Draft Environmental Assessment
For the Issuance of Incidental Harassment Authorizations for the Take of Marine Mammals by Harassment Incidental to Conducting Exploratory Drilling Programs in the U.S. Beaufort and Chukchi Seas

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LOCATION: U.S. Beaufort and Chukchi Seas

ABSTRACT: .... The National Marine Fisheries Service proposes to issue Incidental Harassment Authorizations (IHAs) to Shell Offshore Inc. and Shell Gulf of Mexico Inc. (collectively "Shell") for the take of marine mammals incidental to conducting exploratory drilling programs in the U.S. Beaufort and Chukchi Seas.

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List of Acronyms, Abbreviations, and Initialisms

0-p	0-to-peak
2D	2-dimensional
3D	3-dimensional
4MP	Marine Mammal Monitoring and Mitigation Plan
ABWC	Alaska Beluga Whale Committee
ACIA	Arctic Climate Impact Assessment
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
AEWC	Alaska Eskimo Whaling Commission
AHD	Acoustic Harassment Device
ANO	Alaska Native Organization
ATOC	Acoustic Thermometry of Ocean Climate
BACT	Best Available Control Technology
bbl	barrels
BCB	Bering-Chukchi-Beaufort Seas (stock of bowhead whale)
BLM	Bureau of Land Management
BOD	Biochemical Oxygen Demand
BOEM	Bureau of Ocean Energy Management
BOEMRE	Bureau of Ocean Energy Mangement, Regulation and Enforcement
BOP	Blowout Preventer
BP	BP Exploration Alaska
BSEE	Bureau of Safety and Environmental Enforcement
C	Celsius
CDFO	Canadian Department of Fisheries & Oceans
CFR	Code of Federal Regulations
CEQ	President's Council on Environmental Quality
cm	centimeter
cm^3	cubic centimeter
COMIDA	Chukchi Offshore Monitoring in Drilling Area
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DASAR	Directional Autonomous Seafloor Acoustic Recorder
dB	decibel
DOI	Department of the Interior
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency
ESA	Endangered Species Act
EVOS	Exxon Valdez Oil Spill
FM	frequency-modulated
FMP	Fishery Management Plan
ft	foot/feet
FR	Federal Register

hr	hour
Hz	hertz
IHA	Incidental Harassment Authorization
IMO	International Maritime Organization
IMP	Ice Management Plan
in^3	cubic inch
ION	ION Geophysical
IPCC	Intergovernmental Panel on Climate Change
IWC	International Whaling Commission
kHz	kilohertz
kg	kilogram
km	kilometer
km^2	square kilometer
L-DEO	Lamont-Doherty Earth Observatory
LME	Large Marine Ecosystem
m	meter
m^2	square meter
m^3	cubic meter
mi	mile
mi^2	square mile
MLC	Mudline Cellar
MMO	Marine Mammal Observer
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NAAQS	National Ambient Air Quality Standards
NAO	NOAA Administrative Order
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPFMC	North Pacific Fisheries Management Council
NRC	National Research Council
NSB	North Slope Borough
NSIDC	National Snow and Ice Data Center
NSR	New Source Review
OCS	Outer Continental Shelf
OMB	Office of Management and Budget
OSR	Oil Spill Response
OST	Oil Spill Tanker
p-p	peak-to-peak
PAH	Polycyclic Aromatic Hydrocarbons
POC	Plan of Cooperation
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PSO	Protected Species Observer
psu	practical salinity units
PTS	Permanent Threshold Shift
rms	root-mean-square

s	second
SAR	Search and Rescue
SEL	Sound Exposure Level
SIWAC	Shell Ice and Weather Advisory Center
SPL	Sound Pressure Level
TS	Threshold Shift
TSS	Total Suspended Solids
TTS	Temporary Threshold Shift
U.S.C.	United States Code
USCG	United States Coast Guard
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
VSI	Vertical Seismic Imager
yr	year
ZVSP	Zero-offset Vertical Seismic Profile
μPa	micro pascal

Chapter 1 PURPOSE AND NEED FOR ACTION

1.1 Proposed Action

Pursuant to the National Environmental Policy Act (NEPA), the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), through this Draft Environmental Assessment (EA), analyzes the potential impacts to the human environment that may result from the issuance of Incidental Harassment Authorizations (IHAs) pursuant to section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA; 16 USC 1361 *et seq.*) to Shell Offshore Inc. and Shell Gulf of Mexico Inc. (collectively "Shell") for the take[1] of marine mammals incidental to conducting offshore exploratory drilling programs in the U.S. Beaufort and Chukchi Seas.

On May 10, 2011, NMFS received an application from Shell requesting an authorization for the harassment of marine mammals incidental to conducting an offshore exploratory drilling program in Camden Bay in the Beaufort Sea, Alaska. After addressing comments from NMFS, Shell modified its application and submitted a revised application on September 2, 2011. The proposed activities that have the potential to take marine mammals include operation of the drillship, ice management/icebreaking activities, and zero-offset vertical seismic profile (ZVSP) surveys. The marine mammal species under NMFS' jurisdiction that have the potential to be impacted by Shell's Camden Bay, Beaufort Sea, exploratory drilling program include: beluga whale (*Delphinapterus leucas*); bowhead whale (*Balaena mysticetus*); gray whale (*Eschrichtius robustus*); harbor porpoise (*Phocoena phocoena*); bearded seal (*Erignathus barbatus*); ringed seal (*Phoca hispida*); spotted seal (*P. largha*); and ribbon seal (*Histriophoca fasciata*). NMFS' proposed action is to issue an IHA to Shell for the take of these eight marine mammal species, by harassment, incidental to conducting the Camden Bay exploratory drilling program during the 2012 open-water season (i.e., July through October). NMFS published a Notice of Proposed IHA and request for comments in the *Federal Register* on November 7, 2011 (76 FR 68974).

On June 30, 2011, NMFS received an application from Shell requesting an authorization for the harassment of marine mammals incidental to conducting an offshore exploratory drilling program in the Chukchi Sea, Alaska. After addressing comments from NMFS, Shell modified its application and submitted a revised application on September 12, 2011. The proposed activities that have the potential to take marine mammals include operation of the drillship, ice management/icebreaking activities, and ZVSP surveys. The marine mammal species under NMFS' jurisdiction that have the potential to be impacted by Shell's Chukchi Sea exploratory drilling program include: beluga whale; bowhead whale; gray whale; killer whale (*Orcinus orca*); minke whale (*Balaenoptera acutorostrata*); fin whale (*Balaenoptera physalus*); humpback whale (*Megaptera novaeangliae*); harbor porpoise; bearded seal; ringed seal; spotted seal; and ribbon seal. NMFS' proposed action is to issue an IHA to Shell for the take of these 12 marine mammal species, by harassment, incidental to conducting the Chukchi Sea exploratory drilling program during the 2012 open-water season (i.e., July through October). NMFS published a Notice of Proposed IHA and request for comments in the *Federal Register* on November 9, 2011 (76 FR 69958).

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[1] Take under the MMPA means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. 16 U.S.C. 1362(13).

1.2 Purpose and Need

Under the MMPA, the "taking" of marine mammals, incidental or otherwise, without a permit or exemption is prohibited, with a few exceptions. One such exception (as stated in section 101(a)(5)(D)) is for the incidental, but not intentional, "taking," by U.S. citizens, while engaging in an activity (other than commercial fishing) of small numbers of marine mammals of a species or population stock provided that the taking will have a negligible impact on such species or stock, will not have an unmitigable adverse impact on the availability of such species or stock for taking for subsistence uses, and, where applicable, the permissible methods of taking and requirements pertaining to the mitigation, monitoring, and reporting are set forth. Additionally, pursuant to section 101(a)(5)(D) of the MMPA, monitoring plans are required to be independently peer reviewed where the proposed activity may affect the availability of a species or stock for taking for subsistence uses.

The purpose and need of the proposed action is to ensure compliance with the MMPA and its implementing regulations in association with Shell's proposed exploratory drilling programs in the Beaufort and Chukchi Seas, Alaska. In response to the receipt of two IHA application requests from Shell for the two separate exploratory drilling programs, NMFS proposes to issue IHAs pursuant to section 101(a)(5)(D) of the MMPA.

This Draft EA is prepared in accordance with the NEPA of 1969 (42 U.S.C. 4321 *et seq.*) and describes the potential environmental impacts that may result from the issuance of NMFS' proposed IHAs to Shell.

1.3 Scoping Summary

The purpose of scoping is to identify the issues to be addressed and the significant issues related to the proposed action, as well as to identify and eliminate from detailed study the issues that are not significant or that have been covered by prior environmental reviews. An additional purpose of the scoping process is to identify the concerns of the affected public, Federal, State, and local agencies, and Indian tribes.

The MMPA and its implementing regulations governing issuance of an IHA require that upon receipt of a valid and complete application for an IHA, NMFS publish a notice of receipt in the *Federal Register* (50 Code of Federal Regulations [CFR] §216.104(b)(1)). The notice summarizes the purpose of the requested IHA, includes a statement about what type of NEPA analysis is being considered, and invites interested parties to submit written comments concerning the application and NMFS' analysis.

NOAA Administrative Order (NAO) 216-6 established agency procedures for complying with NEPA and the implementing regulations issued by the President's Council on Environmental Quality (CEQ). NAO 216-6 specifies that the issuance of an IHA under the MMPA is among a category of actions that require further environmental review and the preparation of NEPA documentation.

1.3.1 Comments on MMPA Applications and EA

On November 7, 2011, NMFS published a Notice of Proposed IHA for Shell's Camden Bay, Beaufort Sea, exploratory drilling program in the *Federal Register* (76 FR 68974), which announced the availability of Shell's IHA application for public comment for 30 days. On November 9, 2011, NMFS published a Notice of Proposed IHA for Shell's Chukchi Sea exploratory drilling program in the *Federal Register* (76 FR 69958), which announced the availability of Shell's IHA application for public comment for 30 days. The comment period for the proposed IHAs affords the public the opportunity to provide input on environmental impacts, and many of the issues identified by the public have been considered in developing this Draft EA. All relevant comments submitted during the MMPA public comment period will be addressed and included in the *Federal Register* notices of issuance or denial for each request.

The analyses contained in this Draft EA provide decision-makers and the public with an evaluation of the potential environmental, social, and economic effects of a range of reasonable alternatives, including the proposed action (i.e., issuance of IHAs to Shell). The Draft EA also includes an analysis of the potential cumulative impacts of the proposed action when added to other past, present, and reasonably foreseeable future actions, particularly as they relate to marine resources (e.g., marine mammals, fish, etc.) and subsistence harvest activities. The IHAs, if issued, would authorize the take, by harassment, of eight marine mammal species for the Camden Bay program and 12 marine mammal species for the Chukchi Sea program incidental to conducting offshore exploratory drilling programs during the 2012 open-water season.

This Draft EA is available to the public for review and comment for 30 days. The public is invited to provide comments on the analyses contained in this document. Following the 30-day NEPA public comment period, NMFS will consider all of the relevant comments received when preparing the Final EA. Additionally, any relevant issues raised during the MMPA public comment periods mentioned above will be considered in the Final EA.

1.3.2 Issues within the Scope of this EA

NMFS identified the following issues as relevant to the actions and appropriate for detailed evaluation: (1) disturbance of marine mammals from noises generated by the drillship, associated support vessels (including icebreakers during active ice management/icebreaking) and aircraft, and airguns; and (2) disturbance of marine mammals related to the presence of the drillship and associated support vessels and aircraft. The impacts to marine mammals that are reasonably expected to occur will be acoustic in nature. While not part of the specified activity detailed in Shell's IHA applications or part of NMFS' proposed action, NMFS identified potential impacts from an oil spill as an issue requiring analysis in this Draft EA.

Disturbance from Anthropogenic Noise: The proposed exploratory drilling programs would introduce underwater noise from seismic airguns and other active acoustic sources, as well as noise from survey and support vessels, into the Arctic marine ecosystem. These noises are likely to result in behavioral disturbance to marine mammals located in the vicinity of the project areas.

Disturbance from Drillship and Vessel Presence: The increased amount of vessel activities associated with the proposed exploratory drilling programs also has the potential to result in behavioral disturbance to marine mammals in the vicinity of the proposed project areas.

Impacts from an Oil Spill: Although an oil spill is not reasonably likely to occur and therefore not reasonably likely to result in the take of marine mammals, in the unlikely event that one does occur, marine mammals could potentially be harassed, injured, or killed.

1.4 Applicable Laws and Necessary Federal Permits, Licenses, and Entitlements

This section summarizes the requirements of a number of Federal laws and regulations, State and local permits, licenses, approvals, consultation requirements, and Executive Orders (EOs) that may be applicable to Shell's proposed activities or issuance of an IHA.

1.4.1 National Environmental Policy Act

NEPA establishes a nationwide policy and goal of environmental protection and provides legal authority for Federal agencies to carry out that policy (40 CFR §1500.1(a)). It requires Federal agencies to study and consider the environmental consequences of their actions and to use an interdisciplinary framework for environmental decision-making, which includes the consideration of environmental amenities and values (42 U.S.C. §4332(B)).

The issuance of IHAs is subject to environmental review under NEPA. NMFS may prepare an EA, an Environmental Impact Statement (EIS), or determine that the action is categorically excluded from further review. While NEPA does not dictate substantive requirements for IHAs, it requires consideration of environmental issues in Federal agency planning and decision-making. The procedural provisions outlining Federal agency responsibilities under NEPA are provided in the CEQ's implementing regulations (40 CFR Parts 1500-1508).

NOAA has, through NAO 216-6, established agency procedures for complying with NEPA and the implementing regulations issued by the CEQ. When a proposed action has uncertain environmental impacts or unknown risks, establishes a precedent or decision in principle about future proposals, may result in cumulatively significant impacts, or may have an adverse effect upon endangered or threatened species or their habitats, preparation of an EA or EIS is required. This Draft EA is prepared in accordance with NEPA, the CEQ's implementing regulations, and NAO 216-6.

1.4.2 Marine Mammal Protection Act

Section 101(a)(5)(D) of the MMPA (16 U.S.C. 1371(a)(5)(D)) directs the Secretary of Commerce (Secretary) to authorize, upon request, the incidental, but not intentional, taking of small numbers of marine mammals of a species or population stock, for periods of not more than one year, by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specific geographic region if certain findings are made and a notice of proposed authorization is provided to the public for review.

Authorization for incidental taking of small numbers of marine mammals shall be granted if NMFS finds that the taking will have a negligible impact on the species or stock(s), will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses, and if the permissible methods of taking, other means of effecting the least practicable impact on the species or stock and its habitat, and requirements pertaining to the monitoring and reporting of such takings are set forth. NMFS has defined "negligible impact" in 50 CFR

§216.103 as "an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival." Additionally, NMFS has defined "unmitigable adverse impact" in 50 CFR §216.103 as:

> …an impact resulting from the specified activity: (1) That is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by: (i) Causing the marine mammals to abandon or avoid hunting areas; (ii) Directly displacing subsistence users; or (iii) Placing physical barriers between the marine mammals and the subsistence hunters; and (2) That cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

Except with respect to certain activities not pertinent here, the MMPA defines "harassment" as:

> any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild ["Level A harassment"]; or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering ["Level B harassment"].

As part of the IHA process, applicants are required to provide detailed mitigation plans that outline what efforts will be taken to reduce negative impacts to marine mammals, and their availability for subsistence use, to the lowest level practicable. In addition, IHAs require that operators conduct monitoring, which must be designed to result in an increased knowledge of the species and an understanding of the level and type of takings that result from the authorized activities. Where the proposed activity may affect the availability of a species or stock of marine mammal for taking for subsistence uses, the proposed monitoring plan must be independently peer reviewed pursuant to 16 U.S.C. § 1371(a)(5)(D), prior to issuance of the IHA.

NMFS has promulgated regulations to implement the permit provisions of the MMPA (50 CFR Part 216) and has produced Office of Management and Budget (OMB)-approved application instructions (OMB Number 0648-0151) that prescribe the procedures (including the form and manner) necessary to apply for permits. All applicants must comply with these regulations and application instructions in addition to the provisions of the MMPA. Applications for an IHA must be submitted according to regulations at 50 CFR §216.104.

1.4.3 Endangered Species Act

Section 7 of the Endangered Species Act (ESA; 16 U.S.C. §1536) and implementing regulations at 50 CFR Part 402 require consultation with the appropriate Federal agency (either NMFS or the U.S. Fish and Wildlife Service [USFWS]) for Federal actions that "may affect" a listed species or critical habitat. NMFS' issuance of IHAs affecting ESA-listed species or designated critical habitat, directly or indirectly, is a Federal action subject to these section 7 consultation requirements. Accordingly, NMFS is required to ensure that its action is not likely to jeopardize the continued existence of any threatened or endangered species or result in destruction or adverse modification of critical habitat for such species. Section 9 (16 U.S.C. §1538) of the ESA identifies prohibited acts related to endangered species and prohibits all persons, including all Federal, state and local governments, from taking listed species of fish and wildlife, except as specified under provisions for exemption (16 U.S.C. §§1535(g)(2) and 1539). Generally, the USFWS manages land and freshwater species while NMFS manages marine species, including anadromous salmon. However, the USFWS has responsibility for some marine animals such as nesting sea turtles, walrus, polar bears, sea otters, and manatees.

For actions that may result in prohibited "take" of a listed species, Federal agencies must obtain authorization for incidental take through Section 7 of the ESA's formal consultation process. Under the ESA, "take" means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." NMFS has further defined harm as follows: "harm" is "…an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering" (50 CFR 222.102). NMFS has not defined the term "harass".

Under Section 7 of the ESA, Federal agencies consult with the USFWS and/or NMFS and submit a consultation package for proposed actions that may affect listed species or critical habitat. If a listed species or critical habitat is likely to be affected by a proposed Federal action, the Federal agency must provide the USFWS and NMFS with an evaluation of whether or not the effect on the listed species or critical habitat is likely to be adverse. The USFWS and/or NMFS uses this documentation along with any other available information to determine if a formal consultation or a conference is necessary for actions likely to result in adverse effects to a listed species or its designated critical habitat. If a Federal action is likely to adversely affect endangered or threatened species or designated critical habitat, then USFWS and/or NMFS prepares a Biological Opinion, which makes a determination as to whether the action is likely to jeopardize an endangered or threatened species. If take is anticipated, the USFWS and/or NMFS must also issue an Incidental Take Statement, which includes terms and conditions and reasonable and prudent measures which must be followed.

There are three marine mammal species under NMFS' jurisdiction listed as endangered under the ESA with confirmed or possible occurrence in the proposed project area (i.e., the U.S. Beaufort and Chukchi Seas): the bowhead, humpback, and fin whales. NMFS' Permits and Conservation Division has initiated consultation with NMFS' Alaska Regional Office Protected Resources Division under section 7 of the ESA on the issuance of IHAs to Shell under section 101(a)(5)(D) of the MMPA for this activity. Consultation will be concluded prior to a determination on the issuance of an IHA.

1.4.4 Magnuson-Stevens Fishery Conservation and Management Act

Under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), Federal agencies are required to consult with the Secretary of Commerce with respect to any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by such agency which may adversely affect essential fish habitat (EFH) identified under the MSFCMA. These proposed IHAs, while necessary for the conservation and management of marine life, do not affect policies relevant to the National Standards of the MSFCMA. NMFS' Office of Protected Resources Permits and Conservation Division has determined that the issuance of IHAs for the taking of marine mammals incidental to conducting offshore exploratory drilling programs in the U.S. Beaufort and Chukchi Seas will not have an adverse impact on EFH; therefore, an EFH consultation is not required.

1.4.5 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) encourages coastal states to develop comprehensive programs to manage and balance competing uses of and impacts to coastal resources. The CZMA emphasizes the primacy of state decision-making regarding the coastal zone. Section 307 of the CZMA (16 U.S.C. § 1456), called the Federal consistency provision, is a major incentive for states to join the national coastal management program and is a powerful tool that states use to manage coastal uses and resources and to facilitate cooperation and coordination with Federal agencies.

Federal consistency is the CZMA requirement where Federal agency activities that have reasonably foreseeable effects on any land or water use or natural resource of the coastal zone (also referred to as coastal uses or resources and coastal effects) must be consistent to the maximum extent practicable with the enforceable policies of a coastal state's Federally-approved coastal management program. On July 1, 2011, the Federally-approved Alaska Coastal Management Program expired, resulting in a withdrawal from participation in CZMA's National Coastal Management Program. The Federal CZMA consistency provision in Section 307 no longer applies in Alaska.

1.4.6 Clean Air Act

The Clean Air Act (42 U.S.C. § 7401, et seq.) governs the control of air pollutant emissions from both stationary and mobile sources. Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) is authorized to establish National Ambient Air Quality Standards (NAAQS) to limit the concentration of harmful air emissions that, when occurring in sufficient concentrations, can harm human life and wildlife. The Clean Air Act established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.

The Clean Air Act has been amended several times since the first version in 1963. The jurisdiction for approving air quality permits depends on the location of the proposed federal action. Jurisdiction for air pollution control on the outer continental shelf (OCS) is divided into three areas: those within the state's seaward boundary (0 to 3 miles); those within 25 miles of a state's seaward boundary (i.e., 3 to 28 miles from the coast); and those beyond 25 miles of a state's seaward boundary (i.e., 28 to 200 miles from the coast). The Alaska Department of Environmental Conservation (ADEC) issues permits for proposed actions within the state seaward boundary while the EPA issues permits for proposed federal action within and beyond 25 miles of a state's seaward boundary. Permits issued by EPA for sources within the 25-mile state boundary must comply with state air standards.

