator will be required to conduct SSV tests for all airgun arrays and vessels and, at a minimum, report the following results to NMFS within 5 days of completing the test:

   1. The empirical distances from the airgun array and other acoustic sources to broadband received levels of 190 dB down to 120 dB in 10 dB increments and the radiated sounds versus distance from the source vessel.

   2. Measurements made at the beginning of the survey for locations not previously modeled in the Chukchi Sea.

C. Require operators to calibrate their airgun array before beginning a survey in order to minimize horizontal propagation of the noise signal.

D. Ensure the 180 and 190 dB exclusion radii around operating airguns are fully observed by trained PSOs during daylight hours.

E. Design all mitigation and monitoring plans, and oil spill response plans in consultation with NMFS to protect bowhead, fin, and humpback whales, and ringed and bearded seals and be consistent with NMFS's terms and conditions.

To carry out RPM #4, BOEM and BSEE or their lessees or permittees must undertake the following:

A. BOEM/BSEE shall require all protected species observers to complete a protected species observer training course that includes the requirements described in NOAA Fisheries Service 2013 National Standards for a Protected Species Observer and Data Management Program: A model for Seismic Surveys (Baker et al. 2013). Operators may utilize observers trained by third parties based on the requirements below. All protected species observer training programs must:

   1. Furnish BOEM/BSEE a course information packet that includes the name and qualifications (i.e., experience, training completed, or educational background) of the instructor(s), the course outline or syllabus, and course reference material;

2. Furnish each trainee with a document stating successful completion of the course; and
3. Provide BOEM/BSEE with names, affiliations, course completion dates for trainees. The training course must include the following topics:
    - a. Brief overview of the MMPA and the ESA as they relate to seismic acquisition, drilling operations, and protection of marine mammals in the Arctic.
    - b. Brief overview of seismic acquisition and drilling operations.
    - c. Overview of seismic and drilling mitigation measures and the protected species observer program.
    - d. Discussion of the role and responsibilities of the protected species observer, including:
        - i. Legal requirements (why you are here and what you do);
        - ii. Professional behavior (code of conduct);
        - iii. Integrity;
        - iv. Authority of protected species observer to call for shutdown of seismic acquisition operations;
        - v. Assigned duties;
        - vi. What can be asked of the observer;
            1. What cannot be asked of the observer; and
            2. Reporting of violations and coercion;
            3. Identification of marine mammals;
            4. Cues and search methods for locating marine mammals; and,
            5. Distance determination techniques and training.
        - vii. Data collection and reporting requirements;
            1. Forms and reports to BSEE via email on the 1st and 15th of each month; and
            2. Marine mammal(s) in exclusion zone/shutdown report within 24hrs.

To carry out RPM #5, BOEM and BSEE or their lessees or permittees must undertake the following:

A. In the event that an operator reaches 75% of the annual take authorized for their specific activity as described in the ITS (e.g., Scenario 3: 791 instances of exposure to bowhead whales, 14 instances of exposure to fin whale, 14 instances of exposure to humpback whale, 107,047 instances of exposure to ringed seals, and/or 85,547 instances of exposure to bearded seals), immediately report the incident to the Assistant Regional Administrator, Protected Resources Division, NMFS, Juneau office at 907-586-7638, and/or by email to Jon.Kurland@noaa.gov, Alicia.Bishop@noaa.gov, and PR1 Shane Guan 301-427-8429. NMFS AKR will work with BOEM/BSEE and the permittee/lessee to determine what is necessary to minimize the likelihood of further take, and determine if reinitiation of consultation is necessary.

B. BSEE in consultation with BOEM shall prepare a joint annual evaluation (based on data gathered during all of the authorized exploration activities) summarizing annual takes of listed marine mammals compared to those authorized under the programmatic LS 193 opinion. This evaluation must include the effectiveness of mitigation measures designed to avoid exposing listed marine mammals to low-frequency seismic and drilling operations that occurred that year to Protected Resources Division, NMFS, Juneau, AK. This evaluation must identify the specific observations that support the conclusions BOEM/BSEE reach about the effectiveness of the mitigation. This evaluation will be submitted by May of the following year covering activities that have occurred through the previous December. This report must contain the following information:

1. An estimate of the annual number (by species) of NMFS's ESA-listed marine mammals that: (A) are known to have been exposed to the impulsive noise sources (based on visual observation) at received levels greater than or equal to 160 dB re 1µPa (rms), 170 dB re 1 µPa (rms), 180 dB re 1 µPa (rms) and 190 dB re 1 µPa (rms) for cetaceans and pinnipeds with a discussion of any specific behaviors those individuals exhibited; (B) may have been exposed to the impulsive noise sources at received levels between 160 dB re 1 µPa (rms) and ≥190 dB µPa (rms) for all listed marine mammals with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed; (C) are known to have been exposed to the continuous noise sources (based on visual observation) at received levels greater than or equal to 120 dB re 1µPa (rms), 130 dB re 1 µPa (rms), 140 dB re 1 µPa (rms), 150 dB re 1 µPa (rms), and ≥160 dB re 1 µPa (rms) for cetaceans and pinnipeds with a discussion of any specific behaviors those individuals exhibited; and (D) may have been exposed to the continuous noise sources at received levels between 120 dB re 1 µPa (rms) and ≥160 dB µPa (rms) for all listed marine mammals with a discussion of the nature of the probable consequences of that exposure on the individuals that have been exposed.
2. A description of the implementation and effectiveness of the terms and conditions of the biological opinion's Incidental Take Statement (ITS). The report shall confirm the implementation of each Term and Condition, as well as any conservation recommendations, and describe the effectiveness, for minimizing the adverse effects of the action on ESA-listed marine mammals.
3. The draft report should clearly compare the anticipated annual takes (i.e. number of exposures) authorized under the specified annual scenario in the ITS with those recorded during annual oil and gas authorized operations ("take" being defined as an ESA-listed marine mammal exposed to impulsive noise at received levels ≥ 160 dB re 1 µPa (rms), or exposed to continuous noise at received levels ≥ 160 dB re 1 µPa (rms)).
4. The draft report will be subject to review and comment by NMFS AKR. Any recommendations made by NMFS AKR must be addressed in the final report prior to acceptance by NMFS AKR. The draft report will be considered final for the activities described in this opinion if NMFS AKR has not provided comments and recommendations within 90 days of receipt of the draft report.

C. Prepare a joint BOEM/BSEE comprehensive monitoring report (based on data gathered during the full 9 years of authorized activities comprising the first incremental step) summarizing annual takes of listed marine mammals compared to those authorized under the programmatic LS 193 opinion. Within five months of the completion of the proposed action (~November 2024), submit a draft comprehensive monitoring report that analyzes, compares, and summarizes the oil and gas exploration activities that were authorized, and the listed marine mammal take estimates gathered (through the effective period of this opinion) from the PSOs and pursuant to the implementation of the monitoring plans for the LS 193 on-lease area. This report will be provided in future consultation requests.

11. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

1. BOEM/BSEE should implement the following measures to help standardize the Protected Species Observer Program (Baker et al. 2013):
    - Implement standardization for data collection methods, electronic forms, and software used in collaboration with NMFS and non-federal stakeholders;
    - Develop permits or agreements detailing expectations and data collection and reporting of third-party PSO provider companies, including performance standards, conflicts of interest, and standards of conduct;
    - Implement quality assurance standards and manage PSO data for annual data analysis;
    - Establish a process to advertise for and approve PSO procedures;
    - Hold a stakeholder workshop to discuss new PSO procedures;
    - Develop a mechanism, procedure, or regulation to ensure that selected PSO providers are being compensated prior to deployment of approved observers;
    - Develop a debriefing and evaluation system for observers.

2. Upon the approval of an applicant's Oil Spill Response Plan, BOEM/BSEE should require all lessees and permittees to implement the following Marine Mammal Oil Spill Preparedness and Response Structure to enable efficient and effective response in the event of an oil spill:

    A. Preparedness and Response Standards and Thresholds:
    - Samples: Be prepared for sampling of 50 dead pinnipeds the first week. After the first week, the Responsible Party (RP) will fund the storage of carcasses and transport to approved facilities for analysis. Sampling must be performed by a NMFS approved entity.
    - Necropsy: Be prepared to necropsy 50 dead pinnipeds and/or cetaceans. Necropsies must be performed and samples stored by a NMFS approved entity. If mortalities exceed the prescribed threshold of 50 animals, the RP has the responsibility to fund the storage of carcasses and fund transport to approved facilities for analysis.
    - Sample storage: Maintain level of readiness to store 1,000 marine mammal samples, which likely includes multiple samples from individual animals, and therefore, does not represent 1,000 animals. Samples must be stored by a NMFS approved entity.

- Cleaning/rehabilitation threshold
  - The following thresholds apply for live moribund animals whose condition can withstand transport.
    - Pinnipeds: The RP should maintain a level of readiness for 25 live pinnipeds to be cleaned.
      - Approved cleaning protocols and practices by species can be found in the Wildlife Protection Guidelines in the Alaska Subarea Contingency Plans and NMFS National Marine Mammal Oil Spill Guidelines.
      - All cleaned pinnipeds must be tagged prior to release to monitor its survivorship.

B. Readiness Time Horizon:

- Maintain readiness for additional sampling, necropsies, sample storage, and cleaning/rehabilitation for up to one year post-spill.
- OSROs and their contractors should be prepared to respond to NMFS trust species in the event that visibly oiled marine mammals are discovered (external or internal upon necropsy) after the official closure of the event.

3. Request operators to use real-time passive acoustic monitoring while in migratory corridors, critical habitat, and other sensitive areas to alert ships to the presence of marine mammals, primarily to reduce the ship strike risk.

4. Under the BOEM Environmental Studies Program, consider studies specifically designed to assess abundance, population trends, habitat use during open-water and in-ice seasons, and productivity of ringed and bearded seal populations that may be affected by oil and gas development;

5. Work with NMFS and other species experts to develop strategies that could be implemented to prevent oil contacting listed species in the event of a large marine spill;

6. BOEM/BSEE should work with NMFS and other relevant stakeholders (the Marine Mammal Commission, International Whaling Commission, and the marine mammal research community) to develop a method for assessing the cumulative impacts of anthropogenic noise on marine mammals. This analysis includes the cumulative impacts on the distribution, abundance, and the physiological, behavioral and social ecology of these species;

In order to keep NMFS Protected Resources Division informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, BOEM/BSEE should notify NMFS of any conservation recommendations they implement in their final action.

12. REINITIATION OF CONSULTATION

As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded, (2) new information reveals effects of the agency action on listed species or designated critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, section 7 consultation must be reinitiated immediately.

13. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

Section 515 of the Treasury and General Government Appropriations Act of 2001 (Public Law 106-554) (Data Quality Act (DQA)) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

13.1 Utility

This document records the results of an interagency consultation. The information presented in this document is useful to three agencies of the Federal government (NMFS, BOEM, and BSEE), and the general public. These consultations help to fulfill multiple legal obligations of the named agencies. The information is also useful and of interest to the general public as it describes the manner in which public trust resources are being managed and conserved. The information presented in these documents and used in the underlying consultations represents the best available scientific and commercial information and has been improved through interaction with the consulting agency.

This consultation will be posted on the NMFS Alaska Region website http://alaskafisheries.noaa.gov/protectedresources/). The format and name adhere to conventional standards for style.

13.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

13.3 Objectivity

Information Product Category: Natural Resource Plan.

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the ESA Consultation Handbook, ESA Regulations, 50 CFR 402.01 et seq.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the literature cited section. The analyses in this opinion contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA implementation, and reviewed in accordance with Alaska Region ESA quality control and assurance processes.

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APPENDIX A

LS 193 Acoustic Propagation Modeling Report

Chukchi Sea Analysis and Acoustic Propagation Modeling

Task 3 Deliverable

Submitted to:

Michael Williams,
National Marine Fisheries Service
Contract: AB-133F-15-CQ-0017 / DO# 03

19 May 2015

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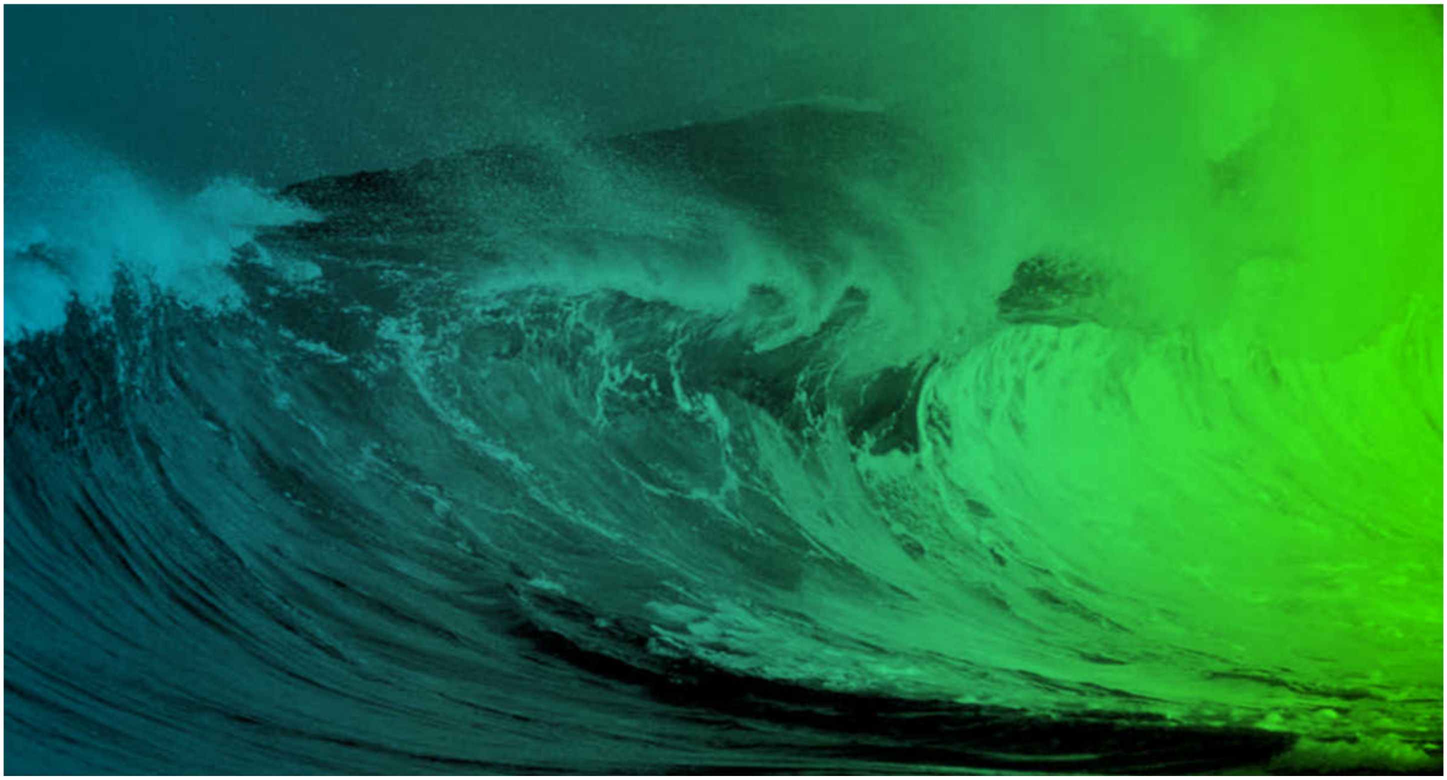

Suggested citation:

Austin, M. C. O'Neill, G. Warner, J. Wladichuk, M. Wood, and A. Allen. 2015. Chukchi Sea Analysis and Acoustic Propagation Modeling: Task 3 Deliverable. JASCO Document #01003. Technical report by JASCO Applied Sciences for Michael Williams, National Marine Fisheries Service

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URS Corporation joined AECOM on October 17, 2014. We are combining our operations and leadership to offer a wider range of services, with more technical experts, to our customers. Together AECOM and URS offer 100,000 employees, including nearly 350 in Alaska. Although the existing NMFS contract is with URS Group, Inc., we will be using AECOM branding for our deliverables, in support of this acquisition.

Contents

Figures

Tables

List of Abbreviations

Abbreviation	What it stands for
AK	Alaska
BOEM	Bureau of Ocean Energy Management
CSESP	Chukchi Sea Environmental Studies Program
CTD	conductivity temperature depth
dB	decibel
DP	dynamic positioning
FWRAM	Full Waveform Range-dependent Acoustic Model
GI	generator-injector
GINA	Geographic Information Network of Alaska
GIS	Geographic Information System
Hz	hertz
kHz	kilohertz
MONM	Marine Operations Noise Model
NMFS	U.S. National Marine Fisheries Service
PC	principal component
PCA	principal component analysis
RAM	Range-dependent Acoustic Model
RL	received level
rms	root-mean-square
SEL	sound exposure level
SL	source level (received level measured or estimated 1 m from the source)
SPL	sound pressure level
SSP	sound speed profile
SSV	sound source verification
TL	transmission loss
UTM	Universal Transverse Mercator geographic coordinate system
WHOI	Woods Hole Oceanographic Institute
ZVSP	Zero-offset Vertical Seismic Profiling

1. Introduction

The National Marine Fisheries Service (NMFS) contracted AECOM/URS Group, Inc. (AECOM) to perform acoustic modeling and analysis of noise from oil and gas exploration activities in the Chukchi Sea. AECOM subcontracted JASCO Applied Sciences Ltd. to perform this task based on their expertise in acoustic modeling and analysis. The purpose of this analysis is to estimate the zones of acoustic influence for endangered and threatened marine mammals. This report provides estimated distances to broadband received sound pressure level (SPL) thresholds from major noise sources—marine geophysical and geohazard surveys, vessel operations, and drilling—for activities the Bureau of Ocean Energy Management (BOEM) is assessing for Lease Sale 193 in the Chukchi Sea Planning Area.

To provide NMFS with a programmatic view of the zones of potential acoustic influence, JASCO modeled and analyzed a range of environmental parameters and then assessed their effects on the distances over which sound propagates. Generic activity scenarios were defined and variability of the modeled sound propagation distances for each was considered in relation to the range of environmental conditions present over the Lease Sale 193 area. Each modeled activity scenario was simulated at four locations that span the range of water depths in the Lease Sale 193 lease block areas to account for the influence of water depth on sound propagation. The modeling analysis also considered a range of water column and seafloor conditions insofar as they related to sound propagation. Average conditions were modeled, as were those that provided minimum and maximum zones of acoustic influence for each anticipated activity. Sound source variability was not modeled, but the modeled source levels were chosen conservatively to ensure the modeled effects zones would not be underestimated.

Ten exploration operations scenarios with different noise sources were defined to characterize the noise associated with typical oil and gas exploration activities within the Lease Sale 193 Chukchi Sea Planning Area (Table 1). Scenarios 1 through 8 were analyzed through numerical sound propagation modeling. Scenarios 9 and 10—anchor handling and mudline cellar construction, respectively—were evaluated with reference to empirical data, rather than modeled because they represent discrete tasks of only a short portion of a drilling program.

For each scenario, only the dominant noise sources were modeled (Table 1); acoustic contributions from ancillary sources were not modeled if they had a negligible influence on the size of the zone of acoustic effects. For example, because airgun impulses dominate the noise field, support vessels and the seismic vessel were excluded from scenarios that included airgun sources.

Three main tasks comprised the acoustic modeling work for this analysis:

- Task 1: Specify Approach
- Task 2: Draft Modeling Scenarios
- Task 3: Final Modeling Scenarios

AECOM and JASCO delivered an interim report for the completion of Task 1 (Austin et al. 2015). The Task 1 report contained: an inventory of available sound source data, a description of the approach to account for variability, a discussion of ambient sound levels and their variability, and scenario descriptions for two draft model scenarios; one that characterized noise from a 2D seismic survey and the other noise from a drilling operation. For Task 2, JASCO modeled these two draft scenarios at one location and presented the draft results at an Acoustic Workshop hosted by NMFS. JASCO described the modeling methodology and presented the draft model results at the Acoustic Workshop. Also during the workshop, NMFS, AECOM and JASCO agreed to the scope for the Final Modeling Scenarios that are presented in this document. This report completes Task 3 and forms the final project deliverable, in conjunction with delivery of the GIS shapefiles that underlie the maps contained herein.

Table 1. Exploration activities scenario descriptions.

Scenario	Description
1	2-D/3-D marine seismic survey; 3200 in^3 airgun array
2	Drilling; a single drillship with a vessel standing by on dynamic positioning (DP)
3	2-D marine seismic survey; 4500 in^3 airgun array
4	Geohazard survey; 40 in^3 airgun array
5	Zero-offset Vertical Seismic Profiling (ZVSP); 500 in^3 airgun array
6	Drilling; two drillships at 10 km separation, each with a vessel on dynamic positioning (DP)
7	Ice management; vessel performing ice management (e.g., during a drilling program)
8	Ice-breaking; icebreaker transiting in significant ice cover
9	Anchor handling (assessed with empirical data)
10	Mudline cellar construction (assessed with empirical data)

2. Background Ambient Noise

To put the sound level modeling results in this report in context, we first discuss the background ambient sound levels in the Chukchi Sea Lease Sale 193 lease block areas, which include all contributing noise sources, both natural and anthropogenic. Background ambient sound levels in any environment are inherently variable due to spatial, seasonal, and daily fluctuations of weather conditions, ice presence, marine mammal vocalizations, and the level of anthropogenic activities.

Background ambient sound influences the zone of audibility for an acoustic signal, since a signal is only audible when its amplitude is above the background sound level’s amplitude, but at the same frequency. The zone of audibility is typically larger than the zone of Level B takes, which the NMFS Interim Sound Threshold Guidance defines as areas where rms SPL (Appendix A) exceeds levels that could disrupt behavior. The current NMFS Level B take thresholds are 160 dB re 1 µPa rms SPL for impulsive-type sounds and 120 dB re 1 µPa rms SPL for continuous-type sounds. Background ambient sound levels seldom exceed 120 dB re 1 µPa and, consequently, do not typically influence the Level B effects zone.

For impulsive sounds, such as airgun pulses, high background levels could alter the range of propagation that corresponds to low rms SPL thresholds because of how pulse SPL is calculated. The rms SPL of an impulsive sound is dependent on the duration of the pulse signal included in the calculation. When background sound levels are high, the lower-level ‘tail’ of the impulsive signal can be masked, with the result being a shortening of the pulse duration. This can lead to higher rms SPL than would otherwise be the case. This modeling analysis did not include background noise in the pulse level calculations but because this effect only applies to low sound level thresholds it does not bear on the estimation of the zone of Level B takes.

Year-round recordings of background ambient sound levels collected through the Chukchi Sea Environmental Studies Program (CSESP) from 2006 to 2013 confirm that the background ambient levels are well below the levels that might affect the acoustic effects zones modeled in this analysis. The CSESP data showed seasonal variation in ambient sound levels (Figure 1), but minimal spatial variability across the Lease Sale 193 area. Additionally, long-term data from one recorder that was in the center of the Chukchi Sea revealed little inter-annual variation (mean broadband level: 99.7 dB re 1µPa; standard deviation: 1 dB). This supports the conclusion from the multi-station analysis that there is a significant difference between seasonal ambient levels (median broadband levels: 104.6 dB re 1 µPa and 94.5 dB re 1µPa for summer and winter, respectively) (Table 2). Actual ambient sound level estimates, without contributions from anthropogenic sources, would be lower than the levels reported here.

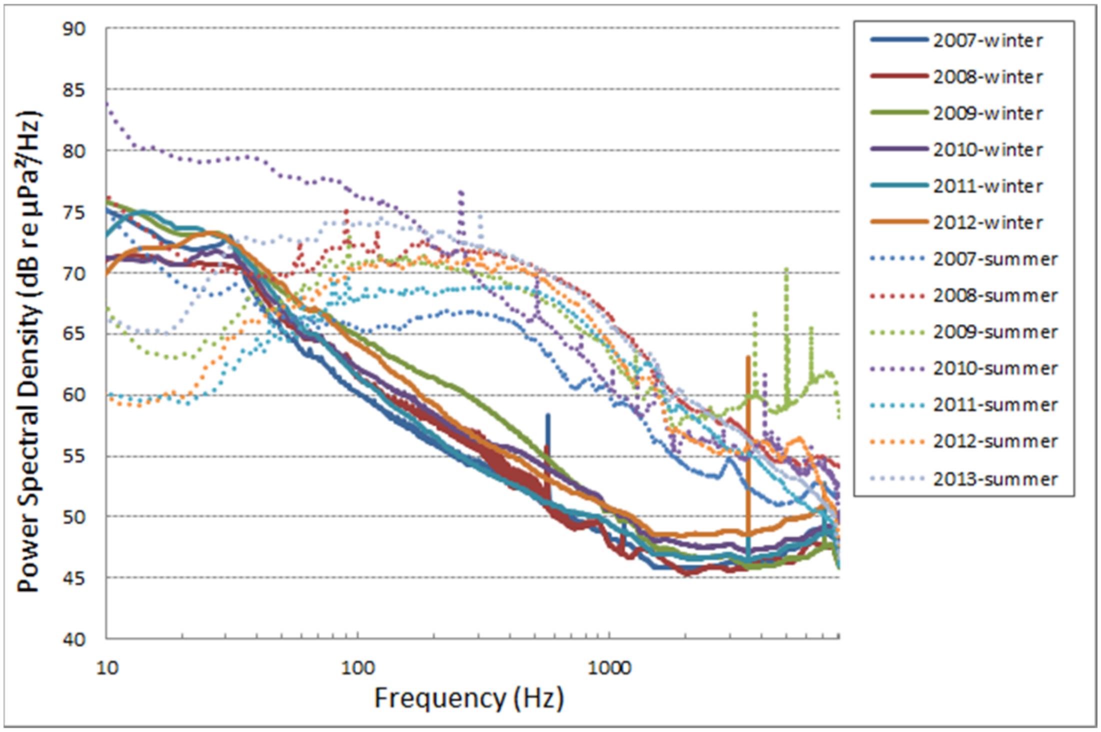

Figure 1. Computed power spectral density levels for background ambient noise (one-minute averages) recorded by an acoustic recorder located at approximately 71˚4′ N, 164˚35′ W in the Chukchi Sea from 2007–2013.

Table 2. Median broadband rms SPL for background ambient noise at an acoustic recorder located approximately 90 miles offshore from Point Lay, Alaska.

Year	rms SPL (dB re 1 µPa)	
	Summer	Winter
2007	103.4	98.0
2008	107.4	91.1
2009	101.5	96.3
2010	105.9	95.8
2011	108.8	92.1
2012	102.9	93.5
2013	102.6	*
Mean	104.6	94.5

* Data not available.

3. Methods

3.1. Modeling Sites and Scenario Configurations

3.1.1. Modeling Sites

To perform this acoustic analysis, the BOEM Chukchi Sea Program Area was divided into five acoustic provinces (Figure 2) based on distinguishing factors including water depth and biological importance. The Province 1 boundary encompassed areas within the BOEM Chukchi Sea Program Area with water depth less than 50 m, excluding Hanna Shoal. Province 2 encompassed the biologically-important Hanna Shoal, the boundary of which was defined to follow the 40 m water depth contour around the shoal. Areas with water depths greater than 50 m fell inside Provinces 3 (50-100 m), 4 (100-500 m), and 5 (> 500 m). Although these provinces have distinct sound propagation conditions, they are outside of the scope for the present analysis. This acoustic modeling study was limited to analyzing acoustic propagation at the Chukchi Sea Lease Sale 193 lease blocks, only Provinces 1 and 2 are considered.

To examine how sound propagation varies with water depth, four modeling sites within Provinces 1 and 2 were chosen based primarily on their bathymetry. Three sites were selected within Province 1 to cover the range of water depths within that province. The water depth at Site 1a is 44 m, at Site 1b it is 36 m, and at Site 1c it is 41 m. In addition to water depth, Site 1c was selected for a number of reasons: its proximity to the shore and therefore the possibility it would generate some unique acoustic propagation results; its proximity to the Ledyard Bay critical habitat; and its proximity to Point Lay. Point Lay is a community that relies heavily on subsistence hunting and is an area that has recently become a Pacific walrus haul-out location. These modeling sites (Figure 2, Table 3) define the source locations for each modeled scenario, listed in Table 1 and described further in the section below.

Table 3. Modeling Site Coordinates

Modeling Site	Longitude	Latitude	Water Depth
1a	163° 46' 0.9264" W	71° 25' 46.8308" N	44.1
1b	165° 19' 43.52" W	70° 53' 50.16" N	35.7
1c	165° 15' 20.8100" W	70° 20' 55.9592" N	40.7
2	163° 27' 36.3645" W	72° 06' 27.0465" N	33.0

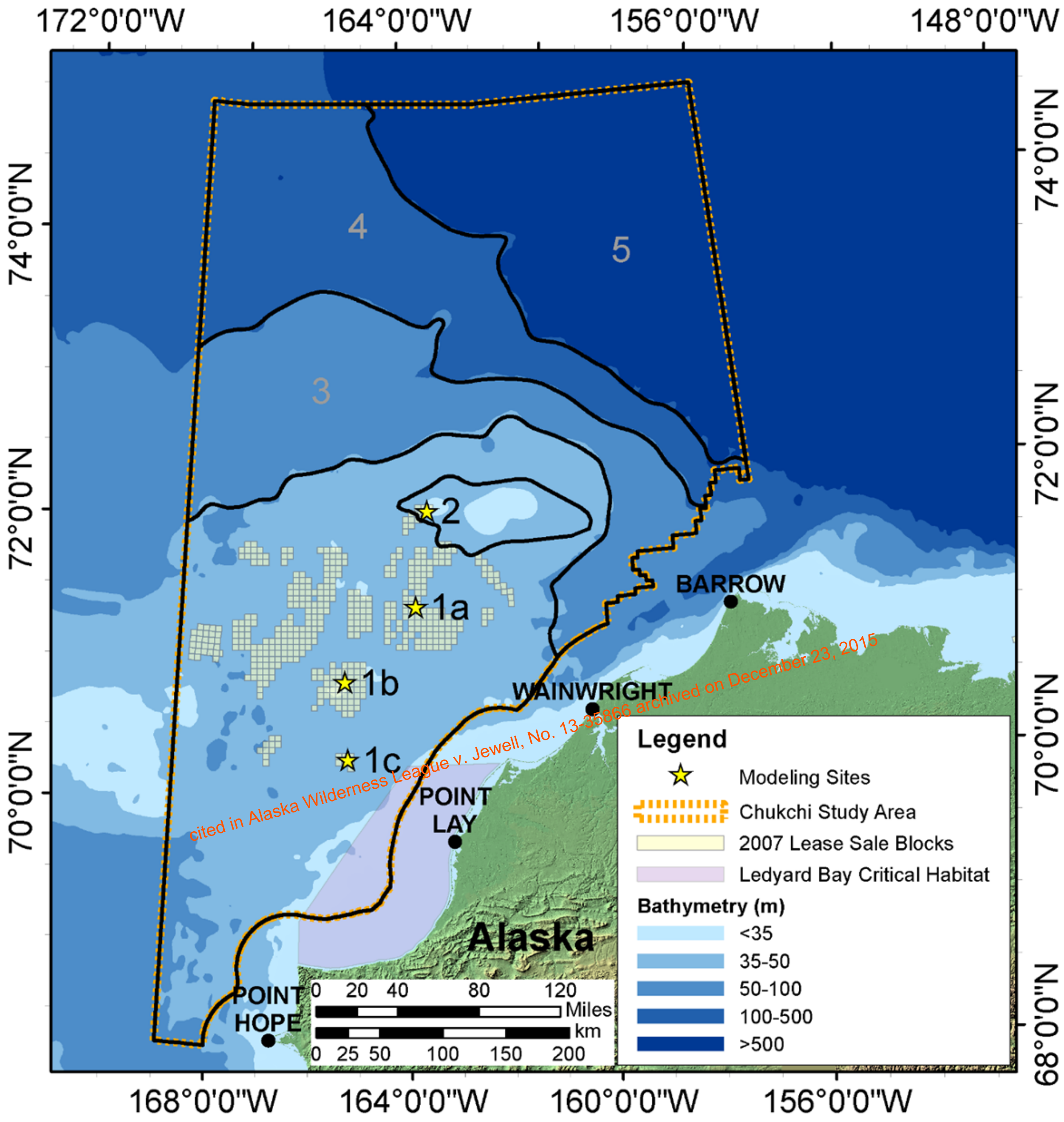

Figure 2. Acoustic provinces and modeling sites used to compute propagation distances for each scenario.

3.1.2. Modeled Scenarios and Configurations

Eight exploration activity scenarios were modeled and each scenario was modeled at all four of the modeling sites. All scenarios except 2 and 6 consisted of a single dominant source, either an airgun array or a vessel, located at the modeling sites identified above. Scenarios 2 and 6 consisted of multiple sound sources of equal importance. For these scenarios, the modeling site locations defined the positions of one source and the locations for the other sources were defined relative to it, as described further below.

Scenario 1 consisted of a 3200 in^3 airgun array that operated at a depth of 6 m, which represents a typical 2-D/3-D seismic survey. The tow direction was toward the shore. Sound levels generated from the seismic survey vessel (towing the airgun array) were not included in this study because the source levels were significantly lower than the airgun signal. Section 3.4.1 has more detail about the source levels.

Scenario 2 consisted of two sources: a drillship that performed drilling operations with a support vessel on dynamic positioning (DP) at 500 m from the drillship. The drillship was placed at the modeling site location and the vessel on DP was positioned at an arbitrarily chosen bearing at 500 m distance. Sections 3.4.2 and 3.4.3 provide more details about the source levels.

Scenario 3 consisted of a 4500 in^3 airgun array that operated at a depth of 8.5 m, which represents a typical 2-D seismic survey. The tow direction was toward the shore. Sound levels generated from the seismic survey vessel (towing the airgun array) were not included in this study because the source levels were significantly lower than the airgun signal. Section 3.4.4 has more details about the source levels.

Scenario 4 consisted of a 40 in^3 airgun array that operated at a depth of 10 m, which represents a typical geohazard seismic survey. The tow direction was toward the shore. Sound levels generated from the seismic survey vessel (towing the airgun array) were not included in this study because the source levels were significantly lower than the airgun signal. Section 3.4.5 has more details about the source levels.

Scenario 5 consisted of a 500 in^3 airgun array operating at a depth of 6 m, which represents a typical Zero-offset Vertical Seismic Profiler (ZVSP). Section 3.4.6 has more details about the source levels.