Under the 1990 Amendments, the Clean Air Act Title V operating permit program was established. EPA regulations implementing Title V are promulgated at 40 CFR Part 71 (for permits issued by EPA) and 40 CFR Part 70 (for permits issued by states). The Title V air quality operating permit, or Title V permit, is an enforceable compilation of all air pollution requirements that are applicable to an air emission source and is typically issued after the major stationary source has begun to operate (post-construction). While most Title V permits are issued by state and local permitting authorities, the EPA also issues Title V permits for special circumstances, such as in Indian country and on the OCS (within and beyond 25 miles of a state's seaward boundary).

On the Alaska OCS, a combination of air permits such as Owner Requested Limits (minor source pre-construction), Prevention of Significant Deterioration (PSD), nonattainment New Source Review (NSR), and Title V permits may be issued by ADEC or the EPA (Clean Air Act Section 328(a)(1)). Regardless of the type of federal permit, actions on the OCS are regulated under 40 CFR Part 55.13. This regulation directs the project sponsor to comply with 40 CFR 52.21, the PSD permit regulation, and 40 CFR Parts 70 and 71, the Title V regulation. The PSD permit must be obtained before construction begins (pre-construction permit), and the Title V operating permit is typically applied for following implementation of the Proposed Action, and thereafter on a regular recurring basis.

On September 19, 2011, the EPA issued final air quality permits to Shell regarding operation of the drillship *Discoverer* and a support fleet of icebreakers, oil spill response vessels, and supply ships for up to 120 days each year in the Chukchi Sea and Beaufort Sea OCS starting in 2012. On October 21, 2011, the EPA issued a final air quality permit to Shell regarding operation of the drillship *Kulluk* and a support fleet of icebreakers, oil spill response vessels, and supply ships for up to 120 days each year in the Beaufort Sea OCS starting in 2012. Shells exploration drilling fleet will emit more than 250 tons of air pollutants a year and therefore, under existing law, must have federal Clean Air Act OCS/PSD permits. The permits set strict limits on air pollution from these vessels.

1.4.7 Clean Water Act

The Clean Water Act (CWA) has several sections or programs applicable to activities in offshore waters, including U.S. Coast Guard (USCG) implementing regulations (33 CFR Part 151). The EPA has promulgated regulations (40 CFR Part 125) to ensure the discharges it regulates through the National Pollution Discharge Elimination System (NPDES) program, pursuant to Section 402 of the CWA, would not cause an unreasonable degradation of the marine environment. The EPA's NPDES Arctic General Permit for Offshore Oil and Gas Exploration on the OCS and contiguous State Waters (Permit Number AKG280000) authorizes certain discharges from oil and gas exploration facilities and establishes effluent limitations, monitoring requirements, and other conditions. Permitted discharges related to exploration drilling include drilling fluids and cuttings, deck drainage, sanitary waste, domestic wastes, desalination unit wastes, blowout-preventer fluid, boiler blowdown, fire control system test water, non-contact cooling water, uncontaminated ballast water, bilge water, excess cement slurry, muds, cuttings, cement at seafloor, and test fluids. The current Arctic general permit expired on June 26, 2011. The EPA plans to reissue separate NPDES exploration General Permits for the Beaufort Sea and the Chukchi Sea in October 2012. EPA expects that tribal consultation and public comment on the new proposed Beaufort and Chukchi oil and gas exploration permits would occur in early 2012. Coverage has been administratively extended under the expired Arctic General Permit until the new General Permits are issued.

1.4.8 Executive Order 12898: Environmental Justice

EO 12898, signed by the President on February 11, 1994, and published February 16, 1994 (59 FR 7629), requires that Federal agencies make achieving "environmental justice" part of their mission by identifying and addressing disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low income populations in the U.S. Many Alaska Natives harvest marine mammals for subsistence purposes and benefit from their continued existence. The potential effects of the proposed action on minority populations are described in Chapter 4.

1.4.9 Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

This EO, signed by the President on November 6, 2000, and published on November 9, 2000 (65 FR 67249), is intended to establish regular and meaningful consultation and collaboration between Federal agencies and Federally-recognized tribal governments in the development of Federal regulatory practices that significantly or uniquely affect their communities.

1.4.10 Co-management Agreements

Through Section 119 of the MMPA, NMFS and the USFWS were granted authority to enter into cooperative agreements with Alaska Native Organizations (ANOs), including, but not limited to, Alaska Native Tribes and tribally authorized co-management bodies. Individual co-management agreements incorporate the spirit and intent of co-management through close cooperation and communication between Federal agencies and the ANOs, hunters, and subsistence users. Agreements encourage the exchange of information regarding the conservation, management, and utilization of marine mammals in U.S. waters in and around Alaska.

Section 119 agreements may involve: (1) developing marine mammal co-management structures and processes with Federal and state agencies; (2) monitoring the harvest of marine mammals for subsistence use; (3) participating in marine mammal research; and (4) collecting and analyzing data on marine mammal populations.

NMFS currently has three co-management agreements with Native Alaskan groups specific to species found in the U.S. Beaufort and Chukchi Seas and which are relevant to the scope of this EA. Those agreements are with the Alaska Beluga Whale Committee for Western Alaska beluga whales, with the Alaska Eskimo Whaling Commission (AEWC) for the Western Arctic stock of bowhead whales (also known as the Bering-Chukchi-Beaufort stock), and with the Ice Seal Committee for the Alaska stocks of ringed, bearded, spotted, and ribbon seals. The NOAA-AEWC cooperative agreement is entered into under Section 112(c) of the MMPA and the Whaling Convention Act.

1.5 *Description of the Specified Activity and Specified Geographic Region*

As described above, Section 101(a)(5)(D) of the MMPA requires that an applicant indicate the specified activity for which incidental take is requested. The applicant's activity is evaluated by NMFS and informs NMFS' development of a proposed action and range of NEPA alternatives. The specified activities are two proposed exploratory drilling programs by Shell in the Beaufort and Chukchi Seas, Alaska, during the 2012 open-water season. This section of the Draft EA summarizes Shell's specified activities for each IHA request, which are also described in Shell's applications for authorization pursuant to Section 101(a)(5)(D) of the MMPA. The applications are available on the Internet on the NMFS Office of Protected Resources website at: http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications. That information is incorporated herein by reference.

1.5.1 Beaufort Sea Exploratory Drilling Program

1.5.1.1 Beaufort Sea Project Location

Shell plans to conduct an offshore exploration drilling program on U.S. Department of the Interior (DOI), Bureau of Ocean Energy Management (BOEM, formerly the Minerals Management Service) Alaska OCS leases located north of Point Thomson near Camden Bay in the Beaufort Sea, Alaska, during the 2012 open-water season. During the 2012 drilling program, Shell plans to complete two exploration wells at two drill sites, one well each on the Torpedo prospect (NR06 04 Flaxman Island lease block 6610, OCS Y 1941 [Flaxman Island 6610—Torpedo "H" or "J" drill site]) and the Sivulliq prospect (NR06 04 Flaxman Island lease block 6658, OCS Y 1805 [Flaxman Island 6658—Sivulliq "N" or "G" drill sites]). Figure 1 depicts the lease block and drill site locations. Table 1 outlines the exact locations of each of the four potential drill sites and their distance from the shore. All drilling is planned to be vertical.

The two Native Alaskan communities closest to the Torpedo and Sivulliq prospects are Kaktovik and Nuiqsut. Kaktovik is located between 55 and 60 miles (mi) (89 and 97 kilometers [km]) away from the four potential drill sites. Nuiqsut is located between 118 and 125 mi (190 and 201 km) away from the four potential drill sites. However, the village of Nuiqsut conducts its fall bowhead whale hunt from Cross Island, which is located between 45 and 50 mi (72 and 81 km) from the four potential drill sites.

Table 1. Locations, distances from shore, and water depths for Shell's proposed 2012 Camden Bay, Beaufort Sea, drill sites.

Drill Site	Distance From Shore	NR06-04 Lease Block No.	Surface Location (NAD 83)		Water Depth
	mi (km)		Latitude (north)	Longitude (west)	ft (m)
Sivulliq G	16.6 (26.7)	6658	70° 23' 46.82"	146° 01' 03.46"	110 (33.5)
Sivulliq N	16.2 (26.1)	6658	70° 23' 29.58"	145° 58' 52.53"	107 (32.6)
Torpedo H	20.8 (33.5)	6610	70° 27' 01.62"	145° 49' 32.07"	120 (36.6)
Torpedo J	23.1 (37.2)	6559	70° 28' 56.94"	145° 53' 47.15"	124 (37.8)

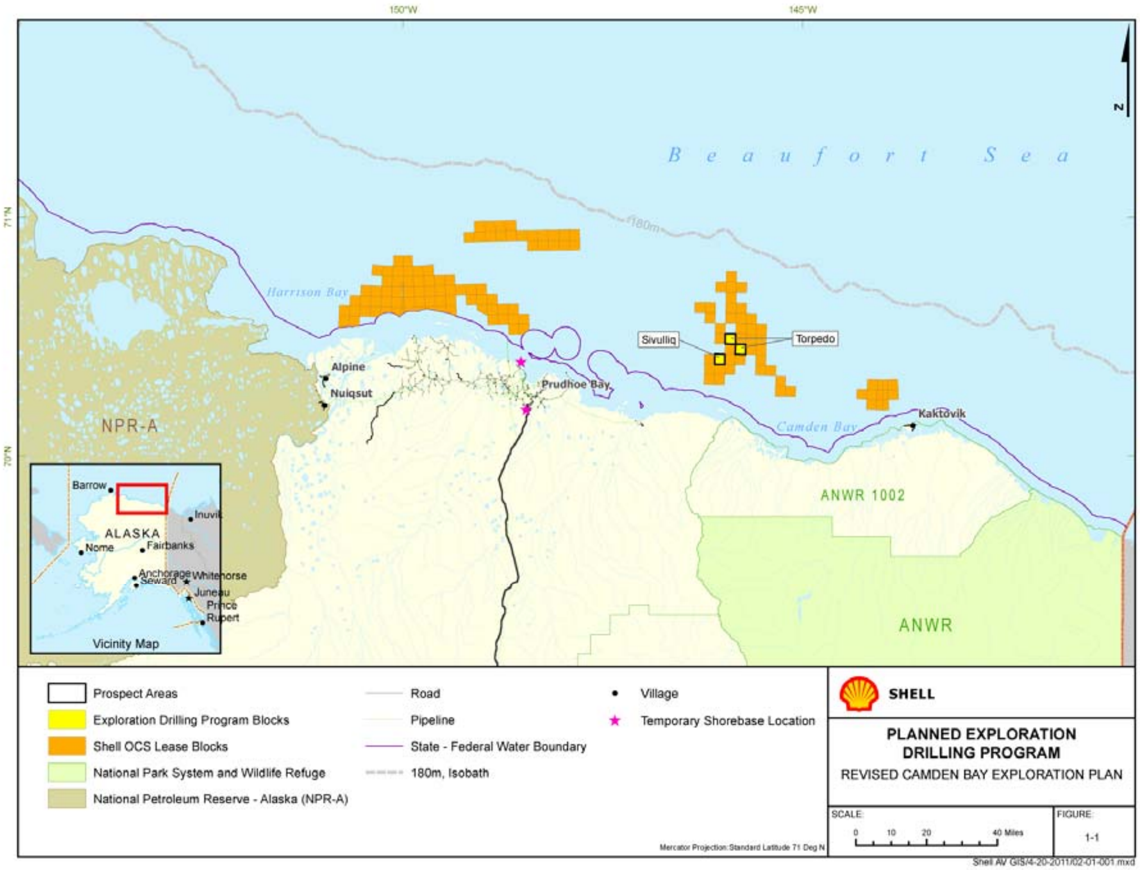

Figure 1. Shell's proposed Camden Bay exploratory drilling program lease block locations (Shell, 2011a).

1.5.1.2 Beaufort Sea Project Description

Activities associated with the 2012 Camden Bay, Beaufort Sea, exploration drilling program include operation of the drillship, associated support vessels, crew change support, and re-supply, ZVSP surveys, and ice management/icebreaking. The drillship will remain at the location of the designated exploration drill sites except when mobilizing and demobilizing to and from Camden Bay, transiting between drill sites, and temporarily moving off location if it is determined ice conditions require such a move to ensure the safety of personnel and/or the environment in accordance with Shell's Ice Management Plan (IMP). Ice management vessels, anchor tenders, and oil spill response (OSR) vessels will remain in close proximity to the drillship during drilling operations.

Shell's base plan is for the drillship and the associated support vessels to transit through the Bering Strait, after July 1, 2012, then through the Chukchi Sea, around Point Barrow, and east through the Alaskan Beaufort Sea, before arriving on location on or about July 10. Shell plans to drill the Torpedo prospect well (Torpedo "H" or "J") first, followed by the Sivulliq well (Sivulliq "N" or "G"), unless adverse surface conditions or other factors dictate a reversal of drilling sequence. In that case, Shell will mobilize to the Sivulliq prospect and drill there first. Because this is an Arctic program, weather and ice conditions will dictate actual operations. At the completion of the drilling season on or before October 31, 2012, one or two ice management vessels, along with various support vessels, such as the OSR fleet, will accompany the drillship as it travels west through the Beaufort Sea, then south through the Chukchi Sea and the Bering Strait. Subject to ice conditions, alternate exit routes may be considered. Shell has planned a suspension of all operations beginning on August 25 for the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts. During the suspension for the whale hunts, the drilling fleet will leave the Camden Bay project area, will move to a location at or north of 71.25° N. latitude and at or west of 146.4° W. longitude and will return to resume activities after the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts conclude. Shell will consult with the Whaling Captain's Associations of Kaktovik and Nuiqsut to ascertain the conclusion of their respective fall subsistence bowhead whale hunts.

In total, Shell anticipates that the exploration drilling program will require approximately 78 drilling days (approximately 44 days for the Torpedo well and 34 days for the Sivulliq well), excluding weather delays, the shutdown period to accommodate the fall bowhead whale harvests at Kaktovik and Cross Island (Nuiqsut), or other operational delays. Time to conduct the ZVSP surveys is included in the 78 drilling days. Shell assumes approximately 11 additional days will be needed for drillship mobilization, drillship moves between locations, and drillship demobilization.

1.5.1.2.1 Exploration Drilling

Shell plans to use one of two drilling vessels for its proposed 2012 Camden Bay exploratory drilling program: the *Kulluk* (owned by Shell and operated by Noble Drilling [Noble]); or the *Discoverer* (owned and operated by Noble). Only one of these drilling vessels would be used for the Camden Bay program, not both. Information on each vessel is provided next, and additional details can be found in Attachment A of Shell's IHA application (Shell, 2011a).

The *Kulluk* has an Arctic Class IV hull design, is capable of drilling in up to 600 ft (182.9 m) of water and is moored using a 12-point anchor system. The vessel is 266 ft (81 m) long. The *Kulluk*'s mooring system consists of 12 Hepburn winches located on the outboard side of the main deck. Anchor wires lead off the bottom of each winch drum inboard for approximately 55 ft (16.8 m). The wire is then redirected by a sheave, down through a hawse pipe to an underwater, ice protected, swivel fairlead. The wire travels from the fairlead directly under the hull to the anchor system on the seafloor. The *Kulluk* would have an anchor radius maximum of 3,117 ft (950 m) for the Sivulliq and Torpedo drill sites. While on location at the drill sites, the *Kulluk* will be affixed to the seafloor using 12, 15 metric ton Stevpris anchors arranged in a radial array.

The *Kulluk* is designed to maintain its location in drilling mode in moving ice with thickness up to 4 ft (1.2 m) without the aid of any active ice management. With the aid of the ice management vessels, the *Kulluk* would be able to withstand more severe ice conditions. In more open-water conditions, the *Kulluk* can maintain its drilling location during storm events with wave heights up to 18 ft (5.5 m) while drilling, and can withstand wave heights of up to 40 ft (12.2 m) when not drilling and disconnected (assuming a storm duration of 24 hours).

The *Discoverer* is a true drillship and is a largely self-contained drillship that offers full accommodations for a crew of up to 140 persons. The *Discoverer* is 514 ft (156.7 m) long with a maximum height (above keel) of 274 ft (83.7 m). It is an anchored drillship with an 8-point anchored mooring system and would likely have a maximum anchor radius of 2,969-2,986 ft (905-910 m) at either the Sivulliq or Torpedo drill sites. While on location at the drill sites, the Discoverer will be affixed to the seafloor using eight 7,000 kg (7.7 ton) Stevpris anchors arranged in a radial array. The underwater fairleads prevent ice fouling of the anchor lines. Turret mooring allows orientation of the vessel's bow into the prevailing ice drift direction to present minimum hull exposure to drifting ice. The vessel is rotated around the turret by hydraulic jacks. Rotation can be augmented by the use of the fitted bow and stern thrusters. The hull has been reinforced for ice resistance. Ice-strengthened sponsons have been retrofitted to the ship's hull.

During the 2012 drilling season, the *Kulluk* or *Discoverer* will be attended by 11 vessels that will be used for ice management, anchor handling, OSR, refueling, resupply, drill mud/cuttings and wastewater transfer, equipment and waste holding, and servicing of the drilling operations. Tables 2 and 3 provide lists of the support vessels to be used during the drilling program and OSR vessels. The workboats associated with OSR training (which are stored on an OSR barge) are not counted among the 11 attending vessels. All vessels are intended to be either in transit or staged (i.e., on anchor) in the Beaufort Sea during the exploration drilling activities. The oil spill tanker (OST) would be staged such that it would arrive at a recovery site, if needed, within 24 hours of departure from the staging location. The purpose of the OST would be to provide a place to store large volumes of recovered crude oil, emulsion and free water in the unlikely event of a spill, and OSR operations.

The *M/V Nordica* (*Nordica*) or a similar vessel will serve as the primary ice management vessel in support of the *Kulluk* or *Discoverer*. *Hull 247* or a similar vessel will provide anchor handling duties, serve as the berthing (accommodations) vessel for the OSR crew, and will also serve as a secondary ice management vessel by managing smaller ice floes that may pose a potential safety issue to the drillship and the support vessels servicing the drillship. This vessel will also provide supplemental oil recovery capability (Vessel of Opportunity Skimming System). When managing ice, the *Nordica* (or similar vessel) and *Hull 247* will generally be confined to a 40º arc up to 3.1 mi (4.9 km) upwind originating at the drilling vessel (see Figure 2). It is anticipated that the ice management vessels will be managing ice for up to 38% of the time when within 25 mi (40 km) of the *Kulluk* or *Discoverer*. Active ice management involves using the ice management vessel to steer larger floes so that their path does not intersect with the drill site. Around-the-clock ice forecasting using real-time satellite coverage (available through Shell Ice and Weather Advisory Center [SIWAC]) will support the ice management duties. When the *Nordica* and *Hull 247* are not needed for ice management, they will reside outside the 25 mi (40 km) radius from the *Kulluk* or *Discoverer* if it is safe to do so. These vessels will enter and exit the Beaufort Sea with the *Kulluk* or *Discoverer*.

The exploration drilling operations will require the transfer of supplies between either the Deadhorse/West Dock shorebase or Dutch Harbor and the drillship. While the drillship is anchored at a drill site, Shell anticipates 24 visits/tie-ups (if the *Kulluk* is the drilling vessel being used) or 8 visits/tie-ups (if the *Discoverer* is being used) throughout the drilling season from support vessels. During resupply, mud/cuttings and other waste streams will be transferred to a deck barge or waste barge for temporary storage, which will be brought south for disposal at the end of the drilling season. Removal of waste and resupply to the drilling vessels will be conducted the same way regardless of drilling vessel.

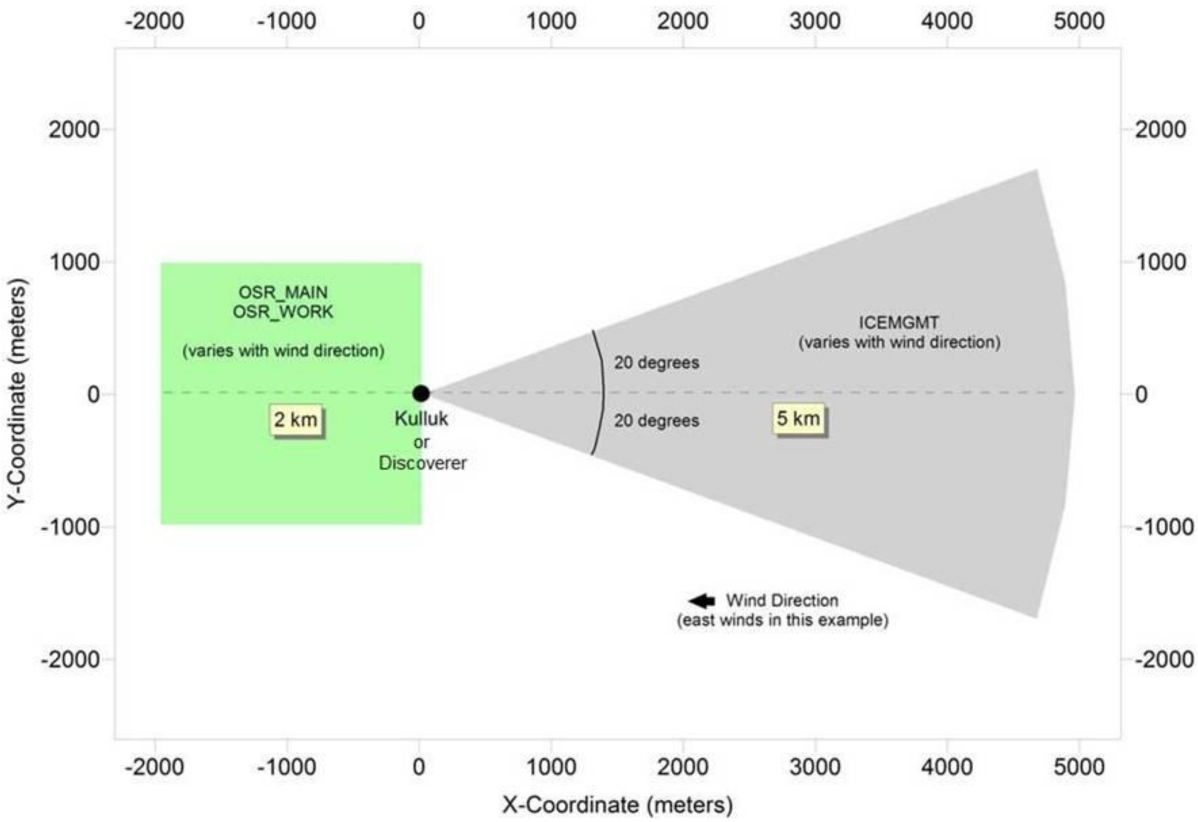

Figure 2. Ice management vessels configuration for the drillship (Shell, 2011a).

An AW139 or Sikorsky S-92 helicopter based in Deadhorse will be used for flights between the shorebase and drill sites. It is expected that on average, up to two flights per day (approximately 12 flights per week) will be necessary to transport supplies and rotate crews. A Sikorsky S92 based in Barrow will be used for search and rescue (SAR) operations. Marine mammal monitoring flights will utilize a de Havilland Twin Otter aircraft. The de Havilland Twin Otter is expected to fly daily. Table 4 presents the aircraft planned to support the exploration drilling program.

Table 2. Proposed support vessel list for Shell's 2012 Camden Bay, Beaufort Sea, exploratory drilling program.

Specification	Ice Management Vessel [1]	Anchor Handler [2,7]	OSV [3]	West Dock Supply Vessel[4]	OSV[5]	Deck Barge[6]	Waste Barge
Length	380.5 ft (116 m)	360.6 ft (110 m)	280 ft (85.4 m)	134 ft (50.3 m)	280 ft (85.4 m)	360 ft (110 m)	500 ft (152.4 m)
Width	85 ft (26 m)	80 ft (24.4 m)	60 ft (18.29 m)	32 ft (11.6 m)	60 ft (18.29 m)	100 ft (30.5 m)	74 ft (22.6 m)
Draft	27.5 ft (8.4 m)	24 ft (7.3 m)	19.24 ft (5.87 m)	7 ft (2.1 m)	16.5 ft (5.0 m)	14 ft (4.3 m)	27.5 ft (8.4 m)
Accommodations (persons) (berths)	82	64	29	17	26	10	-
Maximum Speed	16 knots (30 km/hr)	15 knots (27.8 km/hr)	15 knots (25 km/hr)	10 knots (18.5 km/hr)	13.5 knots (25 km/hr)	10 knots (18.5 km/hr)	-
Fuel Capacity	11,070 bbl	12,575 bbl	8,411 bbl (normal) 11,905 bbl (max)	667 bbl	6,235 bbl (normal)	2,381 bbl	155,000 bbl

[1] Based on *Nordica,* or similar vessel
[2] Based on *Hull 247*, or similar vessel
[3] Based on the *Carol Chouest,* or similar vessel
[4] Based on *Arctic Seal,* or similar vessel
[5] Based on *Harvey Spirit,* or similar vessel
[6] Based on *Southeast Provider & Ocean Ranger*
[7] Hull 247 is under construction by Chouest Offshore. By 2012, she will be christened under a name to be determined.

Table 3. Proposed oil spill response vessel list for Shell's 2012 Camden Bay, Beaufort Sea, exploratory drilling program.

Specification	OSR Barge[1,2]		OST[1,3]	OSR Containment System[1,4]		
	Barge	Tug		Barge	Tug	Anchor Handler[5]
Length	205 ft (62.5 m)	90 ft (27.4 m)	853 ft (260 m)	400 ft (122 m)	136 ft (41.5 m)	275 ft (83.5 m)
Width	90 ft (27.4 m)	32 ft (9.8 m)	112 ft (34 m)	100 ft (30.5 m)	36 ft 11 m	59 ft (18.0 m)
Draft	8.5 ft (2.6 m)		44.6 ft (13.6 m)	12 ft (3.7 m)	20 ft (6.1 m)	20 ft (6.1 m)
Accommodations	--	8	25	--	8	23
Maximum Speed	--	7 knots (13 km/hr)	16 knots (30 km/hr)	--	8 knots (15 km/hr)	16 knots (30 km/hr)
Fuel Storage	--	1,428 bbl (227 m^3)	440,000 bbl (69,952 m^3)	--	3,690 bbl (587 m^3)	7,485 bbl (1,190 m^3)
Liquid Storage	18,636 bbl		513,000 bbl additional 221,408 bbl (35,200 m^3) in separate ballast tanks	80,000 bbl (12,719 m^3)	NA	37,462 bbl (5,956 m^3)
Workboats	(1) 47 ft (14 m) skim boat (3) 34 ft (10 m) work boats (4) mini-barges		NA	NA	NA	

[1] Or similar vessel
[2] Based on the *Arctic Endeavor* & Point Class tug
[3] Based on the *Mikhail Ulyanov*
[4] Based on a standard deck barge, Crowley Invader class ocean going tug, and a *Tor Viking*-style anchor handler.
[5] Vessel included for planning purposes only, not assumed necessary but as an additional tending option if deemed necessary by Shell.

Table 4. Proposed aircraft list for Shell's 2012 Camden Bay, Beaufort Sea, exploratory drilling program.

Aircraft	Flight Frequency
Aircraft (or similar)	
Sikorsky S-92, AW139 or similar – crew rotation	Two round trips between the shorebase and offshore vessels per day (approximately 12/week) throughout the 2012 drilling season
(1) Sikorsky S-92 or AW139 Helicopter – SAR	Trips made only in emergency; training flights
(1) deHavilland Twin Otter (DHC-6) – Used for 4MP	Daily, beginning 5-7 days before drilling and ending 5-7 days after drilling ends

1.5.1.2.2. Zero-offset Vertical Seismic Profile

At the end of each drill hole, Shell may conduct a geophysical survey referred to as ZVSP at each drill site where a well is drilled in 2012. During ZVSP surveys, an airgun array is deployed at a location near or adjacent to the drilling vessel, while receivers are placed (temporarily anchored) in the wellbore. The sound source (airgun array) is fired repeatedly, and the reflected sonic waves are recorded by receivers (geophones) located in the wellbore. The geophones, typically in a string, are then raised up to the next interval in the wellbore, and the process is repeated until the entire wellbore has been surveyed. The purpose of the ZVSP is to gather geophysical information at various depths, which can then be used to tie-in or ground-truth geophysical information from the previous seismic surveys with geological data collected within the wellbore.

Shell intends to conduct a particular form of vertical seismic profile known as a ZVSP, in which the sound source is maintained at a constant location near the wellbore (Figure 3). A typical sound source that would be used by Shell in 2012 is the ITAGA eight-airgun array, which consists of four 150 in^3 airguns and four 40 in^3 airguns. These airguns can be activated in any combination, and Shell intends to utilize the minimum airgun volume required to obtain an acceptable signal. Current specifications of the array are provided in Table 5. The airgun array is depicted within its frame or sled, which is approximately 6 ft x 5 ft x 10 ft (1.8 m x 1.5 m x 3 m) (Figure 4). Typical receivers would consist of a Schlumberger wireline four level Vertical Seismic Imager (VSI) tool, which has four receivers 50-ft (15-m) apart.

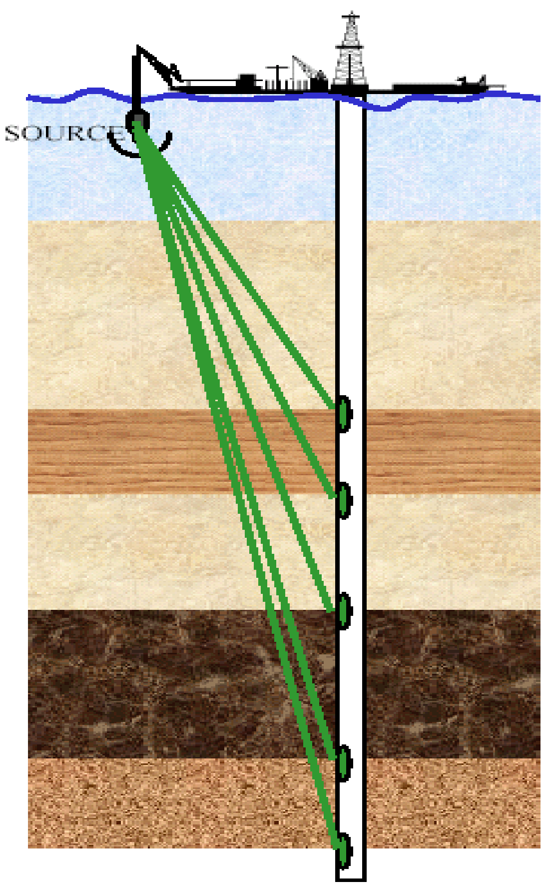

Figure 3. Schematic of ZVSP (Shell, 2011a).

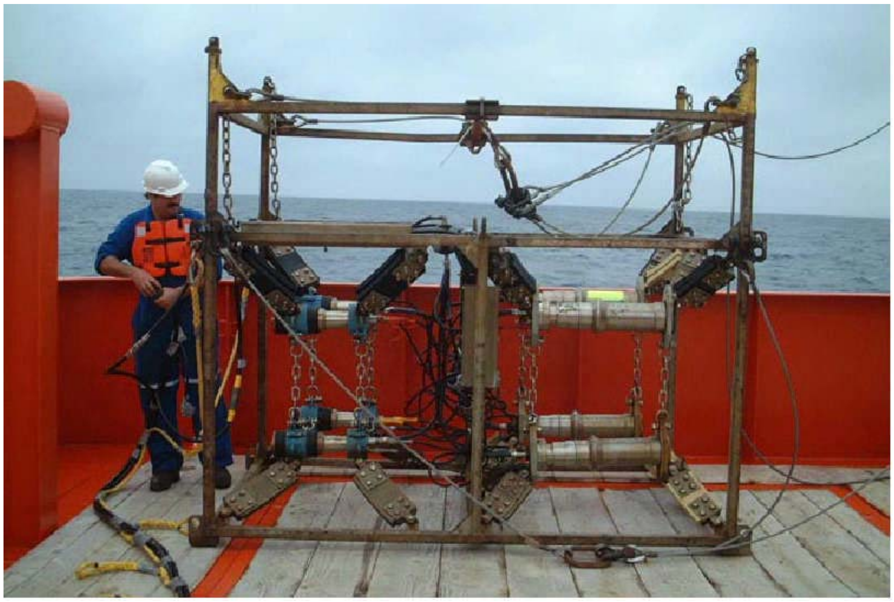

Figure 4. Photograph of the ITAGA 8-airgun array in sled (Shell, 2011a).

Table 5. Airgun array specifications for the proposed ZVSP surveys during Shell's 2012 Camden Bay, Beaufort Sea, exploratory drilling program.

Source Type	No. Sources	Maximum Total Chamber Size	Pressure	Source Depth	Calibrated Peak-Peak Vertical Amplitude	Zero-Peak Sound Pressure Level
SLB, ITAGA Sleeve Array	8 airguns 4 X 150 in^3 (2458 cm^3) 4 X 40 in^3 (655 cm^3)	760 in^3 12,454 cm^3	2,000 psi 138 bar	9.8 ft / 3.0 m 16.4 ft / 5.0 m	16 bar @1 m 23 bar @1 m	238 dB re1μPa @1 m 241 dB re1μPa @1 m

A ZVSP survey is normally conducted at each well after total depth is reached but may be conducted at a shallower depth. For each survey, Shell plans to deploy the airgun array over the side of the *Kulluk* or *Discoverer* with a crane (sound source will be 50-200 ft [15-61 m] from the wellhead depending on crane location) to a depth of approximately 10-23 ft (3-7 m) below the water surface. The VSI, with its four receivers, will be temporarily anchored in the wellbore at depth. The sound source will be pressured up to 2,000 pounds per square inch (psi) and activated 5-7 times at approximately 20-second intervals. The VSI will then be moved to the next interval of the wellbore and reanchored, after which the airgun array will again be activated 5-7 times. This process will be repeated until the entire well bore is surveyed in this manner. The interval between anchor points for the VSI usually is between 200 and 300 ft (61 and 91 m). A normal ZVSP survey is conducted over a period of about 10-14 hours, depending on the depth of the well and the number of anchoring points. Therefore, considering a few different scenarios, the airgun array could be fired between 117 and 245 times during the 10-14 hour period. For example, a 7,000-ft (2,133.6-m) well with 200-ft (61-m) spacing and seven activations per station would result in the airgun array being fired 245 times to survey the entire well. That same 7,000-ft (2,133.6-m) well with 300-ft (91-m) spacing and five activations would result in the airgun array being fired 117 times to survey the entire well. The remainder of the time during those 10-14 hours when the airgun is not firing is used to move and anchor the geophone array.

1.5.1.2.3 Ice Management and Forecasting

Shell recognizes that the drilling program is located in an area that is characterized by active sea ice movement, ice scouring, and storm surges. In anticipation of potential ice hazards that may be encountered, Shell has developed and will implement an IMP (Shell, 2011a) to ensure real-time ice and weather forecasting is conducted in order to identify conditions that might put operations at risk and will modify its activities accordingly. The IMP also contains ice threat classification levels depending on the time available to suspend drilling operations, secure the well, and escape from advancing hazardous ice. Real-time ice and weather forecasting will be available to operations personnel for planning purposes and to alert the fleet of impending hazardous ice and weather conditions. Ice and weather forecasting is provided by SIWAC. The center is continuously manned by experienced personnel, who rely on a number of data sources for ice forecasting and tracking, including:

- Radarsat and Envisat data—satellites with Synthetic Aperture Radar, providing all-weather imagery of ice conditions with very high resolution;
- Moderate Resolution Imaging Spectroradiometer—a satellite providing lower resolution visual and near infrared imagery;
- Aerial reconnaissance—provided by specially deployed fixed wing or rotary wing aircraft for confirmation of ice conditions and position;
- Reports from ice specialists on the ice management and anchor handling vessels and from the ice observer on the drillship;
- Incidental ice data provided by commercial ships transiting the area; and
- Information from NOAA ice centers and the University of Colorado.

Drift ice will be actively managed by ice management vessels, consisting of an ice management vessel and an anchor handling vessel. Ice management for safe operation of Shell's planned exploration drilling program will occur far out in the OCS, remote from the vicinities of any routine marine vessel traffic in the Beaufort Sea causing no threat to public safety or services that occurs near to shore. Shell vessels will also communicate movements and activities through the 2012 North Slope Communications Centers. Management of ice by ice management vessels will occur during a drilling season predominated by open water and thus is not expected to contribute to ice hazards, such as ridging, override, or pileup in an offshore or nearshore environment. The ice-management/anchor handling vessels would manage the ice by deflecting any ice floes that could affect the *Kulluk* or *Discoverer* when it is drilling and would also handle the *Kulluk*'s or *Discoverer*'s anchors during connection to and separation from the seafloor. When managing ice, the ice management and anchor handling vessels will generally be operating at a 40º are up to 3.1 mi (4.9 km) upwind originating at the *Kulluk* or *Discoverer* (see Figure 2).

It is anticipated that the ice management vessels will be managing ice for 38% of the time when within 25 mi (40 km) of the *Kulluk* or *Discoverer*. The ice floe frequency and intensity are unpredictable and could range from no ice to ice sufficiently dense that the fleet has insufficient capacity to continue operating, and the *Kulluk* or *Discoverer* would need to disconnect from its anchors and move off site. If ice is present, ice management activities may be necessary in early July and towards the end of operations in late October, but it is not expected to be needed throughout the proposed drilling season. Shell has indicated that when ice is present at the drill site, ice disturbance will be limited to the minimum needed to allow drilling to continue. First-year ice (i.e., ice that formed in the most recent autumn-winter period) will be the type most likely to be encountered. The ice management vessels will be tasked with managing the ice so that it will flow easily around and past the *Kulluk* or *Discoverer* without building up in front of or around it. This type of ice is managed by the ice management vessel continually moving back and forth across the drift line, directly up-drift of the Kulluk or Discoverer and making turns at both ends. During ice management, the vessel's propeller is rotating at approximately 15-20 percent of the vessel's propeller rotation capacity. Ice management occurs with slow movements of the vessel using lower power and therefore slower propeller rotation speed (i.e., lower cavitation), allowing for fewer repositions of the vessel, thereby reducing cavitation effects in the water. Occasionally, there may be multi-year ice (i.e., ice that has survived at least one summer melt season) ridges that would be managed at a much slower speed than that used to manage first-year ice.

During Camden Bay exploration drilling operations, Shell has indicated that they do not intend to conduct any icebreaking activities; rather, Shell would deploy its support vessels to manage ice as described here. As detailed in Shell's IMP (Shell, 2011a), actual breaking of ice would occur only in the unlikely event that ice conditions in the immediate vicinity of operations create a safety hazard for the drilling vessel. In such a circumstance, operations personnel will follow the guidelines established in the IMP to evaluate ice conditions and make the formal designation of a hazardous, ice alert condition, which would trigger the procedures that govern any actual icebreaking operations. Historical data relative to ice conditions in the Beaufort Sea in the vicinity of Shell's planned operations, and during the timeframe for those operations, establish that there is a very low probability (e.g., minimal) for the type of hazardous ice conditions that might necessitate icebreaking (e.g., records of the National Naval Ice Center archives). This probability could be greater at the shoulders of the drilling season (early July or late October); therefore, for purposes of evaluating possible impacts of the planned activities, Shell has assumed limited icebreaking activities for a very limited period of time, and estimated incidental takes of marine mammals from such activities.

1.5.1.3 Beaufort Sea Exploratory Drilling Program Sound Characteristics

During Shell's proposed exploratory drilling program, sound would be produced by the drillship and its support vessels (including the icebreakers), aircraft, and the airgun array during ZVSP surveys. The drillship produces continuous noise into the marine environment. The drilling vessel to be used will be either the Kulluk or the Discoverer. The two vessels are likely to introduce somewhat different levels of sound into the water during the exploration drilling activities. The airgun array proposed to be used by Shell for the ZVSP surveys produces pulsed noise into the marine environment. The distance at which sounds are detectable depends on the nature of the sound source, ambient noise conditions, and the sensitivity of the receptor. Table 6 outlines the distances to the 190, 180, 160, and 120 dB re 1 μPa (rms) isopleths for the drillships, icebreakers, and airgun array.

1.5.1.3.1 Drilling Sounds

Exploratory drilling will be conducted from either the *Kulluk* or *Discoverer*, vessels specifically designed for such operations in the Arctic. Underwater sound propagation results from the use of generators, drilling machinery, and the rig itself. Received sound levels during vessel-based operations may fluctuate depending on the specific type of activity at a given time and aspect from the vessel. Underwater sound levels may also depend on the specific equipment in operation. Lower sound levels have been reported during well logging than during drilling operations (Greene, 1987b), and underwater sound levels appeared to be lower at the bow and stern aspects than at the beam (Greene, 1987a).

Most drilling sounds generated from vessel-based operations occur at relatively low frequencies below 600 Hz although tones up to 1,850 Hz were recorded by Greene (1987a) during drilling operations in the Beaufort Sea. At a range of 558 ft (170 m) the 20-1000 Hz band level was 122-125 dB for the drillship *Explorer I*. Underwater sound levels were slightly higher (134 dB) during drilling activity from the *Northern Explorer II* at a range of 656 ft (200 m), although tones were only recorded below 600 Hz. Underwater sound measurements from the *Kulluk* at 0.62 mi (1 km) were higher (143 dB) than from the other two vessels. Sounds from the *Kulluk* were measured in the Beaufort Sea in 1986 and reported by Greene (1987a). The back propagated broadband source level from the measurements was 185.5 dB re 1 μPa at 1 m (rms), as reported from the 1/3-octave band levels, which included sounds from a support vessel operating nearby.

Sound measurements from the *Discoverer* have not previously been conducted in the Arctic. However, measurements of sounds produced by the *Discoverer* were made in the South China Sea in 2009 (Austin and Warner, 2010). The results of those measurements were used to model the sound propagation from the *Discoverer* (including a nearby support vessel) at planned exploration drilling locations in the Beaufort Sea (Warner and Hannay, 2011). Broadband source levels of sounds produced by the *Discoverer* varied by activity and direction from the ship but were generally between 177 and 185 dB re 1 μPa at 1 m (rms) (Austin and Warner, 2010).

Table 6. Sound propagation modeling results of the proposed drillships, icebreakers during icebreaking, and airgun array during ZVSP survey activities near Camden Bay, Beaufort Sea. Distances are provided in kilometers.