Scenario 6 consisted of two drillships performing drilling operations, at a distance of 10 km, each with a support vessel on DP at a distance of 500 m. These four sources were positioned such that one drillship was located at the modeling site location and the second drillship was located within existing lease blocks, 10 km away from the first drillship, at the position with greatest water depth; each drillship's associated vessel on DP was positioned at an arbitrarily chosen bearing. Figure 3 illustrates this configuration at modeling Site 1a; similar configurations were defined at each modeling site location. Sections 3.4.2 and 3.4.3 provide further details about the source levels.

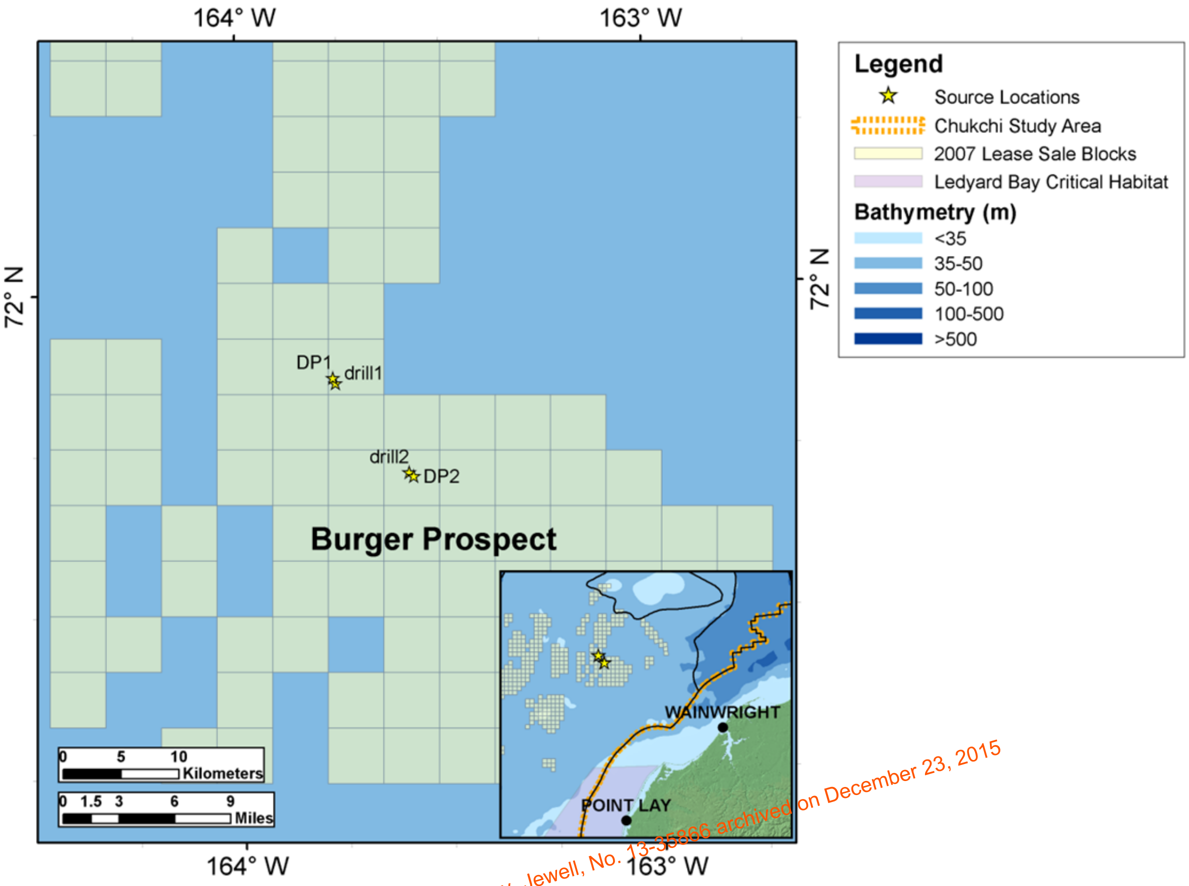

Figure 3. Map displaying the four source locations for Scenario 6 including two drillships (drill1 and drill2) and two vessels on DP (DP1 and DP2) at modeling Site 1a.

Scenario 7 consisted of an ice class vessel performing ice management operations. Section 3.4.7 has more details about the source levels. Scenario 8 consisted of an ice class vessel transiting through 80% ice cover and Section 3.4.8 has more details about these source levels. Because Scenario 8 could only occur when ice is present, the average sound speed profile conditions are not considered representative, thus all Scenario 8 modeling used the mixed sound speed profile rather than the average sound speed profile (see Section 3.5.1). Scenario 9 consisted of a large tug that conducted anchor handling activities that supported setting mooring anchors for a drillship. Scenario 10 consisted of a drillship that conducted mudline cellar construction, which is the excavation of a hole in the seafloor within which sits the blow-out preventer for certain drilling projects.

3.2. Sound Propagation Models

The propagation of sound through the environment was modeled by predicting the acoustic transmission loss- a measure, in decibels, of the decrease in the sound level between a source and a receiver, some distance away. Geometric spreading of acoustic waves is the predominant way by which transmission loss occurs, especially at low frequencies. Transmission loss also happens when the sound is partially absorbed in the seawater, and its amplitude is reduced each time it reflects at the water surface and seabed; some of the sound can be transmitted into the seabed where it is absorbed, and rough surfaces cause additional scattering of sound that would otherwise be reflected uniformly. Transmission loss depends on the acoustic properties of the ocean and seabed and its value changes with frequency. Transmission loss also depends on the depths of the source and receiver underwater.

If the acoustic source level (SL), expressed in dB re 1 μPa @ 1 m, and transmission loss (TL), in units of dB, at a given frequency are known, then the sound level at a receiver, known as the received level (RL) can be calculated in dB by:

$$RL = SL - TL \qquad (1)$$

The acoustic fields around the sources were modeled at frequencies from 10 Hz to 3 kHz using JASCO's Marine Operations Noise Model (MONM, Section 3.2.1) and Full Waveform Range-dependent Acoustic Model (FWRAM, Section 3.2.2), combined with derived source levels (Section 3.4). Source levels were modeled, for airgun arrays (Section 3.3), or derived from empirical data, for vessels and drillships.

3.2.1. Marine Operations Noise Model (MONM)

MONM computes transmission loss via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent Acoustic Model (RAM), which has been modified to account for an elastic seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM computes acoustic fields in three dimensions by modeling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding $N = 360°/\Delta\theta$ number of planes (Figure 4). MONM accounts for the additional reflection loss at the seabed due to partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modeled area; underwater sound speed as a function of depth; and a geoacoustic profile based on the overall stratified composition of the seafloor. MONM's predictions have been validated against experimental data from several underwater acoustic measurement programs conducted by JASCO (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010).

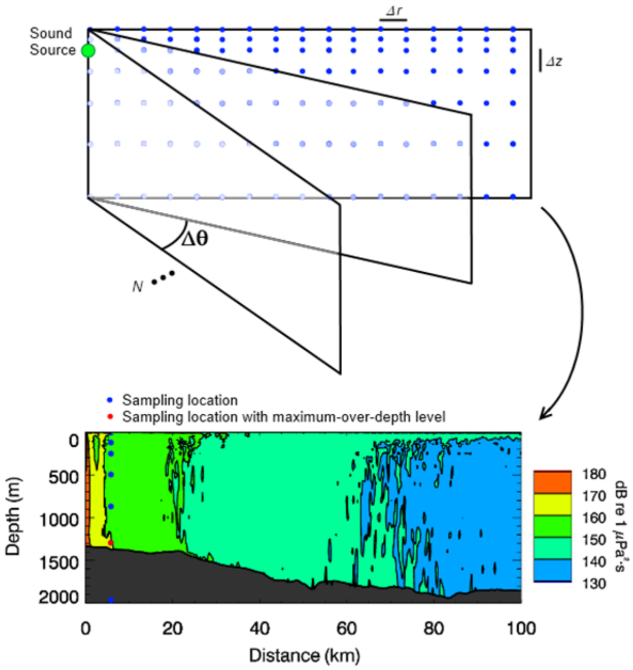

Figure 4. Example output to illustrate the N×2-D and maximum-over-depth modeling approaches used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the center frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modeled to include the majority of acoustic energy emitted by the source. At each center frequency, transmission loss is modeled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received SELs (which equate to 1 s rms SPL for continuous sources such as drilling and vessel activity) are computed by subtracting the band transmission loss values from the source level in that frequency band. Composite broadband received SELs are then computed by summing the received 1/3-octave-band levels.

Sound attenuation due to energy absorption through ion relaxation and water viscosity becomes significant at higher frequencies and at longer ranges. This effect is not modeled by MONM but is taken into account in post-processing by increasing TL as a function of frequency and source-receiver range. The absorption coefficient (dB/m)was calculated using a formula by Francois and Garrison (1982a, 1982b), with salinity and temperature parameters based on average values from Chukchi Sea CTD data.

The received SEL sound field within each vertical radial plane is sampled at various ranges from the source. At each horizontal range, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received SEL. These maximum-over-depth per-pulse SELs are presented as color contours around the source. Ranges from the source to the contours of the sound thresholds of interest are computed and expressed in three ways: $R_{\max}$ - the maximum distance from the source to the contour; $R_{95\%}$ - the radius of a circle encompassing 95% of the area of the contour; R_{ea} - the radius of a circle with area equivalent to the total area of the contour.

3.2.2. Full Waveform Range-dependent Acoustic Model (FWRAM)

A separate model, FWRAM (JASCO Applied Sciences) was used to compute synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments using the parabolic equation approach to solving the acoustic wave equation. This was done to derive a conversion factor to transform the SEL fields computed by MONM to rms SPL. Like MONM, FWRAM accounts for range-varying properties of the acoustic environment. It uses the same N×2-D algorithmic engine as MONM and uses the same environmental inputs (bathymetry, water sound speed profile, and seabed geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands.

The rms SPL and per-pulse SEL are computed directly from the synthetic waveforms; however, the model is computationally expensive and it is not practical to run FWRAM in the same N×2-D resolution as MONM. The SEL fields computed by MONM are converted to rms SPL by adding a range-dependent conversion factor specific to each airgun array and source location derived from four FWRAM runs (in the endfire and broadside directions). The difference between rms SPL and SEL were calculated from each FWRAM run and each depth, and a conversion factor was derived from the 90th percentile value in each 500-m wide range bin.

3.3. Airgun Array Source Model (AASM)

The source levels and directivity of the airgun arrays were predicted with Airgun Array Source Model (AASM; MacGillivray 2006). This model is based on the physics of oscillation and radiation of airgun bubbles described by Ziolkowski (1970). The model solves the set of parallel differential equations governing bubble oscillations. AASM also accounts for nonlinear pressure interactions among airguns, port throttling, bubble damping, and generator-injector (GI) gun behavior that are discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). AASM includes four empirical parameters that were tuned so model output matches observed airgun behavior. The model parameters fit to a large library of empirical airgun data using a “simulated annealing” global optimization algorithm. These airgun data are measurements of the signatures of Bolt 600/B guns ranging in volume from 5 to 185 in^3 (Racca and Scrimger 1986).

For this study, we modeled frequencies between 10 and 3150 Hz. A variety of airgun array measurements made in the Chukchi Sea from 2009 and 2013 were examined to determine the frequency range of the acoustic model. The airgun spectrograms at various received ranges showed that most of the pulse energy occurs between 10 and 3000 Hz.

AASM produces a set of “notional” signatures for each array element based on:

- array layout;
- volume, tow depth, and firing pressure of each airgun; and
- interactions between different airguns in the array.

These notional signatures are the pressure waveforms of the individual airguns at a standard reference distance of 1 m; they account for the interactions with the other airguns in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature was filtered in 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered a directional point source in the far field.

A seismic array consists of many sources and the point-source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{\text{nf}} < \frac{l^2}{4\lambda} \qquad (2)$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, an airgun array length of l = 16 m yields a near-field range of 85 m at 2 kHz and 17 m at 100 Hz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modeling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the inter-airgun separation distances, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

3.4. Acoustic Sources

Source levels in 1/3-octave-bands were determined for each source and used as inputs for the acoustic propagation model. AASM was used to calculate source levels for the four different airgun arrays (40, 500, 3200, and 4500 in^3) (Figure 5). Sections 3.4.5 through 3.4.4 present the airgun array layouts and acoustic source details. Source level details for the continuous sound sources were derived from SSV measurements; these are presented in Sections 3.4.2 through 3.4.8. Broadband source levels for each scenario are summarized in Table 4 and the 1/3-octave-band levels are plotted in Figure 5.

Table 4 Broadband source levels (rms SPL) for each modeled scenario.

Scenario	Source	Broadband Source Level (dB re 1 µPa @ 1m)
1	3200 in^3 airgun array (broadside)	230.8
2	Drillship Vessel using dynamic positioning	180.7 178.2
3	4500 in^3 airgun array (broadside)	231.9
4	40 in^3 airgun array (broadside)	216.7
5	500 in^3 airgun array (broadside)	222.5
6	Drillship Vessel using dynamic positioning	180.7 178.2
7	Ice management	191.7
8	Ice-breaking	198.4

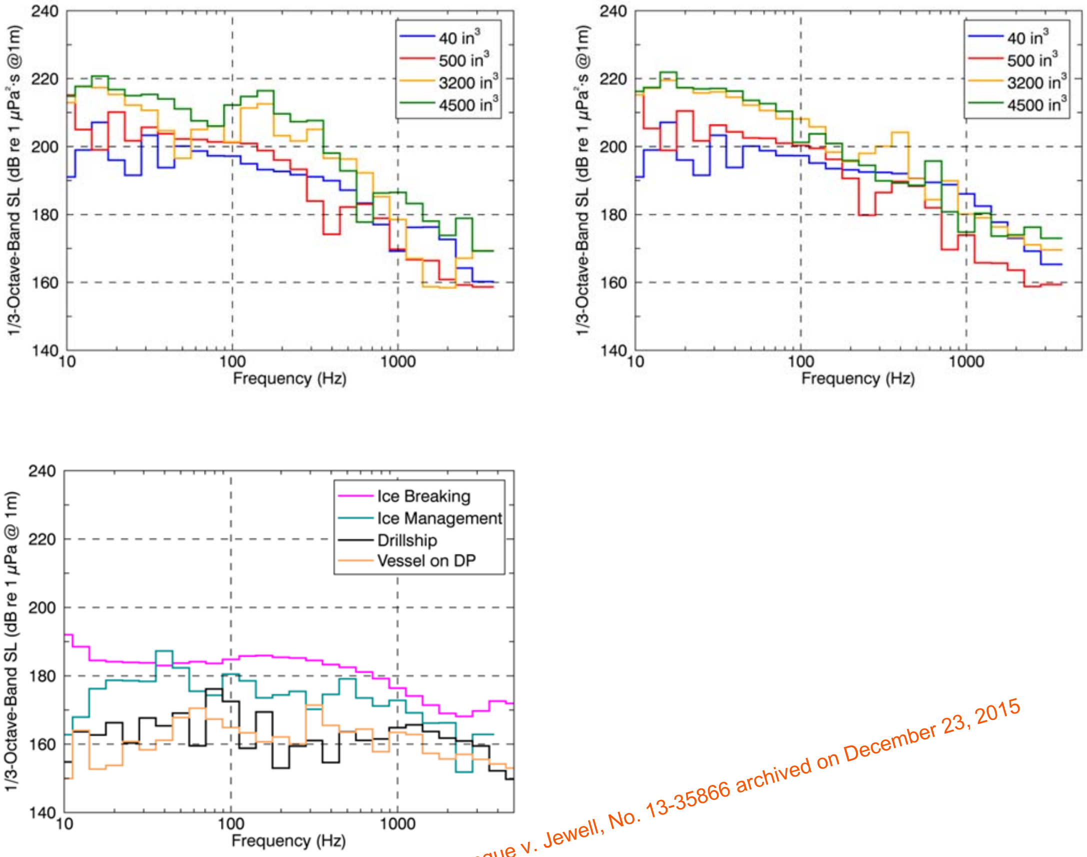

Figure 5. One-third octave-band source levels for all sources; (top left) airgun arrays broadside direction, (top right) airgun arrays endfire direction, (bottom) continuous sources.

3.4.1. 3200 in^3 Airgun Array

An airgun array layout was defined based on 2-D marine seismic survey arrays typically used in shallow Arctic waters, with individual gun volumes between 40 and 250 in^3. The gun volumes were adjusted to achieve a total volume of 3200 in^3. Figure 6 shows the array layout and gun volumes. The array depth is 6 m, a common depth used in Arctic 2-D marine seismic surveys. Source levels for this array were modeled using AASM.

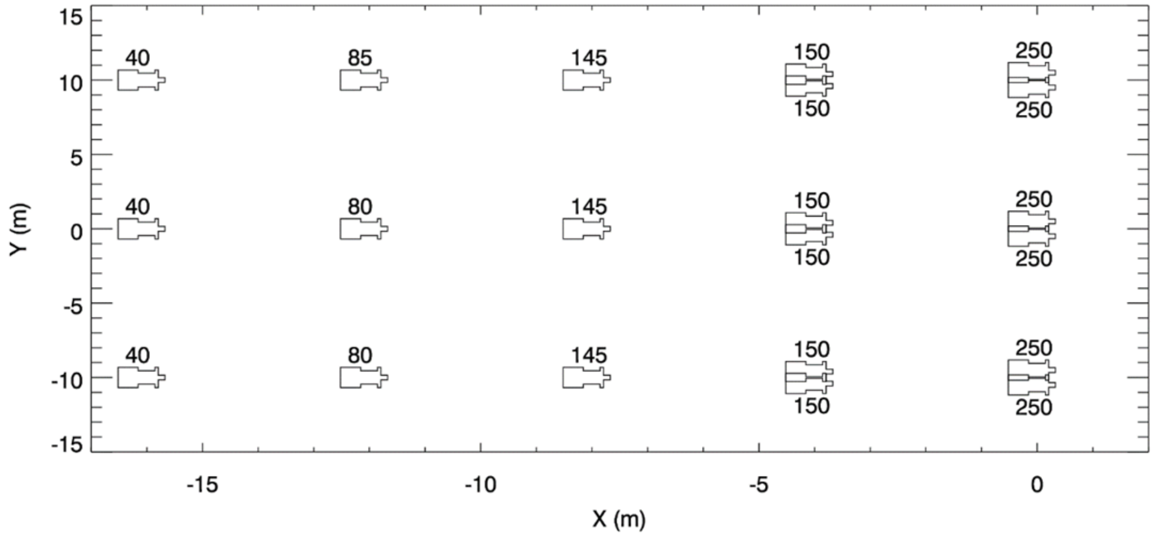

Figure 6. 3200 in^3 airgun array layout and gun volumes. Tow direction is to the right (i.e., in the positive x-direction).

Figure 7 shows the far-field sound pressure signature and power spectral density in the horizontal broadside and endfire directions predicted by AASM. Higher sound levels are emitted directly below the array, but this vertical component of the total sound energy is characterized by steep propagation angles that are only dominant in the sound field at very close ranges. Figure 8 shows the horizontal directivity of the array as a function of frequency. Source directivity is insignificant at 40 Hz or less, but is quite prominent for higher frequencies. The one-third octave levels in the broadside and endfire directions for the airgun array, along with those for all the other airgun array sources, are shown in Figure 5 above.

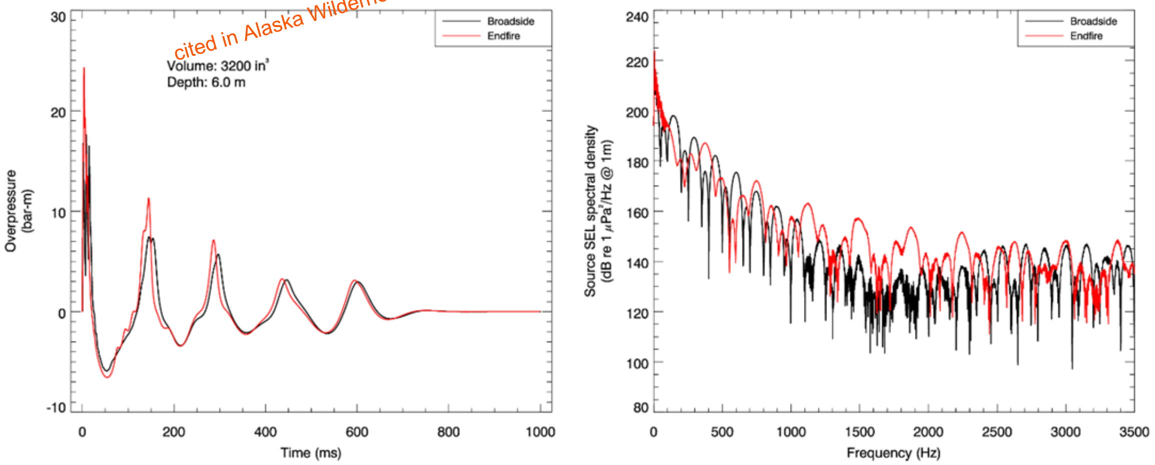

Figure 7. (Left) Horizontal far-field pressure signatures and (right) power spectra for the 3200 in^3 airgun array in the broadside and forward-endfire directions.

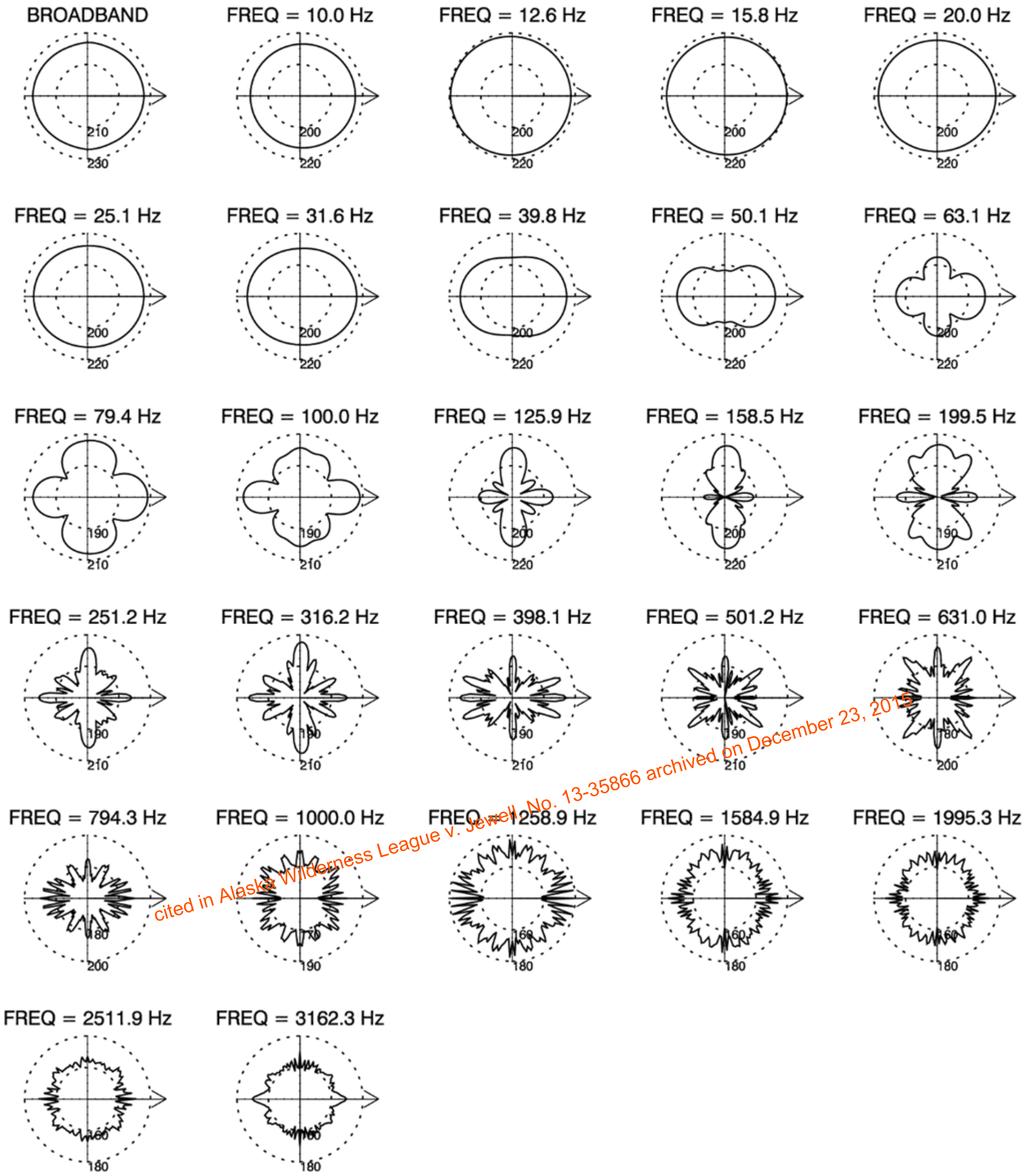

Figure 8. Azimuthal directivity pattern of source level (dB re 1 μPa^2·s) for the 3200 in^3 airgun array, in the broadband, and in 1/3-octave-bands with center frequencies from 10 Hz to 3 kHz. Arrows indicate the array tow direction.

3.4.2. Drilling

Source levels for drilling were taken from estimated source levels from the drillship *Noble Discoverer* drilling top holes into the seafloor in the Chukchi Sea (Mate et al. 2015). The drillship was 157 m in length and had a draft of 8.5 m. The acoustic source depth used for estimating source levels was 3 m. Figure 5 above shows the 1/3-octave-band source levels for the *Noble Discoverer* drilling.

3.4.3. Support Vessel on Dynamic Positioning

Measurements of support vessels on dynamic positioning (DP) have been conducted in the Chukchi Sea for the *Ocean Pioneer*, *Fennica*, and *Nordica* during Shell's exploration programs there in 2010 and 2012. The results are presented in the 90-day reports to NMFS for those programs. The measurement distances and vessel specifications are listed in Table 5. Source level estimates were not provided in the literature so for this study we calculated source levels from mean 1/3-octave-band levels for each vessel and averaged the levels across the vessels to derive an average source level for vessels on DP. For vessels measured at ranges less than 100 m, we used spherical spreading (i.e., 20LogR) to calculate transmission loss and estimated source levels using Equation 1. Because the *Nordica* was measured at a range that exceeded several water depths, spherical spreading would not accurately model transmission loss for this measurement geometry; therefore, we used the same method to estimate TL as for the *Noble Discoverer* drilling (Mate et al. 2015), i.e., MONM at frequencies below 2 kHz and the ray tracing code Bellhop (Porter and Liu 1994) at frequencies above 2 kHz. The 1/3-octave-band SLs for these vessels and the average SL for a vessel on DP are shown in Figure 9; the final SL used in this study is plotted with the other sources in Figure 5 above.

Table 5. Measurements of vessels on DP in the Chukchi Sea.

Vessel	Vessel Length (m)	Vessel Draft (m)	Source/Receiver Slant Range (m)	Water Depth (m)	Reference
Ocean Pioneer	62	4.3	74	46	Chorney et al. (2011)
Fennica	116	8.4	40	48	Austin et al. (2013)
Nordica	116	8.4	460	48	Austin et al. (2013)

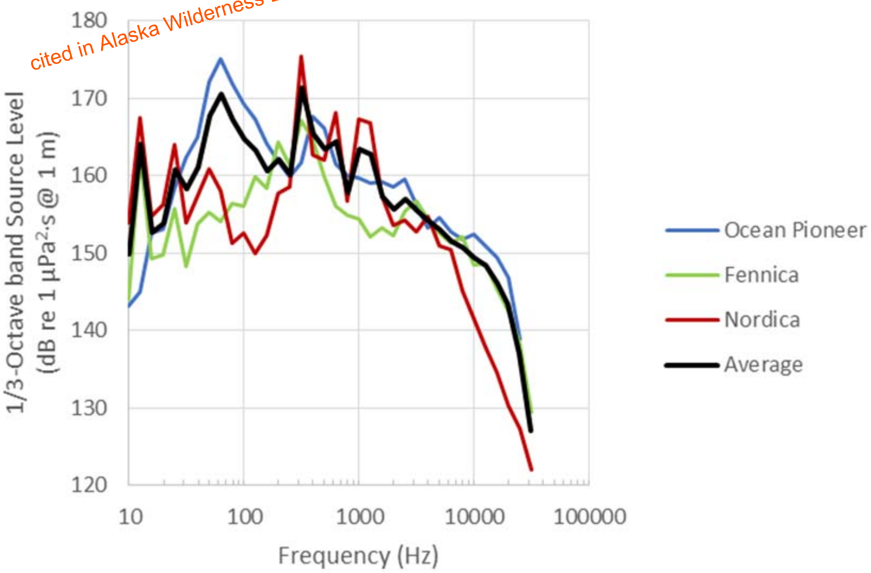

Figure 9. One-third octave-band source levels for the support vessels on DP and the average levels over all vessels.

3.4.4. 4500 in^3 Airgun Array

An airgun array layout was defined based on 2-D marine seismic survey arrays typically used in shallow Arctic waters, with individual gun volumes between 40 and 300 in^3. The gun volumes were adjusted to achieve a total volume of 4500 in^3. Figure 10 shows the array layout and gun volumes. The array depth is 8.5 m, a common depth used in Arctic 2-D marine seismic surveys. Source levels for this array were modeled using AASM.

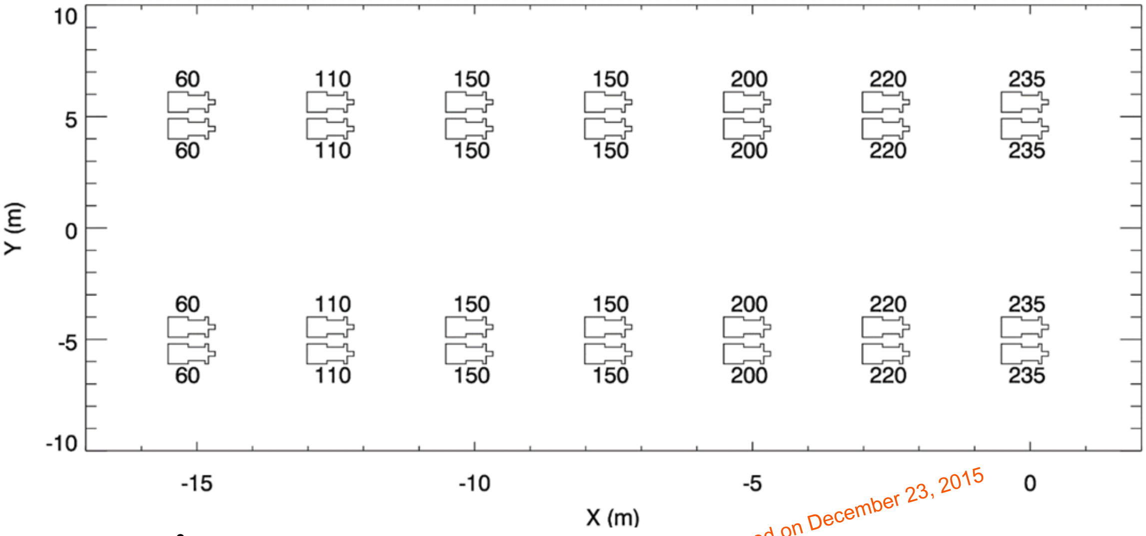

Figure 10. 4500 in^3 **airgun array layout and gun volumes. Tow direction is to the right (i.e., in the positive x-direction).**

Figure 11 shows the far-field sound pressure signature and power spectral density in the horizontal broadside and endfire directions predicted by AASM. Higher sound levels are emitted directly below the array, but this vertical component of the total sound energy is characterized by steep propagation angles that are only dominant in the sound field at very close ranges. Figure 12 shows the horizontal directivity of the array as a function of frequency. Source directivity is insignificant at 50 Hz or less, but is quite prominent for higher frequencies.

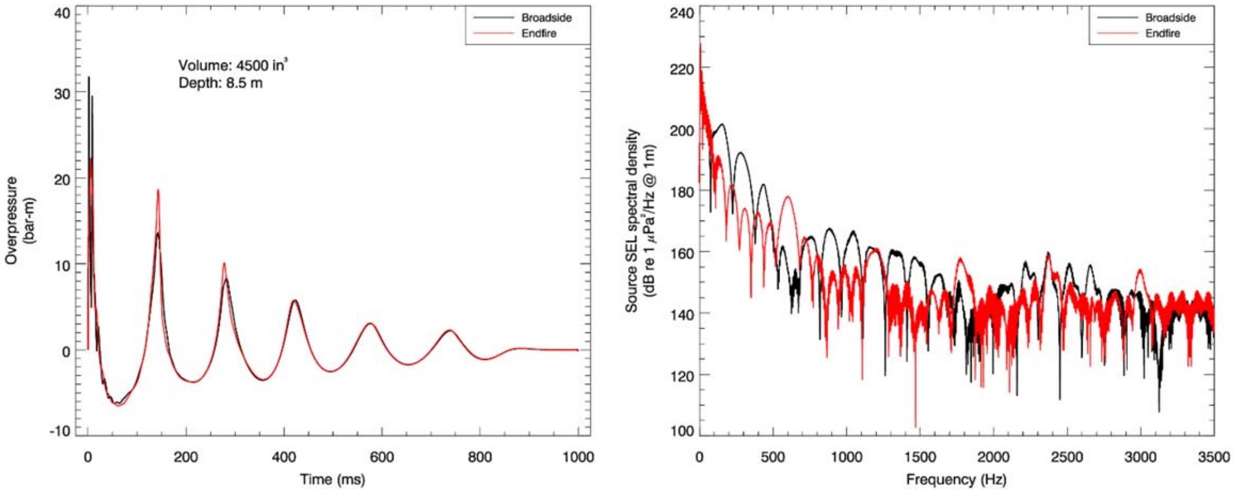

Figure 11. (Left) Horizontal far-field pressure signatures, and (right) power spectra for the 4500 in^3 **airgun array in the broadside and forward-endfire directions.**

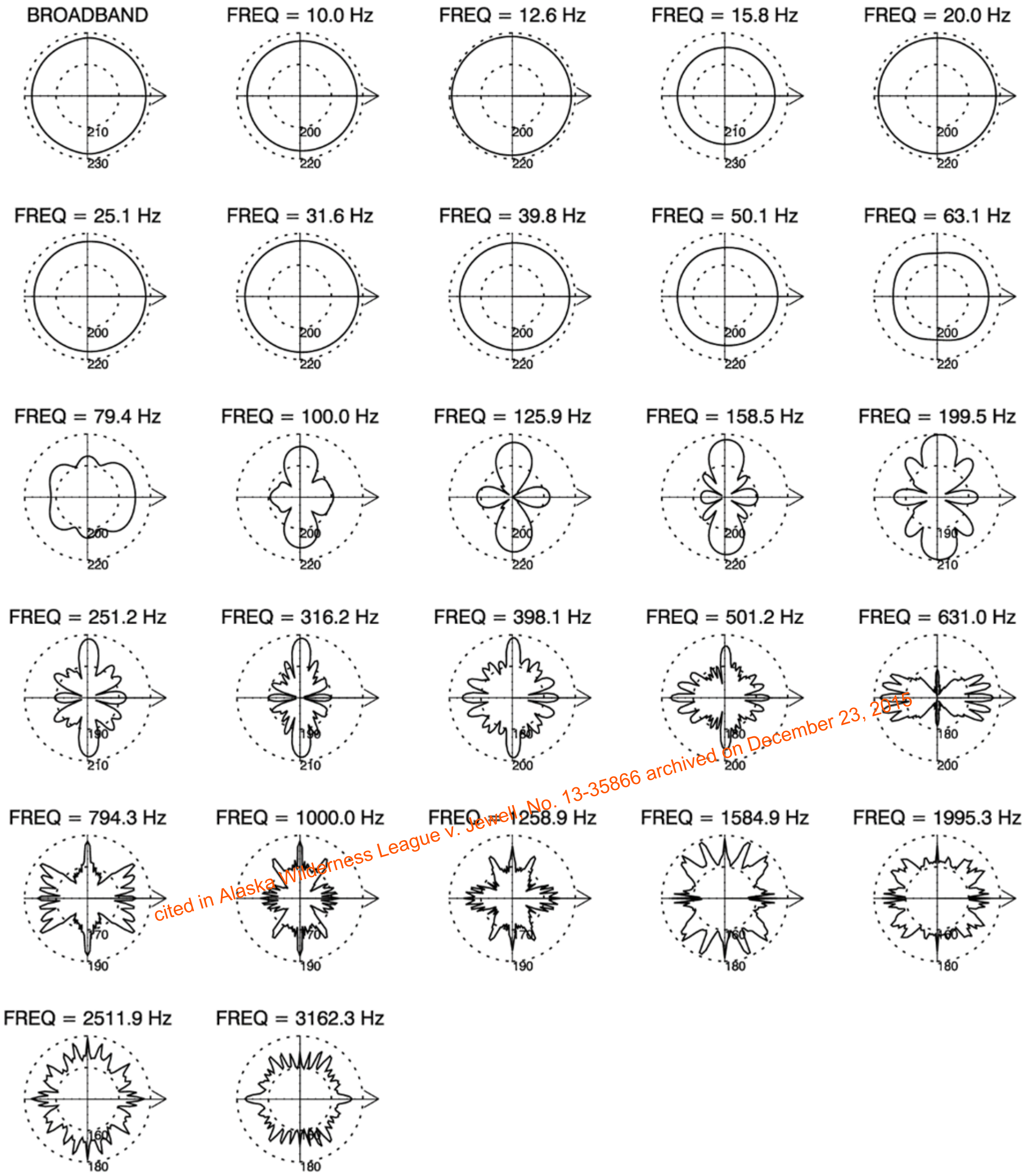

Figure 12. Azimuthal directivity pattern of source level (dB re 1 μPa^2·s) for the 4500 in^3 airgun array, in the broadband, and in 1/3-octave-bands with center frequencies from 10 Hz to 3 kHz. Arrows indicate the array tow direction.