Source	190 dB	180 dB	160 dB	120 dB
Kulluk	NA	0.01	0.06	13.27
Discoverer	NA	0.01	0.03	3.32
Icebreaking	0.01	U	U	7.63
Airgun Array	0.52	1.24	3.67	10.5

NA = Not Applicable; U = Unavailable

1.5.1.3.2 Vessel Sounds

In addition to the drillship, various types of vessels will be used in support of the operations, including ice management vessels, anchor handlers, offshore supply vessels, barges and tugs, and OSR vessels. Sounds from boats and vessels have been reported extensively (Greene and Moore, 1995; Blackwell and Greene, 2002, 2005, 2006). 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 (e.g., Aerts et al., 2008; Hauser et al., 2008; Brueggeman, 2009; Ireland et al., 2009). For example, Garner and Hannay (2009) estimated sound pressure levels of 100 dB at distances ranging from approximately 1.5 to 2.3 mi (2.4 to 3.7 km) from various types of barges. MacDonald et al. (2008) estimated higher underwater sound pressure levels (SPLs) from the seismic vessel Gilavar of 120 dB at approximately 13 mi (21 km) from the source, although the sound level was only 150 dB at 85 ft (26 m) from the vessel. Like other industry-generated sound, underwater sound from vessels is generally at relatively low frequencies.

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. Icebreakers contribute greater sound levels during icebreaking activities than ships of similar size during normal operation in open water (Richardson et al., 1995a). This higher sound production results from the greater amount of power and propeller cavitation required when operating in thick ice. Measurements of the icebreaking supply ship *Robert Lemeur* pushing and breaking ice during exploration drilling operations in the Beaufort Sea in 1986 resulted in an estimated broadband source level of 193 dB re 1 μPa at 1 m (Greene, 1987a; Richardson et al., 1995a).

Sound levels during ice management activities would not be as intense as during icebreaking. During ice management, the vessel's propeller is rotating at approximately 15-20 percent of the vessel's propeller rotation capacity. Instead of actually breaking ice, during ice management, the vessel redirects and repositions the ice by pushing it away from the direction of the drillship at slow speeds so that the ice floe does not slip past the vessel bow. Basically, ice management occurs at slower speed, lower power, and slower propeller rotation speed (i.e., lower cavitation), allowing for fewer repositions of the vessel, thereby reducing cavitation effects in the water than would occur during icebreaking.

1.5.1.3.3 Aircraft Sound

Helicopters may be used for personnel and equipment transport to and from the drillship. Under calm conditions, rotor and engine sounds are coupled into the water within a 26º cone beneath the aircraft. Some of the sound will transmit beyond the immediate area, and some sound will enter the water outside the 26º area when the sea surface is rough. However, scattering and absorption will limit lateral propagation in the shallow water.

Dominant tones in noise spectra from helicopters are generally below 500 Hz (Greene and Moore, 1995). Helicopter sounds contain numerous prominent tones at frequencies up to about 350 Hz, with the strongest measured tone at 20–22 Hz. Received peak sound levels of a Bell 212 passing over a hydrophone at an altitude of approximately 1,000 ft (300 m), which is the minimum allowed altitude for the Northstar helicopter under normal operating conditions, varied between 106 and 111 dB re 1 μPa at 30 and 59 ft (9 and 18 m) water depth (Greene, 1982, 1985). Harmonics of the main rotor and tail rotor usually dominate the sound from helicopters; however, many additional tones associated with the engines and other rotating parts are sometimes present (Patenaude et al., 2002).

Because of doppler shift effects, the frequencies of tones received at a stationary site diminish when an aircraft passes overhead. The apparent frequency is increased while the aircraft approaches and is reduced while it moves away. Aircraft flyovers are not heard underwater for very long, especially when compared to how long they are heard in air as the aircraft approaches an observer. Helicopters flying to and from the drillship will generally maintain straight-line routes at altitudes of at least 1,500 ft (457 m) above sea level, thereby limiting the received levels at and below the surface. Aircraft travel would be controlled by Federal Aviation Administration approved flight paths.

1.5.1.3.4 Vertical Seismic Profile Sound

A typical eight airgun array (4×40 in^3 airguns and 4×150 in^3 airguns, for a total discharge volume of 760 in^3) would be used to perform ZVSP surveys, if conducted after the completion of each exploratory well. The source level for the airgun array proposed for use by Shell will differ based on source depth. At a depth of 9.8 ft (3 m), the SPL is 238 dB re 1 µPa at 1 m, and at a depth of 16.4 ft (5 m), the SPL is 241 dB re 1 µPa at 1 m, with most energy between 20 and 140 Hz.

Airguns function by venting high-pressure air into the water. The pressure signature of an individual airgun consists of a sharp rise and then fall in pressure, followed by several positive and negative pressure excursions caused by oscillation of the resulting air bubble. The sizes, arrangement, and firing times of the individual airguns in an array are designed and synchronized to suppress the pressure oscillations subsequent to the first cycle. Typical high-energy airgun arrays emit most energy at 10–120 Hz. However, the pulses contain significant energy up to 500–1,000 Hz and some energy at higher frequencies (Goold and Fish, 1998; Potter et al., 2007).

1.5.2 Chukchi Sea Exploratory Drilling Program

1.5.2.1 Chukchi Sea Project Location

Shell plans to conduct an offshore exploration drilling program on DOI, BOEM Alaska OCS leases located greater than 64 mi (103 km) from the Chukchi Sea coast during the 2012 open-water season. The leases were acquired during the Chukchi Sea Oil and Gas Lease Sale 193 held in February 2008. During the 2012 drilling program, Shell plans to drill up to three exploration wells at three drill sites and potentially a partial well at a fourth drill site at the prospect known as Burger. Shell has identified a total of six lease blocks on this prospect where drilling could potentially occur. Figure 5 depicts the lease block and drill site locations. Table 7 outlines the exact locations of each of the four potential drill sites and their distance from the shore. All drilling is planned to be vertical. Wainwright is the closest Native Alaskan community to the Burger prospect proposed drill sites.

Table 7. Locations, distances to shore, and water depths for Shell's proposed 2012 Chukchi Sea drill sites.

Drill Site	Approximate Distance from shore mi (km)	Lease Block No.	Surface Location (NAD 83)		Water Depth ft (m)
			Latitude (north)	Longitude (west)	
Burger A	75 (120.7)	6764	71° 18' 30.92"	163° 12' 43.17"	150 (45.8)
Burger F	76 (122.3)	6714	71° 20' 13.96"	163° 12' 21.75"	149 (45.4)
Burger J	69 (111)	6912	71° 10' 24.03"	163° 28' 18.52"	144 (44)
Burger R	75 (120.7)	6812	71° 16' 06.57"	163° 30' 39.44"	143 (43.7)
Burger S	78 (125.5)	6762	71° 19' 25.79"	163° 28' 40.84"	147 (44.9)
Burger V	65 (104.6)	6915	71° 10' 33.39"	163° 04' 21.23"	147 (44.7)

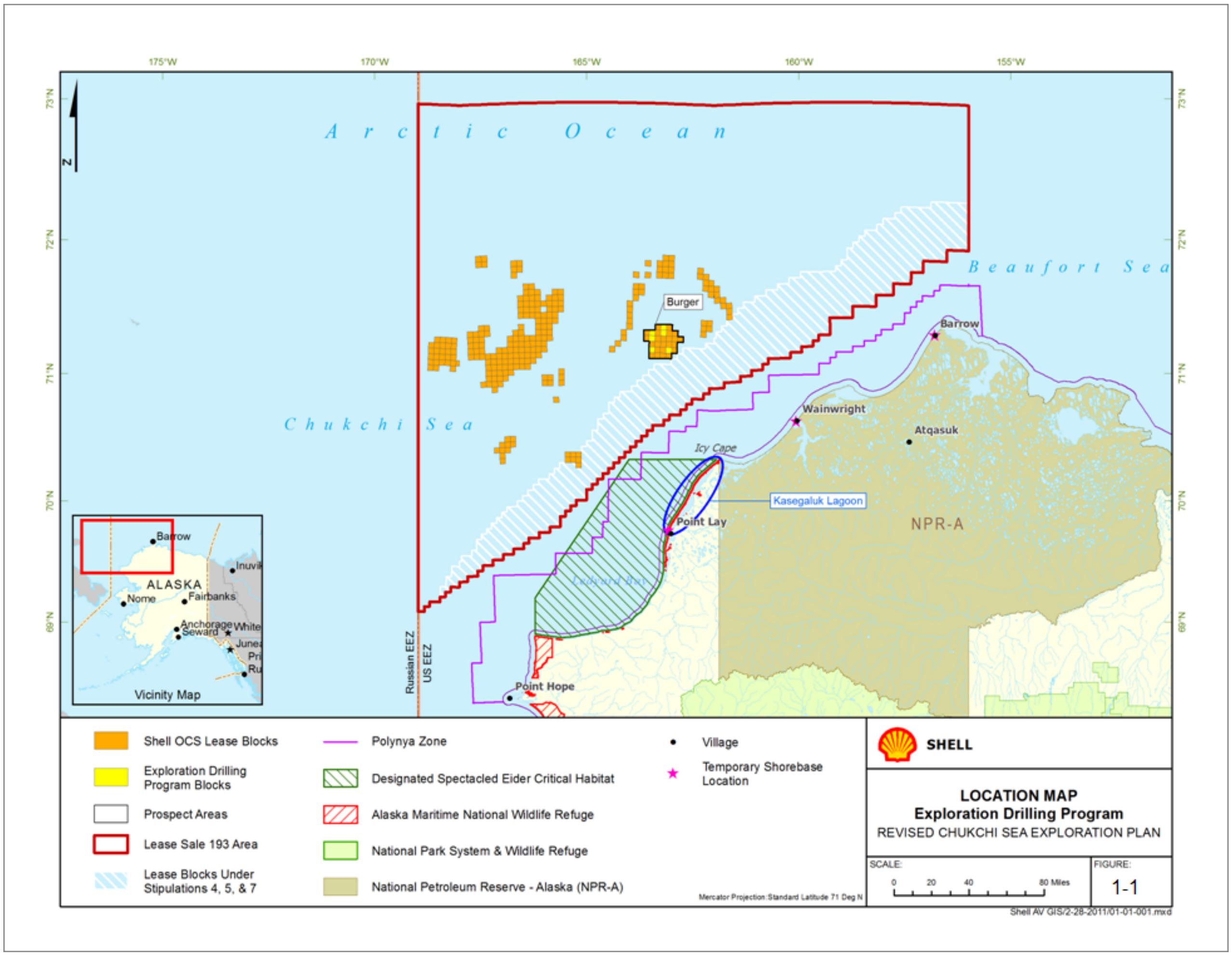

Figure 5. Shell's proposed Chukchi Sea exploratory drilling program lease block locations (Shell, 2011b).

1.5.2.2 Chukchi Sea Project Description

Activities associated with the 2012 Chukchi Sea exploration drilling program include operation of the drillship, associated support vessels, crew change support, and re-supply, ZVSP surveys, and ice management/icebreaking. The drillship will remain at the location of the designated exploration drill sites except when mobilizing and demobilizing to and from the Chukchi Sea, transiting between drill sites, and temporarily moving off location if it is determined ice conditions require such a move to ensure the safety of personnel and/or the environment in accordance with Shell's IMP. Ice management vessels, anchor tenders, and OSR vessels will remain in close proximity to the drillship during drilling operations.

Shell's base plan is for the drillship and associated support vessels to travel north from Dutch Harbor through the Bering Strait, on or about July 1, 2012, then into the Chukchi Sea, before arriving on location approximately July 4. Exploration drilling is expected to be complete by October 31, 2012. At the completion of the drilling season, one or two ice-management vessels, along with various support vessels, such as the OSR fleet, will accompany the drillship as it travels south out of the Chukchi Sea and through the Bering Strait to Dutch Harbor. Subject to ice conditions, alternate exit routes may be considered.

Shell anticipates that the exploration drilling program will require approximately 32 days per well, including mudline cellar construction. Therefore, if Shell is able to drill three exploration wells during the 2012 open-water season, it would require a total of 96 days. If Shell is able to drill part of a fourth well, it would add an additional 1-32 days to the season but would not extend beyond October 31, 2012. These estimates do not include any downtime for weather or other operational delays. Time to conduct the ZVSP surveys for each well is included in the 32 drilling days for each well. Shell also assumes approximately 10 additional days will be needed for transit, drillship mobilization and mooring, drillship moves between locations, and drillship demobilization.

Much of the description provided in Section 1.5.1.2 regarding the Beaufort Sea exploratory drilling program are the same for the Chukchi Sea program. Therefore, only the details that differ between the two sites are described here. The rest of the program would occur as described in Section 1.5.1.2.

Exploration Drilling

Shell proposes to use the ice strengthened drillship *Discoverer* to drill the wells. The *Discoverer* is a true drillship and is a largely self-contained drillship that offers full accommodations for a crew of up to 140 persons. Additional information about the *Discoverer* is provided in Section 1.5.1.2.1 of this EA and Attachment A of Shell's Chukchi Sea IHA Application (Shell, 2011b) and is not repeated here.

During the 2012 drilling season, the *Discoverer* will be attended by eight vessels that will be used for ice management, anchor handling, OSR, refueling, resupply, and servicing of the exploration drilling operations. The ice management vessels will consist of an icebreaker and an anchor handler. The OSR vessels supporting the exploration drilling program include a dedicated OSR barge and an OSR vessel, both of which have associated smaller workboats, an oil spill tanker, and a containment barge. Tables 8 and 9 provide a list of the support and OSR vessels that will be used during the drilling program. Ice management activities would occur as depicted in Figure 2.

Offshore operations will be serviced by helicopters operated out of onshore support base locations. A Sikorsky S-92 or Eurocopter EC225 capable of transporting 10 to 12 persons will be used to transport crews between the onshore support base and the drillship. The helicopters will also be used to haul small amounts of food, materials, equipment, and waste between vessels and the shorebase. The helicopter will be housed at facilities at the Barrow airport. Shell will have a second helicopter for SAR operations. The SAR helicopter is expected to be a Sikorsky S-61, S-92, Eurocopter EC225, or similar model. This aircraft will stay grounded at the Barrow shorebase location except during training drills, emergencies, and other non-routine events.

A fixed wing propeller or turboprop aircraft, such as a Saab 340-B 30-seat, Beechcraft 1900, or deHavilland Dash8 will be used to routinely transport crews, materials, and equipment between the shorebase and hub airports such as Barrow or Fairbanks. A fixed wing aircraft, deHavilland Twin Otter (DHC-6) will be used for marine mammal monitoring flights. Table 10 presents the aircraft planned to support the Chukchi Sea exploration drilling program.

The descriptions of how ZVSP survey activities and ice management/forecasting would be conducted discussed in Section 1.5.1.2 for the Beaufort Sea are the same for Shell's proposed exploratory drilling program in the Chukchi Sea. Those descriptions are not repeated here.

Table 8. Proposed support vessel list for Shell's 2012 Chukchi Sea exploratory drilling program.

Specification	Ice Management Vessel [1]	Anchor Handler [2]	OSV [3]	OSV [4]
Length	380 ft 116 m	275 ft 83.8 m	280 ft 85.3 m	280 ft 85.3 m
Width	85 ft 26 m	59 ft 18 m	60 ft 18 m	60 ft 18 m
Draft	27 ft 8.2 m	20 ft 6.1 m	15.9 ft 4.8 m	19 ft 5.8 m
Accommodations	82 berths	64 berths	37 berths	29 berths
Maximum Speed	16 knots 30 km/hr	16 knots 30 km/hr	13 knots 24 km/hr	13 knots 24 km/hr
Fuel Storage	11,070 bbl 1,760 m^3	7,484 bbl 1,190 m^3	6,233 bbl 991 m^3	7,217 bbl 1,147 m^3

[1] Based on *Fennica,* or similar vessel
[2] Based on *Tor Viking*, or similar vessel
[3] Based on the *Harvey Spirit,* or similar vessel
[4] Based on *C-Leader,* or similar vessel

Table 9. Proposed oil spill response vessel list for Shell's 2012 Chukchi Sea exploratory drilling program.

Specification	OSR Vessel [1,2]	OSR Barge [1]		OST [1,4]	Containment Barge [1,5]		
		Barge [3]	Tug [3]		Barge	Tug	Anchor Handler
Length	301 ft 91.9 m	350 ft 106.7 m	126 ft 38.4 m	853 ft 260 m	400 ft 122 m	136 ft 36.5 m	275 ft 83.7 m
Width	60 ft 18.3 m	76 ft 23.1 m	34 ft 10.4 m	112 ft 34 m	100 ft 30.5 m	36 ft 11.1 m	59 ft 18.0 m
Fuel Storage	6,867 bbl (1,092 m^3)	390 bbl (62 m^3)	1,786 bbl (284 m^3)	221,408 bbl (35,200 m^3)	--	3,690 bbl (587 m^3)	7,484 bbl (1190 m^3)
Liquid Storage	12,690 bbl (2,017 m^3)	76,900 bbl (12,226 m^3)	--	543,000 bbl (86,328 m^3)	--	--	--
Accommodations	41	--	6	25	--	10	64 berths
Maximum Speed	16 knots	--	5 knots	16 knots	--	10 knots	16 knots
Workboats	(3) 34 ft work boats	(1) skim boat 47 ft (14 m) (3) work boats 34 ft (10 m) (4) mini-barges	--	--	--	--	--

[1] Or similar vessel
[2] Based on the *Nanuq*
[3] Based on the barge *Klamath* and the tug Crowley *Sea Robin*
[4] Based on the *Mikhail Ulyanov,* the OST will have a minimum storage capacity of 513,000 bbl.
[5] Based on a standard deck barge, Crowley Invader class ocean going tug, and a *Vidar, or Tor Viking*-style anchor handler

Table 10. Proposed aircraft list for Shell's 2012 Chukchi Sea exploratory drilling program.

Aircraft	Flight Frequency
Aircraft (or similar)	
Sikorsky S-92 or Eurocopter EC225 - crew rotation	Approximately 12 round trips per week between land and offshore vessels throughout the 2012 drilling season
Sikorsky S-61,S-92 or Eurocopter EC225 helicopter – SAR	Trips made only in emergency; training flights
Saab 340-B or Beechcraft 1900 or deHavilland Dash8 (Only 1) – onshore crew/supply trips	Infrequent, up to 4 trips per week from shorebase to hub airports in Barrow, Anchorage, or Fairbanks
deHavilland Twin Otter (DHC-6) – Used for 4MP	Daily, beginning 5-7 days before drilling and ending 5-7 days after drilling ends

1.5.2.3 Chukchi Sea Exploratory Drilling Program Sound Characteristics

Because the same or similar drillships, vessels, and airgun arrays would be used in the Chukchi Sea as are proposed for the Beaufort Sea, the discussion of sound characteristics contained in Section 1.5.1.3 of this Draft EA is applicable here and is therefore not repeated. Please refer to Section 1.5.1.3 for the full discussion of sound characteristics. The only difference is the modeled 120 dB isopleth for the *Discoverer* presented in Table 6 is less in the Chukchi Sea than that modeled for the Beaufort Sea. In the Chukchi Sea, the modeled 120 dB isopleth is 0.81 mi (1.31 km) instead of 2.06 mi (3.32 km). The primary reason for the difference in the distance of the 120 dB isopleth is due to differences in the geoacoustic parameters for the two seas that were input to the model. Water depth, seabed density, and seabed sound speed are generally the most important parameters that influence sound propagation. Additionally, the *Kulluk* is not proposed by Shell to be used in the Chukchi Sea.

1.6 Other NEPA Documents that Influence the Scope this EA

The effects of oil and gas exploratory drilling activities in the U.S. Beaufort and Chukchi Seas have been evaluated to some degree in previous NEPA documents produced by NMFS, as well as the former MMS and the former Bureau of Ocean Energy Management, Regulation and Enforcement, which was split into three separate agencies on October 1, 2011 (BOEM, Bureau of Safety and Environmental Enforcement [BSEE], and Office of Natural Resources Revenue). The NEPA documents formerly prepared by MMS and BOEMRE are now produced by BOEM. Summaries of these documents are contained herein. Portions of these NEPA documents are appropriately incorporated by reference in other chapters of this Draft EA, as directed by 40 CFR 1502.21 of the CEQ's regulations.

In 2003, MMS prepared the ***Beaufort Sea Planning Area Oil and Gas Lease Sales 186, 195, 202 Final Environmental Impact Statement (OCS EIS/EA MMS 2003-001)***. The Final EIS analyzed the environmental effects of these three sales – Sale 186 in 2003, Sale 195 in 2005 and Sale 202 in 2007 – all of which consider leasing the same geographical area in the Beaufort Sea.

In May 2007, MMS issued the **Final EIS for the *Chukchi Sea Planning Area Oil and Gas Lease Sale 193 and Seismic Surveying Activity in the Chukchi Sea*** and also examined a proposal for exploration seismic survey permitting in 2007 in the proposed sale area and two alternatives for the 2007 seismic surveys (OCS EIS/EA MMS 2007-026). In May 2011, BOEMRE issued the ***Revised Draft Supplemental EIS for the Chukchi Sea Planning Area Oil and Gas Lease Sale 193***. The 2008 FEIS for Lease Sale 193 was challenged in the U.S. District Court for the District of Alaska. On July 21, 2010, the District Court issued an Order remanding Sale 193 to BOEMRE to satisfy its obligations under NEPA in accordance with the Court's opinion. The District Court's Order was amended on August 5, 2010, and guidelines for compliance with the Order were established by the Court on September 2, 2010. The Draft Supplemental EIS augments the analysis in the Final EIS for Lease Sale 193 by analyzing the environmental impact of natural gas development and evaluating incomplete, missing, or unavailable information pursuant to 40 CFR 1502.22 to respond to the Court's remand. A Draft Supplemental EIS was made available to the public on October 15, 2010. In March 2011, BOEMRE announced that a Very Large Oil Spill analysis would also be included in the Supplemental EIS. The analysis was completed and integrated within the Revised Draft Supplemental EIS. BOEMRE released the Final Supplemental EIS in August 2011.

In October 2007, NMFS prepared an **EA for the issuance of an IHA to Shell** to take marine mammals incidental to conducting an offshore drilling project in the U.S. Beaufort Sea (NMFS, 2007) and issued a FONSI on October 24, 2007. This EA analyzed the effects on the human environment of issuing an IHA to Shell for the take of marine mammals incidental to conducting open-water offshore exploratory drilling in OCS blocks of the U.S. Beaufort Sea.

In November 2008, MMS published a **Draft EIS for the *Beaufort and Chukchi Sea Planning Areas Oil and Gas Lease Sales 209, 212, 217, and 221*** (*Arctic Multiple Sale Draft EIS*). This Draft EIS evaluated several alternatives for leasing (lease block configurations) and the direct and indirect effects to the human, physical, and biological resources from activities associated with exploration, development, and production scenarios, as well as accidental oil spills. The cumulative-effects analysis described the environmental effects of the proposed action and alternatives with past, present, and reasonably foreseeable future actions occurring in these regions. The Secretary of the Interior cancelled these lease sales for further consideration in the Preliminary Revised Program for the 2007-2012 Five Year Oil and Gas Leasing Program on March 31, 2010. Therefore, a Final EIS was not issued for these lease sales.

In October 2009, MMS published an **EA/FONSI for the Shell *2010 Exploration Drilling Program-Camden Bay, Beaufort Sea, Alaska* (OCS EIS/EA MMS 2009-052)**, which analyzed the environmental impacts of exploration drilling. Shell proposed to drill two exploration wells during the July to October 2010 open-water-drilling season. The EA tiered from existing environmental documents and incorporated by reference other environmental documents (see EA pages 2 and 3 for the list of environmental documents). In August 2011, BOEMRE issued an EA and a FONSI on the **Shell Offshore Inc. *Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Alaska* (OCS EIS/EA BOEMRE 2011-039)**. The purpose of the activities analyzed in the EA is for Shell to evaluate the mineral resource potential of three lease tracts within two distinct oil and gas prospects: "Sivulliq" (NR 06-04 Flaxman Island, block 6658, OCS-Y-1805) and "Torpedo" (NR 06-04 Flaxman Island, block 6659, OCS-Y-1936 and NR 06-04 Flaxman Island, block 6610, OCS-Y-1941). The proposed action calls for two wells each to be drilled into the two prospects (Sivulliq and Torpedo) during the open-water season beginning in 2012.

In December 2009, MMS published an **EA/FONSI for the Shell 2010 Exploration Drilling Program—Burger, Crackerjack, and Southwest Shoebill Prospects in the Chukchi Sea Outer Continental Shelf, Alaska (OCS EIS/EA MMS 2009-061)**. Shell proposed to drill exploration wells at up to three of five possible drill sites during the July to October 2010 open-water-drilling season. The EA tiered from existing environmental documents and incorporated by reference other environmental documents (see EA pages 6 and 7 for the list of environmental documents). In December 2011, BOEM issued an EA and a FONSI **Shell Gulf of Mexico Inc. *Revised Outer Continental Shelf Lease Exploration Plan Burger Prospect, Chukchi Sea, Alaska* (OCS EIS/EA BOEM 2011-061)**. BOEM evaluated the environmental effects of drilling up to six leases acquired by Shell in Chukchi Sea Lease Sale 193 within the prospect known as Burger (OCS-Y-2280, OCS-Y-2267, OCS-Y-2321, OCS-Y-2294, OCS-Y-2278, and OCS-Y-2324). The proposed action calls for Shell to commence drilling the wells during the 2012 open-water season and continue during subsequent open-water seasons.

In November 2011, BOEM issued the Outer Continental Shelf Oil and Gas Leasing Program 2012-2017 Draft Programmatic EIS. The DPEIS evaluates the potential impacts from oil and gas exploration and development on six planning areas of the OCS, including the Western Gulf of Mexico, Central Gulf of Mexico, Eastern Gulf of Mexico, Cook Inlet, Beaufort Sea, and Chukchi Sea. The analysis adopts a broad regional perspective; BOEM intends for more detailed and geographically-focused analyses to be done as the five-year program progresses from the planning stage through the leasing, exploration, and development stages.

NMFS is the lead agency for the purposes of this EA to evaluate the impact of the proposed action to authorize the incidental takes of marine mammals during Shell's proposed Beaufort Sea exploratory drilling program and during Shell's proposed Chukchi Sea exploratory drilling program. This Draft EA applies to the current applications and NMFS' issuance of IHAs for exploratory drilling activities at Shell's proposed drilling prospects that have the potential to incidentally take marine mammals.

Chapter 2 ALTERNATIVES INCLUDING THE PROPOSED ACTION

The NEPA implementing regulations (40 CFR §1502.14) and NAO 216-6 provide guidance on the consideration of alternatives to a Federal proposed action and require rigorous exploration and objective evaluation of all reasonable alternatives. Alternatives must be consistent with the purpose and need of the action and be feasible. This chapter describes the range of potential action (alternatives) determined reasonable with respect to achieving the stated objective, as well as alternatives eliminated from detailed study, and also summarizes the expected outputs and any related mitigation of each alternative. In light of NMFS' stated purpose and need, NMFS considered the following three alternatives for the issuance of IHAs to Shell for the taking of marine mammals incidental to conducting an exploratory drilling program in Camden Bay, Beaufort Sea, Alaska, and in the Chukchi Sea, Alaska.

2.1 Alternative 1—No Action Alternative

Under the No Action Alternative, NMFS would not issue the requested IHAs to Shell for the potential take of marine mammals, by harassment, incidental to conducting exploratory drilling programs in the U.S. Beaufort and Chukchi Seas during the 2012 open-water season. The MMPA prohibits all takings of marine mammals unless authorized by a permit or exemption under the MMPA. The consequences of not authorizing incidental takes are (1) the entity conducting the activity may be in violation of the MMPA if takes do occur, (2) mitigation and monitoring measures cannot be required by NMFS, and (3) mitigation measures might not be performed voluntarily by the applicant. By undertaking measures to further protect marine mammals from incidental take through the authorization program, the impacts of these activities on the marine environment can potentially be lessened. While NMFS does not authorize the oil and gas exploratory drilling activities themselves (that authority falls to BOEM), NMFS does authorize the unintentional, incidental take of marine mammals (under its jurisdiction) in connection with these activities and prescribes, where applicable, the methods of taking and other means of effecting the least practicable impact on the species and stocks and their habitats. If IHAs are not issued, Shell would effectively be precluded from engaging in exploration drilling operations in the U.S. Beaufort and Chukchi Seas during the 2012 open-water season, as approval of the exploration plans by BOEM is contingent upon Shell receiving IHAs from NMFS. Although the No Action Alternative would not meet the purpose and need to allow incidental takings of marine mammals under certain conditions, the CEQ's regulations require consideration and analysis of a No Action Alternative for the purposes of presenting a comparative analysis to the action alternatives.

2.2 Alternative 2—Issuance of IHAs with Required Mitigation, Monitoring, and Reporting Measures

Under this alternative, NMFS would issue two IHAs under section 101(a)(5)(D) of the MMPA to Shell, allowing the take by harassment of small numbers of marine mammal species incidental to conducting open-water exploratory drilling programs (which include operation of the drillship, associated support vessels, including icebreakers, and aircraft, and ZVSP survey activities) in the Beaufort and Chukchi Seas during the 2012 Arctic open-water season. In order to reduce the incidental harassment of marine mammals to the lowest level practicable, Shell would be required to implement the mitigation, monitoring, and reporting measures described in Chapters

5 and 6 of this Draft EA. For authorizations in Arctic waters, NMFS must also prescribe measures to ensure no unmitigable adverse impact on the availability of the affected species or stock for taking for subsistence uses. The impacts to marine mammals and subsistence hunters that could be anticipated from implementing this alternative are addressed in Chapter 4 of this Draft EA. Since the MMPA requires holders of IHAs to reduce impacts on marine mammals to the lowest level practicable and to ensure no unmitigable adverse impact on the availability of marine mammals for subsistence uses, implementation of this alternative would meet NMFS' purpose and need as described in this Draft EA.

2.3 Alternative 3—Issuance of IHAs for Shorter Time Periods with Required Mitigation, Monitoring, and Reporting Requirements

Under this alternative, NMFS would issue two IHAs under section 101(a)(5)(D) of the MMPA to Shell, allowing the take by harassment of small numbers of marine mammal species incidental to conducting open-water exploratory drilling programs (which include operation of the drillship, associated support vessels, including icebreakers, and aircraft, and ZVSP survey activities) in the Beaufort and Chukchi Seas during the 2012 Arctic open-water season. Shell's MMPA applications to NMFS for IHAs requested that takes of marine mammals incidental to conducting the proposed exploratory drilling programs be allowed to occur through October 31. Under Alternative 3, activities in the Chukchi Sea would need to cease by the end of September instead of the end of October. In December 2011, BOEM conditionally approved Shell's Chukchi Sea Exploration Plan. One of the conditions of that approval is a measure designed to mitigate the risk of an end-of-season oil spill by requiring Shell to leave sufficient time to implement cap and containment operations as well as significant clean-up before the onset of sea ice, in the event of a loss of well control. Given current technology and weather forecasting capabilities, Shell must cease drilling into zones capable of flowing liquid hydrocarbons 38 days before the first-date of ice encroachment over the drill site. In a press release issued by BOEM on December 16, 2011, the agency noted that based on a five-year analysis of historic weather patterns, BOEM anticipates November 1 as the earliest anticipated date of ice encroachment. The 38-day period would also provide a window for the drilling of a relief well, should one be required. Activities in the Beaufort Sea would cease at the end of October, as in Alternative 2. The same mitigation and monitoring measures to reduce impacts to marine mammals and the availability of marine mammals for subsistence uses would be required as in Alternative 2, as well as the same reporting requirements. Since the MMPA requires holders of IHAs to reduce impacts on marine mammals to the lowest level practicable and to ensure no unmitigable adverse impact on the availability of marine mammals for subsistence uses, implementation of this alternative would meet NMFS' purpose and need as described in this Draft EA.

2.4 Alternatives Considered but Rejected from Further Consideration

NMFS considered whether other alternatives could meet the purpose and need and support Shell's proposed activities.

2.4.1 Issuance of IHAs with No Required Mitigation, Monitoring, or Reporting Measures

An alternative that would allow for the issuance of IHAs with no required mitigation or monitoring was considered but eliminated from consideration, as it would not be in compliance with the MMPA and therefore would not meet the purpose and need. For that reason, this alternative is not analyzed further in this document.

2.4.2 Use of Alternative Technologies

An alternative that would require Shell to use alternative technologies to explore the mineral potential of Shell's proposed lease tracts at the Torpedo and Sivulliq prospects in the Beaufort Sea and the Burger prospect in the Chukchi Sea was considered but eliminated from further consideration. NMFS is unaware of any alternative techniques currently available that would allow Shell to conduct the two proposed exploratory drilling programs in the U.S. Arctic Ocean. Shell's proposed exploratory drilling programs use the safest techniques known for determining whether a site is capable of producing hydrocarbons in sufficient quantities to justify commercial development.

2.4.3 Permanent Closures of Areas

NMFS has received comments from the public during the scoping process on other NEPA documents and in letters suggesting that certain areas of the Beaufort and Chukchi Seas should be permanently closed to oil and gas leasing due to environmental sensitivity. The appropriate mechanism for considering the permanent exclusion of areas from leasing for exploratory drilling activities is when BOEM requests public comments on its Five Year Lease Plan and in a specific Lease Sale EIS. During that NEPA process, the public is afforded the opportunity to make recommendations regarding potential lease locations.

Areas that have already been leased by BOEM in Federal lease sales cannot legally be closed to exploratory drilling on a permanent basis unless the President, the Secretary of Interior, or Congress makes the decision to close the area to leasing. Then, the lessee agrees to relinquish the leases or compensation is mutually agreed upon by the Federal government and the lessee.

Applicants come to NMFS requesting take authorization for specified activities. The MMPA states that if NMFS finds that the specified activity itself, or with the implementation of mitigation and monitoring measures, will have a negligible impact on affected marine mammal species or stocks and will not have an unmitigable adverse impact on the availability of affected marine mammal species or stocks for taking for subsistence uses, NMFS shall issue the requested incidental take authorization. NMFS is required to make these decisions on an application-specific basis. The decision of whether or not to preclude a lessee from conducting activities on a pre-existing lease falls to DOI under the Outer Continental Shelf Lands Act. In this case, NMFS is using this EA to inform the decision of whether to issue IHAs pursuant to Section 101(a)(5)(D) of the MMPA to Shell for the take of marine mammals incidental to conducting exploratory drilling programs in the U.S. Beaufort and Chukchi Seas during the 2012 open-water season, and the analysis of a permanent closure alternative does not add value. NMFS may, and does in the alternatives carried forward, consider temporary restrictions, such as time/area closures and other mitigation measures to avoid or minimize adverse effects on marine mammals, other marine resources, and subsistence harvest activities through the MMPA process.

2.4.4 Zero Discharge

NMFS has received comments from the public during the scoping process on other NEPA documents suggesting that "zero discharge" practices should be implemented to eliminate discharges of waste into the marine environment. Part of the impetus for making this suggestion was the fact that there have been zero discharge standards in place previously in Norway. An additional basis for this particular recommendation was a specific voluntary ”zero discharge” proposal by Shell to manage five specific waste streams within its lease blocks in Camden Bay in the Beaufort Sea for the exploratory drilling program proposed to be conducted during the 2012 Arctic open-water season by:

1) collecting sanitary waste, bilge water, ballast water, and domestic waste (i.e. gray water) on working ships and/or support vessels, and subsequently transporting those waste materials for disposal out of the activity area; and
2) off-site disposal of drill cuttings and drilling fluids collected after the well casing is set in the top hole.

However, oil and gas exploration activities generate a wide range of waste materials in addition to those associated with the current “zero discharge” proposal put forth by Shell for its 2012 Camden Bay, Beaufort Sea, exploratory drilling program.

The NPDES Arctic General Permit issued by the EPA regulates discharges of drilling muds and cuttings; deck drainage; sanitary wastes; domestic wastes; uncontaminated ballast water; bilge water; desalination unit wastes; blowout preventer fluid; boiler blowdown; fire control system test water; non-contact cooling water; excess cement slurry; and test fluids. The NPDES Arctic General permit includes additional provisions for discharges of drill cuttings and drilling muds, deck drainage, sanitary and domestic wastes, and test fluids.

The Arctic General Permit includes further prohibitions for muds and cutting by restricting discharges within certain water depths, sensitive areas, and ice conditions. The permit was issued in compliance with EPA’s Ocean Discharge Criteria for preventing unreasonable degradation of ocean waters (40 CFR Part 125, Subpart M). These specific criteria are designed to prevent significant adverse changes in ecosystem diversity, productivity, and stability of the biological community within the area of discharge and surrounding biological communities; threats to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms; and loss of aesthetic, recreational, scientific, or economic values, which are unreasonable in relation to the benefit derived from the discharge.

NMFS has the authority to require mitigation measures to effect the least practicable adverse impact to marine mammals and their habitat and to ensure an unmitigable adverse impact to subsistence uses of these species. As part of the mitigation measures to ensure an unmitigable adverse impact to subsistence uses of marine mammal species or stocks, NMFS is considering, within the action alternative carried forward for analysis, the reduction and/or elimination of the discharge of specific wastes that may potentially impact marine mammals or marine mammal habitat. NMFS does not have the authority to require mitigation measures that limit discharge streams for which there is no science supporting the link to impacts to marine mammals or their habitat. Therefore, NMFS does not intend to include an alternative that includes zero discharge of all waste streams, as it will not add value to this analysis. Rather, this EA will analyze the limitation (zero discharge or reduced discharge) of the subset of discharge streams associated with impacts to marine mammals or their habitat for Shell’s Camden Bay, Beaufort Sea, exploratory drilling program. The mitigation analysis will look at how the limitation will reduce adverse impacts to marine mammals and their habitat or to subsistence uses of marine mammals, how effective the measure is likely to be, and the practicability for applicant implementation. This analysis/approach will more effectively support NMFS' purpose and need without creating unnecessary administrative complexity.

Chapter 3 AFFECTED ENVIRONMENT

The purpose of this chapter is to provide baseline information for consideration of the alternatives and to describe the environment that might be affected by the proposed action and alternatives. This chapter describes the affected environment relative to physical, biological, and socio-cultural resources found in the proposed 2012 OCS lease areas described by Shell. The Beaufort and Chukchi Seas environments are covered by the arctic ice pack 7–10 months each year but support a diverse biological ecosystem driven primarily by the seasonal presence of sea ice. The ice pack shapes the habitat for many of the biological organisms, from the primary productivity of the plankton communities to the migration patterns of the bowhead whale. The Arctic Ocean sea ice conditions are influenced by weather, wind, ocean currents, and extreme daylight conditions. The socio-cultural setting of the Beaufort and Chukchi Seas communities is closely intertwined with the biological resources and the ice conditions of the Arctic Ocean. The effects of the alternatives on the environment are discussed in Chapter 4 of this Draft EA.

The following descriptions of the affected environment have been compiled from several other sources, including NMFS and other Federal agency documents. In many cases, the original documents are referenced and the pertinent information has been summarized. In other cases, pertinent sections of documents have been reproduced from the original. All source documents are cited in the text with full references in Chapter 7 of this document.

3.1 Physical Environment

Shell's proposed action areas are located in the OCS of the U.S. Beaufort and Chukchi Seas. The Beaufort Sea proposed action area is located within lease blocks obtained during lease sales 195 and 202 on the continental shelf north of Camden Bay. The Chukchi Sea proposed action area is located within lease blocks obtained during lease sale 193 on the continental shelf in the Central Chukchi Sea OCS Planning Area. The proposed timeframe for Shell's activities are during the open-water season (i.e., ice is mainly absent from the area). However, there is the potential for sea ice to be in the vicinity at the beginning or end of the proposed activities (i.e., early to mid-July and/or October).

3.1.1 Physical Oceanography

Section 3.1.1 of NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011) contains a description of the physical oceanography of both the Beaufort and Chukchi Seas. The description of physical oceanography contains information on water depth, circulation, and bathymetry, temperature and salinity, and tides, as well as other properties. That information is incorporated herein by reference and summarized next along with additional information specific to Shell's Camden Bay, Beaufort Sea, and Chukchi Sea proposed drill sites.

The Beaufort and Chukchi Seas are the northernmost seas bordering Alaska. The Beaufort and Chukchi Seas are parts of the Arctic Ocean, but both are linked, atmospherically and oceanographically, to the Pacific Ocean. The atmospheric connection involves the Aleutian Low, which affects regional meteorological conditions. The oceanographic link is via the Bering Strait, which draws relatively warm nutrient-rich water into the Arctic Ocean from the Bering Sea (Weingartner and Danielson, 2010).

The Beaufort Sea is a semi-enclosed basin with a narrow continental shelf extending 19 to 50 mi (30 to 80 km) from the coast (Chu et al., 1999). The continental shelf of the Beaufort Sea is relatively shallow, with an average water depth of about 121 ft (37 m). Bottom depths on the shelf increase gradually to a depth of about 262 ft (80 m) then increase rapidly along the shelf break and continental slope to a maximum depth of around 12,467 ft (3,800 m) (Weingartner, 2008; Greenberg et al., 1981). The proposed drill sites for Shell's Camden Bay, Beaufort Sea, exploratory drilling program are located in the relatively shallow continental shelf waters of the Beaufort Sea. As noted in Table 1 in this Draft EA, the water depths for the four potential drill sites at the two prospects considered by Shell for the 2012 exploratory drilling program are between 107 and 124 ft (32.6 and 37.8 m) deep.

The shallow continental shelf waters of the Beaufort Sea are subjected to seasonally varying conditions, such as heating, cooling, wind stress, ice formation and melting, and terrestrial freshwater input. Seasonal variations in the temperature and salinity of the continental shelf waters are large (Chu et al., 1999). Such physical and chemical gradients influence the productivity and trophic structure of the Beaufort Sea shelf. At the Sivulliq prospect, the seafloor slopes regionally from the south to the north at a gradient of less than 1º (less than 1.7%). Local small-scale gradients are variable along the numerous ice gouge ridges within the area that was surveyed previously (Fugro, 2009a). These ice gouges have local relief varying from less than 1.6 ft (0.5 m) to about 8.2 ft (2.5 m) from ridge to trough and average local gradients of about 20º (40%). Seafloor gradient and relief at the proposed Sivulliq drill sites is typical of the prospect. Maximum ice gouge depth in the Sivulliq prospect area is estimated at 8.2 ft (2.5 m). At the Torpedo prospect, the seafloor slopes regionally from the south to the north at a gradient of less than 1º (less than 1.7%). Local small-scale gradients are variable along the numerous ice gouge ridges within the area that was surveyed previously (Fugro, 2009b). These ice gouges have local relief varying from less than 1.6 ft (0.5 m) to about 3.3 ft (1 m) from ridge to trough and average local gradients of about 20º (40%). Seafloor gradient and relief at the proposed Torpedo drill sites is typical of the prospect. Maximum ice gouge depth in the Torpedo prospect area is estimated at 4.1 ft (1.3 m).