3.4.5. 40 in^3 Airgun Array

An airgun array layout was defined based on geohazard seismic survey arrays with a total volume of 40 in^3 recently used in shallow Arctic waters. The current array layout consisted of four 10 in^3 guns, with two at 1.75 m water depth and two directly below them at 2.25 m. The horizontal spacing between the two guns is 80 cm. AASM was used to model source levels for this array.

Figure 13 shows the far-field sound pressure signature and power spectral density in the horizontal, broadside, and endfire directions predicted by AASM. Higher sound levels are emitted directly below the array, but this vertical component of the total sound energy is characterized by steep propagation angles that are only dominate the sound field at very close ranges. Figure 14 shows the horizontal directivity of the array as a function of frequency, which is insignificant at 500 Hz or less, but is quite prominent for higher frequencies.

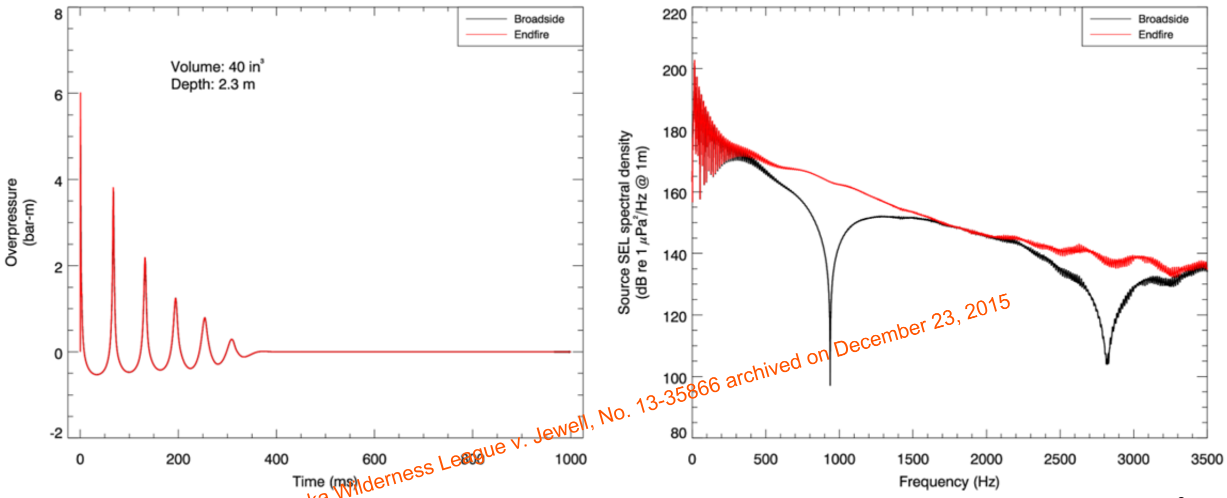

Figure 13. (Left) Horizontal far-field pressure signatures, and (right) power spectra for the 40 in^3 **airgun array in the broadside and forward-endfire directions.**

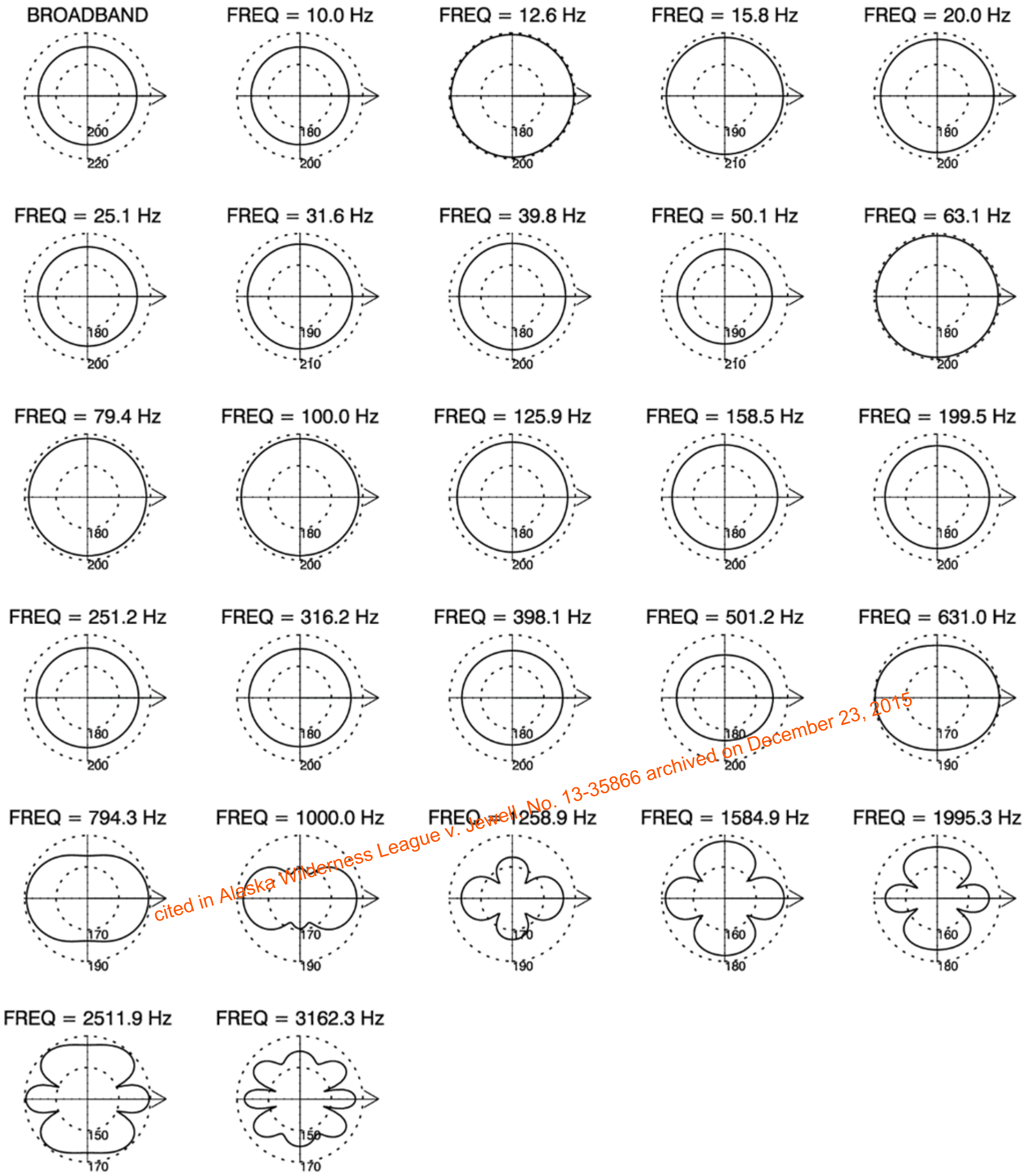

Figure 14. Azimuthal directivity pattern of source level (dB re 1 μPa^2·s) for the 40 in^3 airgun array, in the broadband, and in 1/3-octave-bands with center frequencies from 10 Hz to 3 kHz. Arrows indicate the array tow direction.

3.4.6. 500 in^3 Airgun Array

An airgun array layout was defined based on Zero-offset Vertical Seismic Profiler (ZVSP) arrays typically used in shallow Arctic waters with a total volume of 500 in^3. The array layout consisted of two 110 in^3 guns and two 140 in^3 guns, all operating at 6 m water depth. Source levels for this array were modeled using AASM.

Figure 15 shows the far-field sound pressure signature and power spectral density in the horizontal broadside and endfire directions predicted by AASM. Higher sound levels are emitted directly below the array, but this vertical component of the total sound energy is characterized by steep propagation angles that are only dominant in the sound field at very close ranges. Figure 16 shows the horizontal directivity of the array as a function of frequency. Source directivity is insignificant at 500 Hz or less, but is quite prominent for higher frequencies.

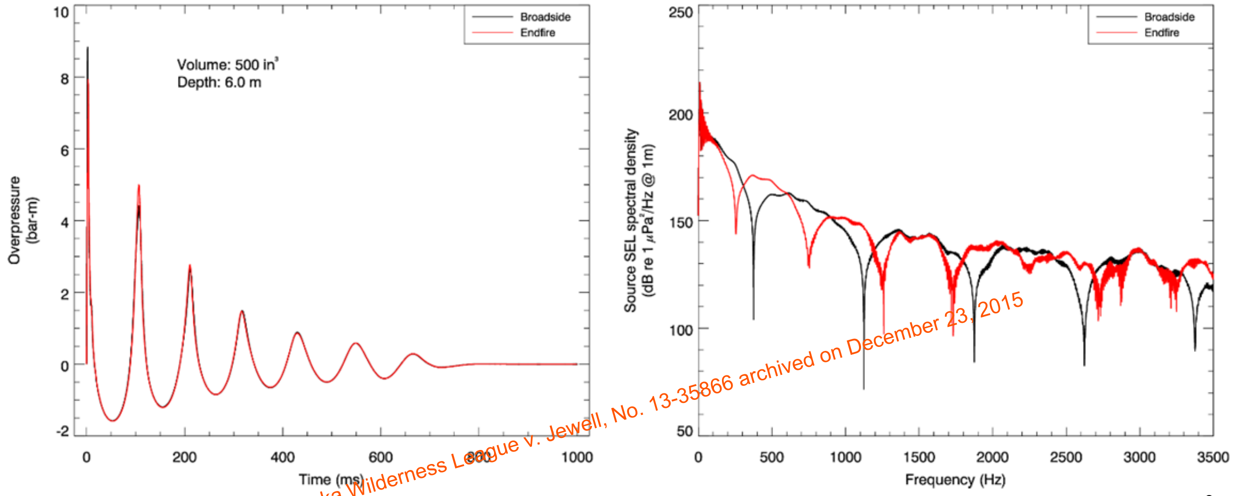

Figure 15. (Left) Horizontal far-field pressure signatures, and (right) power spectra for the 500 in^3 **airgun array in the broadside and forward-endfire directions.**

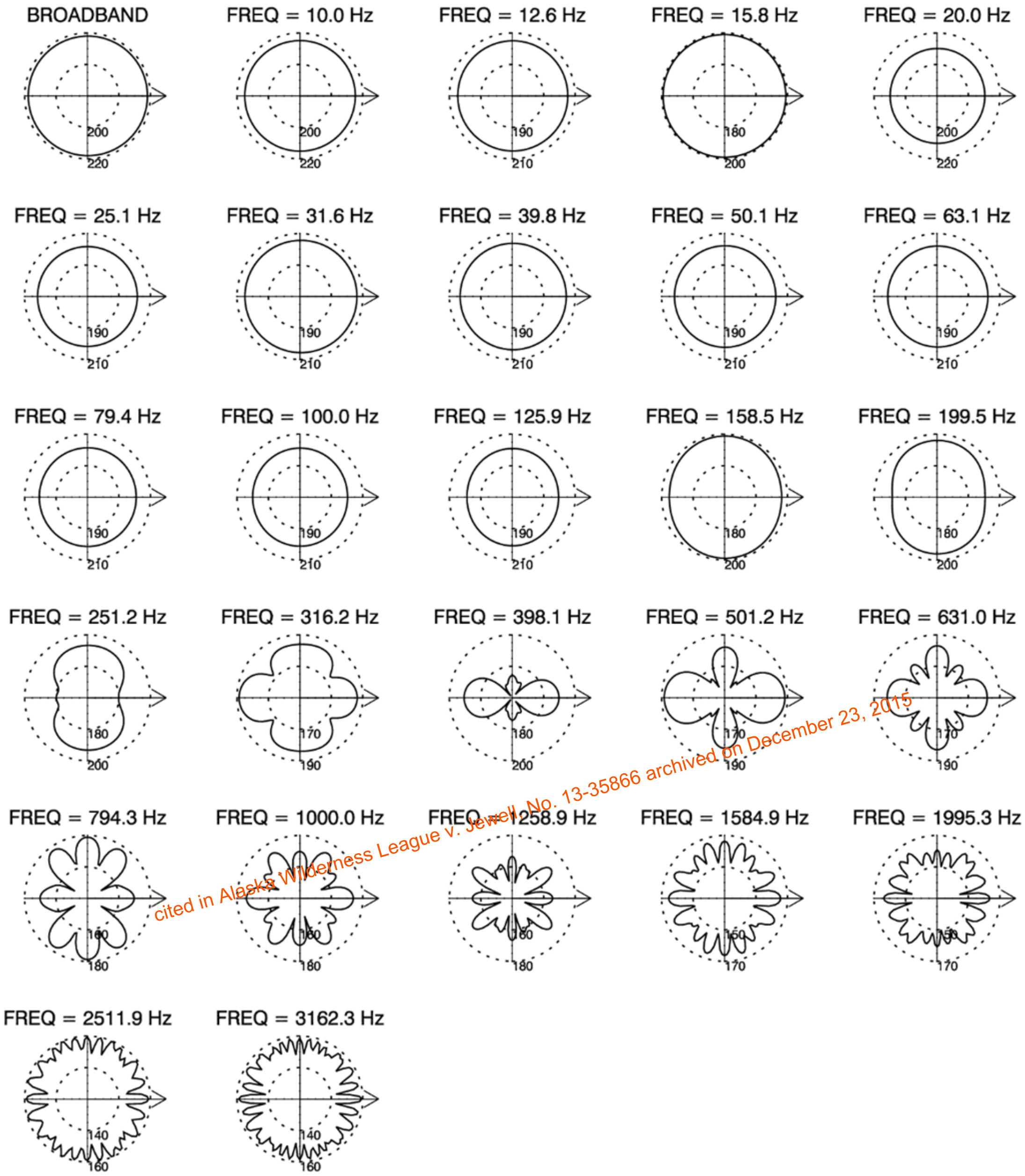

Figure 16. Azimuthal directivity pattern of source level (dB re 1 μPa^2·s) for the 500 in^3 **airgun array, in the broadband, and in 1/3-octave-bands with center frequencies from 10 Hz to 3 kHz. Arrows indicate the array tow direction.**

3.4.7. Ice Management

Source levels for the ice management scenario were calculated from measurements JASCO staff took of the *Tor Viking* as it managed ice as part of the *Noble Discoverer* drilling activities in the Burger prospect area (Austin et al. 2013). The recorded levels were back-propagated by calculating the transmission loss in 1/3-octave frequency bands using MONM and by using Equation 1 at each frequency. The source depth of 2.6 m was determined based on a point source equivalent model position involving the vessel draft and propeller size (Gray and Greeley 1980). The 1/3-octave-band levels used for this study for the ice management scenario are shown in Figure 5 above.

3.4.8. Ice-breaking

The 1/3-octave-band source levels for the icebreaker used in this study are based on measurements of the *USCGC Healy* (Roth et al. 2013). The levels are representative of the vessel transiting in 80% ice cover. Because the cavitation noise of the propeller is the main source of the noise levels, we placed the source depth at 4.77 m, based on a point source equivalent model position based on the vessel draft and propeller size (Gray and Greeley 1980). The 1/3-octave-band levels for the ice-breaking scenario are shown in Figure 5 above.

3.5. Acoustic Environment

3.5.1. Water Sound Speed Profiles

Seasonally (July through September) from 2008–2013 numerous studies collected CTD measurements in the central region of the northeastern Chukchi Sea shelf. Figure 17 shows the locations of the CTD measurements we used to analyze the sound speed profiles (SSPs) for Provinces 1 and 2. Because the two locations are close to one another and similar bathymetry, this analysis treated them as one location. The CTD data measures the temperature and salinity against water depth. We used Coppens' (1981) equations to calculate sound speeds from the CTD data:

$$\begin{aligned} c(z,T,S) &= 1449.05+45.7T-5.21t^{2}-0.23t^{3} \\ &\quad +(1.333-0.126t+0.009t^{2})(S-35)+\Delta \\ \Delta &= 16.3Z+0.18Z^{2} \\ Z &= (z/1000)(1-0.0026\cos(2\phi)) \\ t &= T/10 \end{aligned} \tag{1}$$

where z is depth in meters, T is temperature in degrees Celsius, S is salinity in psu, and φ is latitude in radians.

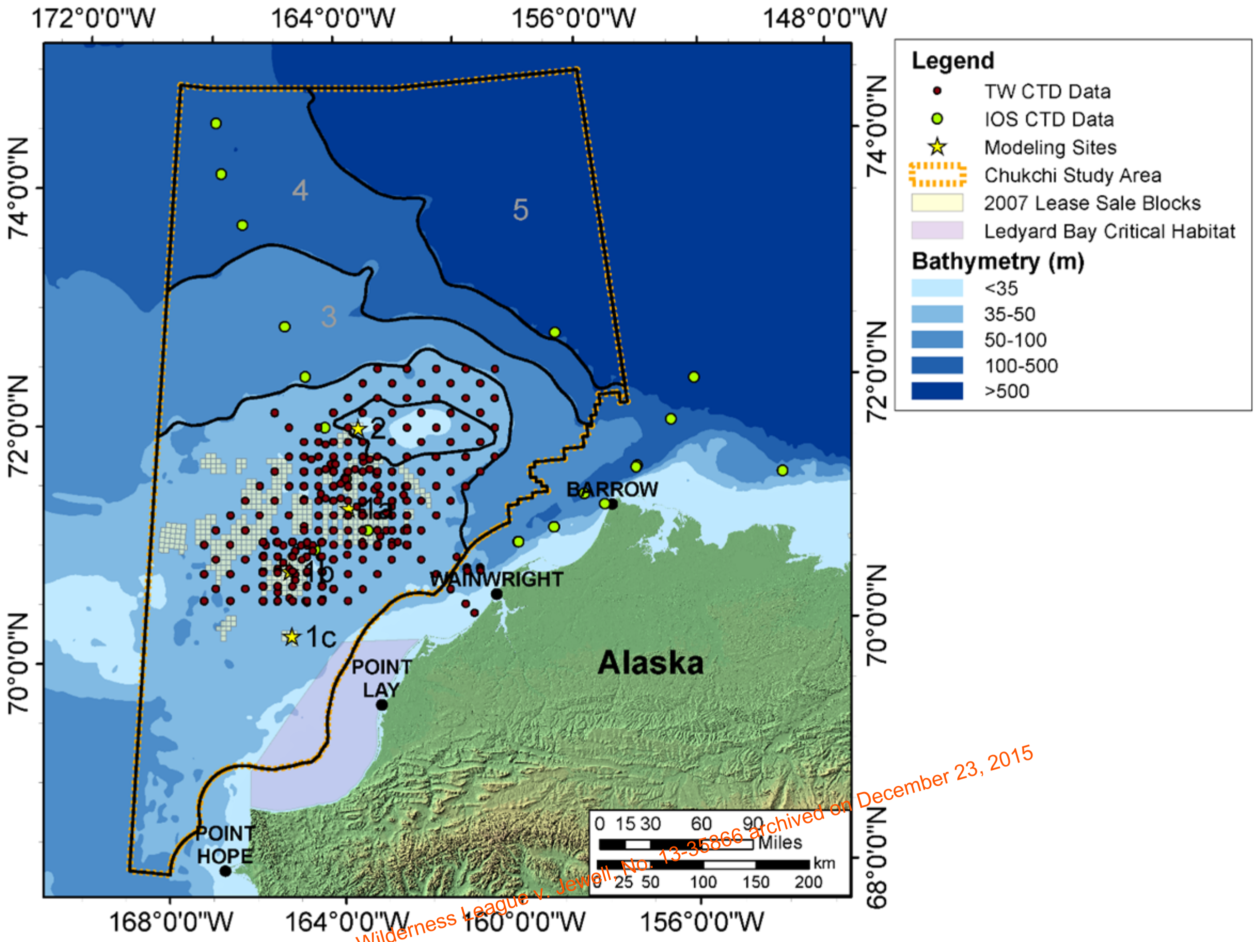

Figure 17. Locations of CTD measurements used in the analysis of SSPs for modeling Sites 1 and 2.

The dataset provides 1395 separate SSPs, with a high degree of variability. To determine the profile most likely to be observed, a principal component analysis (PCA) was used on the dataset. The use of a PCA in this case recasts the data in terms of new dimensions, the first of which controls the greatest amount of variability seen in the SSPs, with successive dimensions affecting the profile variability with diminishing capacity. The dimensions in this case correspond to a set of unique depth-dependent deviations from the average SSP. The process reveals how the SSPs are likely to vary over the summer months, and by using the results from the PCA, representative SSPs can be generated based on the original dataset. This full analysis is described further in Appendix B.

The average measured SSP is shown in Figure 18, which also shows a downward refracting profile, which is typical of the start of August, and a mixed profile, which is typical of October as determined by the PCA.

The average SSP is typical of the Chukchi Sea; it features a mixed surface layer over decreasing temperatures with depth. The downward refracting profile is attributed to a heated surface layer over a sharp temperature decrease, which refracts sound toward the sediment. The mixed profile deviates slightly from an isovelocity profile; in this case, the water is well mixed across the water column and the effects of refraction are less pronounced.

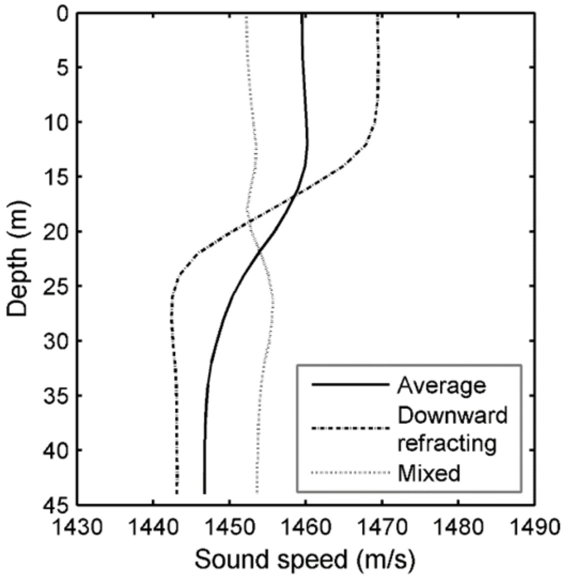

Figure 18. The average SSP and the synthesized mixed and downward refracting SSPs based on the principal component analysis. These form the standard SSPs used in the modeling.

3.5.2. Geoacoustics

Seabed properties are important for acoustic modeling, particularly for shallower environments where sounds increasingly interact with the seabed. Geoacoustic data has been derived from core sampling in the NMFS database from survey cruises, from data obtained by the Woods Hole Oceanographic Institute (WHOI) Healy cruises, and from generated results from previous JASCO projects.

Because many studies have been conducted in the southern part of the project area, Province 1 has considerably more geoacoustic data. These were analyzed based on reflectivity and collated into three distinct categories: Profile 1 (Warner 2014) is a high-reflectivity sediment profile based on a geoacoustic inversion at Burger Prospect (Table 6); Profile 2 (Austin et al. 2006) is a medium-reflectivity sediment based on core samples from the Klondike site (Table 7); Profile 3 (Johnston et al. 2009) is a low-reflectivity sediment based on soil profiles and paleontological data from the Crackerjack and Shoebill sites (Table 8).

Table 6. Geoacoustic Profile 1 for high-reflectivity bottom for Province 1.

Depth below seafloor (m)	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–14.5	1.45	1630	0.26	98	0.13
> 14.5	2.32	2384	0.1		

Table 7. Geoacoustic Profile 2 for medium-reflectivity bottom for Provinces 1 and 2.

Depth below seafloor (m)	Material	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–4	Sandy silt and silty sand	1.8	1600	0.4	200	4.0
4–500	Sandy silt and silty sand	2.2	1800	0.5		
> 500	Bedrock	2.3	3000	0.2		

Table 8. Geoacoustic Profile 3 for a low-reflectivity bottom for Province 1.

Depth below seafloor (m)	Material	Density (g/cm^3)	P-wave speed (m/s)	P-wave attenuation (dB/λ)	S-wave speed (m/s)	S-wave attenuation (dB/λ)
0–50	Clayey silt and silty clay	1.45	1449	0.1	115	2.0
50	Clayey silt and silty clay	1.5	1512	0.2		
50	Silt-sand-clay	1.646	1554	0.2		
700	Silt-sand-clay	2.296	2128	1.1		
> 700	Bedrock	2.3	2800	0.2		

3.5.3. Bathymetry

Bathymetry data for this study was obtained from the University of Alaska's Geographic Information Network of Alaska (GINA) gridded bathymetry dataset. GINA data consists of a combination of topography and bathymetry information from three publicly available gridded datasets, sampled and merged into identically registered 30 s latitude/longitude grids (Lindquist et al. 2004). For this work, latitude/longitude point bathymetry data from GINA were converted into UTM (zone 4) coordinates and interpolated onto a regular x/y grid at 200 m resolution.

4. Variability Analysis

Underwater sound transmission loss depends on factors such as water depth and how it varies between source and receiver (bathymetry), the water column sound speed profile (SSP), and the geoacoustic properties (i.e., the density, and the speed and attenuation of compressional and shear waves) of the seafloor. In addition to these environmental parameters, sound transmission loss also depends on source-specific parameters such as the frequency content of the sound and the source depth, as well as the receiver depth. The environmental parameters are defined as fixed inputs to the acoustic propagation model MONM, though in reality these parameters can vary with both space and time. As these parameters change, so do the resulting sound propagation ranges.

Statistical approaches can be implemented to incorporate variability of these environmental parameters by computing many realizations of the model, with input parameters chosen randomly from a fixed range of possible values, and then examining the statistical distribution of the model outputs. This approach requires significant computation time. Instead, for this analysis a set of input parameters was selected that represent the average conditions expected for the environment, as well as those parameters that are expected to result in the least and the greatest amount of sound propagation.

An analysis of the correlation between sound transmission loss and environmental conditions was conducted in Task 1 for various source types (Austin et al. 2015). The analysis included examining empirical propagation distances measured during a large number of sound source verification (SSV) studies in the Chukchi Sea since 2006. The SSV studies were conducted at different locations, with different water depths, and at different times of year, an assumed proxy for water column sound-speed conditions. This analysis revealed that sound propagation was more strongly correlated with water depth than time of year.

The Task 3 analysis considered the effects of variation in water depth and bathymetry on the propagation distances by modeling at a selection of model sites, with water depths spanning the conditions across the lease blocks. The impact from variation in other environmental parameters was examined by comparing outputs from the model configured for low-, average-, and high-sound propagation conditions. The influence of the set of water column sound speed parameters were considered separately from the influence of the set of geoacoustic parameters by holding one set of parameters fixed at the average conditions while varying the others.

This variability analysis was conducted only at Site 1a but it is expected that each modeling site would exhibit the same trends. MONM was configured separately with the low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustic profiles with the water column sound speed fixed at the average profile. Then MONM was configured separately with the downward refracting, average, and mixed sound speed profiles with the geoacoustic profile fixed with the medium-reflectivity profile. Results for each of these parameter combinations for Scenario 1 are presented here as an example; results for each of the other scenarios show the same trends and are shown in Appendix B.

Maximum propagation distances, $R_{\max}$, corresponding with medium-reflectivity geoacoustics and with the three different sound speed profiles are shown in Table 9; those corresponding with the average sound speed profile and with low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics are shown in Table 10. Variation of the sound speed profile has only a very small effect on the $R_{\max}$ values in comparison to the effect of variation in the geoacoustic profile. This phenomenon was consistent across all scenarios modeled at modeling Site 1a, and it is expected that would be the case at each modeling site. This finding is consistent with the Task 1 analysis, which revealed a weak correlation between sound propagation and time of year, considered a proxy for sound speed profile. Based on this variability analysis, it is unlikely that variation in the sound speed profile will influence the sizes of the effects zones considered in this Task 3 modeling study. Hence, the results in Section 5 consider only the effect of varying geoacoustic profiles while the water column sound speed profile is fixed at the average profile. Because Scenario 8 could only occur when ice is present, the average sound speed profile conditions are not considered representative, thus all Scenario 8 modeling used the mixed sound speed profile rather than the average sound speed profile (see Section 3.5.1).

Table 9. Scenario 1 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	0.43	0.43	0.45
180	1.34	1.35	1.37
160	6.04	6.32	6.29

Table 10. Scenario 1 at modeling Site 1a: R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	0.22	0.43	0.50
180	0.72	1.35	1.45
160	4.14	6.32	9.11

5. Results

Eight scenario configurations were modeled for each of the four modeling sites (Section 3.1). This section presents the results for these eight scenarios as well as for the two scenarios that were not modeled, but for which measured radii are presented.

For each scenario, the results are shown graphically on maps with isopleth contours of rms SPL, maximized over water depth, and in tables listing the distances from the sources to the sound level contours. The distances are expressed using R_{max}, $R_{95\%}$, and R_{ea} for the average environmental conditions. Distances expressed using R_{max} are also presented for the three modeled geoacoustic profiles.

5.1. Scenario 1

Scenario 1 consisted of a 3200 in^3 airgun array operating at a depth of 6 m, which represents a typical 2-D/3-D seismic survey. The tow direction is toward shore. Sound levels generated from the seismic survey vessel (towing the airgun array) were not included in this study because the source levels were significantly lower than the airgun signal. Details about the source levels are shown in Section 3.4.1. Figures 19 through 22 show isopleth maps of modeled, unweighted, maximum-over-depth, broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 µPa for Scenario 1 at each modeling site. Tables Table 11 through 18 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 1 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 1 at each modeling site.