The Chukchi Sea is predominantly a shallow sea with a mean depth of 131 to 164 ft (40 to 50 m). Gentle mounds and shallow troughs characterize the seafloor morphology of the Chukchi Sea (Chu et al., 1999). The Chukchi Sea shelf is approximately 311 mi (500 km) wide and extends roughly 497 mi (800 km) northward from the Bering Strait to the continental shelf break (Weingartner, 2008). Beyond the shelf break, water depths increase quickly beyond 3,281 ft (1,000 m). The western edge of the Chukchi Sea shelf extends to Herald Canyon, and the eastern edge is defined by Barrow Canyon (Pickart and Stossmeiser, 2008), which separates the Beaufort and Chukchi Seas. The proposed drill sites for Shell's Chukchi Sea exploratory drilling program are located in the continental shelf waters of the Central Chukchi Sea. As noted in Table 7 in this Draft EA, the water depths for the six potential drill sites at the Burger prospect considered by Shell for the 2012 exploratory drilling program are between 143 and 150 ft (43.7 and 45.8 m) deep.

The seafloor in the vicinity of the proposed Burger A drill site is largely flat with a low gradient and featureless except for ice gouges. On average the seafloor near the Burger A drill site slopes very slightly (< 1º) to the southeast but is virtually horizontal. Several ice gouges cross the block exhibiting a northeast-southwest preference. Gouge troughs are as much as about 1.3 ft (0.4 m) deeper than the elevation of the surrounding seafloor, and the associated ridges can rise by as much as 2.3 ft (0.7 m). Widths of gouges typically range from approximately 66-98 ft (20-30 m). The nearest prominent gouge is located approximately 1,854 ft (565 m) southeast of the drill site, where the total relief from top of ridge to bottom of trough is about 1.3 ft (0.4 m). Comparison of 1989 and 2009 data sets, which overlap, indicates that while ice gouging has had significant impact on the seafloor at the survey site, there has been no identifiable ice gouging in the last 20 years (Fugro GeoConsulting, Inc., 2010a).

The seafloor in the vicinity of the proposed Burger F drill site is largely flat with a low gradient and featureless except for ice gouges. On average the seafloor appears to slope very slightly (< 1^{o}) to the southeast, but is virtually horizontal. Ice gouges crisscross the block, with most gouges exhibiting an east-west preference. Gouge troughs are as much as about 5 ft (1.5 m) deeper than the elevation of the surrounding seafloor, and the associated ridges can rise by about as much as 3.3 ft (1 m). Widths of the mapped gouges typically range from approximately 66-98 ft (20-30 m). The nearest prominent gouge is located approximately 82 ft (25 m) south of the drill site, where the total relief from top of ridge to bottom of trough is about 5 ft (1.5 m). Comparison of 1989 and 2009 data sets, which overlap, indicates that while ice gouging has had significant impact on the seafloor at the survey site, there has been no identifiable ice gouging in the last 20 years (Fugro GeoConsulting, Inc., 2010b).

The seafloor in the vicinity of the proposed Burger J drill site is largely flat with the notable exception of several ice gouges that crisscross the block exhibiting both southwest-northeast and northwest-southeast trends (GEMS, 2009). Gouge troughs are as much as about 1.6 ft (0.5 m) deeper than the elevation of the surrounding seafloor and the associated ridges can rise as much as about 1.6 ft (0.5 m) above the seafloor. Widths of the mapped gouges typically range from approximately 66-164 ft (20-50 m). The closest gouges are located about 328 ft (100 m) to the northwest and 328 ft (100 m) to the southeast of the drill site. The northern gouge has relief up to 3.28 ft (1.0 m) from the sediment ridge to trough base, while the southern gouge has less than 1.6 ft (0.5 m) of relief from ridge to trough base. GEMS (2009) commented that a few of the gouges appeared to be "fresh-looking gouges based upon sharpness" but did not speculate as to how recently they had been formed.

The seafloor in the vicinity of the proposed Burger R drill site is largely flat with a low gradient and features a low-relief, elongated (northwest –southeast trending) slight topographic high to the northeast of the proposed drill site. Locally, the seafloor is irregular and the gradient is higher due to the presence of ice gouges. Ice gouges crisscross the block, with most gouges exhibiting a northeast-southwest preference. Gouge troughs are as much as about 3.9 ft (1.2 m) deeper than the elevation of the surrounding seafloor, and the associated ridges can rise by about as much as 2.8 ft (0.9 m). Widths of the mapped gouges typically range from approximately 98-263 ft (30-80 m), with the exception of an approximately 394 ft (120 m) wide gouge trending west to east in the northern half of the survey area. The nearest prominent gouge is located approximately 410 ft (125 m) north of the drill site, where the total relief from top of ridge to bottom of trough is about 3.0 ft (0.9 m). Comparison to other nearby shallow hazard survey data within the vicinity of the Burger R drill site suggest that while ice gouging has had significant impact on the seafloor at the survey site, there has been no identifiable ice gouging in the last 20 years.

The seafloor in the vicinity of the Burger S drill site is largely flat with a low gradient and featureless except for ice gouges (Fugro GeoConsulting, Inc., 2010c). On average, the seafloor appears to slope very slightly (< 1º) to the northeast but is virtually horizontal. Ice gouges cross the block, with overall gouge trends appearing to be random. Gouge troughs are as much as 2 ft (0.6 m) deeper than the elevation of the surrounding seafloor, and the associated ridges can rise by as much as 1.3 ft (0.4 m). Widths of the mapped gouges typically range from approximately 66-98 ft (20-30 m), with the exception of a 492-656 ft (150-200 m) wide, arc-shaped gouge in the southwest portion of the survey area. The proposed drill site is approximately 2,870 ft (875 m) south of the ice gouge with the greatest total relief. The total relief from the top of ridge to bottom of trough of this east-west trending ice gouge is about 3.3 ft (1 m). Comparison to other nearby shallow hazard surveys in the vicinity of the Burger S drill site suggest that the rate of gouging on the Chukchi Shelf is low. These studies indicate that while ice gouging has had a significant impact on the seafloor nearby the Burger S drill site, there has been no identifiable gouging in the past 20 years (Fugro GeoConsulting, Inc., 2010c).

The seafloor in the vicinity of the Burger V drill site is largely flat (very slight dip to the northeast) and featureless except for ice gouges (Fugro GeoConsulting, Inc., 2010d). Locally, the seafloor is irregular and the gradient is higher due to the presence of ice gouges. Ice gouges cross the block, with most gouges exhibiting a northeast-southwest preference. The exceptions are two northwest-southeast trending gouges in the northeast portion of the survey area. Gouge troughs are as much as 1.6 ft (0.5 m) deeper than the elevation of the surrounding seafloor, and the associated ridges can rise by as much as 2.3 ft (0.7 m). Widths of the mapped gouges typically range from approximately 82-148 ft (25-45 m), with the exception of an approximately 787 ft (240 m) wide gouge trending northwest-southeast in the northeast portion of the survey area. The nearest prominent gouge is located approximately 590 ft (180 m) northwest of the drill site, where the total relief from top of ridge to bottom of trough is about 2.3 ft (0.7 m). Comparison to other nearby shallow hazard survey data within the vicinity of the Burger V drill site suggests that while ice gouging has had significant impact on the seafloor at the survey site, there has been no identifiable ice gouging in the last 20 years (Fugro GeoConsulting, Inc., 2010d).

Throughout the summer, temperature increases and salinity decreases due to surface warming and associated ice melting and freshwater input from rivers to the Beaufort Sea. The sea surface temperature increases to a maximum value near 8 degrees Celsius (°C), and the sea surface salinity decreases to a minimum value below 20 practical salinity units (psu) (Chu et al., 1999). During the summer of 2008, the vertical profiles of salinity and temperature within the Sivulliq and Torpedo prospect areas showed stratification. The sea at Torpedo demonstrated greater display of stratification, with warmer surface water and salinity lower than that measured near the Sivulliq prospect (Trefry and Trocine, 2009; Dunton et al., 2009).

Temperature and salinity in the Chukchi Sea vary seasonally and are influenced by sea ice formation and melting. During winter (January to May), shelf waters cool to the freezing point, and salinity in the water increases during sea ice formation. Salinities decrease as ice melts and

Bering Sea water moves onto the shelf during spring and summer (Weingartner, 2008; Woodgate et al., 2005; Weingartner et al., 2011). Water properties also vary regionally across the Chukchi Sea. The eastern Chukchi is influenced by the warmer, fresher waters of the Alaskan Coastal Current and eastern Bering Strait (Woodgate et al., 2005). The largest seasonal variability in temperature and salinity occurs in the eastern Chukchi, where variations in ice cover modify the shelf waters (Woodgate et al., 2005).

Recent tide gauge observations at Barrow show coastal water levels are driven primarily by wind stress and barometric pressure changes from the passage of storm centers and frontal passages (Gill et al., 2011). Storm surge on the coast and coastal water level withdrawal can be significant (about 3.3 ft [1 m] amplitude; Gill et al., 2011). Tides are small in the Chukchi Sea, and the tidal range is generally less than 1 ft (0.3 m). Tidal currents are largest on the western side of the Chukchi and near Wrangel Island, ranging up to 5 cm/s (0.1 knots) (Woodgate et al., 2005). Storm surges are both positive and negative.

3.1.2 Sea Ice

3.1.2.1 Sea Ice Dynamics

Sea ice, formed by the freezing of sea water, is a dominant feature of the Arctic environment. Annual formation and decay of sea ice influence the oceanography and dynamics of the Beaufort and Chukchi Seas, impacting the physical, biological, and cultural aspects of life in this region. Sea ice is a central determinant in the degree of light that penetrates into the sea, supplies a surface for particles and snow deposits to accumulate, and provides a biological habitat above, below, and within the ice. Moreover, sea ice can transport contaminants throughout the arctic region. Sea ice generally reaches its maximum extent in March and minimum extent in September.

Ice cover consists of drifting pack ice over the middle and outer Beaufort Sea shelf and landfast ice on the inner shelf (Weingartner, 2008). Landfast ice usually starts to form in October and can extend 12.4 to 25 mi (20 to 40 km) offshore. Stamukhi, or grounded ice, forms along the seaward edge of the landfast ice. It may help protect the inner shelf from forces exerted by pack ice (Weingartner et al., 2009).

Sea ice covers the Beaufort shelf for about nine months of the year (Eicken et al., 2006). In recent years, the Alaska Beaufort Sea shelf has been ice-free from late-July through early October (Weingartner, 2008). Sea ice formation in the Chukchi Sea begins in mid-October near Wrangel Island, while the central Chukchi may remain ice free through early November. By December, the entire region is generally ice-covered (Woodgate et al., 2005).

Iñupiat hunters in Barrow describe three basic sea-ice zones: 1) *Tuvag* is the innermost zone of landfast ice, which consists of first-year ice mixed with varying amounts of multi-year ice; 2) *Uiñiq* includes the open lead, or flaw lead, and the ice fragments moving within it, which is a very dynamic area where seal and whale hunting occur; and 3) S*arri* is the outer realm of pack ice comprised of fast and varying currents and shifting sea ice (George et al., 2004).

3.1.2.2 Landfast Ice

Landfast ice is, by definition, stationary. It is contiguous with the land and strongly associated with the 66 ft (20 m) isobath, where it coincides with grounded ridges of ice (Eicken et al., 2006). Coastline and bathymetry are the primary determinants of landfast ice extent (Mahoney et al., 2007a). Most landfast ice is floating and held in place by non-floating landfast ice. Tide cracks commonly form in landfast ice along northern Alaska beaches in response to sea level fluctuations affecting the floating ice (Mahoney et al., 2007b).

A combination of processes lead to the formation patterns of landfast ice (Eicken et al., 2006). Wind and current patterns during fall and winter are critical to ice formation (George et al., 2004). Landfast ice generally starts forming in October, and, at its maximum extent in March and April, covers roughly 25% of the Beaufort shelf area (Weingartner, 2008; Mahoney et al., 2007a). Formation of landfast ice is a complex process, and the landfast ice may form, break up, and reform several times before becoming stable (Eicken et al., 2006; Mahoney et al., 2007b).

The ice retreats with the onset of spring in May and June (Eicken et al., 2006). Timing of the ice retreat correlates with increasing temperature and atmospheric changes (Mahoney et al., 2007a). Areas of open water (e.g. polynyas and leads), act as heat sinks for solar radiation and allow for increased wind and wave action, which destabilizes landfast ice (Mahoney et al., 2007a).

The landfast ice is important to the biology, economy, and cultures of the Arctic. It is used by various seal species, polar bears, and Arctic fox, is critical to Iñupiat hunting, and has been used as a platform for transportation in nearshore areas (George et al., 2004; Eicken et al., 2006).

The Camden Bay area is part of ice zone number 2, which extends from Point Barrow to Barter Island (Mahoney et al., 2007a). The landfast ice in this zone typically forms first, stabilizing earlier than zones to the east or west. In the Camden Bay area, between 1996 and 2004, the seaward landfast ice edge varied in extent from less than 31 mi (50 km) in 2001 to more than 155 mi (250 km) in 2000 (Mahoney et al., 2007a). Atmospheric circulation and temperature closely correlate with the timing of landfast ice breakup. In zone 2, offshore bathymetry is more important during breakup of the ice than any coastline effects (Mahoney et al., 2007a). Once breakup has begun, overfloods from the Shaviovik and Canning Rivers clear the ice in the near shore area (ADEC, 2006).

Shell's planned drill sites in the Burger prospect are located seaward of areas over which landfast ice forms during the time operations are proposed to be present.

3.1.2.3 Stamukhi or Shear Zone

The stamukhi ice zone lies seaward of the landfast ice and is characterized by pressure ridges, leads, and polynyas (large areas of open water) resulting from interactions between relatively stable landfast-ice and mobile pack-ice. In the Chukchi Sea, the most intense ridging occurs in waters from 49 to 131 ft (15 to 40 m) deep, while moderate ridging extends seaward and shoreward of these regions (MMS, 2007a). In the Beaufort Sea, ridges occur at depths ranging from 59 to 82 ft (18 to 25 m) (Mahoney et al., 2007a). Grounded ridges help to stabilize the seaward edge of the landfast-ice zone. Extensive sea-ice rafting may occur in areas adjacent to pressure ridges, and ice thicknesses of two to four times the sheet thickness may be found within a few hundred meters of the ridge. Shear ridges are straighter, usually have one vertical side, and are composed of ice pieces that range in size from a few centimeters to several meters. The outer edge of the stamukhi zone advances seaward during the ice season (MMS, 2007a).

Stamukhi is not anticipated to occur in the area of Shell's planned Camden Bay prospects during the proposed timeframe for operations (i.e., July through October). In the Chukchi Sea, the most intense ice ridging occurs in water depths of 49-131 ft (15-40 m) shoreward of Shell's planned drill sites at the Burger prospect.

3.1.2.4 Pack Ice and Ice Gouges

Pack ice occurs beyond the shear zone and consists predominantly of a multiyear aggregation of permanent ice floes that are consistently moving. During winter, movement in the pack ice zone of the Beaufort Sea generally is small and tends to occur only during strong wind events of several days' duration. The long-term direction of ice movement tends to be from east to west; however, there may be short-term perturbations from this general trend due to variable weather (MMS, 2008).

The seabed of the Alaskan Beaufort Sea shows evidence of modification by ice keels, which gouge the seafloor. The keels of sea-ice pressure ridges cut through seafloor sediments to form 'V' shaped incisions called gouges, also referred to as scours. Most ice gouges are less than 2 ft (0.5 m) deep, but the deepest gouges exceed 7 ft (2 m) in depth (NRC, 2011). Gouging is associated with ice keels driven by forces from the associated ice pack. A study of ice gouging in the Alaskan Beaufort Sea showed that the maximum number of gouges occur in the 66 to 99 ft (20 to 30 m) water-depth range (Machemehl and Jo, 1989). Ice gouges are important to pipeline engineers involved in the design and burial of Arctic offshore pipelines (Machemehl and Jo, 1989).

3.1.2.5 Leads and Polynyas

Polynyas are semi-permanent areas of open water that can be up to thousands of square kilometers in size (ACIA, 2005). There are generally two types of polynyas: persistent polynyas that form off of south and west facing coasts, and north coast polynyas that form along north facing coasts (Stringer and Groves, 1991). The frequency with which polynyas change from ice-covered to open water and vice-versa is influenced by wind, currents, and solar warming (Stringer and Groves, 1991).

Leads are open channels, or lanes of water that form between large pieces of ice as a result of forces generated by winds and /or currents. Flaw leads occur along landfast ice when winds separate drift ice from fast ice (ACIA, 2005). Pack ice shifting north is the simplest way for a lead to form along the landfast ice edge. Leads formed this way are generally narrow and short lived. Leads most commonly open along the boundary between landfast ice and pack ice. Pack ice moving parallel to landfast ice may generate leads well inside of the pack ice boundary (Eicken et al., 2006).

Spatial patterns of lead occurrence and size are consistent between years in the eastern Chukchi and the central Beaufort Seas. The number of leads and mean size of leads are greater in the eastern Chukchi and off the Mackenzie Delta than in the central Beaufort Sea. Prevailing easterly winds usually force ice offshore in these areas and create recurring leads and polynyas along the landfast ice. Linear leads are prevalent in winter, while patches of open water are more common in late May or early June (Eicken et al., 2006).

Ice conditions to the west of Point Barrow are more dynamic than to the east, with leads radiating out of Point Barrow (Eicken et al., 2006). Point Barrow juts out into the Beaufort and Chukchi Seas, forming an obstacle to westward drifting Beaufort Sea pack ice (Mahoney et al., 2007a). As a result, the area to the west of Point Barrow in the Chukchi Sea is dominated by a semi-permanent polynya or flaw zone (Norton and Graves, 2004). Grounded ice on Hanna Shoal also creates a series of leads. Ice movement is more stagnant in the eastern Beaufort, and winter breakouts are more common in the western Beaufort and eastern Chukchi (Eicken et al., 2006).

Leads and polynyas are important habitat for several seal species, polar bears, and migrating bowhead and beluga whales. Iñupiat hunters rely on these leads and open-water for spring whaling of bowheads from April to June (Norton and Gaylord, 2004).

3.1.2.6 Changes in Sea Ice

Arctic sea ice is changing in extent, thickness, distribution, age, and timing of melt. Analysis of long-term data sets show substantial decreases in both extent (area of ocean covered by ice) and thickness of sea ice cover during the past 30 years. Sea ice extent, the primary measure by which Arctic ice conditions are judged, has been monitored using satellite imagery since 1979. The annual maximum extent (March) and minimum extent (September) are the measures used for interannual comparisons (Perovich et al., 2011). The September 2011 minimum ice extent was the second lowest since 1979, surpassed only by the record low in 2007 (NSIDC, 2011b; see Figure 6). The summers of 2007 to 2011 experienced the five lowest minimums in the satellite record; eight of the ten lowest minimums occurred during the last decade (Perovich et al., 2011; NSIDC, 2011b). The March 2010 ice extent was 4% lower than the 1979 to 2000 average. A time series of anomalies in sea ice extent (1979 to 2011) reveals both interannual variability and general decreasing trends. March ice extent decreased at a rate of -2.7% per decade, while September extent decreased -12% per decade (Perovich et al., 2011; NSIDC, 2011b).

Sea ice age is another indicator of ice cover and changes. Following the record summer melt of 2007, there was a record low amount of multiyear ice (ice that has survived at least one summer melt season) in March 2008. Multiyear ice increased modestly in 2009 and 2010. Despite this, 2010 had the third lowest March multiyear ice extent since 1980. Most of the two to three year old ice remained in the central Arctic due to atmospheric patterns in the winter of 2010. Although some older ice from north of the Canadian Archipelago moved into the Beaufort and Chukchi Seas, it did not survive the summer melt period (Perovich et al., 2010).

Loss of multiyear ice is considered a key factor in ice thinning and retreat in the Beaufort and Chukchi shelves. Analysis of a satellite-derived record of sea ice age for 1980 through March 2011 shows a particularly extensive loss of the oldest ice types. The fraction of multiyear sea ice in March decreased from about 75% in the mid 1980s to 45% in 2011, while the proportion of the oldest ice declined from 50% of the multiyear ice pack to 10% (Maslanik et al., 2011). Multiyear ice (as detected by satellite) was studied in the winters from 1979-2011. The multiyear extent and area are declining at rates of -15.1% and -17.2% per decade, respectively.