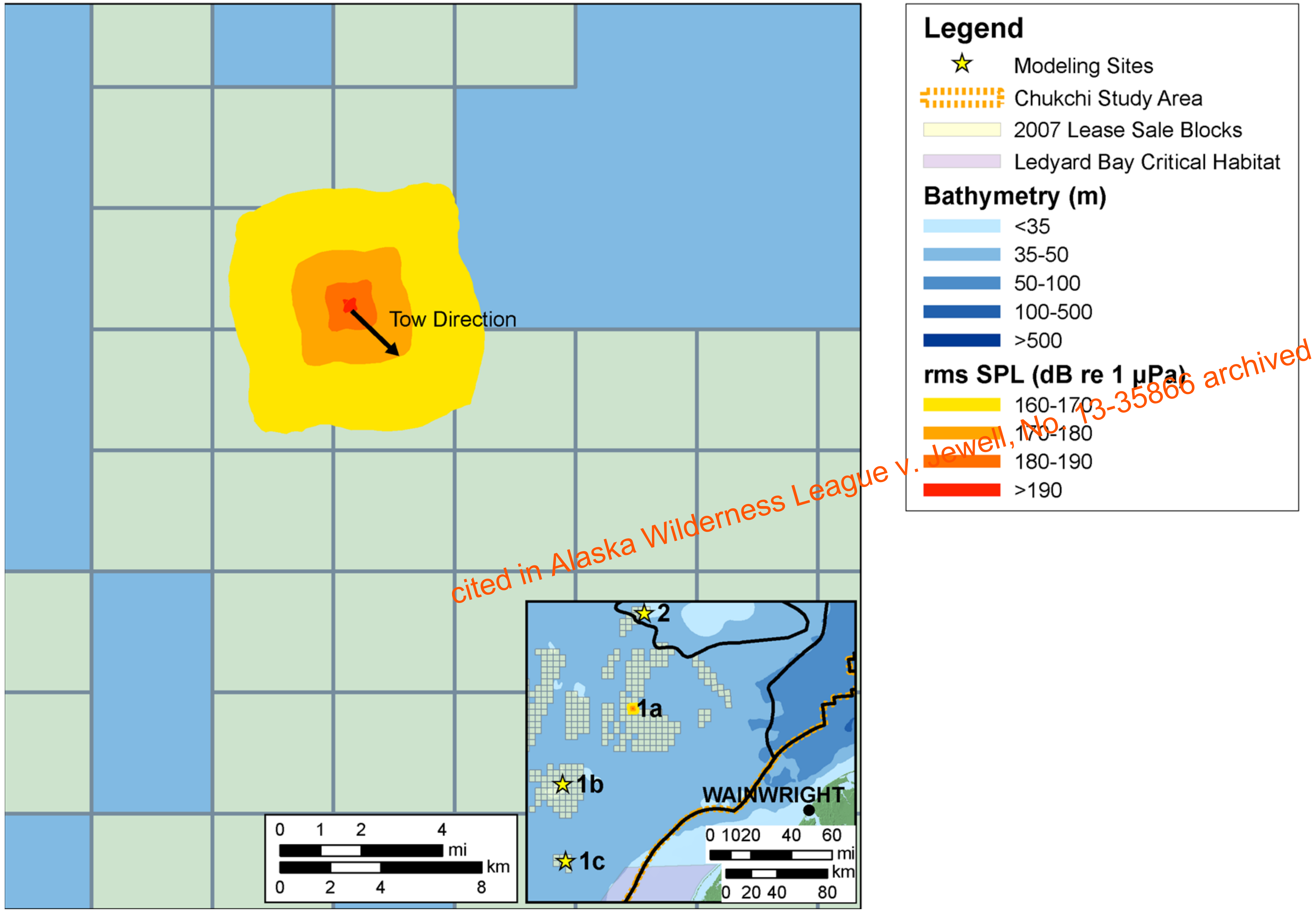

Figure 19. Scenario 1 at modeling Site 1a: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 3200 in^3 airgun array operating at a depth of 6 m, representative of a typical 2-D/3-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 1 Site 1a

Table 11. Scenario 1 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.43	0.38	0.31
180	1.35	1.14	1.05
160	6.32	5.42	5.21

Table 12. Scenario 1 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.14	0.22	0.31	0.43	0.36	0.50
180	0.47	0.72	1.05	1.35	1.17	1.45
160	3.41	4.14	5.21	6.32	7.64	9.11

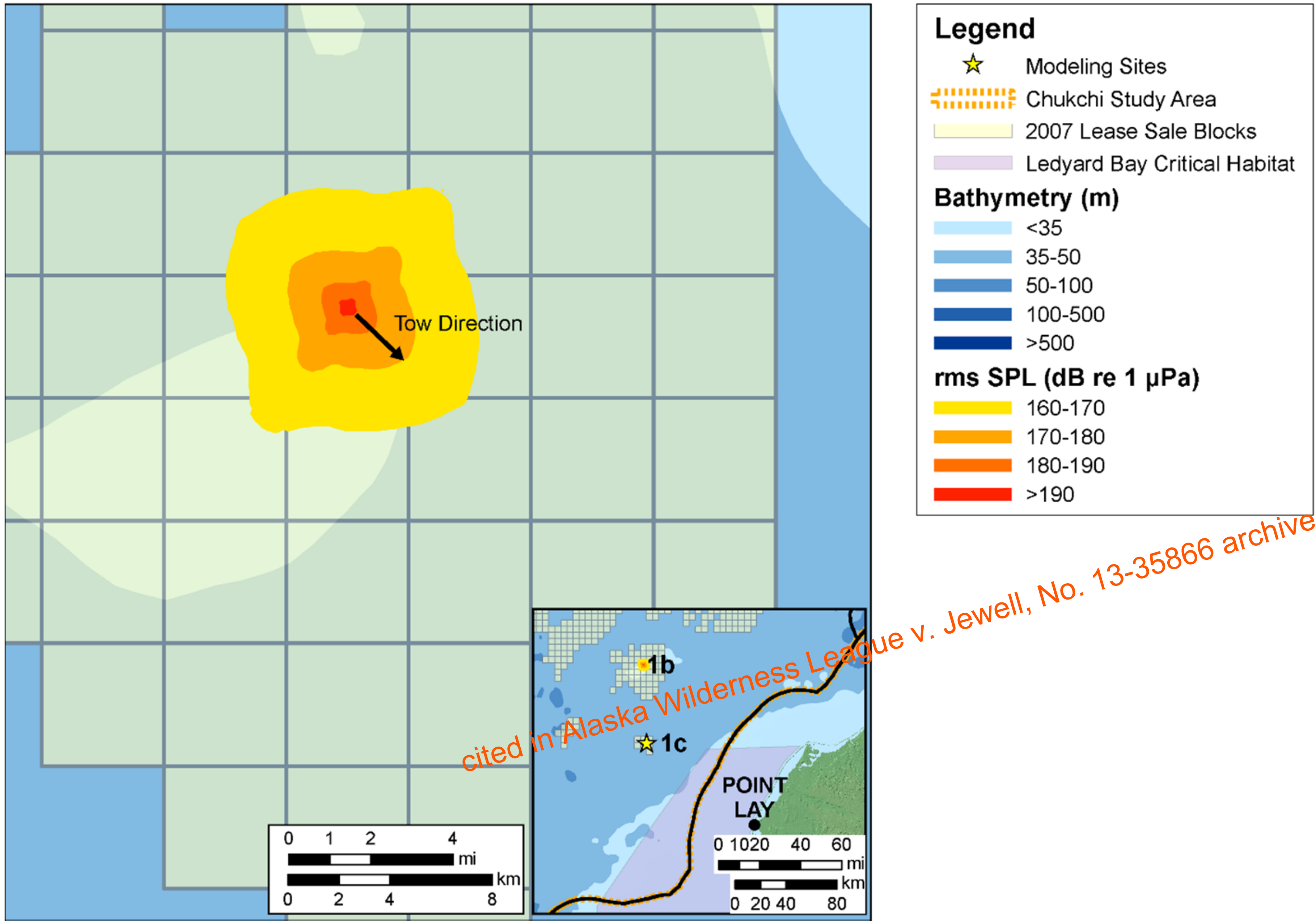

Figure 20. Scenario 1 at modeling Site 1b: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 3200 in^3 airgun array operating at a depth of 6 m, representative of a typical 2-D/3-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 1 Site 1b

Table 13. Scenario 1 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.51	0.42	0.35
180	1.36	1.18	1.11
160	6.32	5.22	5.10

Table 14. Scenario 1 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.15	0.24	0.35	0.51	0.43	0.57
180	0.51	0.75	1.11	1.36	1.29	1.57
160	3.37	4.08	5.10	6.32	7.84	9.05

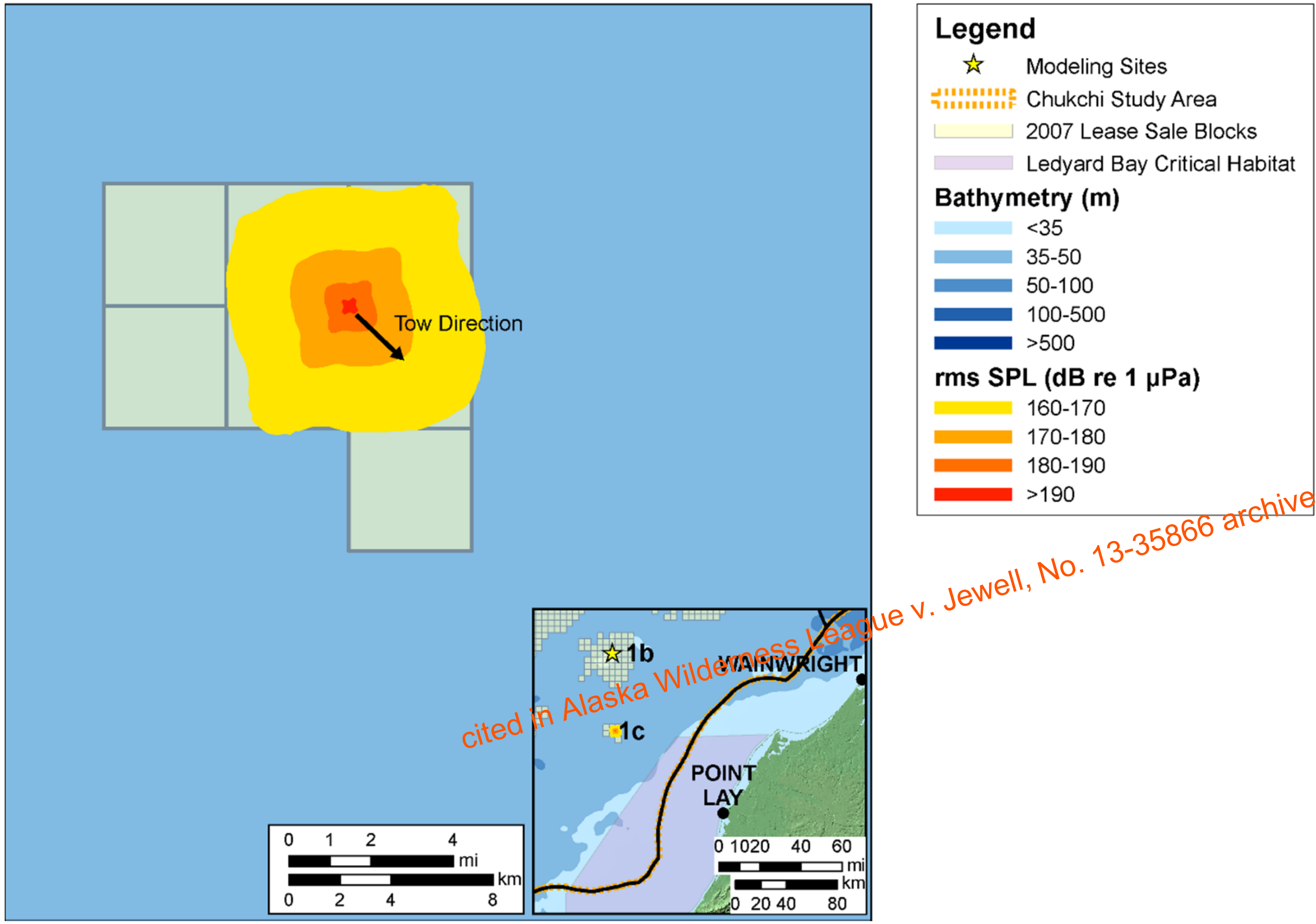

Figure 21. Scenario 1 at modeling Site 1c: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 3200 in^3 airgun array operating at a depth of 6 m, representative of a typical 2-D/3-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 1 Site 1c

Table 15. Scenario 1 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.45	0.38	0.32
180	1.32	1.15	1.06
160	6.13	5.34	5.18

Table 16. Scenario 1 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.14	0.23	0.32	0.45	0.379	0.530
180	0.48	0.74	1.06	1.32	1.19	1.51
160	3.41	4.27	5.18	6.13	7.72	8.92

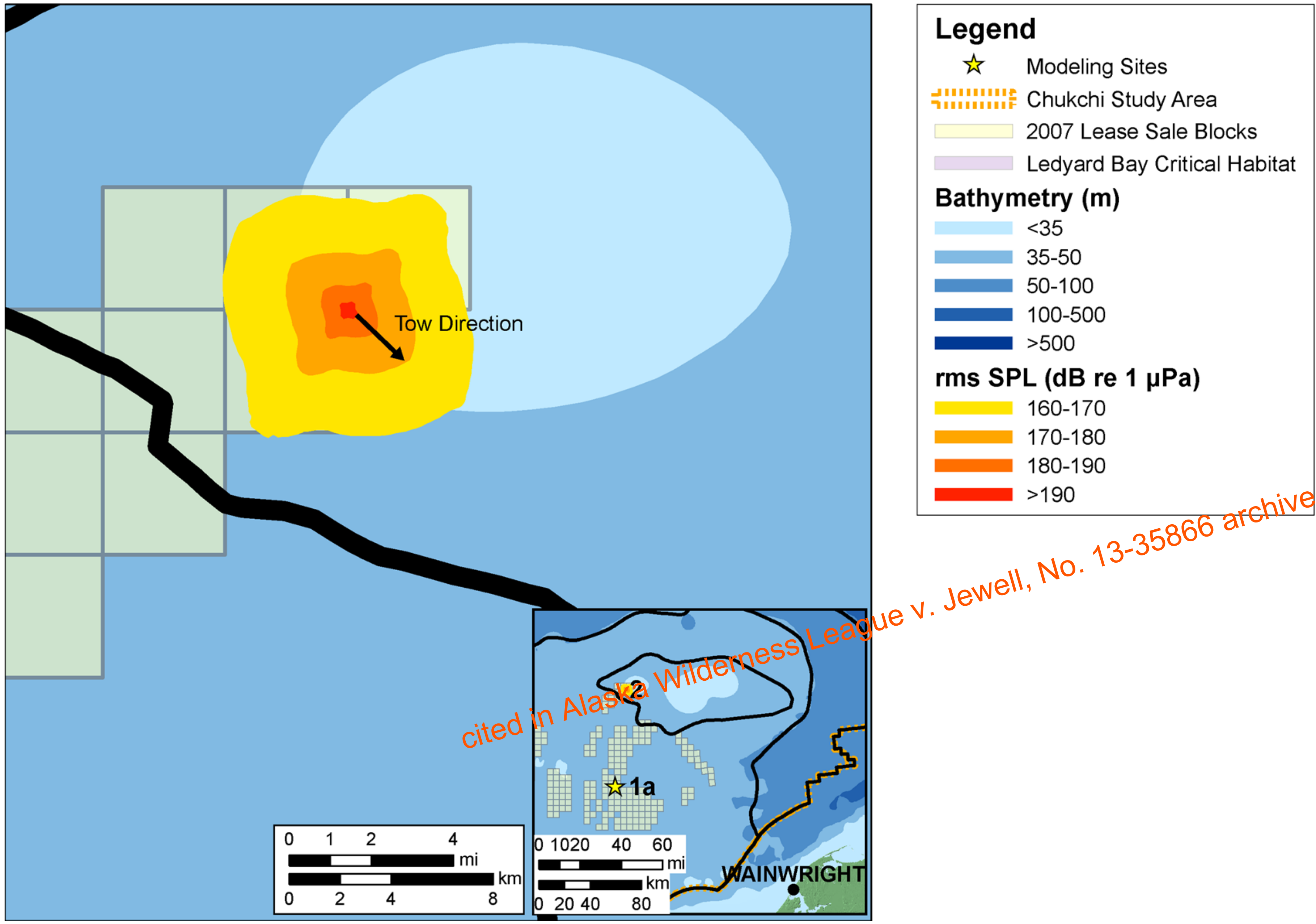

Figure 22. Scenario 1 at modeling Site 2: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 3200 in^3 airgun array operating at a depth of 6 m, representative of a typical 2-D/3-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 1 Site 2

Table 17. Scenario 1 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.50	0.43	0.36
180	1.39	1.21	1.14
160	6.26	5.15	5.02

Table 18. Scenario 1 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.15	0.23	0.36	0.50	0.45	0.59
180	0.51	0.74	1.14	1.39	1.34	1.66
160	3.37	4.10	5.02	6.26	7.58	8.52

5.2. Scenario 2

Scenario 2 consisted of a drillship performing drilling operations with a support vessel on DP 500 m from the drillship. Details about the source levels are shown in Sections 3.4.2 and 3.4.3. Figures 23 through 26 show isopleth maps of modeled unweighted maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 µPa for Scenario 2 at each modeling site. Tables Table 19 through 26 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 2 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 2 at each modeling site. These radii are relative to the support vessel for thresholds ≤ 160 dB and are relative to the center point between the drillship and the support vessel for the 120 dB threshold.

Scenario 2 Site 1a

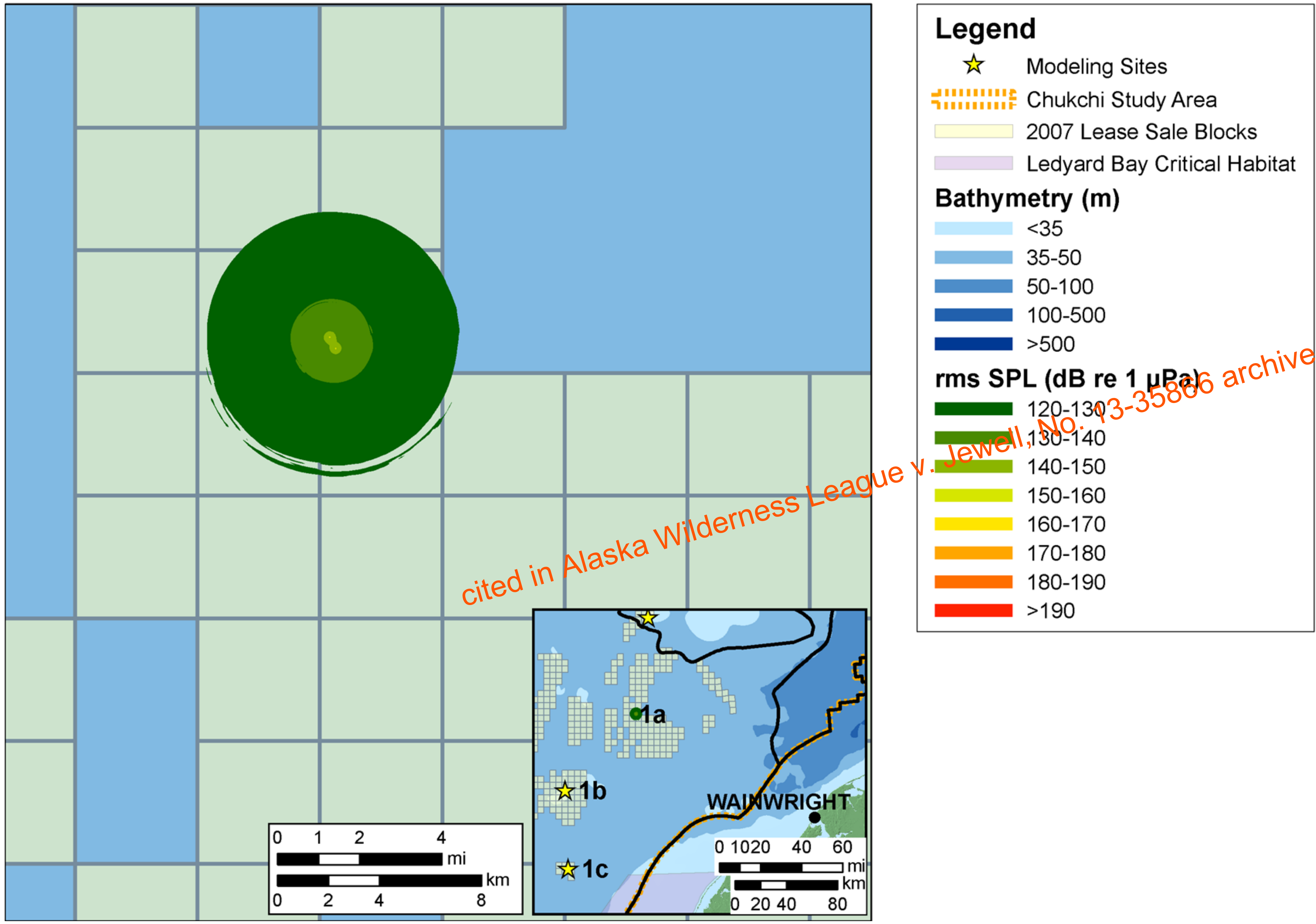

Figure 23. Scenario 2 at modeling Site 1a: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A drillship performing drilling operations with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Table 19. Scenario 2 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	5.29	4.91	4.99

*Not reached.

Table 20. Scenario 2 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	2.21	2.33	4.99	5.29	6.52	6.97

*Not reached.

Scenario 2 Site 1b

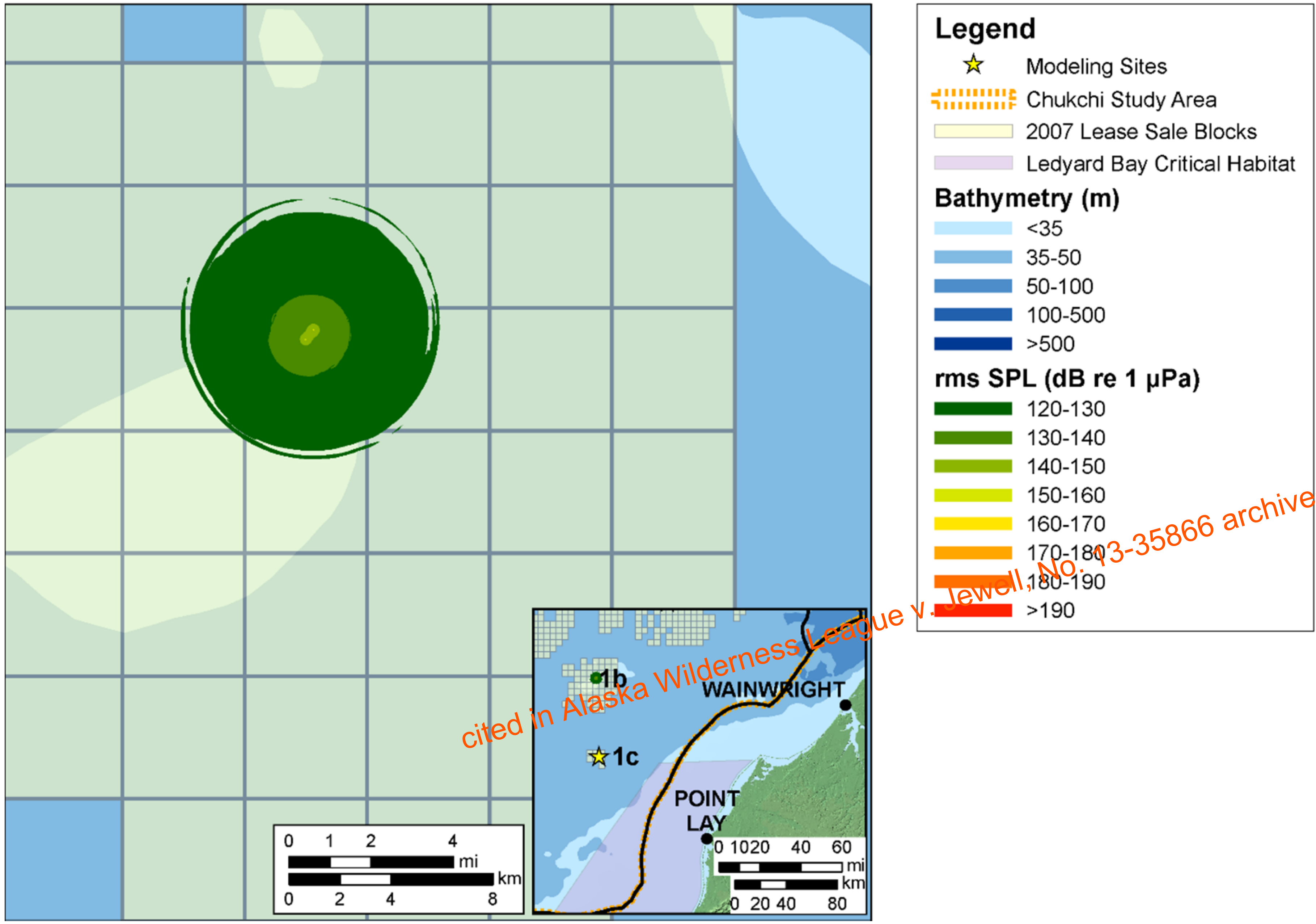

Figure 24. Scenario 2 at modeling Site 1b: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A drillship performing drilling operations with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Table 21. Scenario 2 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	5.48	4.80	4.86

*Not reached.

Table 22. Scenario 2 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	2.11	2.18	4.86	5.48	6.59	7.63

*Not reached.

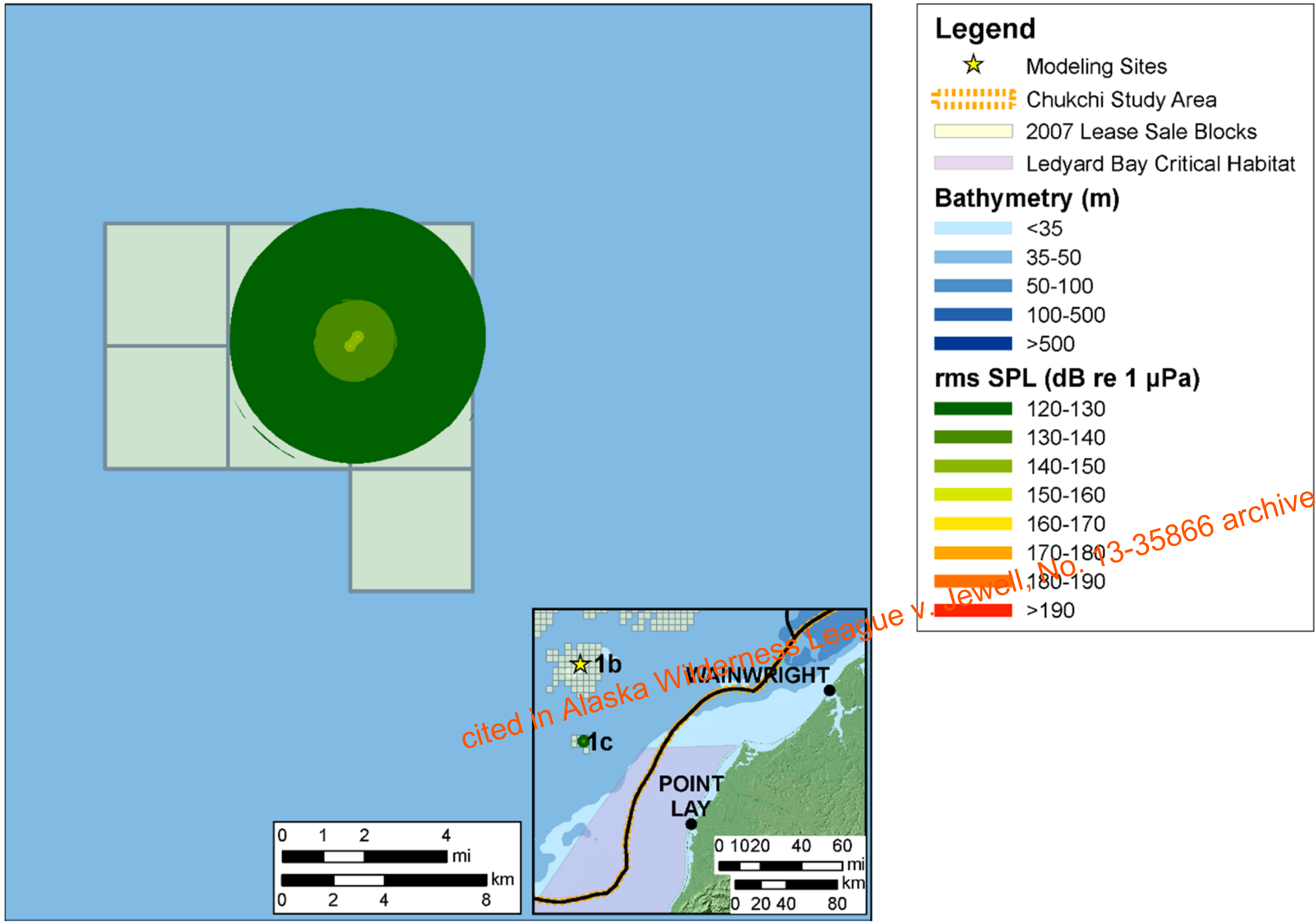

Figure 25. Scenario 2 at modeling Site 1c: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A drillship performing drilling operations with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Scenario 2 Site 1c

Table 23. Scenario 2 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	5.50	4.86	4.96

*Not reached.

Table 24. Scenario 2 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	2.19	2.41	4.96	5.50	7.39	6.51

*Not reached.

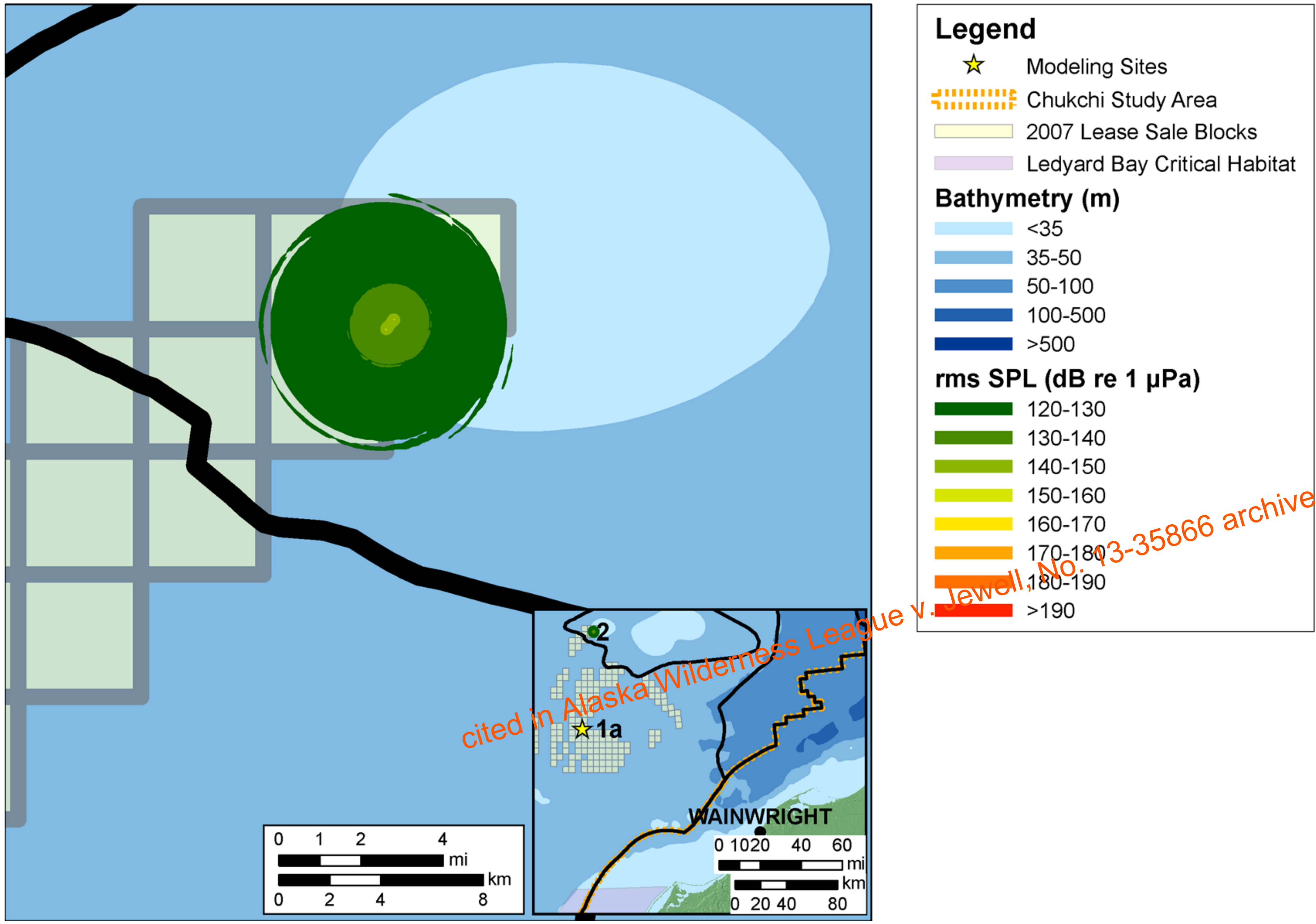

Figure 26. Scenario 2 at modeling Site 2: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A drillship performing drilling operations with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Scenario 2 Site 2

Table 25. Scenario 2 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	5.16	4.73	4.78

*Not reached.

Table 26. Scenario 2 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	2.07	2.21	4.78	5.16	6.51	7.37

*Not reached.

5.3. Scenario 3

Scenario 3 consisted of a 4500 in^3 airgun array operating at a depth of 8.5 m, which represents a typical 2-D seismic survey. The tow direction is toward shore. Sound levels generated from the seismic survey vessel (towing the airgun array) were not included in this study because the source levels are significantly lower than the airgun signal. Details about the source levels are shown in Section 3.4.4. Figures 27 through 30 show isopleth maps of modeled unweighted maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 μPa for Scenario 3 at each modeling site. Tables Table 27 through 34 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 3 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 3 at each modeling site.

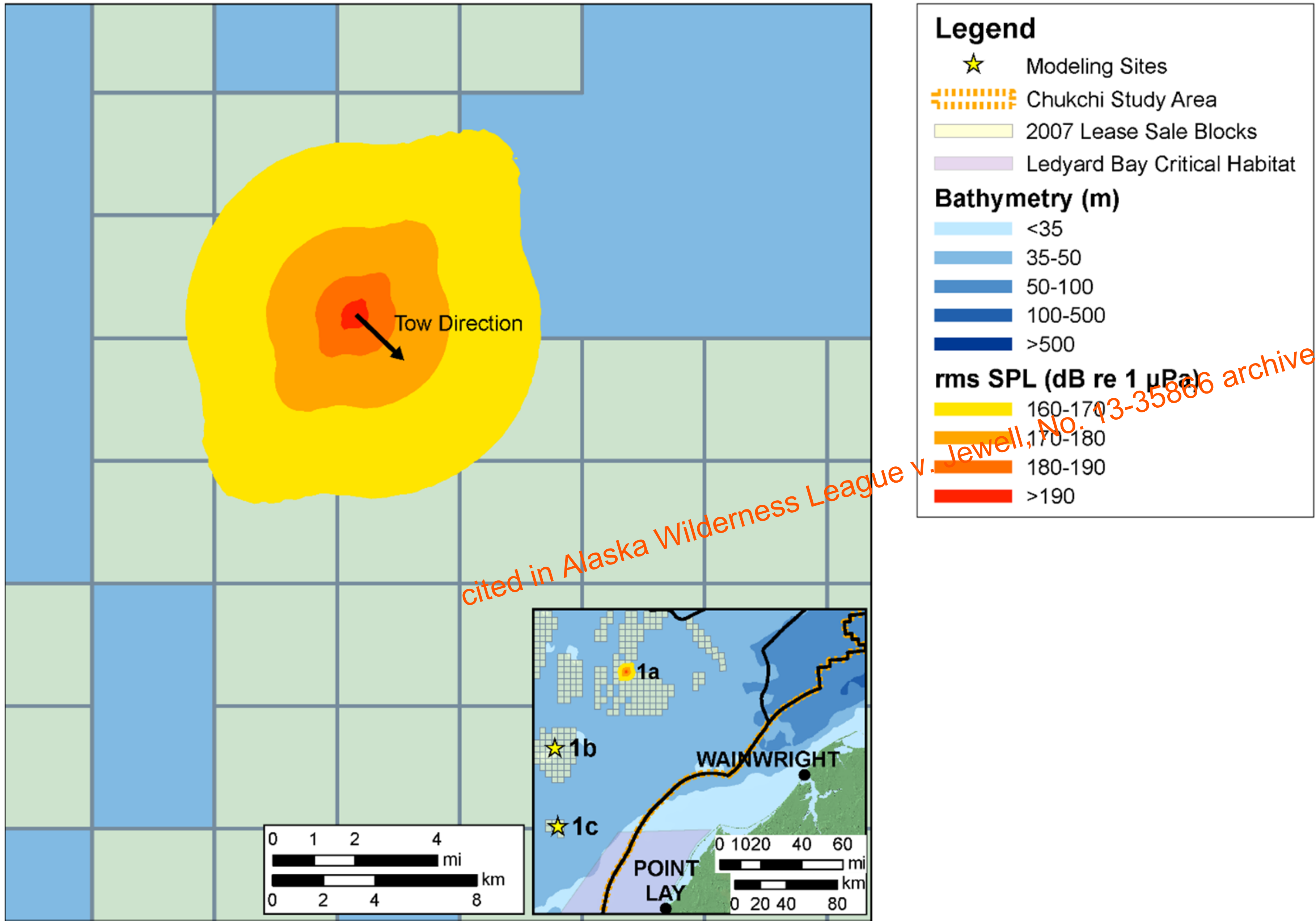

Figure 27. Scenario 3 at modeling Site 1a: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 4500 in^3 airgun array operating at a depth of 8.5 m, which represents a typical 2-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 3 Site 1a

Table 27. Scenario 3 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.73	0.63	0.57
180	2.09	1.69	1.63
160	8.86	7.49	7.28

Table 28. Scenario 3 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.27	0.46	0.57	0.73	0.65	0.77
180	0.86	1.22	1.63	2.09	1.91	2.24
160	5.22	6.39	7.28	8.86	11.0	13.8

Scenario 3 Site 1b

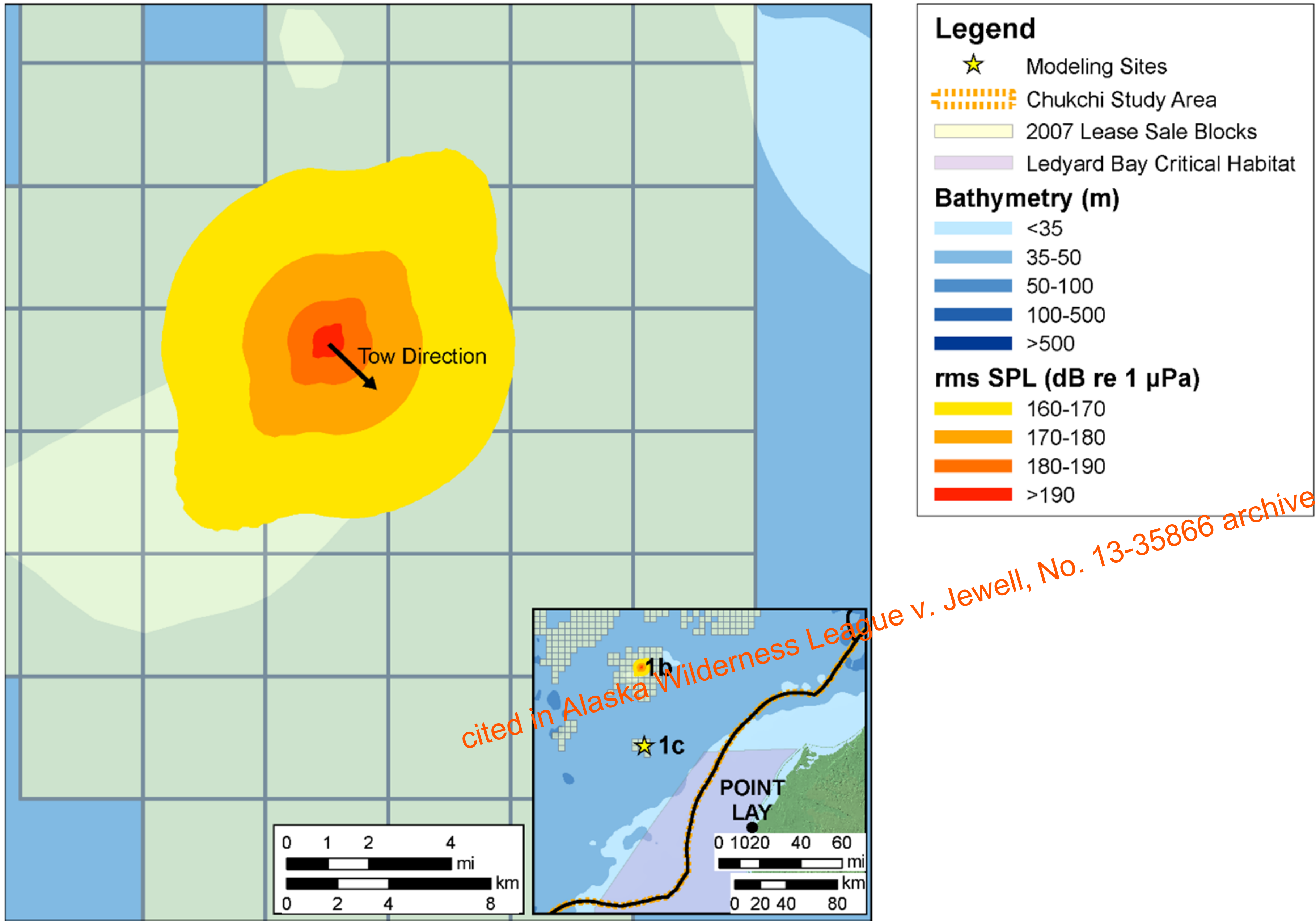

Figure 28. Scenario 3 at modeling Site 1b: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 4500 in^3 airgun array operating at a depth of 8.5 m, which represents a typical 2-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Table 29. Scenario 3 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.85	0.72	0.66
180	2.10	1.79	1.73
160	9.73	7.68	7.26

Table 30. Scenario 3 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.29	0.46	0.66	0.85	0.78	0.93
180	0.96	1.32	1.73	2.10	2.1	2.48
160	5.15	6.63	7.26	9.73	11.6	15.4

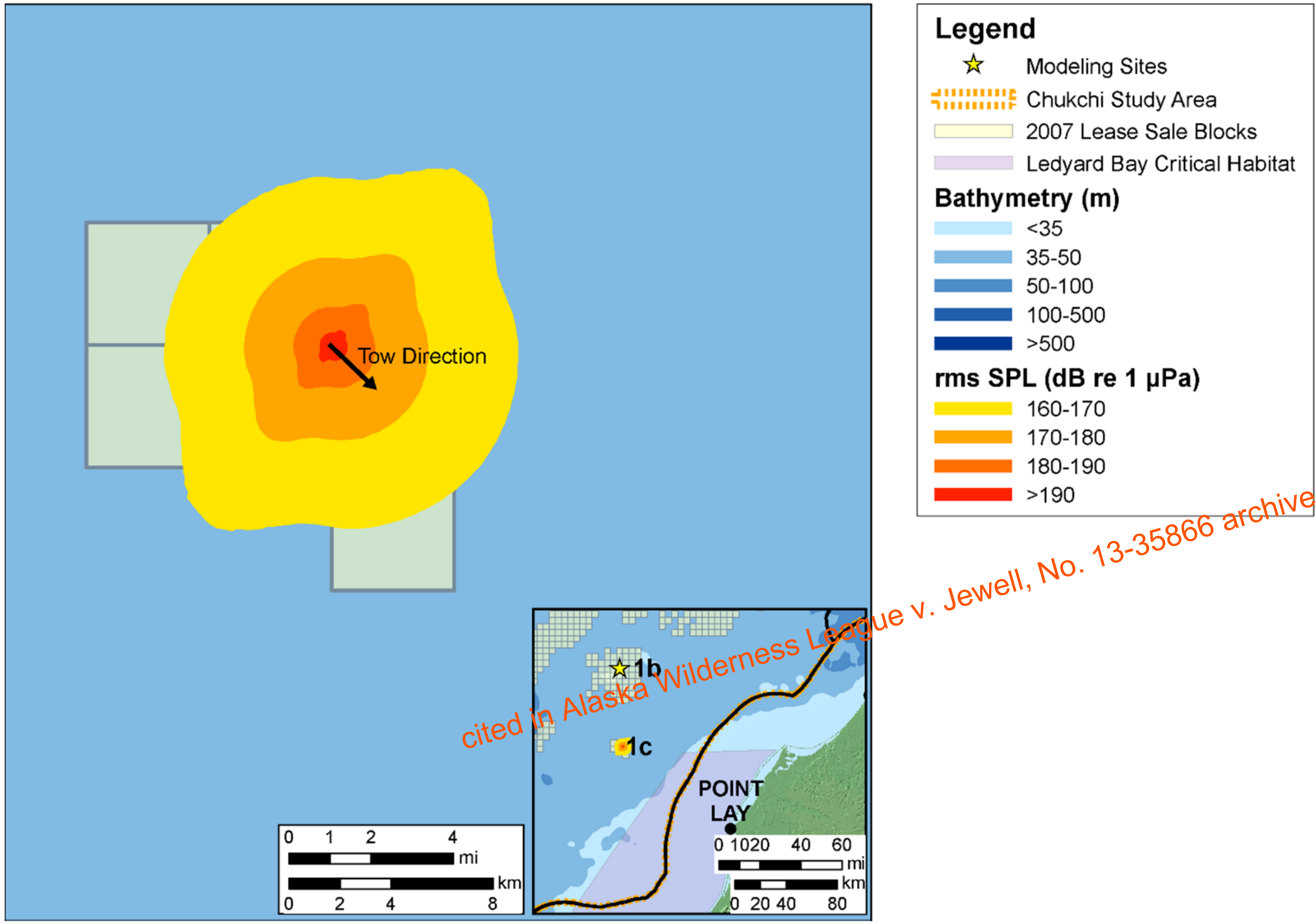

Figure 29. Scenario 3 at modeling Site 1c: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 4500 in^3 airgun array operating at a depth of 8.5 m, which represents a typical 2-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 3 Site 1c

Table 31. Scenario 3 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.78	0.66	0.59
180	2.02	1.75	1.67
160	9.05	7.45	7.23

Table 32. Scenario 3 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.28	0.46	0.59	0.78	0.69	0.83
180	0.88	1.21	1.67	2.02	1.96	2.31
160	5.24	6.30	7.23	9.05	10.9	13.0

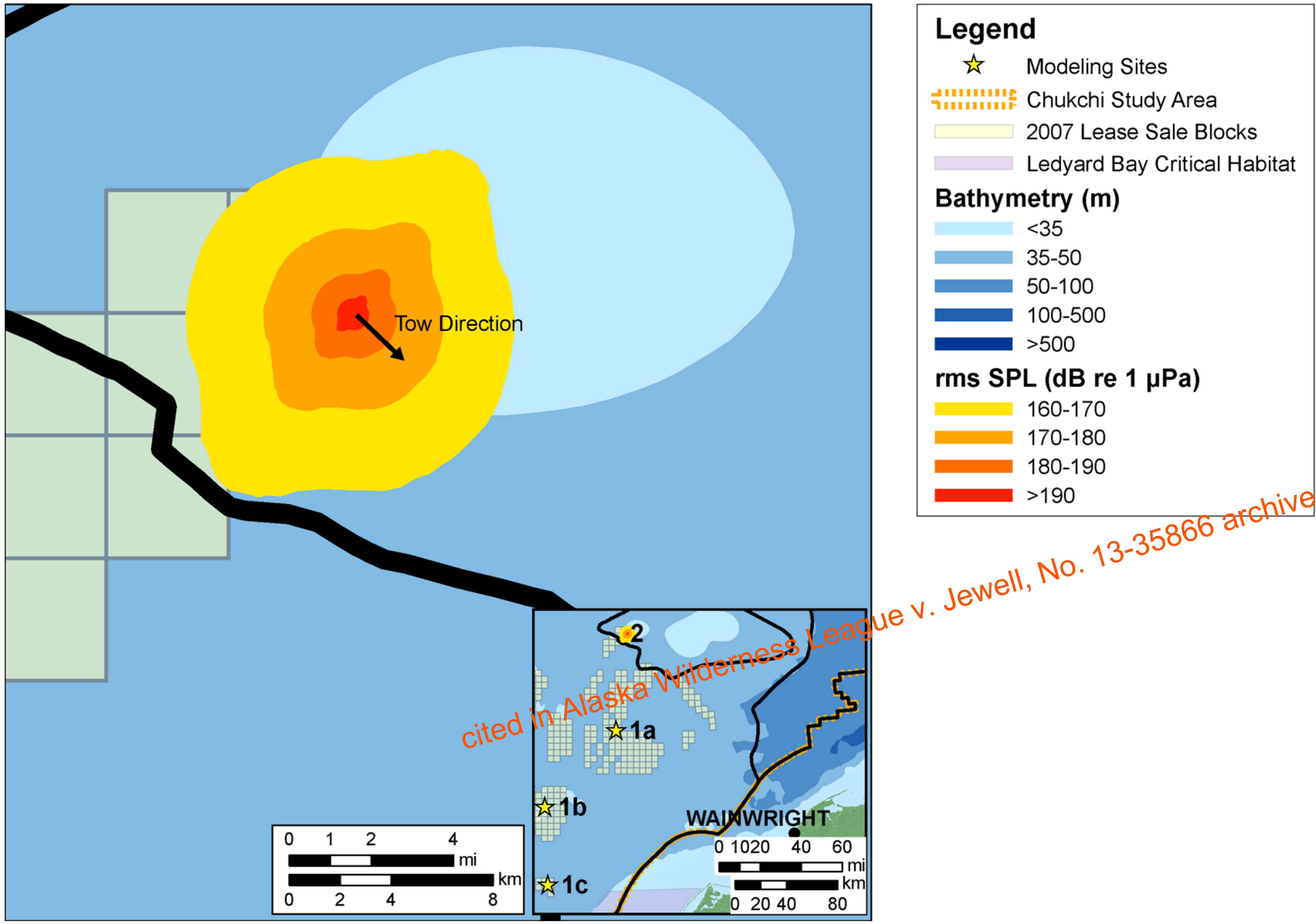

Figure 30. Scenario 3 at modeling Site 2: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 4500 in^3 airgun array operating at a depth of 8.5 m, which represents a typical 2-D seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 3 Site 2

Table 33. Scenario 3 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.86	0.73	0.66
180	2.18	1.82	1.73
160	8.69	6.96	6.77

Table 34 .Scenario 3 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.29	0.46	0.66	0.86	0.80	0.97
180	0.98	1.35	1.73	2.18	2.16	2.52
160	5.10	6.52	6.77	8.69	10.3	13.3

5.4. Scenario 4

Scenario 4 consisted of a 40 in^3 airgun array operating at a depth of 10 m, which represents a typical geohazard seismic survey. The tow direction is toward shore. Sound levels generated from the seismic survey vessel (towing the airgun array) were not included in this study because the source levels are significantly lower than the airgun signal. Details about the source levels are shown in Section 3.4.5. Figures 31 through 34 show isopleth maps of modeled unweighted maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 µPa for Scenario 4 at each modeling site. Tables Table 35 through 42 present the *R*max, *R*95%, and R_{ea} rms SPL threshold ranges for Scenario 4 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 4 at each modeling site.

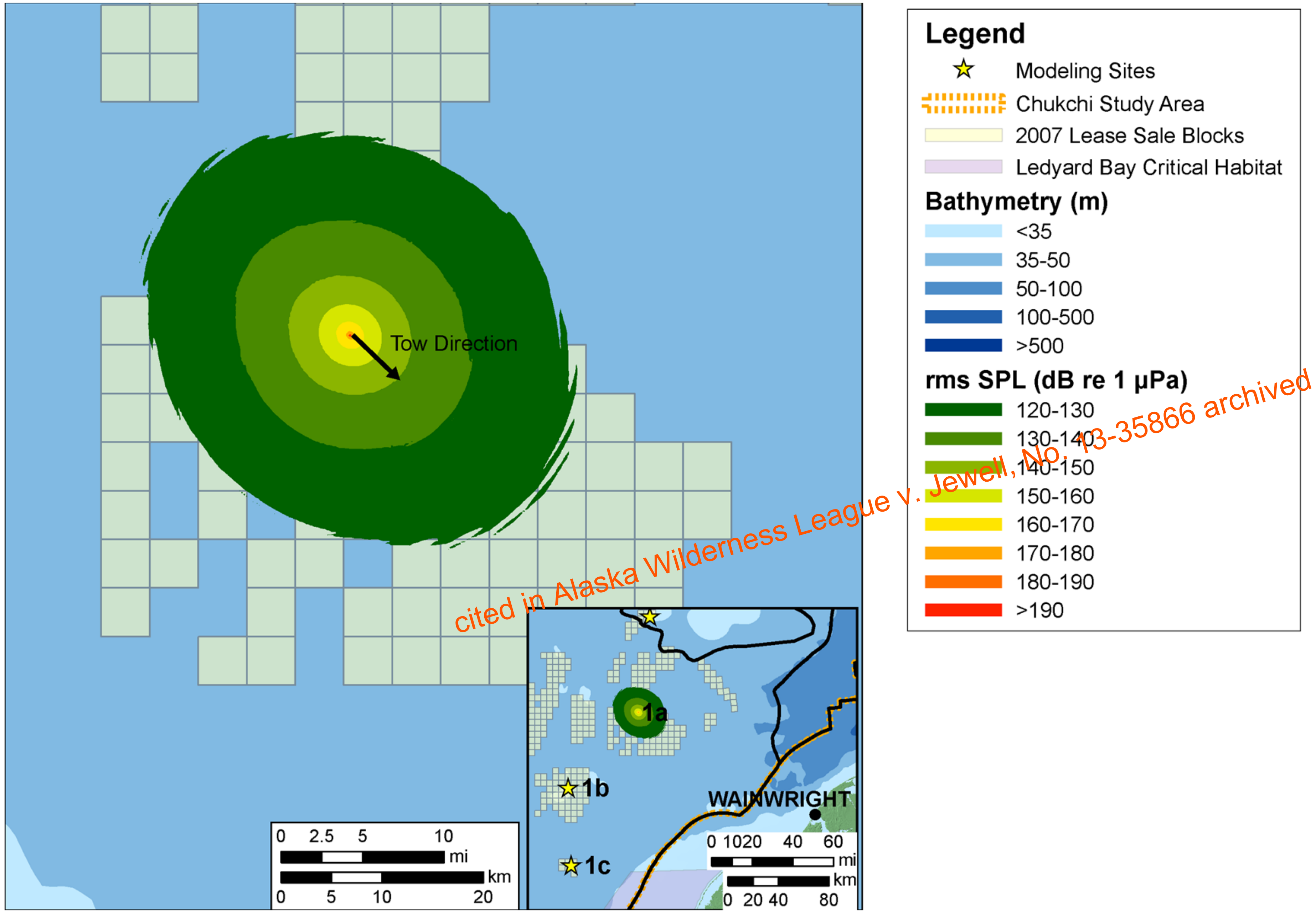

Figure 31. Scenario 4 at modeling Site 1a: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 40 in^3 airgun array operating at a depth of 10 m, representative of a typical geohazard seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 4 Site 1a

Table 35. Scenario 4 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.02	0.02	0.02
180	0.11	0.11	0.11
160	1.47	1.37	1.40

Table 36. Scenario 4 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.02	0.02	0.02	0.02	0.02	0.02
180	0.07	0.07	0.11	0.11	0.11	0.12
160	0.57	0.64	1.40	1.47	1.43	1.49

Scenario 4 Site 1b

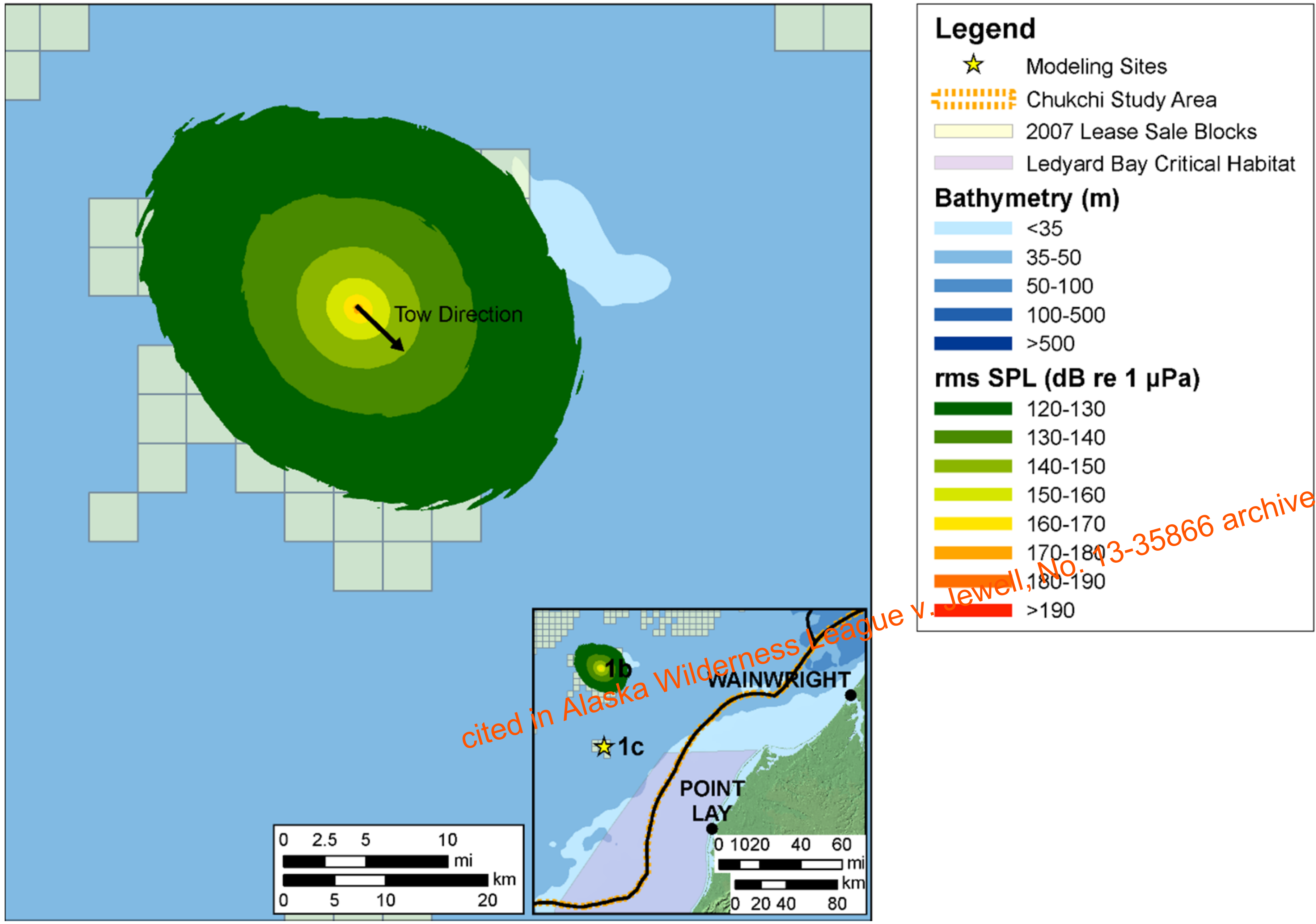

Figure 32. Scenario 4 at modeling Site 1b: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 40 in^3 airgun array operating at a depth of 10 m, representative of a typical geohazard seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Table 37. Scenario 4 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.02	0.02	0.02
180	0.11	0.10	0.11
160	1.53	1.42	1.41

Table 38. Scenario 4 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.02	0.02	0.02	0.02	0.02	0.02
180	0.07	0.07	0.11	0.11	0.11	0.12
160	0.61	0.68	1.41	1.53	1.49	1.57

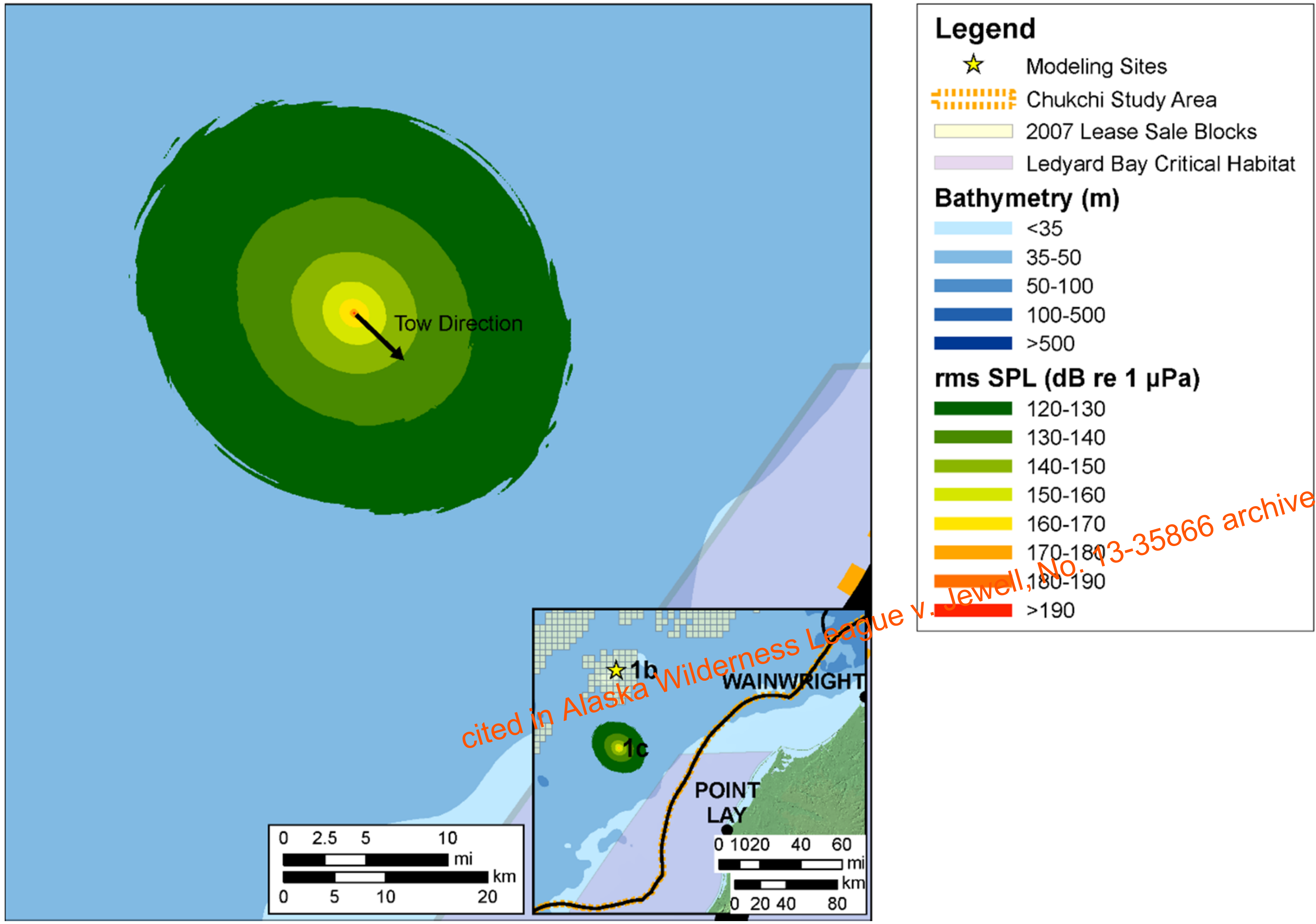

Figure 33. Scenario 4 at modeling Site 1c: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 40 in^3 airgun array operating at a depth of 10 m, representative of a typical geohazard seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 4 Site 1c

Table 39. Scenario 4 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.02	0.02	0.02
180	0.11	0.10	0.11
160	1.52	1.40	1.39

Table 40. Scenario 4 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.02	0.02	0.02	0.02	0.02	0.02
180	0.07	0.07	0.11	0.11	0.10	0.12
160	0.57	0.66	1.39	1.52	1.45	1.60

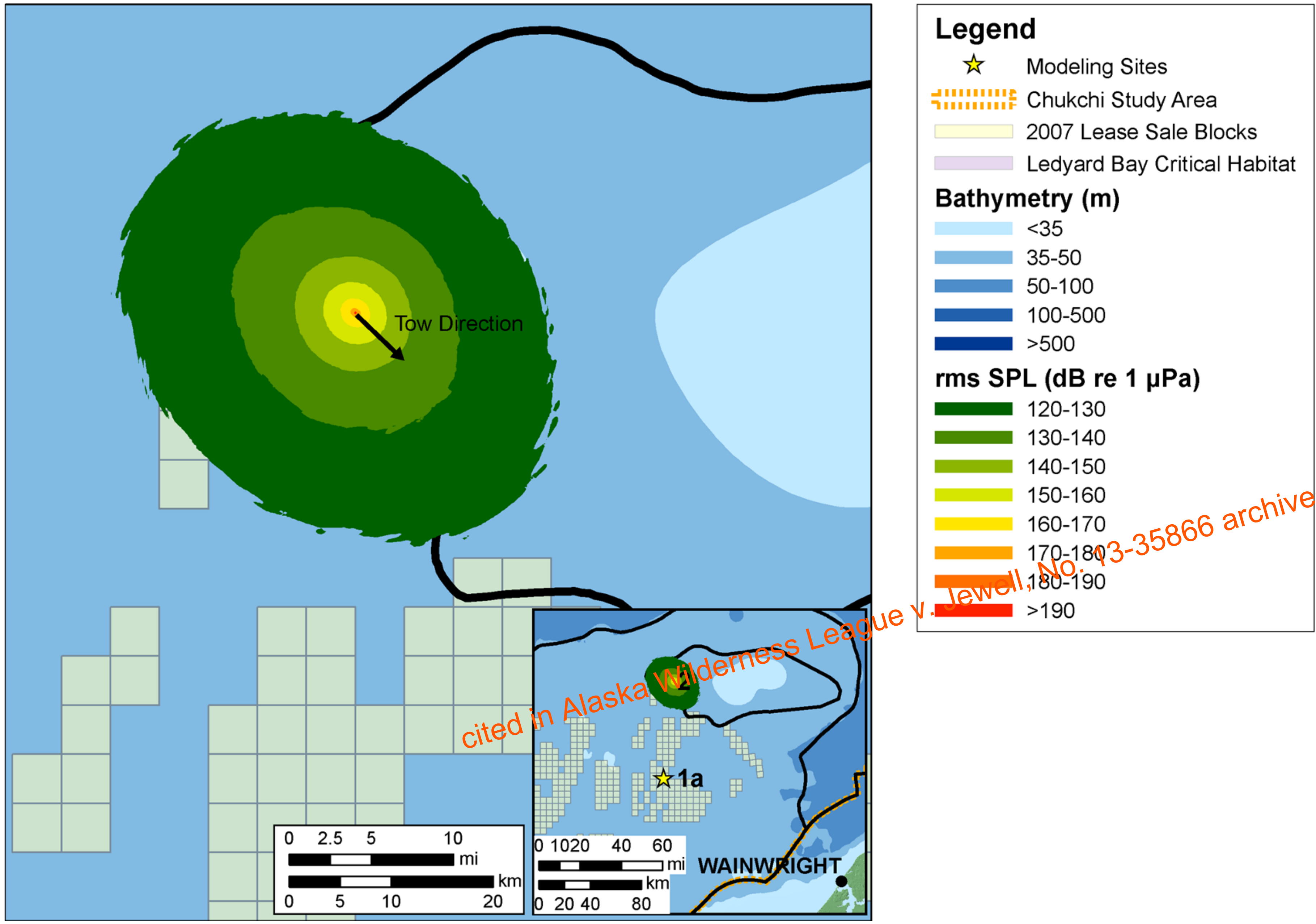

Figure 34. Scenario 4 at modeling Site 2: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 40 in^3 airgun array operating at a depth of 10 m, representative of a typical geohazard seismic survey. Tow direction is toward shore. An overview of the region appears in the lower right inset.

Scenario 4 Site 2

Table 41. Scenario 4 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.01	0.01	0.02
180	0.11	0.10	0.10
160	1.53	1.40	1.42

Table 42. Scenario 4 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.02	0.01	0.02	0.01	0.02	0.01
180	0.07	0.07	0.10	0.11	0.11	0.11
160	0.62	0.68	1.42	1.53	1.52	1.66

5.5. Scenario 5

Scenario 5 consisted of a 500 in^3 airgun array operating at a depth of 6 m, which represents a typical Vertical Seismic Profiler (ZVSP). Details about the source levels are shown in Section 3.4.6. Figures 35 through 38 show isopleth maps of modeled unweighted maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 μPa for Scenario 5 at each modeling site. Tables Table 43 through 50 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 5 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 5 at each modeling site.

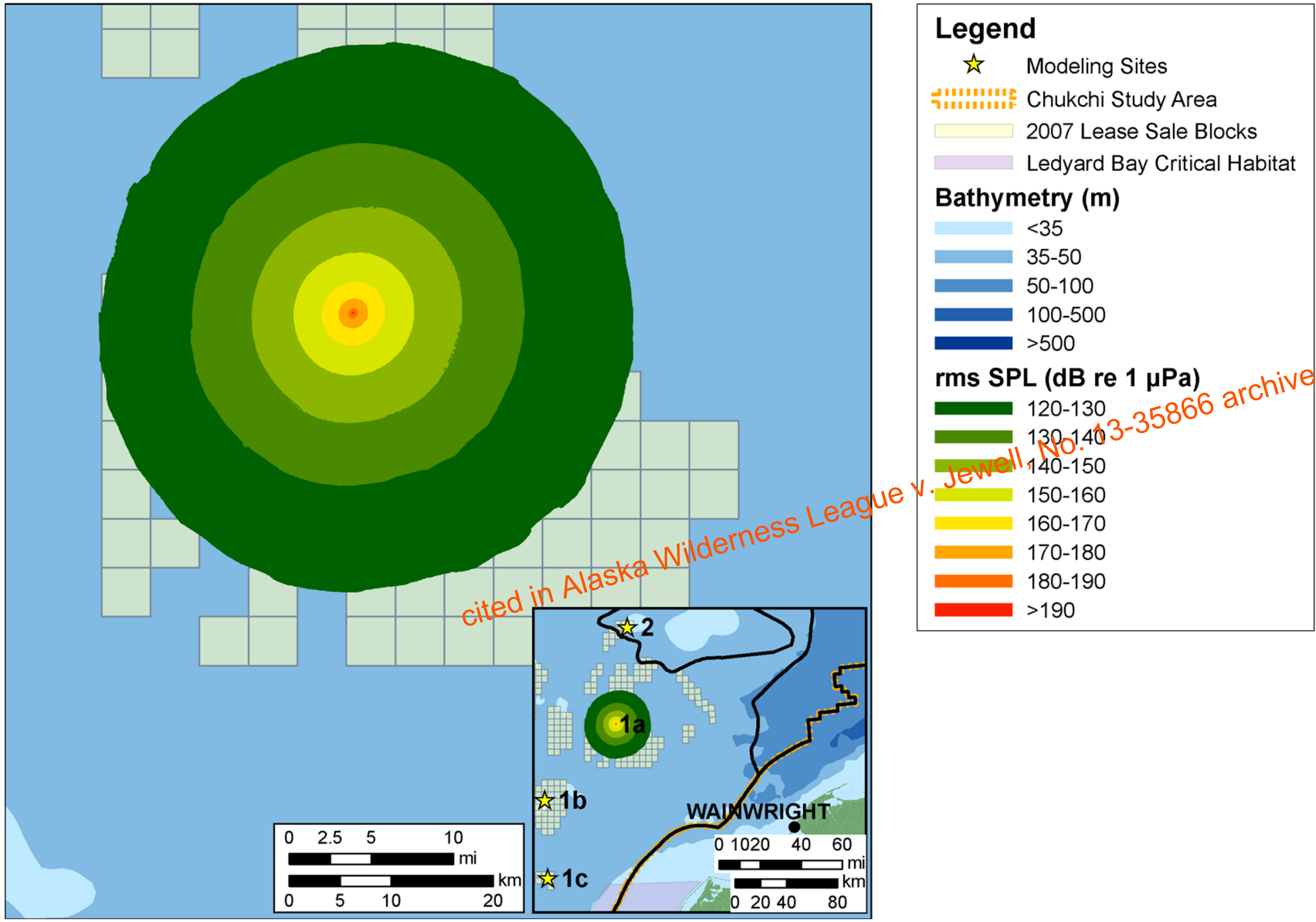

Figure 35. Scenario 5 at modeling Site 1a: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile.A 500 in^3 seismic airgun array operating at a depth of 6 m, representative of a typical ZVSP survey. An overview of the region appears in the lower right inset.