A record low value occurred in 2008 followed by higher values in 2009, 2010, and 2011 (Comiso, 2011). The Beaufort and Chukchi Seas have experienced reductions of overall mean thickness of level ice due to the replacement of multi-year by first-year ice over large areas (Shirawasa et al., 2009).

a) left map and graph **b) right map and graph**

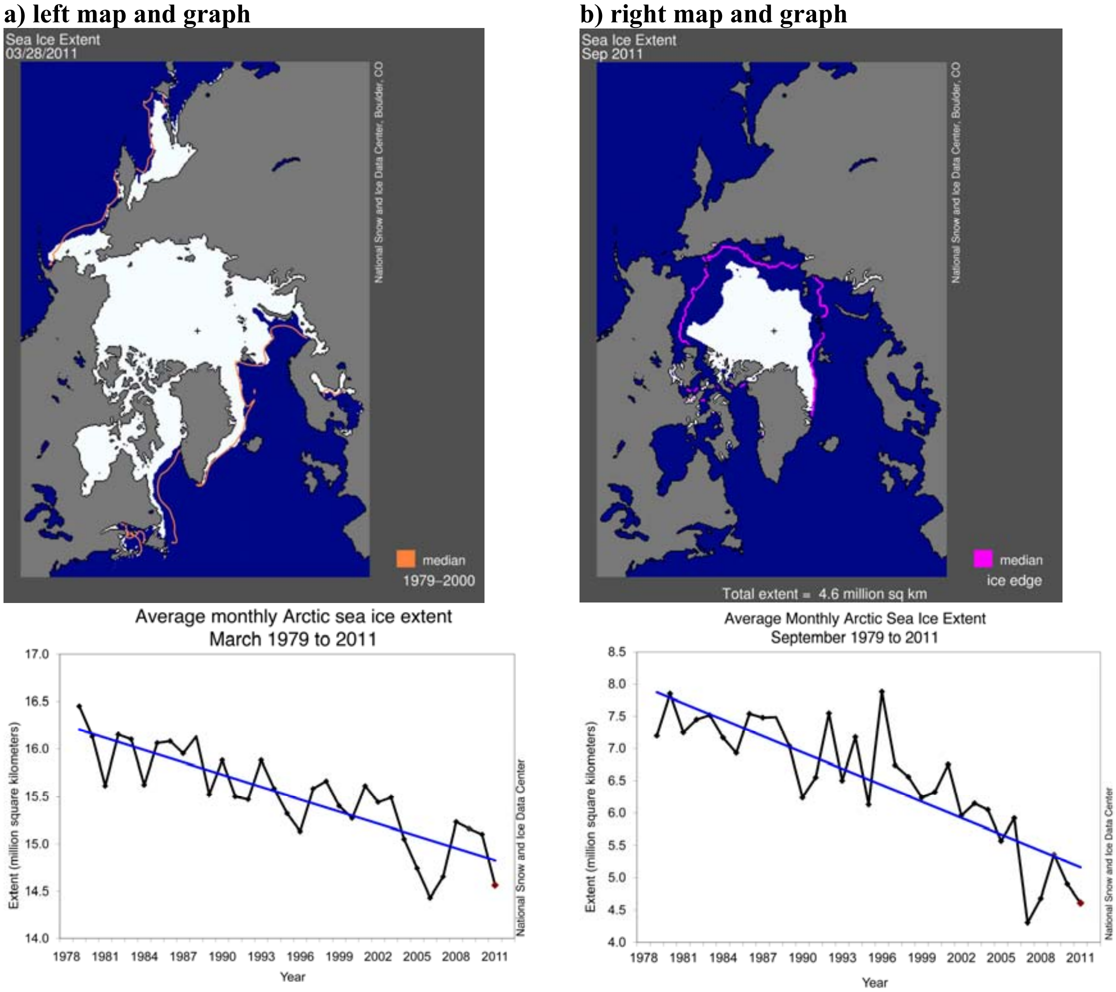

Figure 6. a) Map shows the maximum sea ice extent (in white) for March 2011, and also the median sea ice extent (red line) for the period 1979–2000. Graph shows the average monthly sea ice extent over the period 1979–2011 (Map and graph source: NSIDC, 2011a). b) Map shows the minimum sea ice extent (in white) for September 2011, and the median sea ice extent (red line) for the period 1979–2000. Graph shows the average monthly sea ice extent over the period 1979–2011 (Map and graph source: NSIDC, 2011b).

The landfast ice season has shortened since the 1970s, with coastlines being ice-free over a month earlier for the Beaufort Sea and two weeks earlier for some areas of the Chukchi Sea (Mahoney et al., 2007a). Landfast ice has also been less stable in recent years, with break-offs at the beach occurring as late as January and February or near to the beach in March. Lack of multiyear ice and decreased pressure ridges decrease stability and increase the likelihood of early break-offs and break-up events (George et al., 2004; Petrich et al., 2012). Iñupiat hunters have described these changes to the landfast ice, including thinning ice, changing pressure ridge patterns, and the loss of multiyear ice. These changes affect the ability to haul large whales onto the ice during spring whaling (Gearheard et al., 2006).

3.1.3 Air Quality

Air quality is a function of the air pollutant emission sources within an area, atmospheric conditions (such as wind direction and speed), and characteristics of the area itself (topography and air shed size). Pollutants transported from outside an area can also affect its air quality. Air pollutants are emitted from both anthropogenic and natural sources. Industrial, residential, transportation-related, and construction-related emissions are anthropogenic sources; these sources can be either ongoing or temporary. Natural sources include windblown dust, forest fires, and volcanic eruptions; these typically contribute only to temporary increases in air pollution.

Air quality in the majority of Alaska's Arctic region, including the Beaufort and Chukchi Seas, is generally considered very good due to minimal human habitation and industrial development, along with the distance from population centers such as Anchorage or Fairbanks (MMS, 2007c). Widely scattered air pollutant emission sources exist in the onshore coastal regions of the Draft EA proposed project areas, with the only major industrial complex of more concentrated emission sources being Prudhoe Bay, Kuparuk, and Endicott oil-production facilities in the North Slope Area Wide Oil and Gas Lease Sale Area (North Slope area). Dust and other pollutants from combustion sources in Europe and Asia also have the potential to be transported to the Arctic, having temporary and usually seasonal effects on visibility.

Section 3.1.5 of NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011) contains a description of air quality in the proposed project area. The description of air quality that is relevant here contains information on the regulatory framework and pollutants of concern, Arctic (regional) haze, and existing air quality in the proposed project area. That information is incorporated herein by reference and summarized next.

Air quality in Alaska is regulated by the EPA and ADEC. The EPA has established NAAQS, which specify maximum allowable concentrations for six principal criteria pollutants (EPA, 2011e). Nonattainment areas are geographic regions where air pollutant concentrations exceed the NAAQS for a pollutant. An area is designated as unclassified when there is insufficient information to determine attainment status; these are typically areas where air pollution is not considered a problem (often rural areas), and no monitoring is conducted. The areas in and around the Beaufort and Chukchi Seas are uniformly classified as attainment, that is, the air quality in these areas meet the NAAQS for all criteria pollutants (MMS, 2007c). There are no designated nonattainment areas within or near the Draft EA proposed project areas (ADEC, 2011a).

Regional haze refers to haze that impairs visibility in all directions over a large area. In general, visibility is measured by the farthest distance a viewer can see a landscape or feature, which may be limited by tiny particles in the air absorbing and scattering sunlight, which in turn degrades color, contrast, and clarity of the view. Many sources produce the particulate matter that causes haze. Class I airsheds are Federally designated areas under the CAA where no degradation of visibility is allowed. Alaska has four Class I areas subject to the rule (ADEC, 2011b). Denali National Park is the closest Class I area to any of the EA proposed project area, ranging from approximately 404 mi (650 km) southeast of Kotzebue and approximately 466 mi (750 km) south of the more industrialized Prudhoe Bay area, to well over 621 mi (1,000 km) south of some of the outer OCS region (Wilderness Net, 2011). The National Park Service and USFWS monitor regional haze at Denali. Potential new sources of air pollution as part of this Draft EA are expected to have no appreciable effect at this distant Class I area, so no further description of the area is provided.

Based on the physical environment, land uses, and low population density of the EA project area, existing air quality is assumed to be generally good in all of the offshore and onshore locations, although, dust emissions in even remote areas can cause localized increased particulate concentrations. The levels of some pollutants are expected to be slightly higher in the onshore areas due to increased numbers of fuel combustion sources; however, these areas are still in attainment of air quality standards. In addition, fairly consistent winds in these areas provide adequate transport and dispersion of these localized emissions. External (international) sources of air pollution may also have an influence on air quality in the EA project area, including temporary increases in levels of dust and combustion pollutants, which may affect visibility (Arctic haze).

The EA project areas included in this discussion are in attainment (or unclassifiable) for all criteria pollutants. The dataset shown in Table 11 was compiled using maximum monitored values and should be conservatively representative of the OCS areas, including the corresponding onshore areas. Therefore, it is expected that this compiled dataset is reasonably representative for the three air quality area zones covered in this EA (outer OCS, inner OCS, and onshore).

Table 11. Background air pollutant concentrations

Pollutant	Averaging Period	Measured Concentration (μg/m^3)	Percent of Air Quality Standard
PM_{10}	Annual	7.5	15.0
	24-hour	55.1	36.7
CO	8-hour	1097	11.0
	1-hour	1749	4.4
NO_2	Annual	11.3	11.3
SO_2	Annual	2.6	3.3
	24-hour	13.0	3.6
	3-hour	41.6	3.2

Source: Compiled from monitoring data for BPX Liberty and BPX Prudhoe Bay monitoring sites (Environ 2010).
Note:
μg/m^3 = micrograms of pollutant per cubic meter of air

As shown in Table 11, the maximum measured concentrations are all well below the NAAQS and Alaska State Standards. These values are indicative of the relatively good air quality in the area, and show that there is still room for future development that would not necessarily jeopardize the regions ability to meet the Federal and State of Alaska air quality standards.

3.1.4 Acoustic Environment

The need to understand the marine acoustic environment is critical when assessing the effects of oil and gas exploration and development on humans and wildlife. Sounds generated by oil and gas exploration and development within the marine environment can affect its inhabitants' behavior (e.g., deflection from loud sounds) or ability to effectively live in the marine environment (e.g., masking of sounds that could otherwise be heard). Understanding of the existing environment is necessary to evaluate what the potential effects of oil and gas exploration and development may be.

This section summarizes the various sources of natural ocean sounds and anthropogenic sounds documented in the Arctic subregion and, where available, describes the sound characteristics of these sources and their relevance for Shell's exploratory drilling program activities.

Ambient sound levels are the result of numerous natural and anthropogenic sounds that can propagate over large distances and vary greatly on a seasonal and spatial scale (NRC, 2003a). This is especially the case in the dynamic Arctic environment with its highly variable ice, temperature, wind, and snow conditions. Where natural forces dominate, there will be sounds at all frequencies and contributions in ocean sound from a few hundred Hz to 200 kHz (NRC, 2003a).

In the Arctic Ocean, the main sources of underwater ambient sound would be associated with:

- Ice, wind, and wave action;
- Precipitation;
- Subsea earthquake activity;
- Vessel and industrial transit;
- Sonar and seismic-survey activities; and
- Biological sounds.

The contribution of these sources to the background sound levels differs with their spectral components and local propagation characteristics (e.g., water depth, temperature, salinity, and ocean bottom conditions). In deep water, low-frequency ambient sound from 1–10 Hz mainly comprises turbulent pressure fluctuations from surface waves and the motion of water at the air-water interfaces. At these infrasonic frequencies, sound levels depend only slightly on wind speed. Between 20–300 Hz, distant anthropogenic sound (ship transiting, etc.) dominates wind-related sounds. Above 300 Hz, the ambient sound level depends on weather conditions, with wind- and wave-related effects mostly dominating sounds. Biological sounds arise from a variety of sources (e.g., marine mammals, fish, and shellfish) and range from approximately 12 Hz to over 100 kHz. The relative strength of biological sounds varies greatly; depending on the situation, biological sound can be nearly absent to dominant over narrow or even broad frequency ranges (Richardson et al., 1995).

Typical background sound levels within the ocean are shown as a function of frequency (Figure 7; Wenz, 1962). The sound levels are given in underwater dB frequency bands written as dB re

1 μPa^2/Hz. Sea state or wind speed is the dominant factor in calculating ambient noise levels above 500 Hz.

3.1.4.1 Sources of Natural Ocean Sounds

Sources of natural ocean sounds in the Arctic subregion that contribute to the ambient sound levels are from non-biological and biological origins. Examples of non-biological natural sound sources include movements of sea ice, wind and wave action, surface precipitation, and subsea earthquakes. Biological sources of sound production are fish, marine mammals, and sea birds. The contribution of natural sounds to the overall ambient sound level has been well documented for the Beaufort Sea close to Northstar Island (Blackwell et al., 2008).

Information on ambient sound levels in the Chukchi Sea was scarce or lacking prior to 2006. Since then, studies have been conducted in the Chukchi Sea using a large array of bottom-mounted, autonomous acoustic recorders to provide information on ambient sound levels and the contribution of natural and anthropogenic sources (Martin et al., 2009).

3.1.4.1.1 Non-Biological Sound Sources

Non-biological natural sound sources in the Beaufort and Chukchi seas include the wind stirring the surface of the ocean, lightning strikes, subsea earthquakes, and ice movements. Burgess and Greene (1999) report that collectively, these sources create an ambient noise range of 63-133 dB re 1 μPa.

The presence of ice can contribute significantly to ambient noise levels and affects sound propagation. As noted by the NRC (2001:39), "An ice cover radically alters the ocean noise field…" with factors such as the "…type and degree of ice cover, whether it is shore-fast pack ice, moving pack ice and…floes, or at the marginal ice zone…," and temperature, all affecting ambient noise levels. The NRC (2001, citing Urick, 1984) reported that variability in air temperature over the course of the day can change received sound levels by 30 dB between 300 and 500 Hz.

Temperature affects the mechanical properties of the ice, and temperature changes can result in cracking. In winter and spring, landfast ice produces significant thermal cracking noise (Milne and Ganton, 1964; Lewis and Denner, 1987, 1988). In areas characterized by a continuous fast-ice cover, the dominant source of ambient noise is the ice cracking induced by thermal stresses (Milne and Ganton, 1964). The spectrum of cracking noise typically displays a broad range from 100 Hz–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. Ice deformation occurs primarily from wind and currents and usually produces low frequency noises. Data are limited, but at least in one instance it has been shown that ice-deformation noise produced frequencies of 4-200 Hz (Greene, 1981). As icebergs melt, they produce additional background noise as the icebergs tumble and collide.

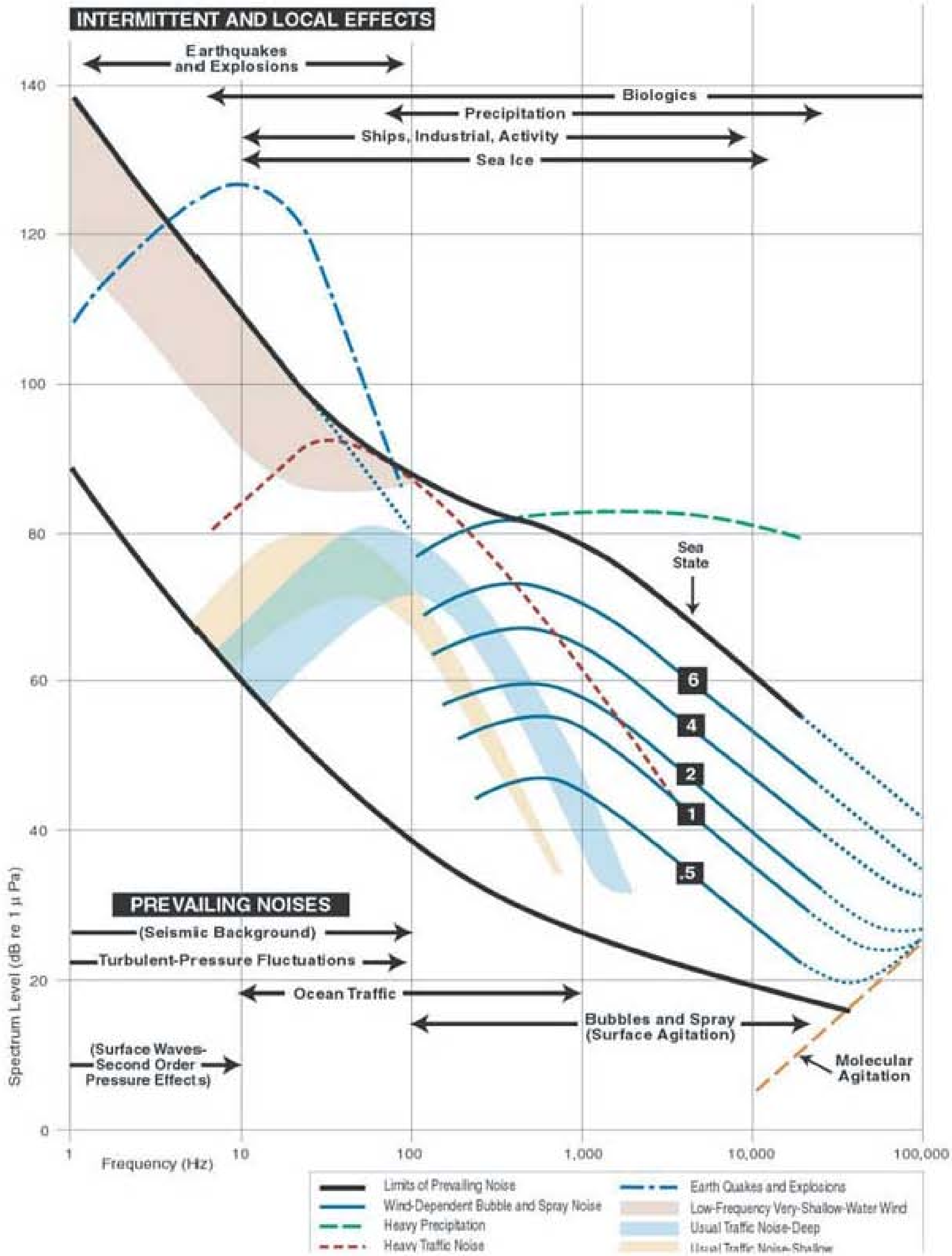

Figure 7. Background sound levels within the ocean (Source: Wenz (1962); adopted from the NRC (2003a) Ocean Noise and Marine Mammals. National Academy Press, Washington, DC).

While sea ice can produce significant amounts of background noise, it also can function to dampen ambient noise. Areas of water with 100% sea-ice cover can reduce or completely eliminate noise from waves or surf (Richardson et al., 1995). Because ice effectively decreases water depth, industrial sounds may not propagate as well at the lowest frequencies (Blackwell and Greene, 2002). The marginal ice zone, the area near the edge of large sheets of ice, usually is characterized by quite high levels of ambient noise compared to other areas, in large part due to the impact of waves against the ice edge and the breaking up and rafting of ice floes (Milne and Ganton, 1964; Diachok and Winokur, 1974). In the Arctic, wind and waves (during the open-water season) are important sources of ambient noise with noise levels tending to increase with increased wind and sea state, all other factors being equal (Richardson et al., 1995).

Precipitation in the form of rain and snow would be another source of sound. These forms of precipitation can increase ambient sound levels by up to 35 dB across a broad band of frequencies, from 100 Hz to more than 20 kHz (Nystuen and Farmer, 1987). In general, it is expected that precipitation in the form of rain would result in greater increases in ambient sound levels than snow. Thus, ocean sounds caused by precipitation are quite variable and transitory.

Seismic events such as earthquakes caused by a sudden shift of tectonic plates or volcanic events where hydrothermal venting or eruptions occur can produce a continual source of sound in some areas. This sound can be as much as 30–40 dB above background sound and can last from a few seconds to several minutes (Schreiner et al., 1995). Shallow hazard surveys conducted in the Alaskan Chukchi Shelf have found that it is generally not seismically active (Fugro, 1989).

3.1.4.1.2 Biological Sound Sources

The sounds produced by marine life are many and varied. Marine mammals and many fish and marine invertebrates are known to produce sounds (Wenz, 1962; Tavolga, 1977; Zelick et al., 1999).

Fishes produce different types of sounds using different mechanisms and for different reasons. Sounds may be intentionally produced as signals to predators or competitors, to attract mates, or as a fright response. Sounds are also produced unintentionally including those made as a by-product of feeding or swimming. The three main ways fishes produce sounds are by using sonic muscles that are located on or near their swim bladder (drumming); striking or rubbing together skeletal components (stridulation); and by quickly changing speed and direction while swimming (hydrodynamics). The majority of sounds produced by fishes are of low frequency, typically less than 1,000 Hz. However, there is not much information on marine invertebrates and fish sounds in the Arctic region.

Marine mammals can contribute significantly to the ambient sound levels in the acoustic environment of the Beaufort and Chukchi Seas. 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 (Cummings et al., 1983). Ringed seal calls have a source level of 95-130 dB re 1 μPa at 1 m, with the dominant frequency under 5 kHz (Richardson et al., 1995). Bowhead whales, which are present in the Arctic region from early spring to mid- to late fall, produce sounds with source levels ranging from 128-189 dB re 1 μPa at 1 m in frequency ranges from 20-3,500 Hz. Richardson et al. (1995) summarized that most bowhead whale calls are "tonal frequency-modulated (FM)" sounds at 50-400 Hz. There are many other species of marine mammals in the arctic marine environment whose vocalizations contribute to ambient noise including, but not limited to, the gray whale, walrus, ringed seal, beluga whale, spotted seal, fin whale (in the southwestern areas) and, potentially but less likely, the humpback whale. In air, sources of sound will include seabirds (especially in the Chukchi Sea near colonies), walruses, and seals.

3.1.4.2 Sources of Anthropogenic Sounds

Human sources include noise from vessels (motor boats used for subsistence and local transportation, commercial shipping, research vessels, etc.), navigation and scientific research equipment, airplanes and helicopters, human settlements, military activities, and marine development. Table 12 provides a comparison of manmade sound levels from various sources associated with the marine environment.

3.1.4.2.1 Vessel Activities and Traffic

Shipping is the dominant source of sound in the world's oceans in the range from 5 to a few hundred Hz (National Academy of Sciences, 2005). Commercial shipping is the major contributor to sound in the world's oceans and contributes to the 10–100 Hz frequency band (NRC, 2003a). Some of the more intense anthropogenic sounds come from oceangoing vessels, especially larger ships such as supertankers. Shipping noise, often at source levels of 150-190 dB, dominants the low frequency regime of the spectrum. It is estimated that over the past few decades the shipping contribution to ambient noise has increased by as much as 12 dB (Hildebrand, 2009).