Scenario 5 Site 1a

Table 43. Scenario 5 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.14	0.13	0.13
180	0.52	0.49	0.49
160	3.24	3.10	3.14

Table 44. Scenario 5 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.08	0.08	0.13	0.14	0.15	0.17
180	0.23	0.25	0.49	0.52	0.60	0.62
160	1.94	2.11	3.14	3.24	3.89	4.06

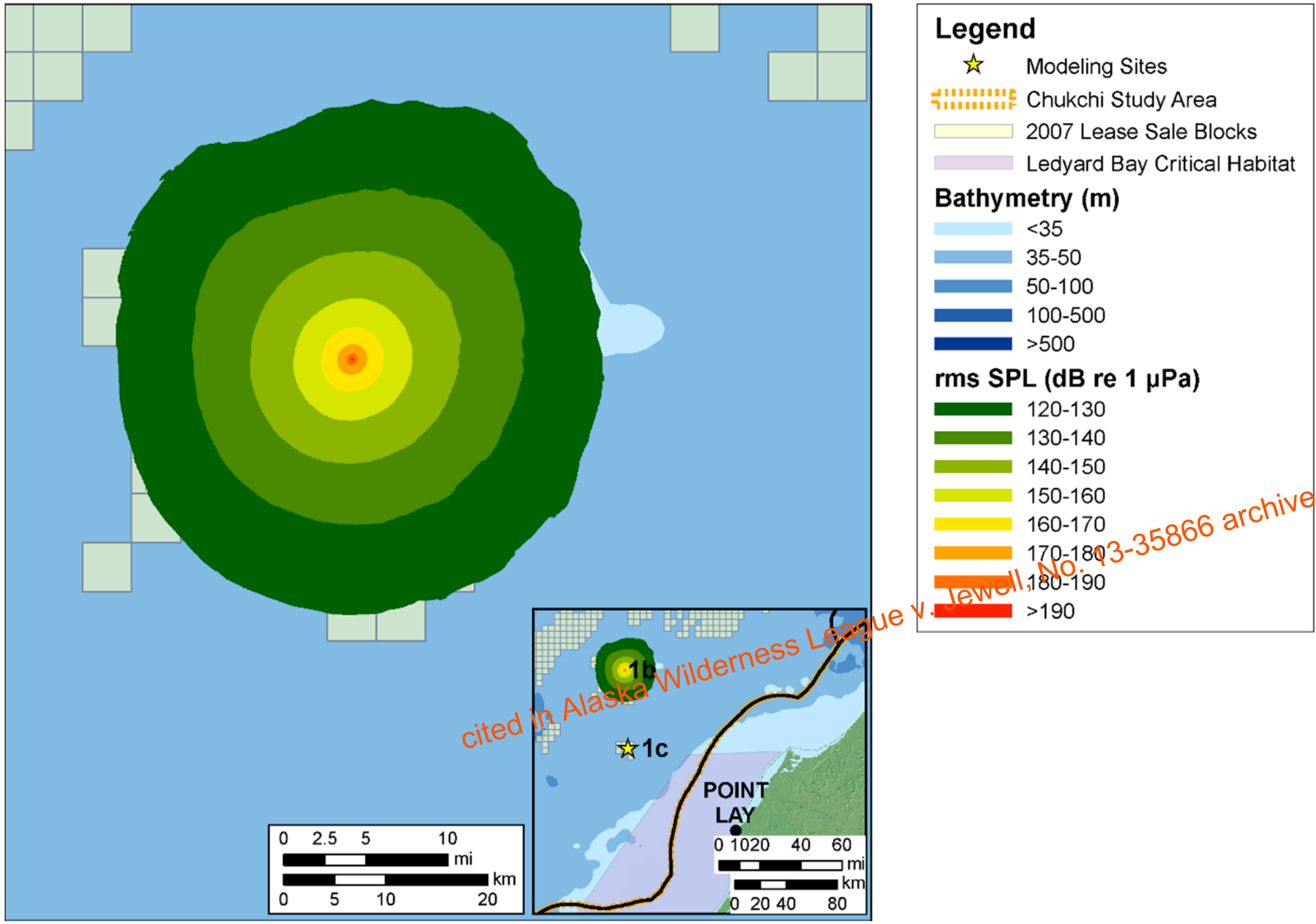

Figure 36. Scenario 5 at modeling Site 1b: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 500 in^3 seismic airgun array operating at a depth of 6 m, representative of a typical ZVSP survey. An overview of the region appears in the lower right inset.

Scenario 5 Site 1b

Table 45. Scenario 5 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.13	0.12	0.13
180	0.60	0.57	0.57
160	3.24	3.06	3.12

Table 46. Scenario 5 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.08	0.08	0.13	0.13	0.17	0.17
180	0.25	0.27	0.57	0.60	0.61	0.63
160	2.03	2.07	3.12	3.24	3.63	3.80

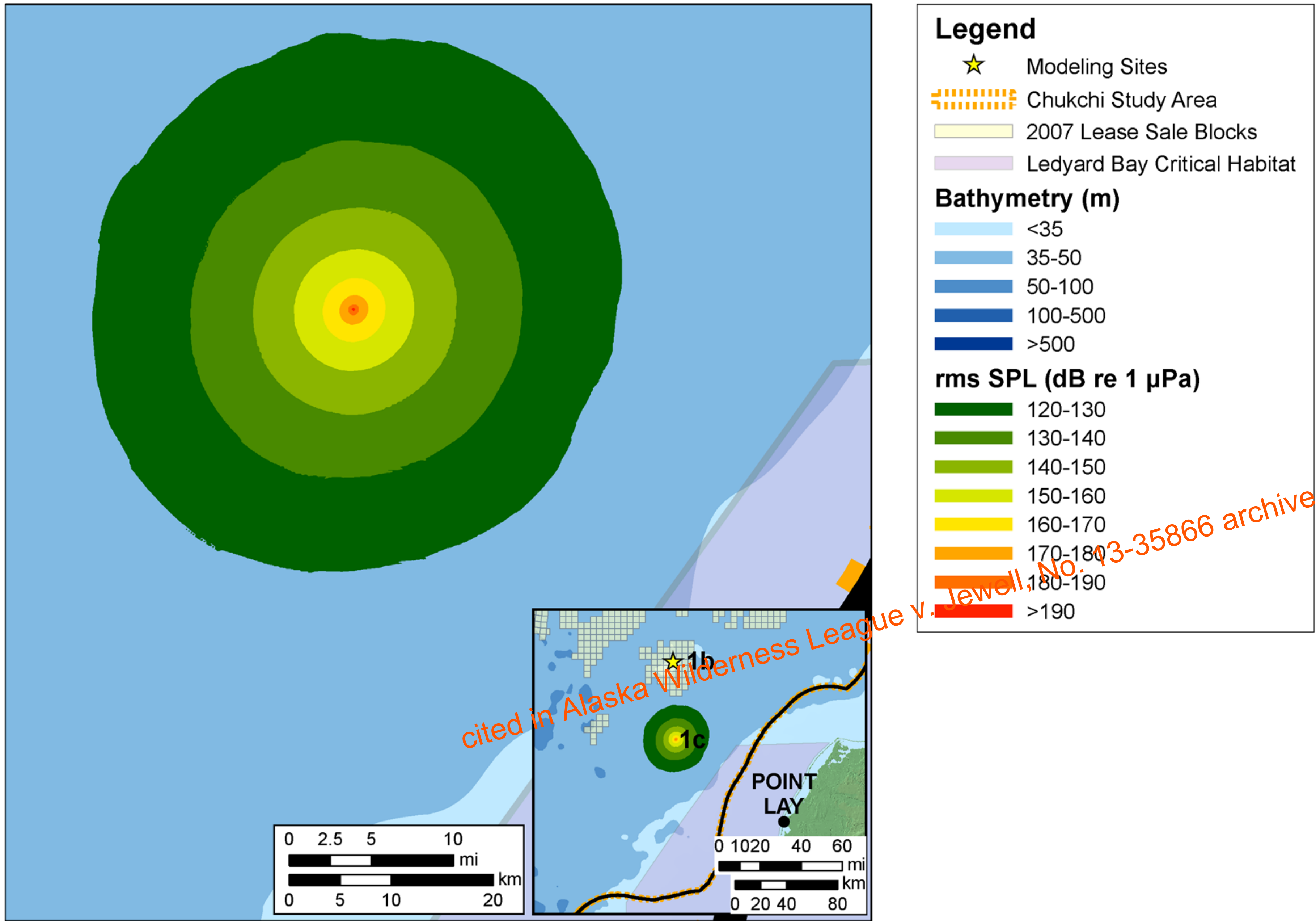

Figure 37. Scenario 5 at modeling Site 1c: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 500 in^3 seismic airgun array operating at a depth of 6 m, representative of a typical ZVSP survey. An overview of the region appears in the lower right inset.

Scenario 5 Site 1c

Table 47. Scenario 5 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.14	0.13	0.13
180	0.54	0.51	0.51
160	3.20	3.04	3.10

Table 48. Scenario 5 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.08	0.08	0.13	0.14	0.16	0.17
180	0.24	0.26	0.51	0.54	0.59	0.62
160	1.99	2.04	3.10	3.20	3.78	3.90

Scenario 5 Site 2

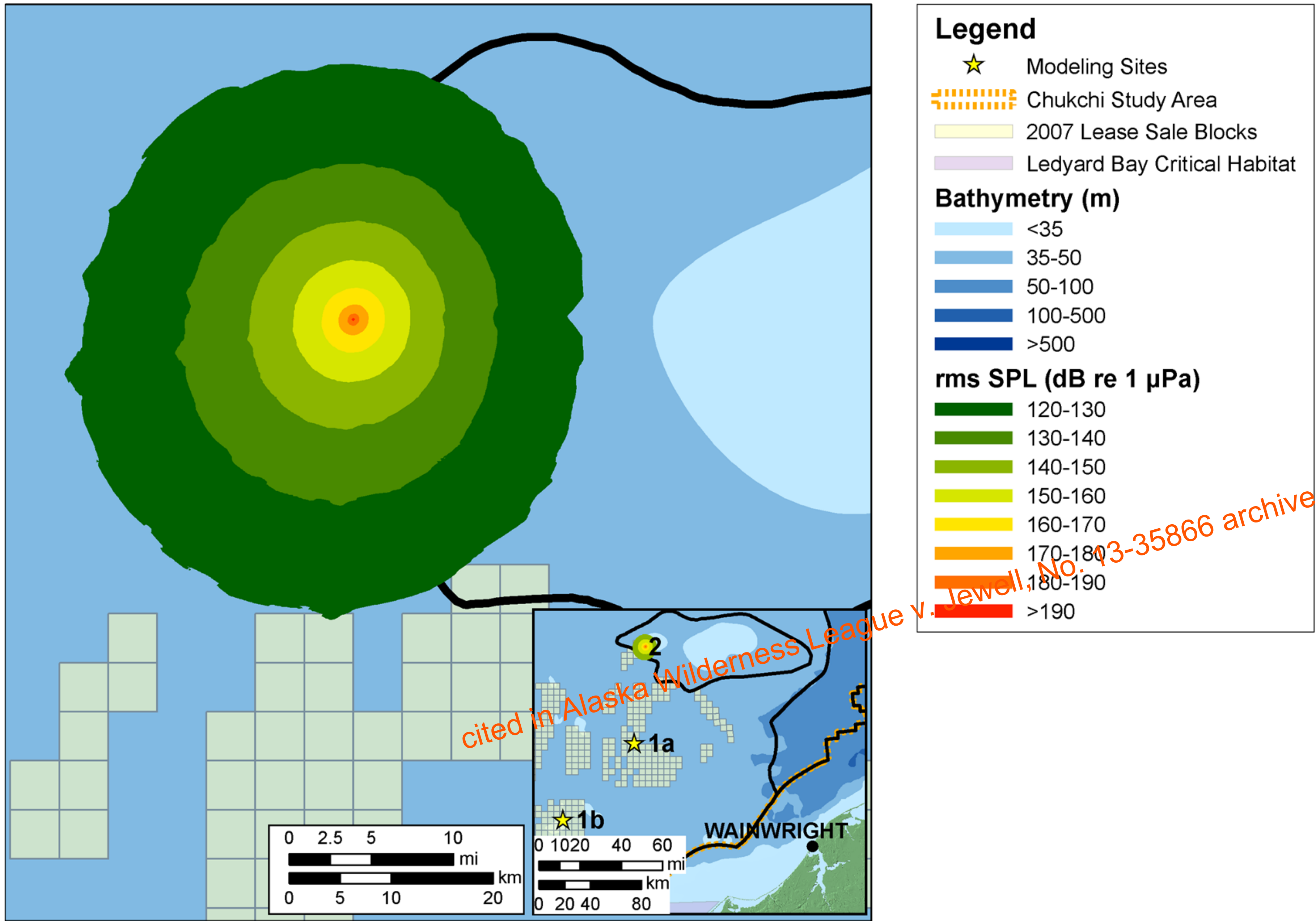

Figure 38. Scenario 5 at modeling Site 2: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. A 500 in^3 seismic airgun array operating at a depth of 6 m, representative of a typical ZVSP survey. An overview of the region appears in the lower right inset.

Table 49. Scenario 5 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	0.13	0.12	0.12
180	0.62	0.58	0.58
160	3.25	3.06	3.13

Table 50. Scenario 5 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.08	0.08	0.12	0.13	0.16	0.16
180	0.24	0.26	0.58	0.62	0.61	0.64
160	2.02	2.08	3.13	3.25	3.72	3.94

5.6. Scenario 6

Scenario 6 consisted of two drillships performing drilling operations, at a distance of 10 km, each with a support vessel on DP at a distance of 500 m. Details about the source levels are shown in Sections 3.4.2 and 3.4.3. Figures 39 through 42 show isopleth maps of modeled unweighted maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 µPa for Scenario 6 at each modeling site. Tables Table 51 through 58 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 6 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 2 at each modeling site. The radii are relative to one of the support vessels for thresholds ≤ 160 dB and are relative to the center point of all four source locations for the 120 dB threshold.

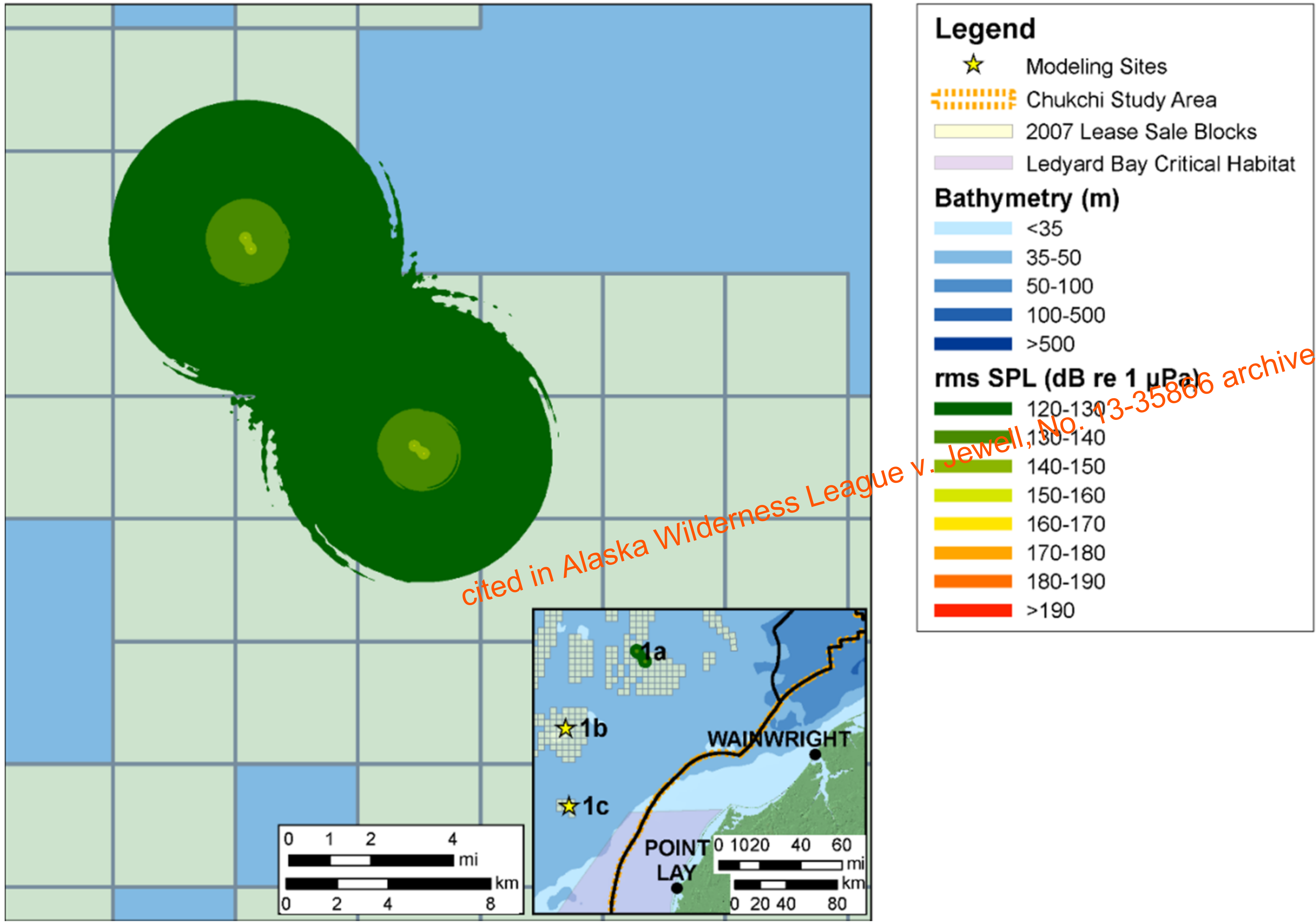

Figure 39. Scenario 6 at modeling Site 1a: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. Two drillships performing drilling operations at 10 km distance, each with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Scenario 6 Site 1a

Table 51. Scenario 6 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	10.8	9.64	7.80

*Not reached.

Table 52. Scenario 6 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	3.14	7.61	7.80	10.8	10.4	13.2

*Not reached.

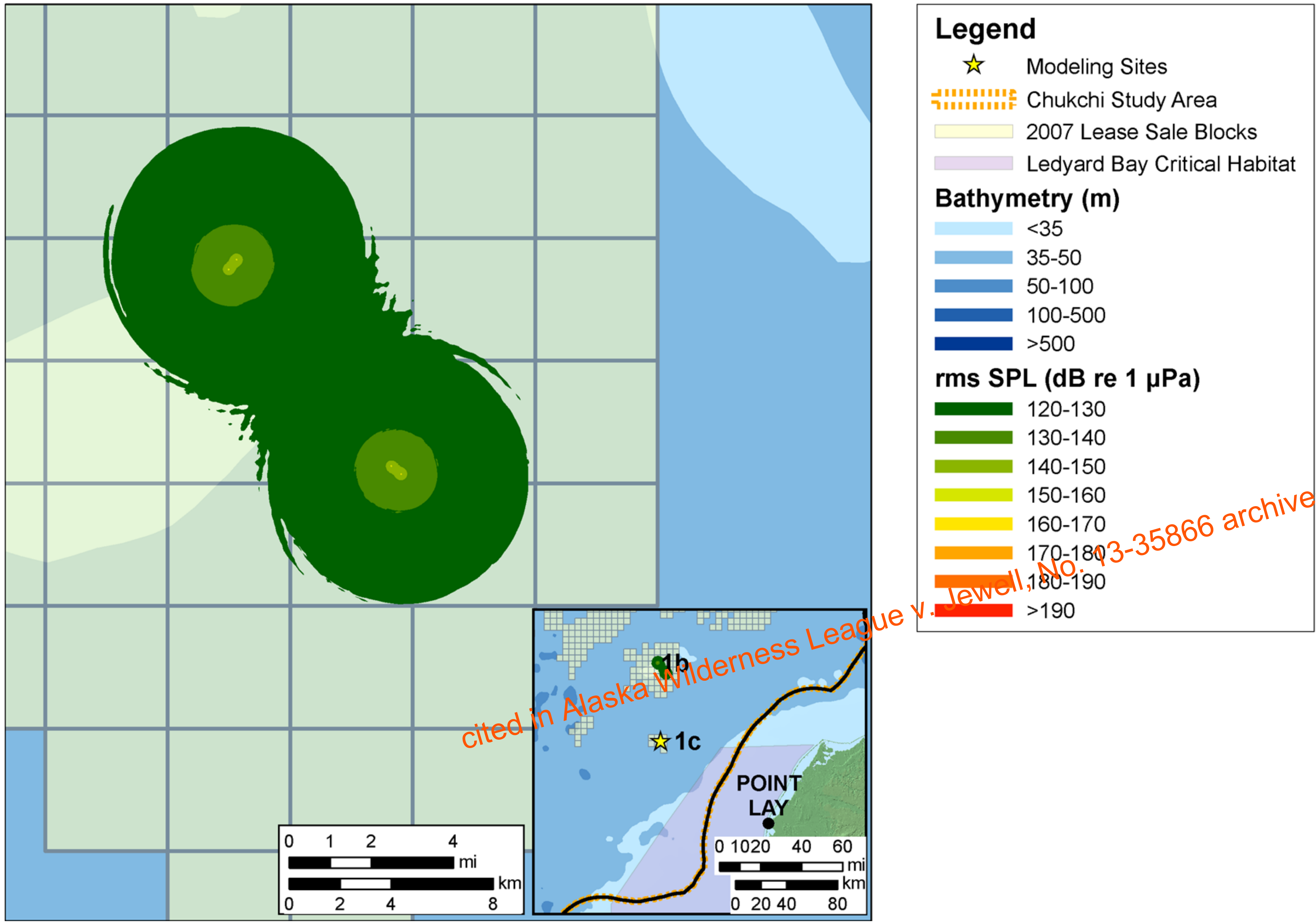

Figure 40. Scenario 6 at modeling Site 1b: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. Two drillships performing drilling operations at 10 km distance, each with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Scenario 6 Site 1b

Table 53. Scenario 6 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	10.4	9.34	7.38

*Not reached.

Table 54. Scenario 6 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	3.01	7.45	7.38	10.4	9.96	12.76

*Not reached.

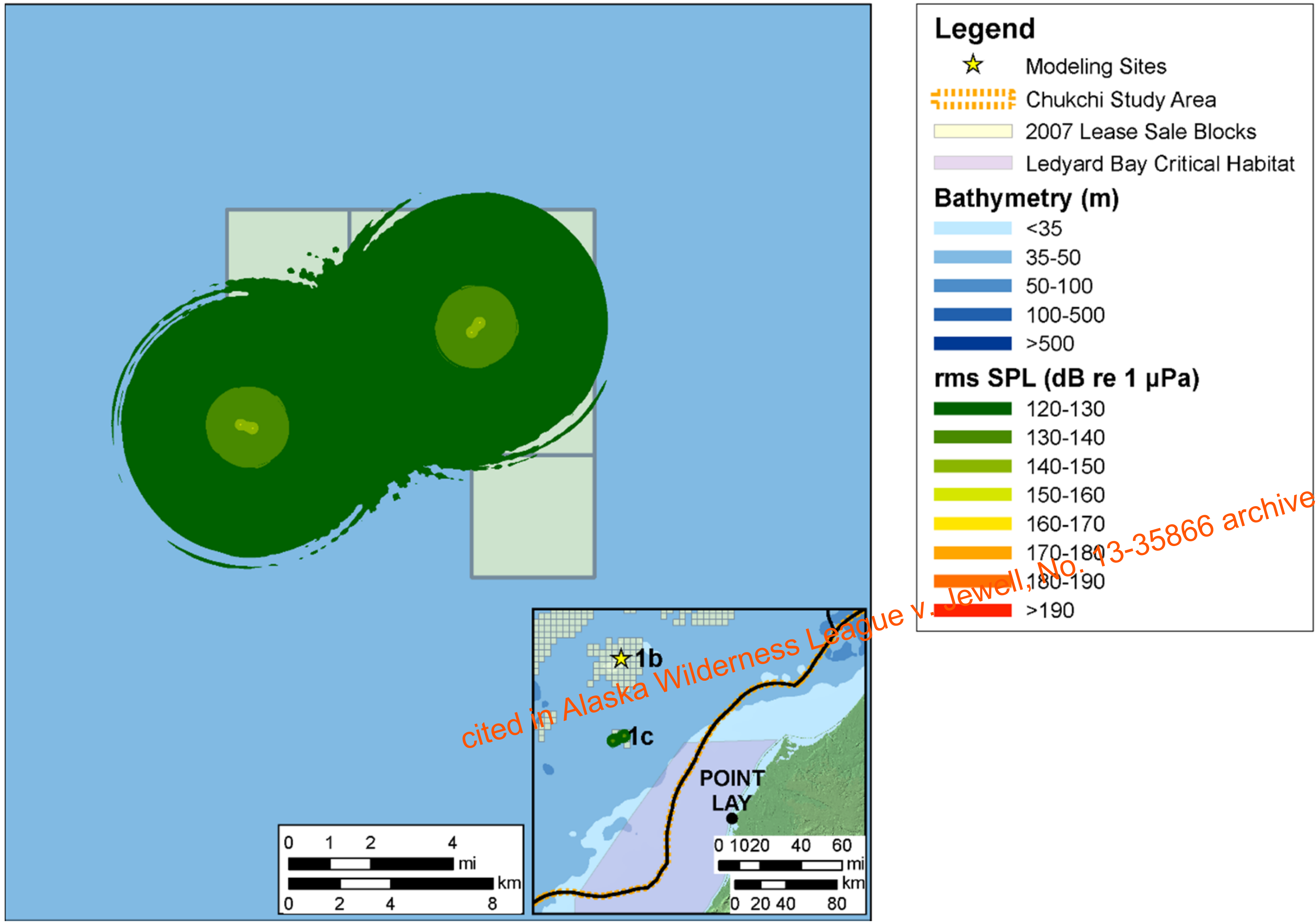

Figure 41. Scenario 6 at modeling Site 1c: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. Two drillships performing drilling operations at 10 km distance, each with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Scenario 6 Site 1c

Table 55. Scenario 6 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	10.3	9.18	7.57

*Not reached.

Table 56. Scenario 6 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	3.10	7.24	7.57	10.3	10.1	12.9

*Not reached.

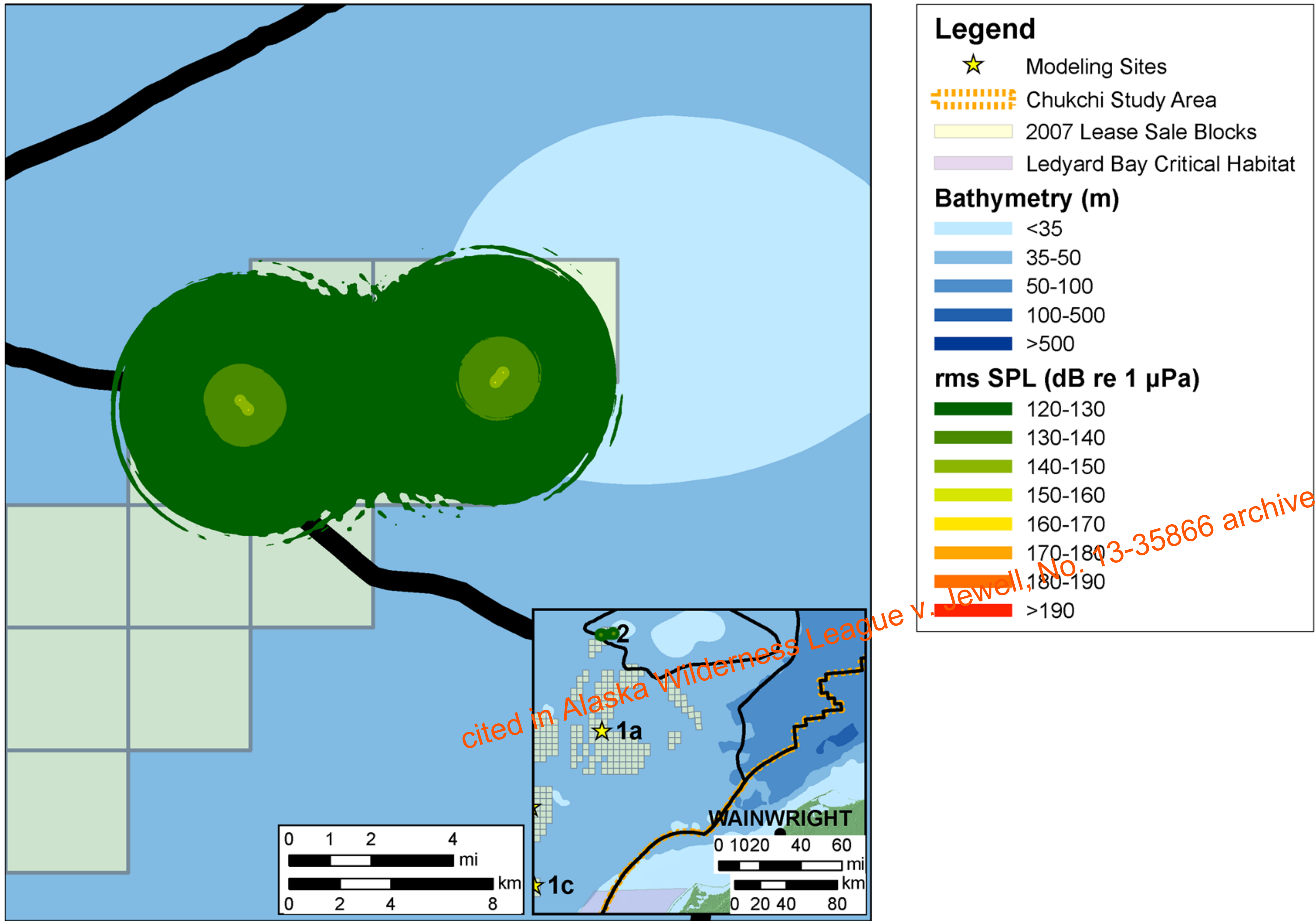

Figure 42. Scenario 6 at modeling Site 2: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. Two drillships performing drilling operations at 10 km distance, each with a support vessel on DP at 500 m distance. An overview of the region appears in the lower right inset.

Scenario 6 Site 2

Table 57. Scenario 6 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	10.3	9.13	7.38

*Not reached.

Table 58. Scenario 6 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.01	0.01	0.01	0.01	0.01	0.01
120	3.01	7.18	7.38	10.3	9.86	12.4

*Not reached.

5.7. Scenario 7

Scenario 7 consisted of an ice class vessel performing ice management operations. Details about the source levels are shown in Section 3.4.7. Figures 43 through 46 show isopleth maps of modeled unweighted maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 μPa for Scenario 7 at each modeling site. Tables Table 59 through 66 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 7 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 2 at each modeling site.

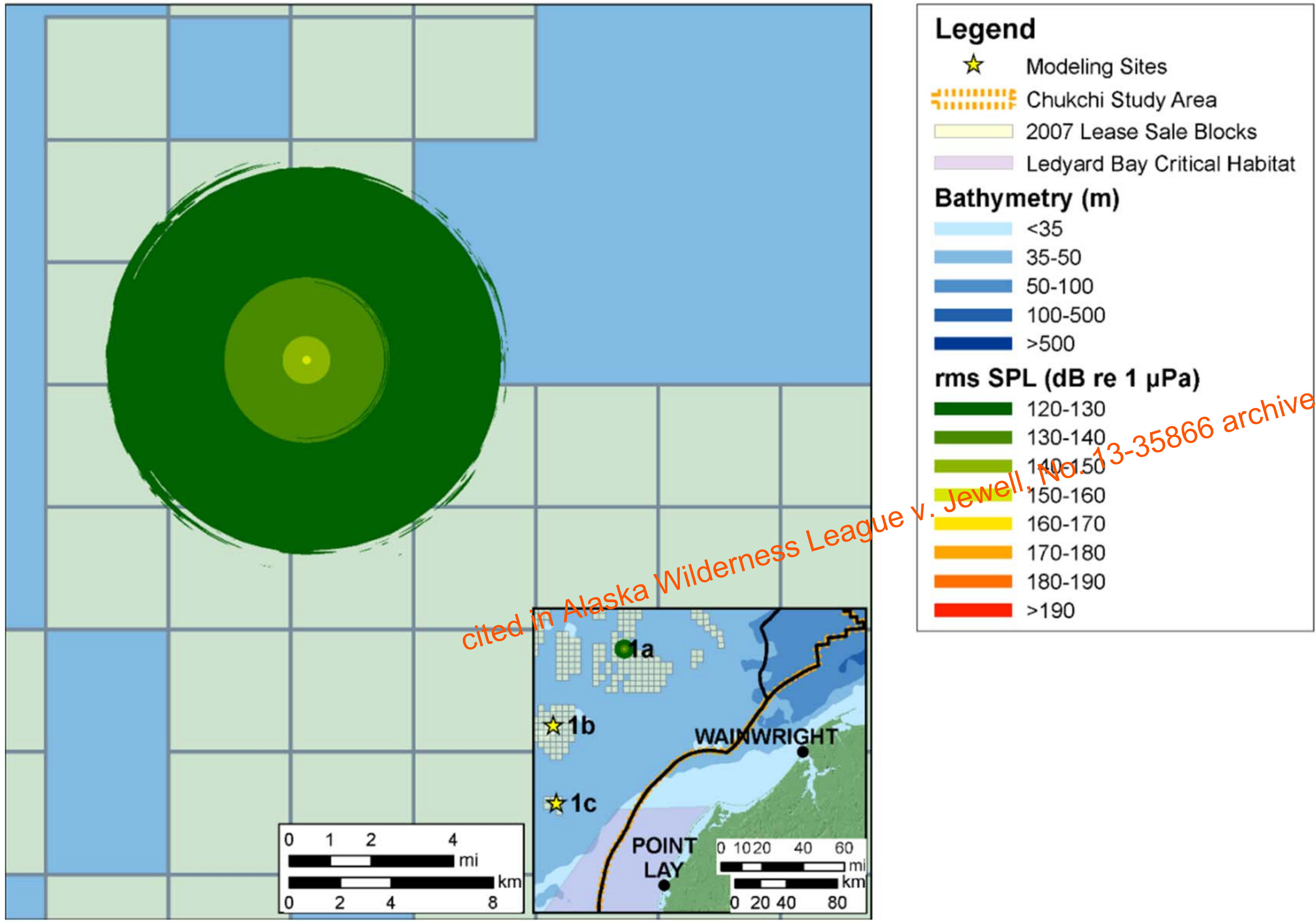

Figure 43. Scenario 7 at modeling Site 1a: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. An ice class vessel performing ice management operations. An overview of the region appears in the lower right inset.

Scenario 7 Site 1a

Table 59. Scenario 7 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.03	0.03	0.03
120	8.51	7.51	7.70

*Not reached.

Table 60. Scenario 7 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.03	0.03	0.03	0.03	0.03	0.03
120	3.43	3.45	7.70	8.51	11.7	13.0

*Not reached.

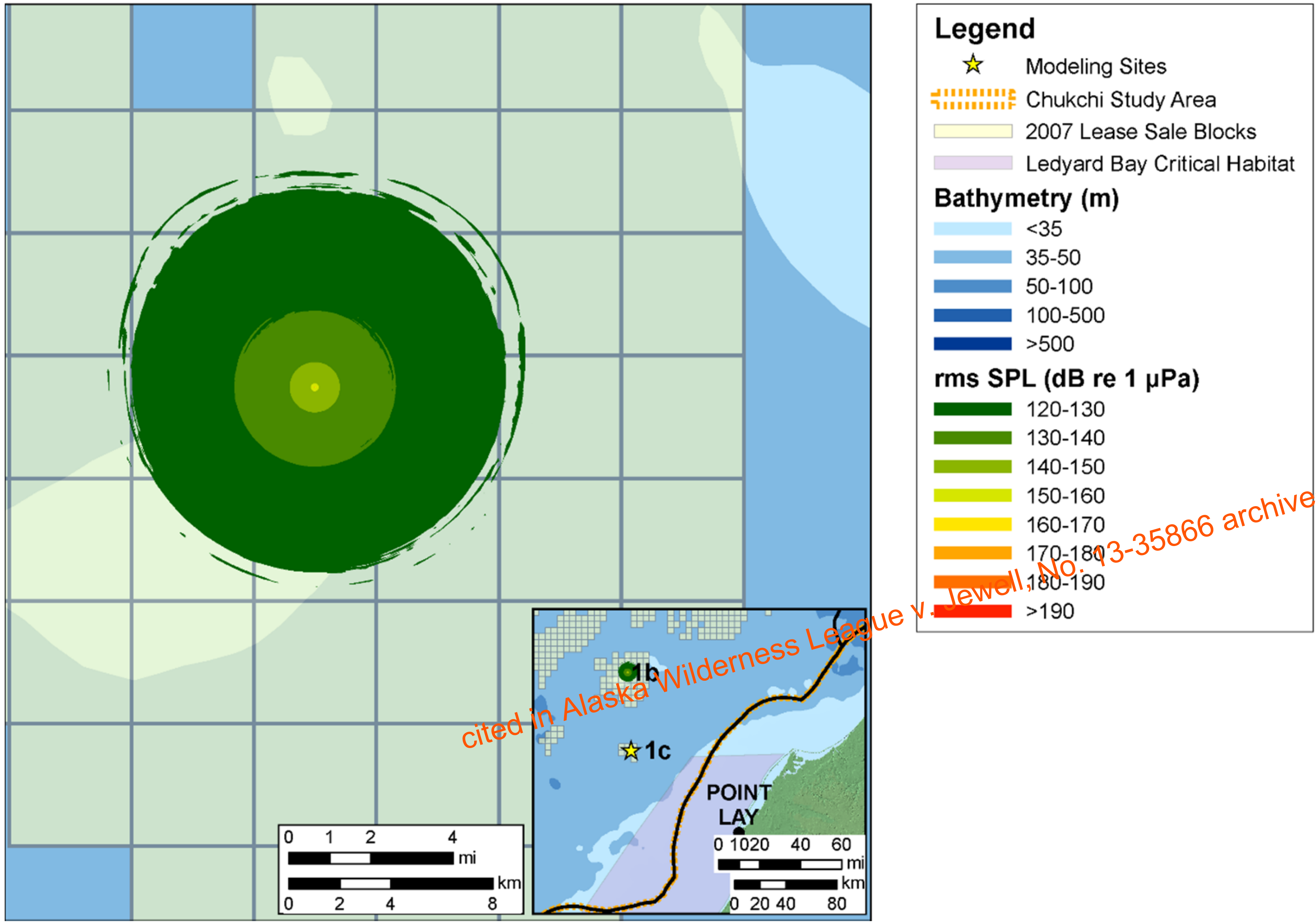

Figure 44. Scenario 7 at modeling Site 1b: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. An ice class vessel performing ice management operations. An overview of the region appears in the lower right inset.

Scenario 7 Site 1b

Table 61.Scenario 7 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.03	0.03	0.03
120	8.90	7.54	7.57

*Not reached.

Table 62. Scenario 7 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.03	0.03	0.03	0.03	0.03	0.03
120	3.52	3.61	7.57	8.90	11.6	14.0

*Not reached.

Scenario 7 Site 1 c

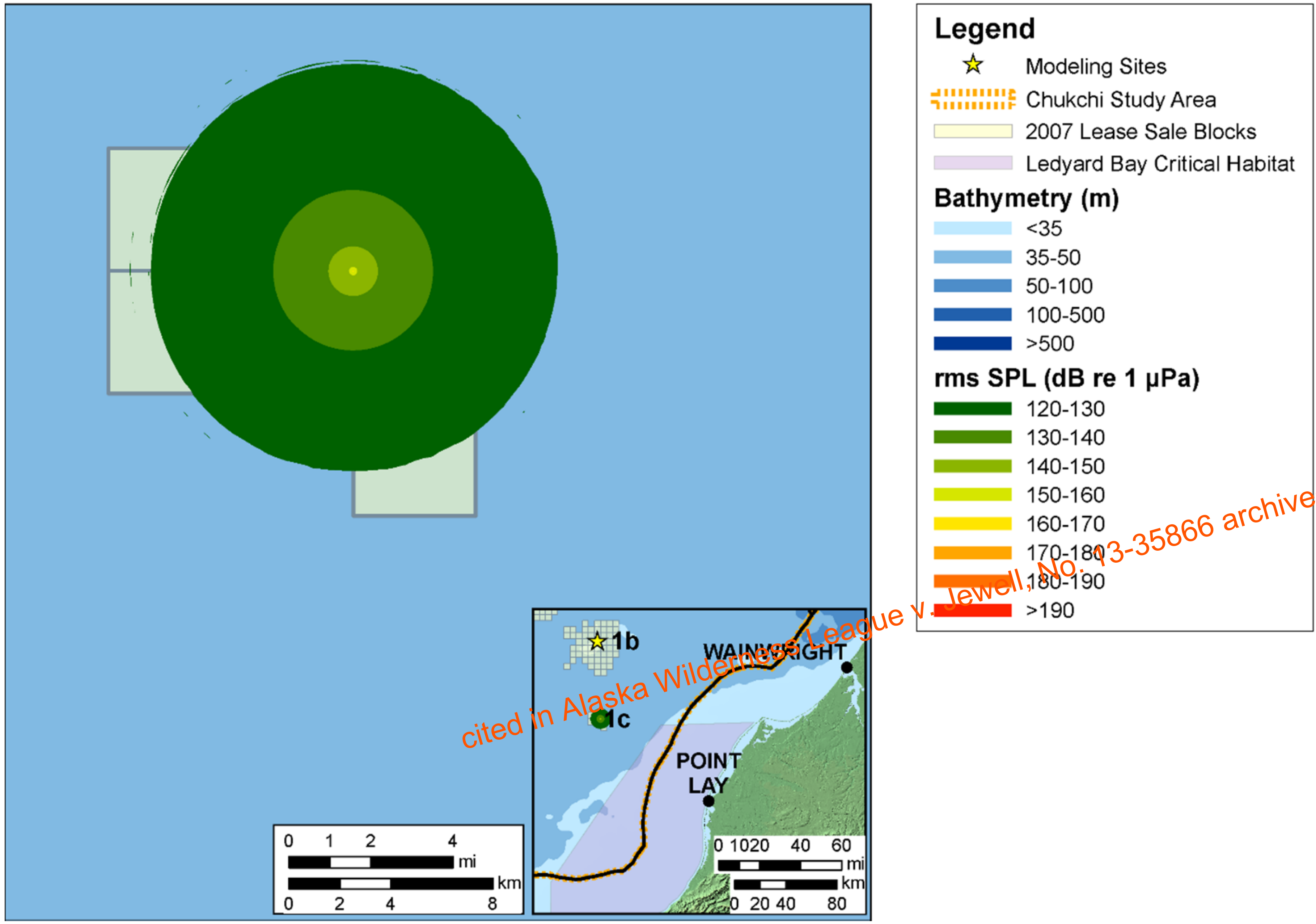

Figure 45. Scenario 7 at modeling Site 1c: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. An ice class vessel performing ice management operations. An overview of the region appears in the lower right inset.

Table 63. Scenario 7 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.03	0.03	0.03
120	8.90	7.73	7.84

*Not reached.

Table 64. Scenario 7 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.03	0.03	0.03	0.03	0.03	0.03
120	3.66	3.72	7.84	8.90	11.8	13.4

*Not reached.

Scenario 7 Site 2

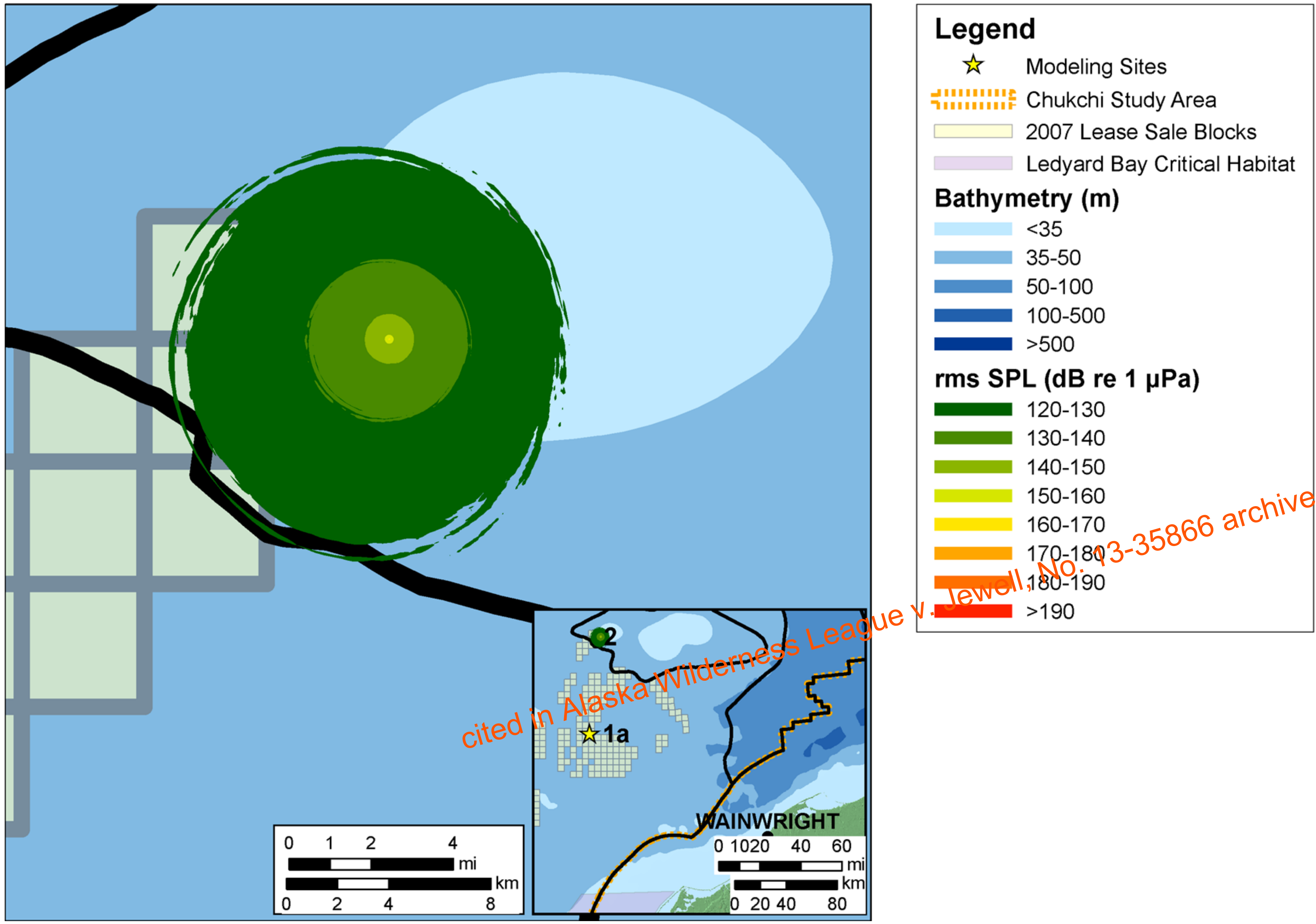

Figure 46. Scenario 7 at modeling Site 2: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and average sound speed profile. An ice class vessel performing ice management operations. An overview of the region appears in the lower right inset.

Table 65. Scenario 7 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and average sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	*
180	*	*	*
160	0.03	0.03	0.03
120	8.96	7.79	7.61

*Not reached.

Table 66. Scenario 7 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	*	*	*	*	*	*
180	*	*	*	*	*	*
160	0.03	0.03	0.03	0.03	0.03	0.03
120	3.53	3.83	7.61	8.96	11.7	14.4

*Not reached.

5.8. Scenario 8

Scenario 8 consisted of an ice class vessel transiting through 80% ice cover. Details about the source levels are shown in Section 3.4.8. Because this scenario will only occur when ice is present, the average sound speed profile conditions are not representative and all Scenario 8 modeling used the mixed sound speed profile rather than the average sound speed profile (see Section 3.5.1). Figures 47 through 50 show isopleth maps of modeled un-weighted, maximum-over-depth broadband (10 Hz to 3 kHz) sound pressure levels in dB re 1 µPa for Scenario 8 at each modeling site. Tables 76 through 74 present the R_{max}, $R_{95\%}$, and R_{ea} rms SPL threshold ranges for Scenario 8 at each modeling site and the R_{max} for the three modeled geoacoustic profiles for Scenario 2 at each modeling site.

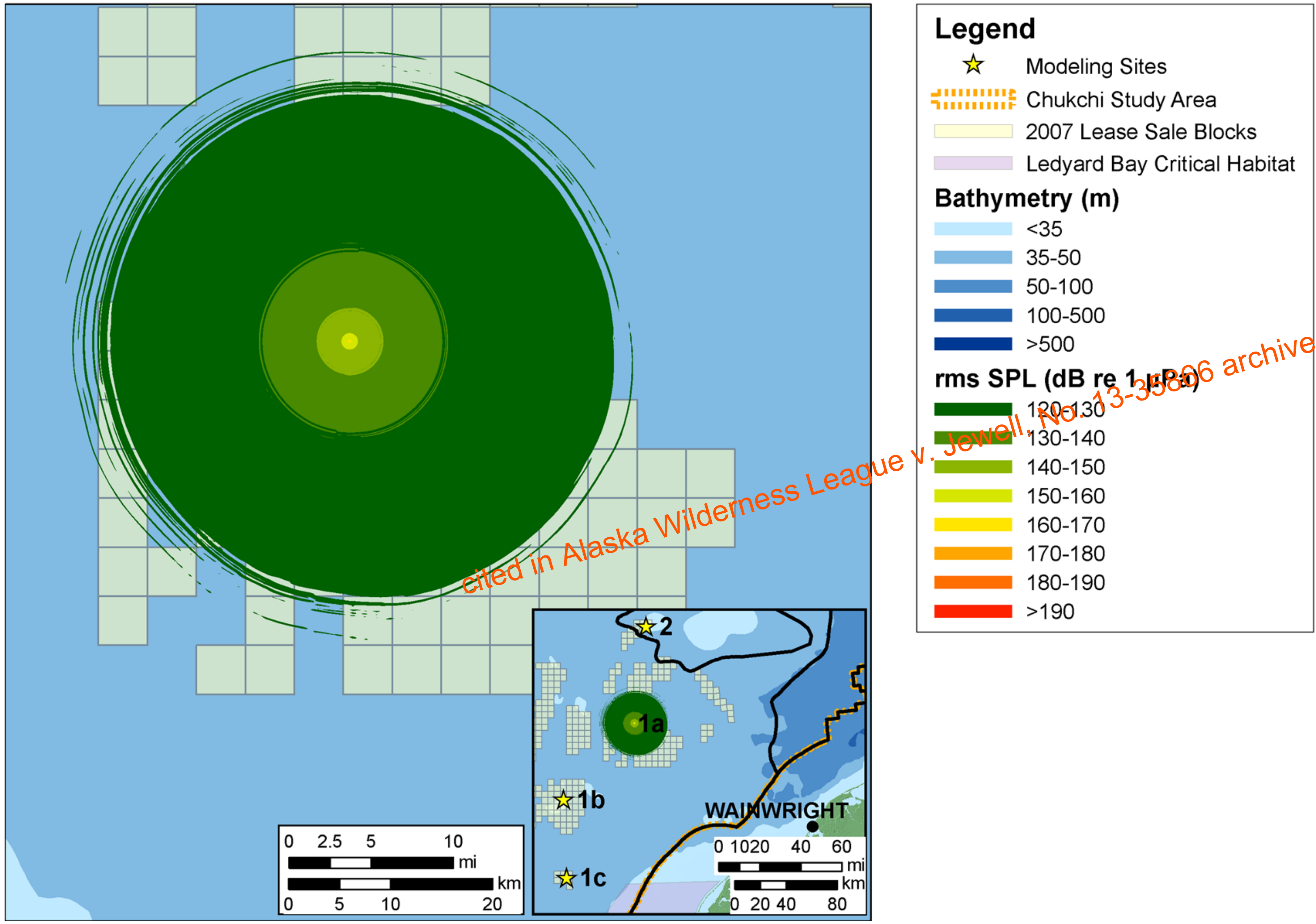

Figure 47. Scenario 8 at modeling Site 1a: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and mixed sound speed profile. An ice class vessel transiting through 80% ice cover. An overview of the region appears in the lower right inset.

Scenario 8 Site 1a

Table 67. Scenario 8 at modeling Site 1a: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and mixed sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	0.01
180	0.01	0.01	0.01
160	0.16	0.16	0.16
120	29.4	25.0	25.2

*Not reached.

Table 68. Scenario 8 at modeling Site 1a: R_{ea} and R_{max} radii of rms SPL contours with mixed sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.01	*	0.01	*	0.01	*
180	0.01	0.01	0.01	0.01	0.01	0.01
160	0.09	0.09	0.16	0.16	0.18	0.18
120	10.1	10.7	25.2	29.4	35.6	40.7

*Not reached.

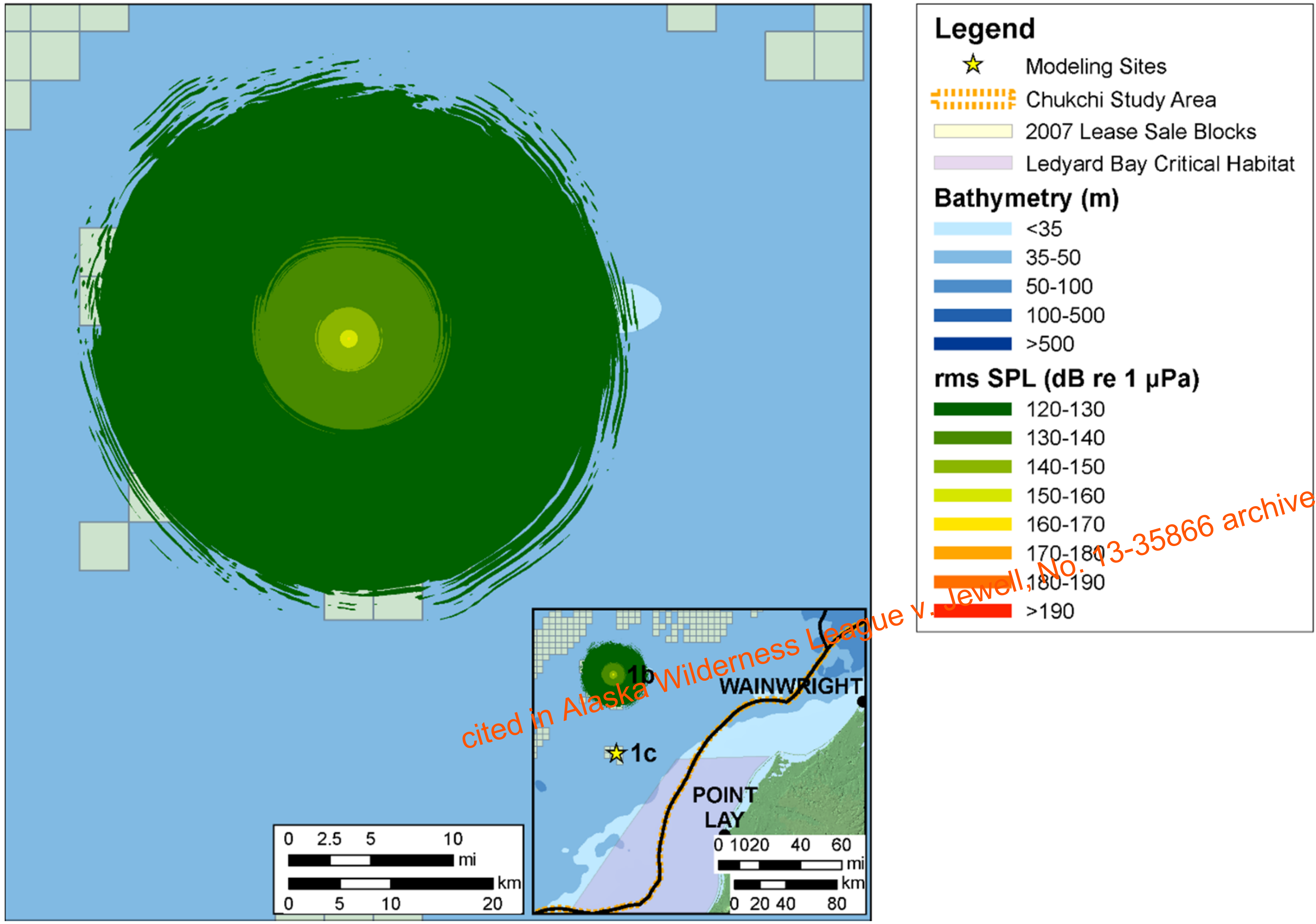

Figure 48. Scenario 8 at modeling Site 1b: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and mixed sound speed profile. An ice class vessel transiting through 80% ice cover. An overview of the region appears in the lower right inset..

Scenario 8 Site 1b

Table 69. Scenario 8 at modeling Site 1b: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and mixed sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	0.01
180	0.01	0.01	0.01
160	0.15	0.14	0.15
120	30.2	25.7	25.9

*Not reached.

Table 70. Scenario 8 at modeling Site 1b: R_{ea} and R_{max} radii of rms SPL contours with mixed sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.01	*	0.01	*	0.01	*
180	0.01	0.01	0.01	0.01	0.01	0.01
160	0.09	0.09	0.15	0.15	0.17	0.17
120	10.3	10.7	25.9	30.2	36.1	42.5

*Not reached.

Scenario 8 Site 1c

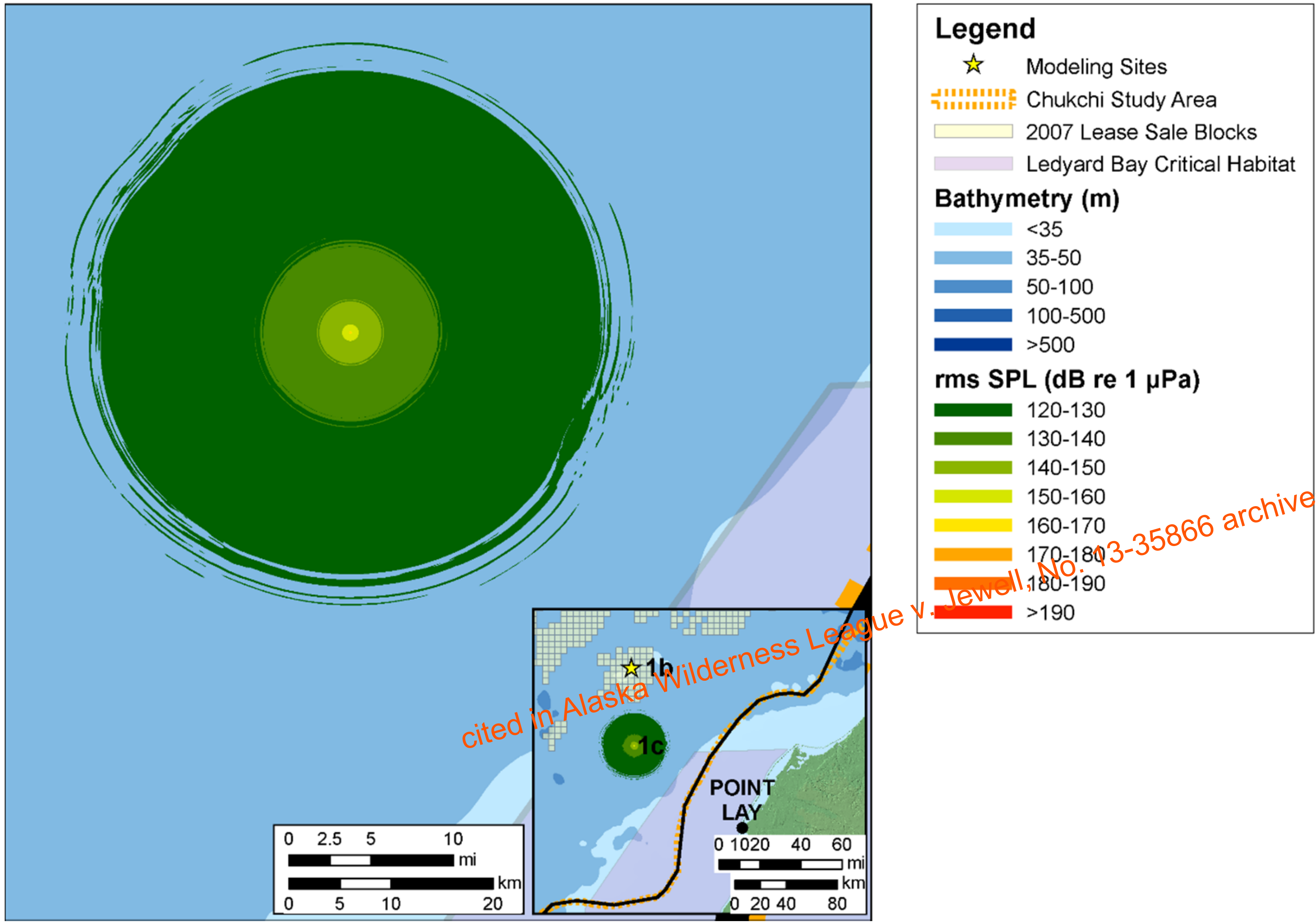

Figure 49. Scenario 8 at modeling Site 1c: Contours of rms SPL (dB re 1 μPa, maximum-over-depth) with medium-reflectivity geoacoustics and mixed sound speed profile. An ice class vessel transiting through 80% ice cover. An overview of the region appears in the lower right inset.

Table 71. Scenario 8 at modeling Site 1c: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and mixed sound speed profile.

rms SPL (dB re 1 μPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	0.01
180	0.01	0.01	0.01
160	0.15	0.15	0.15
120	28.6	25.0	25.2

*Not reached.

Table 72. Scenario 8 at modeling Site 1c: R_{ea} and R_{max} radii of rms SPL contours with mixed sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 μPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.01	*	0.01	*	0.01	*
180	0.01	0.01	0.01	0.01	0.01	0.01
160	0.09	0.09	0.15	0.15	0.17	0.17
120	10.4	10.7	25.2	28.6	35.9	42.0

*Not reached.

Scenario 8 Site 2

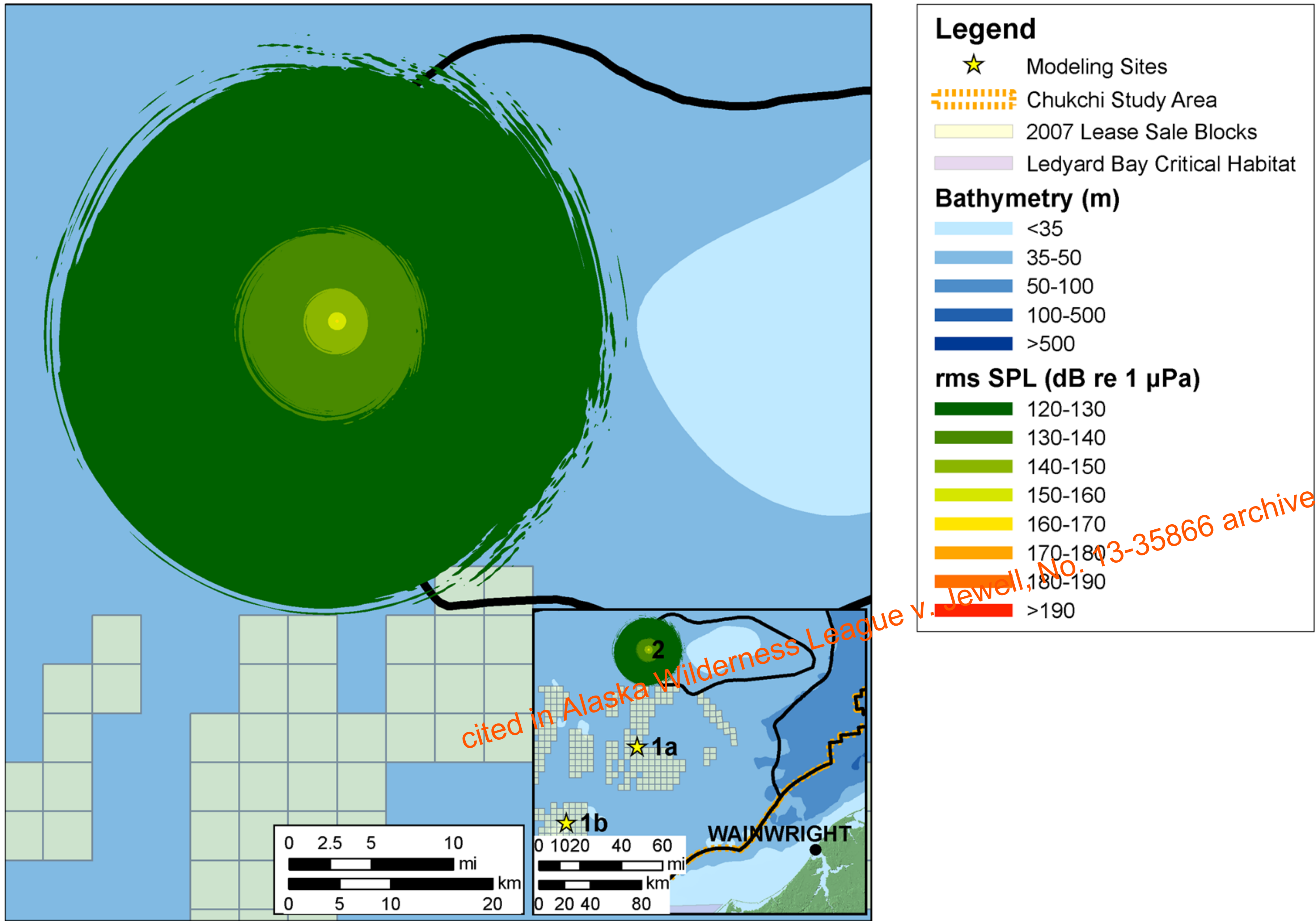

Figure 50. Scenario 8 at modeling Site 2: Contours of rms SPL (dB re 1 µPa, maximum-over-depth) with medium-reflectivity geoacoustics and mixed sound speed profile. An ice class vessel transiting through 80% ice cover. An overview of the region appears in the lower right inset.

Table 73. Scenario 8 at modeling Site 2: R_{max}, $R_{95\%}$, and R_{ea} radii of rms SPL contours with medium-reflectivity geoacoustics and mixed sound speed profile.

rms SPL (dB re 1 µPa)	R_{max} (km)	$R_{95\%}$ (km)	R_{ea} (km)
190	*	*	0.01
180	0.01	0.01	0.01
160	0.16	0.15	0.15
120	30.1	26.2	26.5

*Not reached.

Table 74. Scenario 8 at modeling Site 2: R_{ea} and R_{max} radii of rms SPL contours with mixed sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	Low-reflectivity		Medium-reflectivity		High- reflectivity	
	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)	R_{ea} (km)	R_{max} (km)
190	0.01	*	0.01	*	0.01	*
180	0.01	0.01	0.01	0.01	0.01	0.01
160	0.09	0.09	0.15	0.16	0.16	0.17
120	10.1	10.8	26.5	30.1	38.2	44.8

*Not reached.

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5.9. Scenario 9

Scenario 9 consisted of a large tug that conducted anchor handling activities in support of setting mooring anchors for a drillship. This activity produces intermittent bursts of high intensity sound when the drillship first arrives at a well location. Since this activity does not last long, and since it only applies to drillships, not to all types of offshore drilling units, it has not been modeled in this analysis. Radii for this activity are estimated from measurements collected during Shell's 2012 drilling program in the Chukchi Sea (Austin et al. 2013). Table 75 is a list of radii of propagation computed from an empirical fit to the measured levels. Shell measured these data at the seafloor but model results indicate that received levels maximized-over-depth can exceed the levels at the seafloor by 1.3 dB. An increase of 1.3 dB applied to the empirical fit of the measured levels provided an estimate of the radii of propagation maximized over depth. The resulting radii are listed in Table 76.

Table 75. Scenario 9: Radii for the Chukchi Sea as measured during Shell's 2012 Chukchi Sea Drilling Program (Austin et al. 2013).

rms SPL (dB re 1 µPa)	*Radius* (km)
190	< 0.01
180	0.02
160	0.18
120	14.0

Table 76. Scenario 9: Radii for the Chukchi Sea based on levels measured during Shell's 2012 Chukchi Sea Drilling Program (Austin et al. 2013), corrected to estimate the maximum over depth.

rms SPL (dB re 1 µPa)	*Radius* (km)
190	0.01
180	0.02
160	0.20
120	16.0

5.10. Scenario 10

Scenario 10 consisted of a drillship conducting mudline cellar construction, which is the excavation of a hole in the seafloor within which sits the blow-out preventer for certain drilling projects. Not all drilling projects are designed to include a mudline cellar, so this activity might not occur for each drilling program; however, for those programs that do incorporate this activity, there is a brief period of high intensity sound when drilling begins. Since this activity does not last long, and since it only applies to some drilling programs, it has not been modeled in this analysis. Radii for this activity are estimated from measurements collected during Shell's 2012 drilling program in the Chukchi Sea (Austin et al. 2013). Table 77 is a list of radii of propagation computed from an empirical fit to the measured levels. Shell measured these data at the seafloor but model results indicate that received levels maximized-over-depth can exceed the levels at the seafloor by 1.3 dB. An increase of 1.3 dB applied to the empirical fit of the measured levels provided an estimate of the radii of propagation maximized over depth. The resulting radii are listed in Table 78.

Table 77. Scenario 10: Radii for the Chukchi Sea as measured during Shell's 2012 Chukchi Sea Drilling Program (Austin et al. 2013).

rms SPL (dB re 1 µPa)	*Radius* **(km)**
190	< 0.01
180	< 0.01
160	0.71
120	8.20

Table 78. Scenario 10: Radii for the Chukchi Sea as measured during Shell's 2012 Chukchi Sea Drilling Program (Austin et al. 2013), corrected to estimate the maximum over depth..

rms SPL (dB re 1 µPa)	*Radius* **(km)**
190	< 0.01
180	0.01
160	0.08
120	9.3

6. Discussion

6.1. Comparison of Radii Between Sites

For each modeled scenario, the radii were similar between the four sites. Tables 79 and 80 present the greatest R_{max} over all the sites for the airgun and continuous source scenarios, respectively. As the variability analysis showed (Section 4), the radii were minimally affected by variation of the sound speed profiles; therefore, the summary tables below present radii for the average sound speed profile and the two geoacoustic profiles that produced the largest radii (medium- and high-reflectivity).

Table 79. Maximum R_{max} radii in km for the airgun scenarios with average sound speed profile.

	Medium-reflectivity			High-reflectivity		
rms SPL (dB re 1 µPa)	**190 dB**	**180 dB**	**160 dB**	**190 dB**	**180 dB**	**160 dB**
Scenario 1 (3200 in^3 array)	0.5	1.4	6.3	0.6	1.7	9.1
Scenario 3 (4500 in^3 array)	0.9	2.2	9.7	1.0	2.5	15.4
Scenario 4 (40 in^3 array)	0.02	0.1	1.5	0.02	0.1	1.7
Scenario 5 (500 in^3 array)	0.1	0.6	3.3	0.2	0.6	4.1

Table 80. Maximum R_{max} radii in km for the continuous source scenarios with average sound speed profile for Scenarios 2, 6, and 7, and mixed sound speed profile for Scenario 8.

	Medium-reflectivity				High-reflectivity			
rms SPL (dB re 1 µPa)	**190 dB**	**180 dB**	**160 dB**	**120 dB**	**190 dB**	**180 dB**	**160 dB**	**120 dB**
Scenario 2 (one drillship with vessel on DP)	*	*	0.01	5.5	*	*	0.01	7.6
Scenario 6 (two drillships with vessels on DP) **	*	*	0.01	7.8	*	*	0.01	10.4
Scenario 7 (ice management)	*	*	0.03	8.9	*	*	0.03	14.4
Scenario 8 (ice-breaking–mixed SSP)	*	0.01	0.16	30.2	*	0.01	0.18	44.8

*Not reached.
**Maximum R_{ea} radii shown for Scenario 6 since this footprint is very non-circular.

For the average sound speed profile and medium-reflectivity geoacoustics, the largest radius for the airgun sources was 9.7 km, which corresponds to the 160 dB radii for the 4500 in^3 array (Scenario 3); this increased to 15.4 km when modeled using the high-reflectivity geoacoustic profile. The high-reflectivity geoacoustics profile had a greater effect when initial higher source levels were considered, because those scenarios involve an increased number of seabed interactions before acoustic losses reduce the sound to defined levels. As such, there was little difference between radii modeled with the two geoacoustic profiles for the 40 in^3 array, whereas for the 4500 in^3 array—the largest considered in this report—the radii for the 160 dB level was more than 50% larger with the high-reflectivity geoacoustic profile than with the medium-reflectivity profile.

For the continuous source scenarios, the largest radii with the medium-reflectivity geoacoustics was 30.2 km, which corresponded to the 120 dB radii for the ice-breaking vessel (Scenario 8); this increased to 44.8 km with the high-reflectivity geoacoustics. Because the sound speed profile has little influence over the radii compared to the geoacoustic profile, even though a different sound speed profile was used to model Scenario 8, the ice-breaking vessel traveling through significant ice cover will ensonify a much greater area than the ice-managing vessels, given the same environmental conditions.

The radii between modeling sites tended to be relatively consistent due to the similar bathymetries of the modeling regions. There was no one modeling site that consistently resulted in the largest radii for all sound level thresholds, because the propagation distances depend on the threshold level, water depth, and source characteristics (source depth and frequency spectrum). However, there are trends between modeling sites. The largest radii typically resulted at Sites 1b and 2 when considering thresholds greater than 160 dB re 1 μPa, but often resulted at Sites 1a and 1b when considering the lower thresholds. This is primarily because the shallower water depths at Sites 2 and 1b result in more sound being concentrated in the water column, compared to the deeper water sites, at closer ranges that correspond to the higher sound level thresholds. However, the increased number of bottom-interactions at the shallower sites results greater sound attenuation over longer ranges, so the lower-level sound thresholds tend to extend to greater ranges at the deeper water sites. The largest radii did not ever occur at Site 1c.

Bathymetric differences between modeling sites mean sites can be grouped into ranges of water depths. A range of water depths were assigned to each modeling site — Site 1a: >42 m, Site 1b: 34.5-38.5 m, Site 1c: 38.5-42 m, and Site 2: <34.5 m. Individual lease blocks were categorized based on their average water depth and matched to representative modeling sites. Figure 51 shows Lease Sale 193 lease blocks color-coded according to their representative modeling sites. This grouping allows application of one of the four model results for the activity under consideration within any particular block.

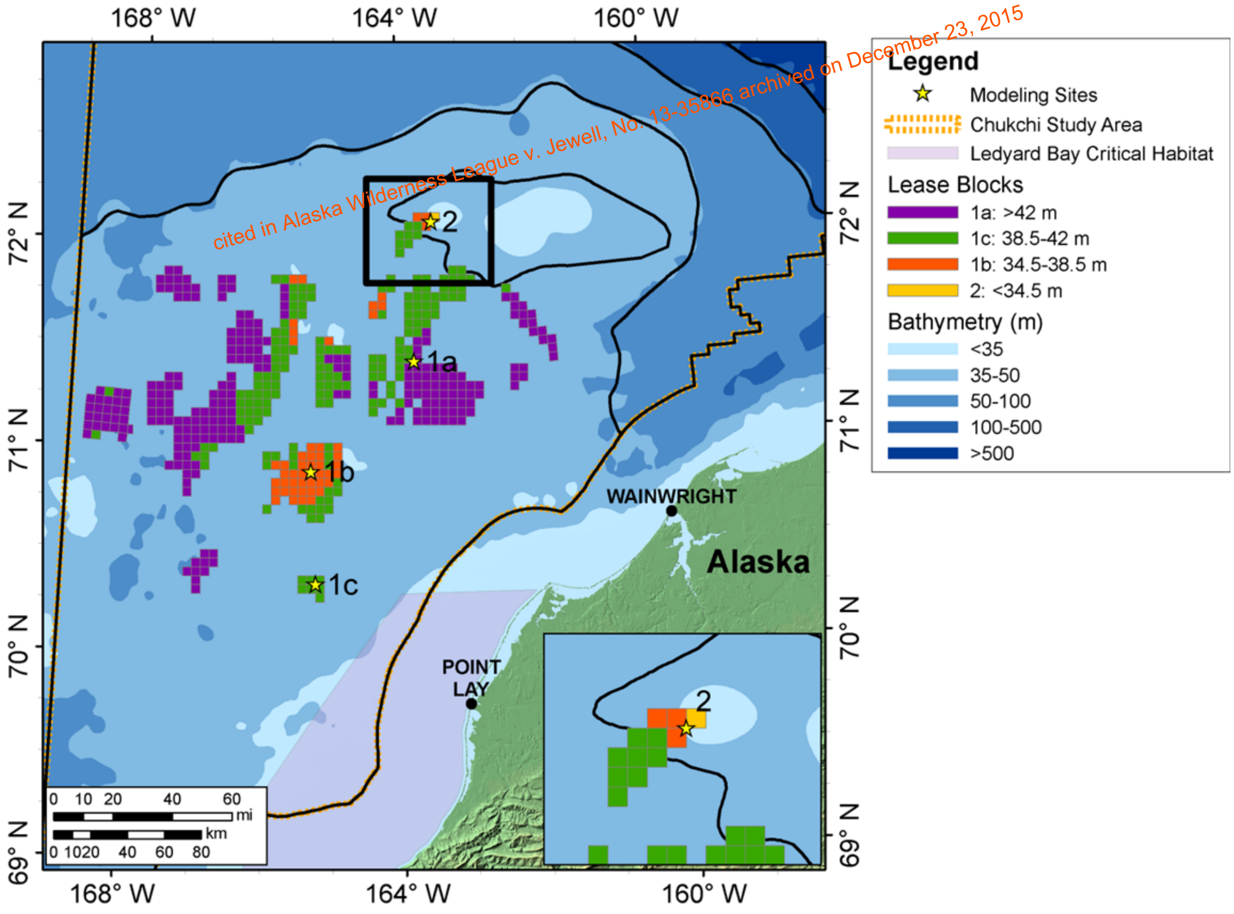

Figure 51. Chukchi Sea lease blocks with their representative modeling sites, based on water depth.

6.2. Ancillary Noise Sources

This analysis considered only the dominant noise sources in each scenario. A small airgun array was modeled for Scenario 4 because that was the loudest source that could be associated with a geohazard survey. Although sub-bottom profilers and high frequency sonar sources are also often used during geohazard surveys, these were not modeled because their frequencies typically extend beyond the best hearing range for the marine mammal species of concern, and because their sound footprints are relatively small. For completeness of consideration of all potential exploration activity sources, Table 81 lists radii for examples of these sources from measurements collected during Statoil's 2011 geohazard survey (Warner and McCrodan 2011) .

Table 81. Radii for the non-airgun geohazard survey sources as measured in the Chukchi Sea (Warner and McCrodan 2011).

Source	**Radius (km)**			
rms SPL (dB re 1 μPa)	**190 dB**	**180 dB**	**160 dB**	**120 dB**
Single beam range			0.04	1.0
Sub-bottom profiler range			0.03	0.45
Side-scan sonar range	0.02	0.05	0.23	5.10*
Multibeam sonar range				0.33*
Single beam (18 kHz) range	0.01**	0.01**	0.03**	0.34
Single beam (200 kHz) range	0.01**	0.02**	0.03**	0.08
High-precision acoustic positioning system (22/23 kHz)	0.004**	0.009**	0.04**	1.0
High precision acoustic positioning system (21/21.5 kHz)		0.001**	0.007**	0.37

*Extrapolated beyond maximum measurement range.
**Extrapolated beyond minimum measurement range.

6.3. Sound Propagation Distances to 120 dB re 1 μPa

This acoustic analysis provided the propagation distances for the sound levels thresholds that corresponded to the zones of acoustic influence for impulsive and continuous sound sources. The minimum sound level threshold is 120 dB re 1 μPa, a level NMFS intends to use to define an Action Area within which they will assess acoustic impacts. Although this threshold strictly only applies to continuous sound sources, it is possible that marine mammals could also show minor reactions to impulsive sounds at this level (Malme et al. 1984). To provide NMFS with the maximum range to the 120 dB re 1 μPa threshold for all scenarios, we considered the scenario with the largest modeled acoustic footprint: Scenario 3, the 4500 in^3 airgun array that operated at a depth of 8.5 m, at Site 1b. For this scenario, modeled using the average sound speed profile and high-reflectivity geoacoustics, the 120 dB threshold extended to a maximum range of 113 km (R_{max}). To calculate the most conservative estimate of sound propagation, we also modeled this scenario using the mixed sound speed profile (which results in longer propagation distances because it reduces sound interaction with the seafloor and the resulting sound absorption) and the high-reflectivity geoacoustics. In this case the maximum extent of the 120 dB threshold was 219 km (R_{max}). At these very long distances, there is considerable uncertainty of the model estimates because the model does not account for scattering effects. Supporting the estimates for these long ranges Ireland et al., (2009) reported 120 dB re 1 μPa propagation distances up to 120 km based on SSV measurements in 2008.

7. Conclusion

A complete investigation of the zones of potential acoustic influence involves acoustic modeling and analysis that considers spatial and temporal variability of environmental parameters. To achieve this analysis JASCO modeled eight different scenarios that represent typical offshore oil and gas exploration and operations at four sites with different water depths within the lease blocks of Lease Sale 193 in the Chukchi Sea. The variability analysis (Austin et al. 2015) showed that changing the sound speed profile minimally affected the radii compared to the geoacoustics; therefore, three representative geoacoustic profiles were modeled at each site to cover the range of potential radii.

For the airgun scenarios, the greatest sound propagation distance, $R_{max,}$ at 160 dB, modeled using the medium-reflectivity geoacoustics, was approximately 10 km for the 4500 in^3 array; the second largest was 6 km for the 3200 in^3 array. These radii increased to 15 and 9 km, respectively, when modeled with the high-reflectivity geoacoustics. For the continuous source scenarios, the greatest value for R_{max} for the medium-reflectivity geoacoustics at 120 dB was approximately 30 km for the ice-breaking vessel; the scenario with two drillships, each with a vessel on DP had the second largest radii at 11 km. These increased to 45 and 13 km, respectively, when modeled with the high-reflectivity geoacoustics.

The largest sound propagation distance at a threshold of 120 dB re 1 µPa was also investigated to predict the maximum propagation from all considered scenarios. The largest modeled R_{max} for 120 dB re 1 µPa was 219 km. It was produced by the 4500 in^3 airgun array operating at a depth of 8.5 m, which represents a typical 2-D seismic survey, with mixed sound speed profile and high-reflectivity geoacoustics at modeling Site 1b. This distance was 113 km when modeled using the average sound speed profile and high-reflectivity geoacoustics; a value that is closer empirical results so is thought to be more representative of the propagation distance to 120 dB re 1 µPa.

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Appendix A.

Acoustic Metrics

For the purpose of this assessment, it is important to define the metrics used to characterize anthropogenic sounds associated with exploration activities, and the natural sounds that comprise ambient noise. Underwater sound amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 μPa. Several sound level metrics are commonly used to evaluate the loudness of impulsive noise and its effects on marine life. These are described in this Appendix.

The root-mean-square (rms) SPL (dB re 1 μPa) is the rms pressure level in a stated frequency band over a defined time window (T, in seconds) containing the acoustic event:

$$\text{rms SPL} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \tag{A-1}$$

The rms SPL is a measure of the nominal or effective sound level over the time window duration. For continuous sounds, such as from drilling or vessel operations, the choice of T is not usually important as long as the source remains performing the same activity at the same distance and orientation from the receiver over the time window. It is important to indicate the actual duration chosen with the measurement so it can be interpreted with consideration of the possible changes in source operations over that time.

Impulsive events, such as acoustic pulses from airguns, have more strongly time-dependent pressure signals. The rms SPL metric is still used for these types of sounds, but here the choice of the time window with respect to the pulse timing is important – the level will be much higher if the time window is chosen over the high amplitude part of the pressure impulse than during the quieter periods between impulses. The duration of the time window, T, is also important as it is a divisor in Equation A-1, and larger values of T can lower the rms SPL of a given pressure signal. For impulsive noise, T is often defined as the “90% energy pulse duration” (T_{90}): the interval over which the pulse energy curve rises from 5% to 95% of its total energy. The SPL computed over this T_{90} interval is commonly referred to as the 90% rms SPL (dB re 1 μPa):

$$\text{90\% rms SPL} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} p^2(t)dt \Big/ p_0^2\right) \tag{A-2}$$

The sound exposure level (SEL, dB re 1 μPa^2·s) is a measure of the total acoustic energy contained in one or more acoustic events. While the current effects thresholds considered here are not based on SEL, we use SEL for impulsive sources to estimate rms SPL levels. The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T_{100}):

$$\text{SEL} = 10\log_{10}\left(\int_{T_{100}} p^2(t)dt \Big/ T_0 p_0^2\right) \tag{A-3}$$

where T_0 is a reference time interval of 1 s. The SEL represents the total acoustic energy received at some location during an acoustic event; it measures the total sound energy to which an organism at that location would be exposed.

Because the rms SPL and SEL are both computed from the integral of square pressure, these metrics are related by an expression, which depends only on the duration of the energy time window T:

$$\text{rms SPL} = \text{SEL} - 10\log_{10}(T) \tag{A-4}$$

$$\text{rms SPL} = \text{SEL} - 10\log_{10}(T_{90}) - 0.458 \tag{A-5}$$

where the 0.458 dB factor accounts for the rms SPL containing 90% of the total energy from the per-pulse SEL.

Appendix B.

Sound Speed Profile Determination for Provinces 1 and 2

This section describes the technique used to reduce the number of usable sound speed profiles from all those observed in the Chukchi Sea to just three that represent the range of profile behaviors. Principal component analysis uses statistical methods to produce orthogonal modes of variation within the data, with the first mode representing the greatest amount of variability within the dataset, the second mode representing the second most variability within the dataset, and so on. Each profile can then be considered as a standard baseline result supplemented by weighted combinations of these modes, with the most deviation principally described by the first few prominent modes. By weighting these first modes in this way, the profiles can be well represented by fewer dimensions.

The analysis only included profiles with CTD measurements that extended beyond 35 m depth. From these, the sound speed was calculated as described in Section 3.5.1. The valid sound speed profiles were resampled to fit a depth vector of 0 m to 44 m with a step size of 2 m with sound speeds linearly extrapolated to extend to the seafloor This provided results for 1153 SSPs (observations, n) each with 23 sampled sound speeds with depth (variables, p).

Because the SSP's shape is more meaningful to the equation than the absolute values of the sound speed, we subtracted the mean from each SSP resulting in a new average sound speed over depth of zero. The SSPs were then combined into a matrix, $\mathbf{C}$, of dimensions $n \times p$. The average observed sound speed at each depth across all profiles was subtracted from each element within the same column, resulting in a matrix, $\mathbf{D}$, which is the deviation from the mean observed value. The covariance matrix is defined as

$$\boldsymbol{\sigma} = \frac{1}{n-1}\mathbf{D}^{\mathrm{T}} \cdot \mathbf{D} \tag{B-1}$$

Subsequently, the orthogonal modes are contained in the matrix solved by

$$\mathbf{V}^{-1}\boldsymbol{\sigma}\mathbf{V} = \mathbf{E} \tag{B-2}$$

where $\mathbf{E}$ is the diagonal matrix containing the eigenvalues of the matrix $\boldsymbol{\sigma}$. Each matrix column of $\mathbf{V}$ provides the eigenmode, each being associated to the eigenvalues in $\boldsymbol{\sigma}$. The relative importance of each mode is determined by sorting the eigenvalues from highest to lowest. The proportion of variability that depends on each mode is the ratio of the relevant eigenvalue to the sum of all eigenvalues; in this case, the distribution shown in Figure B-1.

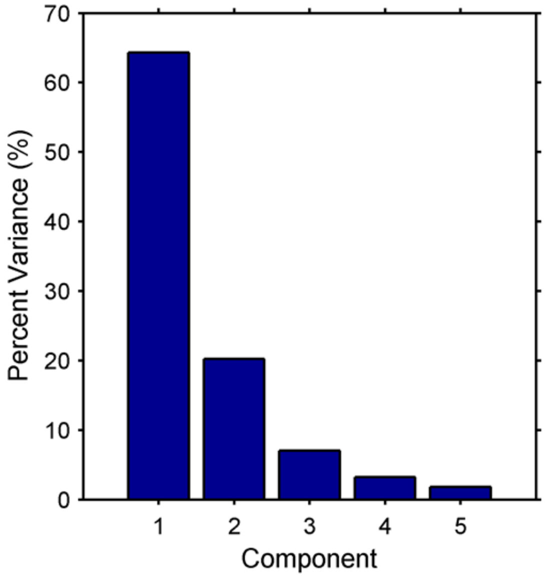

Figure B-1. The weighting distribution of the principal components from sound speed profiles for the Chukchi Sea. The first component, (bar 1), accounts for just over 60% of the variance in the SSPs; the second component accounts for approximately 20% of the SSP variation.

The result shows that the first two principal components (PC) determine over 80% of the variation. This suggests that each sound speed profile can be reasonably defined by adding the average SSP to weighted contributions from mode 1 and mode 2. The average SSP is shown in Figure B-2(a) and the first two modes in Figure B-2(b). The first eigenmode indicates the difference in sound speed between the surface layer and the deeper layer, whereas the second eigenmode determines the transition depth between the surface and deeper layer.

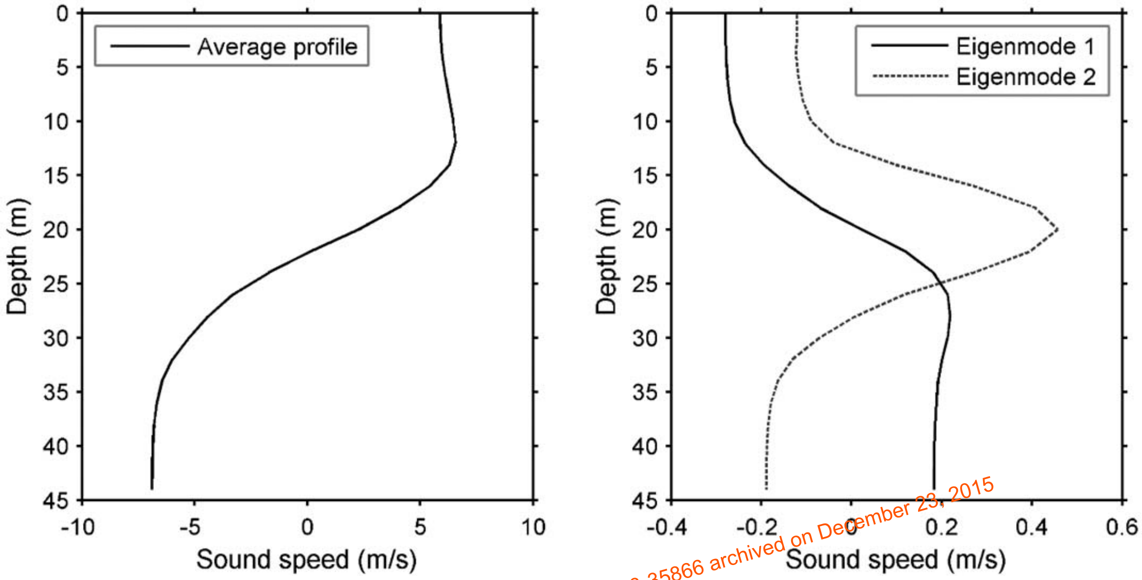

Figure B-2. (Left) The zero-centered average SSP observed in the Chukchi Sea, on which all other profiles in the analysis are based. (Right) The first two eigenmodes that represent the principal dimensions of variation; all profiles in the dataset can be reasonably defined by summing the average sound speed and specific amounts of these first two modes.

The normalized principal component values of each SSP are determined by first taking an empirical standard deviation vector, s, defined as the square root of the diagonal elements of the covariance matrix, $\boldsymbol{\sigma}$. This is expanded into a matrix by stacking the vectors, one for each observation, to give the matrix $\mathbf{S}$. The standard score matrix is then the element-by-element division of

$$\mathbf{Z} = \frac{\mathbf{D}}{\mathbf{S}} \tag{B-3}$$

The normalized principal component value is

$$\mathrm{PC}_N = \mathbf{Z} \cdot \mathbf{v}_N \tag{B-4}$$

where vN is the Nth eigenmode and the Nth column of the matrix, V. Each measured SSP that makes up the dataset is weighted by the two modes shown in Figure B-2b, which was calculated using Equation B-4. Figure B-3 shows the scaled values of the first two components for every profile used in the analysis. The marker color represents the time of year. A profile located close to the origin is typically very similar to the average SSP (see Figure B-2a). A profile located at (5,0) is a typical October profile, and is the culmination of the average SSP and a significant amount of eigenmode 1 giving it a relatively flat profile. Although the plot shows a great deal of variability between profiles, definite trends exist with respect to the time of year. Early in the season, negative values of the first principal component have a large spread of second principal component values. By October, however, the profiles are clustered around (-5,-2).

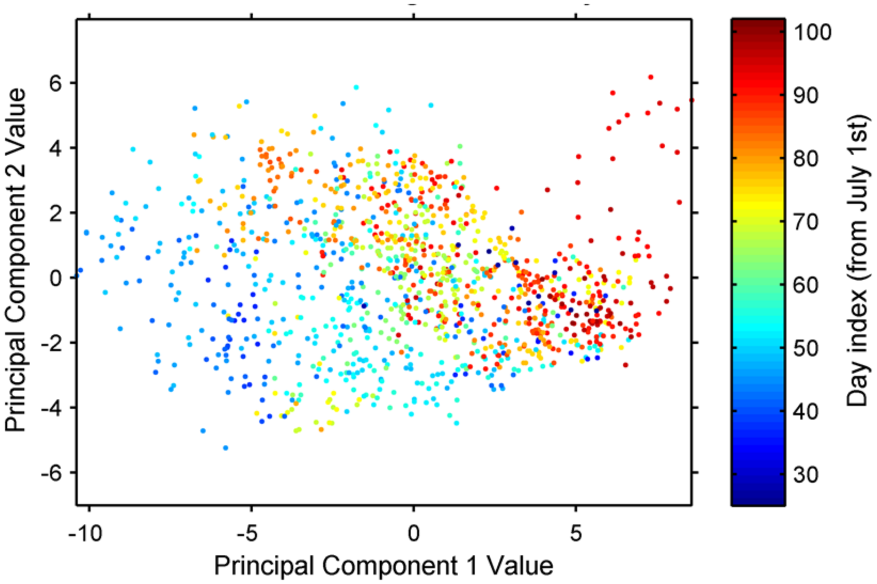

Figure B-3. The first two principal component values for every sound speed profile. The location of each profile on the plot indicates the relative weighting of the first two eigenmodes added to the average sound speed profile.

A two-dimensional histogram helps identify common SSP clusters at different times of the year. Figure B-4 shows the distribution of Principal Component 1 (PC1) and PC2 values for the measurements taken at the beginning of August and at the beginning of October.

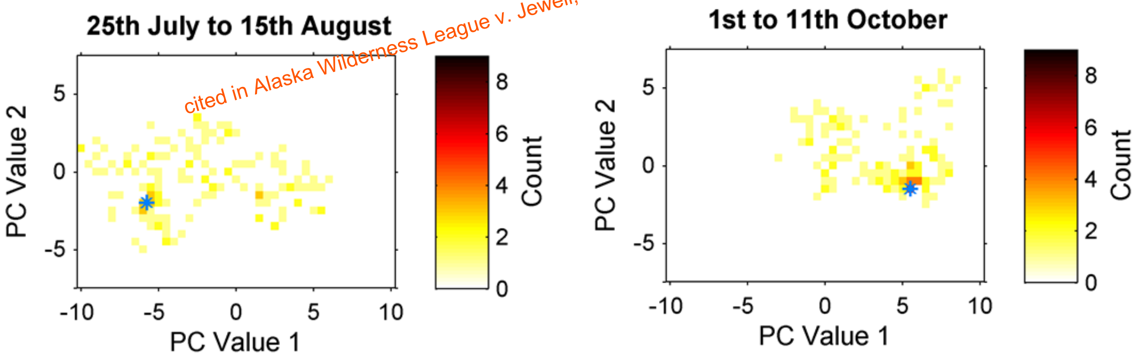

Figure B-4. Two-dimensional histograms indicate the most common combinations of PC1 and PC2 values. A blue star indicates the most common PC value.

Using the modal values for PC1 and PC2, new SSPs can be synthesized based on the original measurements. The August profile has PC1 and PC2 values of −5.75 and −2.0 respectively. The October profile has PC1 and PC2 values of 5.5 and −1.5 respectively. The statistical SSPs using just the first two principal components are generated by

$$\mathbf{c} = \bar{c} + \boldsymbol{\mu} + s_1 \mathrm{PC}_1 \mathbf{v}_1 + s_2 \mathrm{PC}_2 \mathbf{v}_2 \qquad \text{(B-5)}$$

where $\bar{c}$ is the average sound speed over all observations, $\boldsymbol{\mu}$ is the average sound speed profile (Figure B-2a), s_1 and s_2 are the first two elements in the empirical standard deviation vector used for scaling, PC_1 and PC_2 are the first two principal component values, and v_1 and v_2 are the first two eigenmodes. The generated SSPs are shown in Figure B-5. The average SSP is typical of the Chukchi Sea; it features a mixed surface layer over a decrease in temperature with depth, which gives rise to a downward refracting profile. The downward refracting profile, typical of an August profile, is attributed to a heated surface layer over a sharp temperature decrease, which refracts sound toward the sediment. The mixed profile, which occurs when water is well mixed across the water column and has less pronounced refraction effects, is typical of an October profile; deviates slightly from an isovelocity profile.

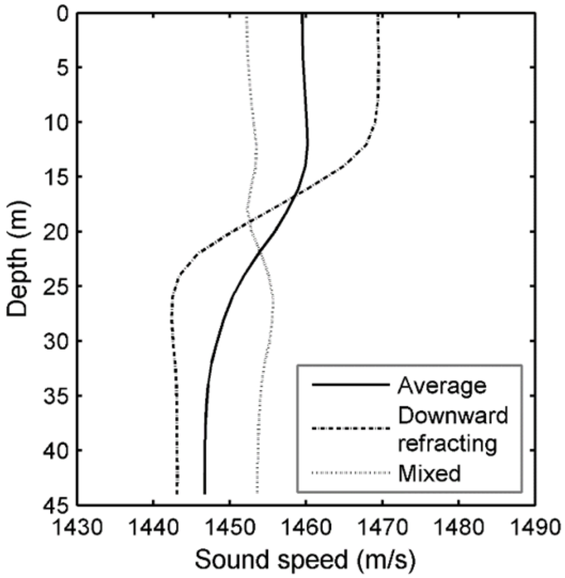

Figure B-5. The synthesized SSP based on the most commonly observed SSP in the Chukchi Sea.

Appendix C.

Variability Analysis for all Scenarios at Modeling Site 1a

The tables in this Appendix present the R_{max} radii for Scenarios 1-7 at modeling Site 1a; these accompany the Scenario 1 results shown as an example in Section 4. There are two tables of radii for each site, the first presents the results for the medium-reflectivity geoacoustics with the three SSPs, and the second table presents the results for the average SSP and the three geoacoustic profiles. These tables show that the geoacoustic profile has more of an effect on the radii at a site than the sound speed profile. The results provide the basis for using the variability in geoacoustic properties to inform the analysis of the effects of exposure to sounds from the sources modeled.

Table C-1. Scenario 1 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	0.43	0.43	0.45
180	1.34	1.35	1.37
160	6.04	6.32	6.29

Table C-2. Scenario 1 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	0.22	0.43	0.50
180	0.72	1.35	1.45
160	4.14	6.32	9.11

Table C-3. Scenario 2 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	5.23	5.29	5.78

*Not reached.

Table C-4. Scenario 2 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	2.33	5.29	6.97

*Not reached.

Table C-5. Scenario 3 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	0.73	0.73	0.73
180	2.05	2.09	2.04
160	8.99	8.86	10.5

Table C-6. Scenario 3 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	0.46	0.73	0.77
180	1.22	2.09	2.24
160	6.39	8.86	13.8

Table C-7. Scenario 4 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	0.02	0.02	0.02
180	0.11	0.11	0.11
160	1.47	1.47	1.47

Table C-8. Scenario 4 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	0.02	0.02	0.02
180	0.07	0.11	0.12
160	0.64	1.47	1.49

Table C-9. Scenario 5 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	0.13	0.14	0.14
180	0.52	0.52	0.53
160	3.23	3.24	3.21

Table C-10. Scenario 5 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	0.08	0.14	0.17
180	0.25	0.52	0.62
160	2.11	3.24	4.06

Table C-11. Scenario 6 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	10.8	10.8	11.5

*Not reached.

Table C-12. Scenario 6 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	*	*	*
180	*	*	*
160	0.01	0.01	0.01
120	7.61	10.8	13.2

*Not reached.

Table C-13. Scenario 7 at modeling Site 1a: R_{max} radii of rms SPL contours with medium-reflectivity geoacoustics and downward refracting, average, and mixed sound speed profiles.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Downward Refracting	Average	Mixed
190	*	*	*
180	*	*	*
160	0.03	0.03	0.03
120	7.88	8.51	10.0

*Not reached.

Table C-14. Scenario 7 at modeling Site 1a: R_{max} radii of rms SPL contours with average sound speed profile and low-reflectivity, medium-reflectivity, and high-reflectivity geoacoustics.

rms SPL (dB re 1 µPa)	R_{max} (km)		
	Low-reflectivity	Medium-reflectivity	High-reflectivity
190	*	*	*
180	*	*	*
160	0.03	0.03	0.03
120	3.45	8.51	13.0

*Not reached.