The types of vessels that are commonly found in the Beaufort and Chukchi Seas include vessels to transport goods, such as tugs and barges, scientific research vessels, such as icebreakers, vessels used for local resident transportation and subsistence activities (e.g., whaling), such as skiffs with outboard motors or smaller enclosed vessels, and vessels associated with oil and gas exploration and development, predominately seismic source vessels, support vessels, and drillships. In addition, interest in the Arctic has led to several tourist cruise ships spending time in arctic waters during the past few years (Lage, 2009). In the Beaufort and Chukchi Seas, vessel transit and associated sounds presently are limited primarily to late spring, summer, and early autumn, when open waters are unimpeded by broken ice or ice sheets.

Due to the shortness of the open water season, vessel transiting—particularly large vessel transiting—is minimal in arctic marine waters. Richardson et al. (1995) described the range of frequencies for shipping activities to be from 20–300 Hz. They note that smaller boats used principally for fishing or whaling generate a frequency of approximately 300 Hz (Richardson et al., 1995).

Sound energy in the Arctic is particularly efficient at propagating over large distances because in these regions the oceanic sound channel reaches the ocean surface and forms the Arctic half-channel (Urick, 1983). In shallow water, vessels more than 6.2 mi (10 km) away from a receiver generally contribute only to background noise (Richardson et al., 1995). In deep water, traffic noise up to 2,485 mi (4,000 km) away may contribute to background-noise levels (Richardson et al., 1995). Shipping traffic is most significant at frequencies from 20-300 Hz (Richardson et al., 1995). Barging associated with activities such as onshore and limited offshore oil and gas activities, fuel and supply shipments, and other activities contributes to overall ambient noise levels in some regions of the Beaufort Sea. The use of aluminum skiffs with outboard motors during fall subsistence whaling in the Alaskan Beaufort Sea also contributes noise. Fishing boats in coastal regions also contribute sound to the overall ambient noise. Sound produced by these smaller boats typically is at a higher frequency, around 300 Hz (Richardson et al., 1995).

Icebreaking and ice management vessels used in the Arctic for activities including research and oil and gas activities produce stronger, but also more variable, sounds than those associated with other vessels of similar power and size (Greene, 1987; Richardson et al., 1995). Even with rapid attenuation of sound in heavy ice conditions, the elevation in noise levels attributed to icebreaking can be substantial out to at least 3.1 mi (5 km) (Richardson et al., 1991). In some instances, icebreaking sounds are detectable from more than 31 mi (50 km) away. In general, spectra of icebreaker noise are wide and highly variable over time (Richardson et al., 1995).

Table 12. A comparison of the most common anthropogenic in-water sound levels from various sources[1]

Source	Activities	dB at source
Vessel Activity		
	Tug Pulling Barge	171
	Fishing Boat	151-158
	Zodiac (outboard)	156
	Supply Ship	181
	Tankers	169-180
	Supertankers	185-190
	Freighter	172
Ice Breaking		
	Ice Management	171-191
	Icebreaking[2]	193
Dredging		
	Clamshell Dredge	150-162
	Aquarius (cutter suction dredge)	185
	Beaver Mackenzie Dredge	172
Drilling		
	Kulluk (conical drillship) – drilling	185
	Explorer II (drillship) – drilling	174
	Artificial Island – drilling	125
	Ice Island (in shallow water) – drilling	86
Seismic and Marine Surveys		
	Airgun Arrays	235-259
	Single Airguns	216-232
	Vibroseis	187-210
	Water Guns	217-245
	Sparker	221
	Boomer	212
	Depth Sounder	180
	Sub-bottom Profiler	200-230
	Side-scan Sonar	220-230
	Military	200-230

Sources: [1] Richardson *et al.* 1995; [2] *Robert Lemeur*

3.1.4.2.2 Oil and Gas Development and Production Activities

There currently are a few oil-production facilities on artificial islands in the Beaufort Sea. Typically, noise propagates poorly from artificial islands, as it must pass through gravel into the water (Richardson et al., 1995). Much of the production noise from oil and gas operations on gravel islands is substantially attenuated within 2.5 mi (4 km) and often not detectable at 5.8 mi (9.3 km).

Richardson and Williams (2004) summarized results from acoustic monitoring of BP offshore Northstar production facility from 1999-2003. Northstar is located on an artificial gravel island in the central Alaskan Beaufort Sea. In the open-water season, in-air broadband measurements reached background levels at 0.62-2.5 mi (1-4 km) and were not affected by vessel presence. However, Blackwell and Greene (2004) pointed out that "…an 81 Hz tone, believed to originate at Northstar, was still detectable 23 mi (37 km) from the island." Based on sound measurements from Northstar obtained during March 2001 and February-March 2002 (during the ice-covered season), Blackwell et al. (2004a) found that background levels were reached underwater at 5.8 mi (9.4 km) when drilling was occurring and at 1.9-2.5 mi (3-4 km) when it was not. Irrespective of drilling, in-air background levels were reached at 3.1-6.2 mi (5-10 km) from Northstar.

During the open-water season, vessels such as tugs, self-propelled barges, and crew boats were the main contributors to Northstar-associated underwater sound levels, with broadband sounds from such vessels often detectable approximately 18.6 mi (30 km) offshore. In 2002, sound levels were up to 128 dB re 1 μPa at 2.3 mi (3.7 km) when crew boats or other operating vessels were present (Richardson and Williams, 2003). In the absence of vessel noise, averaged underwater broadband sounds generally reached background levels 1.2-2.5 mi (2-4 km) from Northstar. Underwater sound levels from a hovercraft, which BP began using in 2003, were quieter than similarly sized conventional vessels.

Typically, noise propagates poorly from artificial islands, as it must pass through gravel into the water (Richardson et al., 1995). Richardson et al. (1995) reported that during unusually quiet periods, drilling noise from ice-bound islands would be audible at a range of about 6.2 mi (10 km), when the usual audible range would be ~1.2 mi (2 km). Richardson et al. (1995) also reported that broadband noise decayed to ambient levels within ~0.9 mi (1.5 km), and low-frequency tones were measurable to ~5.9 mi (9.5 km) under low ambient-noise conditions, but were essentially undetectable beyond ~0.9 mi (1.5 km) with high ambient noise.

3.1.4.2.3 Geophysical and Seismic Surveys

The most intense sound sources from geophysical and seismic surveys would be impulse sound generated by the airgun arrays. These impulse sounds are created by the venting of high-pressure air from the airguns into the water column and the subsequent production of an air-filled cavity (a bubble) that expands and contracts, creating sound with each oscillation. Airgun output usually is specified in terms of zero-to-peak (0-peak, or 0-p) or peak-to-peak (peak-peak, or p-p) levels.

While the seismic airgun pulses are directed towards the ocean bottom, sound propagates horizontally for several kilometers (Greene and Richardson, 1988; Hall et al., 1994). In waters

82-164 ft (25-50 m) deep, sound produced by airguns can be detected 31-46.6 mi (50-75 km) away, and these detection ranges can exceed 62 mi (100 km) in deeper water (Richardson et al., 1995) and thousands of kilometres in the open ocean (Nieukirk et al., 2004). Typically, an airgun array is towed behind a vessel at 13-26 ft (4-8 m) depth and is fired every 10-15 seconds. The ship also may be towing long cables with hydrophones (streamers), which detect the reflected sounds from the seafloor.

Airgun-array sizes are quoted as the sum of their individual airgun volumes (in cubic inches) and can vary greatly. The array output is determined more by the number of guns than by the total array volume. For single airguns, the zero-peak acoustic output is proportional to the cube root of the volume. As an example, compare two airgun configurations with the same total volume. The first array consists of one airgun with a total volume of 100 in^3 resulting in a cube root of 4.64. The second array has the same total volume, but consists of five 20-in^3 guns. The second array has an acoustic output nearly three times higher (5 times the cube root of 20 = 13.57) than the single gun, while the gun volumes are equal. The output of a typical 2D/3D array has a theoretical point-source output of ~255 dB + 3 dB (Barger and Hamblen, 1980; Johnston and Cain, 1981); however, this is not realized in the water column, and maximum real pressure is more on the order of 232 dB + 3 dB and typically only occurs within 3.3-6.6 ft (1-2 m) of the airguns, as indicated in Table 12.

The depth at which the source is towed has a major impact on the maximum near-field output, and on the shape of its frequency spectrum. The rms received levels that are used as impact criteria for marine mammals are not directly comparable to the peak or peak-to-peak values normally used to characterize source levels of airguns. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in much of the biological literature.

Tolstoy et al. (2004) collected empirical data concerning 190-, 180-, 170-, and 160-dB (rms) distances in deep (~10,500 [3,200 m]) and shallow (~98 ft [30 m]) water for various airgun-array configurations during the acoustic calibration study conducted by Lamont-Doherty Earth Observatory in the northern Gulf of Mexico. Results demonstrate that received levels in deep water were lower than anticipated based on modeling, while received levels in shallow water were higher.

Seismic sounds vary, but a typical 2D/3D seismic survey with multiple guns would emit energy at about 10-120 Hz, and pulses can contain some energy up to at least 500-1,000 Hz (Richardson et al., 1995). Goold and Fish (1998) recorded a pulse range of 200 Hz-22 kHz from a 2D survey using a 2,120-in^3 array.

Richardson et al. (1995) summarized that typical signals associated with vibroseis sound sources used for on-ice seismic survey sweep from 10-70 Hz, but harmonics extend to about 1.5 kHz (Richardson et al., 1995). In this activity, hydraulically driven pads mounted beneath a line of trucks are used to vibrate, and thereby energize the ice. Noise incidental to the activity is introduced by the vehicles associated with this activity.

3.1.4.2.4 Miscellaneous Sources

Acoustical systems are associated with some research, military, commercial, or other vessel use of the Beaufort or Chukchi Seas. Such systems include multibeam sonar, sub-bottom profilers, and acoustic Doppler current profilers. Active sonar is used for the detection of objects underwater. These range from depth-finding sonar, found on most ships and boats, to powerful and sophisticated units used by the military. Sonar emits transient, and often intense, sounds that vary widely in intensity and frequency. Acoustic pingers used for locating and positioning oceanographic and geophysical equipment also generate noise at high frequencies. LGL, Ltd. (2005) describes many examples of acoustic navigational equipment.

3.1.5 Water Quality

Water quality is a term used to describe the physical, chemical, and biological characteristics of water, usually with regard to its ability to perform or support a particular function. Water quality criteria or standards can be generally defined using an established set of parameters that are related to the utility of the water for a particular set of purposes (e.g. protection of marine biota, maintenance of subsistence food resources).

Since drilling of the first OCS exploration well in 1981, a variety of onshore and offshore oil exploration and development projects have been conducted in and adjacent to both the Alaskan Beaufort and Chukchi Seas (NRC, 2003b). Over 20 discoveries have been made in areas such as Endicott (an offshore field in state waters), Sagavanirktok Delta North (onshore near Prudhoe Bay), and Badami (Beaufort Sea) (Brown et al., 2010). Brown et al. (2010) report that, "because of this past development, the Alaska Arctic Region OCS is not considered to be "pristine" from a chemical perspective." In addition to inputs resulting from oil and gas exploration and development, anthropogenic materials may be introduced to the Beaufort and Chukchi Seas through influx from the Bering Sea, river runoff, coastal erosion, and atmospheric deposition (Woodgate and Aagaard, 2005). However, the majority of the water flowing into the Beaufort and Chukchi Seas is relatively free from the influence of human activity, and there are currently no impaired waters (as defined by the CWA 303(d)) identified within the Arctic Region by the State of Alaska (ADEC, 2010).

3.1.5.1 Applicable Regulations

Pursuant to the CWA, certain discharges from oil and gas exploration facilities in the Beaufort and Chukchi Seas require authorization by EPA in the form of a NPDES permit. To be eligible for permitting under the NPDES program, discharges into the ocean may not cause an unreasonable degradation of the marine environment as determined under 40 CFR Part 125, Subpart M.

The 2006-2011 Arctic NPDES General Permit (AKG280000) for wastewater discharges from Arctic oil and gas facilities expired in June, 2011; the reissuance of this permit is expected in October, 2012. EPA extended coverage under the previous 2006-2011 NPDES permit to those oil and gas operators who submitted Notices of Intent to operate in the open water between June, 2011 and October, 2012. Shell requested this extended coverage and EPA determined that their

Notices of Intent met the requirements of the Arctic General Permit and authorized those proposed discharges.

Also applicable are USCG regulations related to pollution prevention and discharges for vessels carrying oil, noxious liquid substances, garbage, municipal or commercial waste, and ballast water are found in 33 CFR Part 151.

3.1.5.2 Water Quality Parameters

Common indicators of water quality include: temperature; salinity; turbidity and total suspended solids; trace metals; hydrocarbons; and other organic contaminants. Measurements have been taken for several of these parameters over the last decade in the Beaufort Sea. In the Chukchi Sea, water quality issues have been noted closer into shore, mostly in the area near the Red Dog Mine near Kivalina and Kotzebue, which is south of Shell's proposed Chukchi Sea Burger prospect. MMS' Arctic Multiple Sale Draft EIS (MMS, 2008), BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011) contain full descriptions of baseline information of common indicators of water quality in the Beaufort and Chukchi Seas and for the areas in Camden Bay, Beaufort Sea, and in the Chukchi Sea where Shell proposes to drill in particular. That information is incorporated herein by reference. Additional information can also be found in Section 3.1.8 of NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011).

3.2 Biological Environment

The Beaufort and Chukchi Seas support a diverse assemblage of marine species: lower trophic organisms; freshwater, anadromous, and marine fishes; marine and coastal birds; and marine mammals. The area where Shell's activities are proposed to occur do not contain any park land, prime farmlands, wetlands, wild and scenic rivers, or critical habitat, or districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places.

3.2.1 Lower Trophic Organisms

Lower trophic organisms serve as the basis of the food web in the Arctic Ocean. They provide nutrition for birds, fish, and marine mammals. The lower trophic levels that occur in the proposed project areas can be categorized as: epontic (living on the underside of or in sea ice); pelagic (living in the water column); and benthic (living on or in the sea bottom) (BOEMRE, 2011a). Abundance and distribution of these organisms depend largely on physical environmental factors such as nutrient availability, light availability, water turbidity, wind, and currents. Currents from the Bering Sea provide primary production that promotes growth and biodiversity in the U.S. Arctic Ocean, as well as transport detritus and larval invertebrates. The degree to which ice is present also directly affects the timing and spatial distribution of lower trophic organisms.

The Beaufort and Chukchi Seas are Large Marine Ecosystems (LMEs) with a subarctic and high arctic climate (Ray and Hayden, 1993). Both are characterized by a short summer open-water period of growth and then a long winter ice-covered season. As a result, the net annual growth rates of organisms are slow, resulting in slow recovery to disruption or damage. Several ongoing, broad-scale changes have been observed in lower-trophic level resources, making the Chukchi Sea food web more like the ones in the Northern Bering Sea (Grebmeier and Dunton, 2000; Grebmeier et al., 2006). For example, plankton blooms are now more prolonged, and the relative importance of the benthic activity has changed, as shown in part by changes in the distribution of benthic feeding gray whales. The authors conclude that reductions in the ice cover create the more prolonged plankton blooms, and that the plankton is grazed more efficiently by pelagic consumers such as fish, allowing less to settle to the benthos where it was consumed mainly by marine mammals and seabirds. This section of the Draft EA describes the lower trophic level environments in the Beaufort and Chukchi Seas, trophic level interactions, and the influence of climate change on lower trophic level ecology.

3.2.1.1 Lower Trophic Level Environments

3.2.1.1.1 Epontic

Microalgae are found in sea ice as it forms in the fall, but the origin of the cells is not known (Horner and Schrader, 1982). One possibility is that the species may be present in low numbers in the water column and may be incorporated into the ice as it forms (Horner and Schrader, 1982; MMS, 1991). The primary producers in the epontic community are ice algae, which live within or attached to the undersurface of sea ice. The ice algae form a concentrated food source for a variety of animals, including amphipods, copepods, ciliates, worms, and fishes, especially in the early spring (Gradinger et al., 2009).

The primary production of epontic communities is largely tied to under-ice light levels, which decrease with increasing ice thickness, snow cover, and sedimentation. Gradinger and Bluhm (2005) found that algal blooms were up to two orders of magnitude lower in ice that had high sedimentation loads. Years with thicker snow cover on the ice yield less productive populations of ice algae (Alexander et al., 1974). Light appears to be the major factor controlling the distribution, development, and production of the ice algal assemblage. These epontic algal communities provide the sole source of fixed carbon for higher trophic levels in ice covered waters, when other sources do not exist (NRC, 2004). For example, Lee et al. (2007) documented increases in primary productivity in benthic communities resulting from additions by epontic organisms during winter months and as ice recedes.

The ice-algal bloom occurs mostly in April and May, prior to the pelagic phytoplankton bloom, which does not occur until the ice has melted in the area and there is a significant increase in light availability for photosynthesis (MMS, 1987). The overall contribution of ice algae to the primary productivity of the Beaufort and Chukchi Seas may be small in comparison to that of the pelagic phytoplankton community, but it could provide a useful source of food during the spring prior to the pelagic phytoplankton bloom as the ice melts during the summer season, usually around July.

3.2.1.1.2 Pelagic

Planktonic organisms occur in the water column and are subject to the movement of the water, as they are unable to effectively swim against currents. Plankton is comprised of two basic groups, phytoplankton, the primary producers or plant component of the plankton, and zooplankton, the animal component of the plankton (MMS, 1991).

The timing of sea ice breakup is critical for phytoplankton production as it provides a stable surface layer with an abundance of light needed for photosynthesis. Spring algal blooms often occur near the sea-ice edge due to wind-driven upwelling of nutrients. Phytoplankton abundance and distribution can be determined with the use of satellite technology by measuring chlorophyll concentrations or ocean color, i.e. "greenness" of the surface water (Wang et al., 2005). High chlorophyll concentrations have been recorded in the southwestern Chukchi Sea and along the coast of the Beaufort Sea (Wang et al., 2005). In fact, primary production rates in the southwest Chukchi Sea are among the highest ever recorded. Generally, these values are much lower near the coast, yet there are areas of high productivity on the continental slope of the Beaufort Sea, in the northern part of the Chukchi shelf between the 164 and 328 ft (50 and 100 m) isobaths, in the southern part of the Chukchi southwest of Point Hope, and on the shelf northwest of Point Barrow (Sukhanova et al., 2009). Primary productivity in the Chukchi Sea is generally higher in nearshore areas, such as Ledyard Bay, than in the areas of Shell's proposed Burger prospect. Figure 8 shows areas of high primary productivity in the Chukchi Sea as indicated by the chlorophyll α concentration in seawater. The abundance of phytoplankton in the Chukchi Sea Lease Sale 193 Area is far less than that of the Bering Sea and waters further south. Chlorophyll concentrations recorded in the Burger Prospect area in July–October 2008 and 2009 are summarized below in Table 13.

Table 13. Average chlorophyll concentrations in the Burger prospect during 2008 and 2009.

Time Period	Chlorophyll Concentration (mg / m²)	
	2008	2009
July-August	104.8	21.4
August-September	47.1	20.1
September-October	30.9	25.1

[1] Source: Hopcroft et al. 2009, 2010

In the Beaufort Sea, the highest concentration of chlorophyll was observed near Barrow (Dunton et al., 2003). Additionally, the Barter Island coast near Kaktovik is another productive area (Dunton et al., 2003), as this area exhibits upwelling of nutrient-rich water from offshore areas. Coastal zones (within 3 mi [5 km]) are the most productive areas for phytoplankton in the Beaufort Sea (MMS, 2003). Chlorophyll α concentrations in coastal waters have been measured at 100 times greater than in offshore surface waters. Shell's Sivulliq and Torpedo prospects are located 16-20 mi (26-32 km) offshore and are outside the areas identified as the most productive areas for phytoplankton in the Beaufort Sea. Additionally, a survey in Steffanson Sound, west of Camden Bay closer to Prudhoe Bay, found that phytoplankton in the water column contributed about one-third of the lower trophic primary production while the algae dependent on sea ice contributed two-thirds of the primary production (Horner and Schrader, 1982). The period of time that ice is present temporally limits the contribution of ice algae, or epontic species. The ice algal community is present primarily during April through early June. Shell's proposed exploration drilling activities at the Sivulliq and Torpedo drill sites would occur after the ice algae community largely disappears.

Zooplankton life histories and community structures are intricately coupled to phytoplankton production as prey resources. Therefore, areas with high primary phytoplankton productivity will also possess high zooplankton abundance and diversity (Hopcroft et al., 2010). In addition, the spatial distribution of zooplankton communities is strongly tied to physical and chemical differences in water masses (Iken et al., 2010). The zooplankton communities in the Beaufort and Chukchi Seas are largely dominated by copepods, mostly *Calanus* and *Pseudocalanus*, followed by larvaceans, and euphausids (Ashijan et al., 2003; Hopcroft et al., 2010). Zooplankton samples in the Beaufort Sea also have included coelenterates, nematodes, annelids, mollusks, tunicates, decapod crustaceans, and barnacles (MMS, 1991). Pteropods, cniderians, and ctenophores are also important constituents of these pelagic communities. This community structure is more similar to that in the Pacific and Bering Seas compared to the Arctic due to the high transport rate of water masses northward along the Anadyr current. Zooplankton are a primary food source for fish and some birds and marine mammals. Among the species of zooplankton, krill are important food sources for bowhead whales (Lowry, 1993) and ringed seals (Frost and Lowry, 1984).

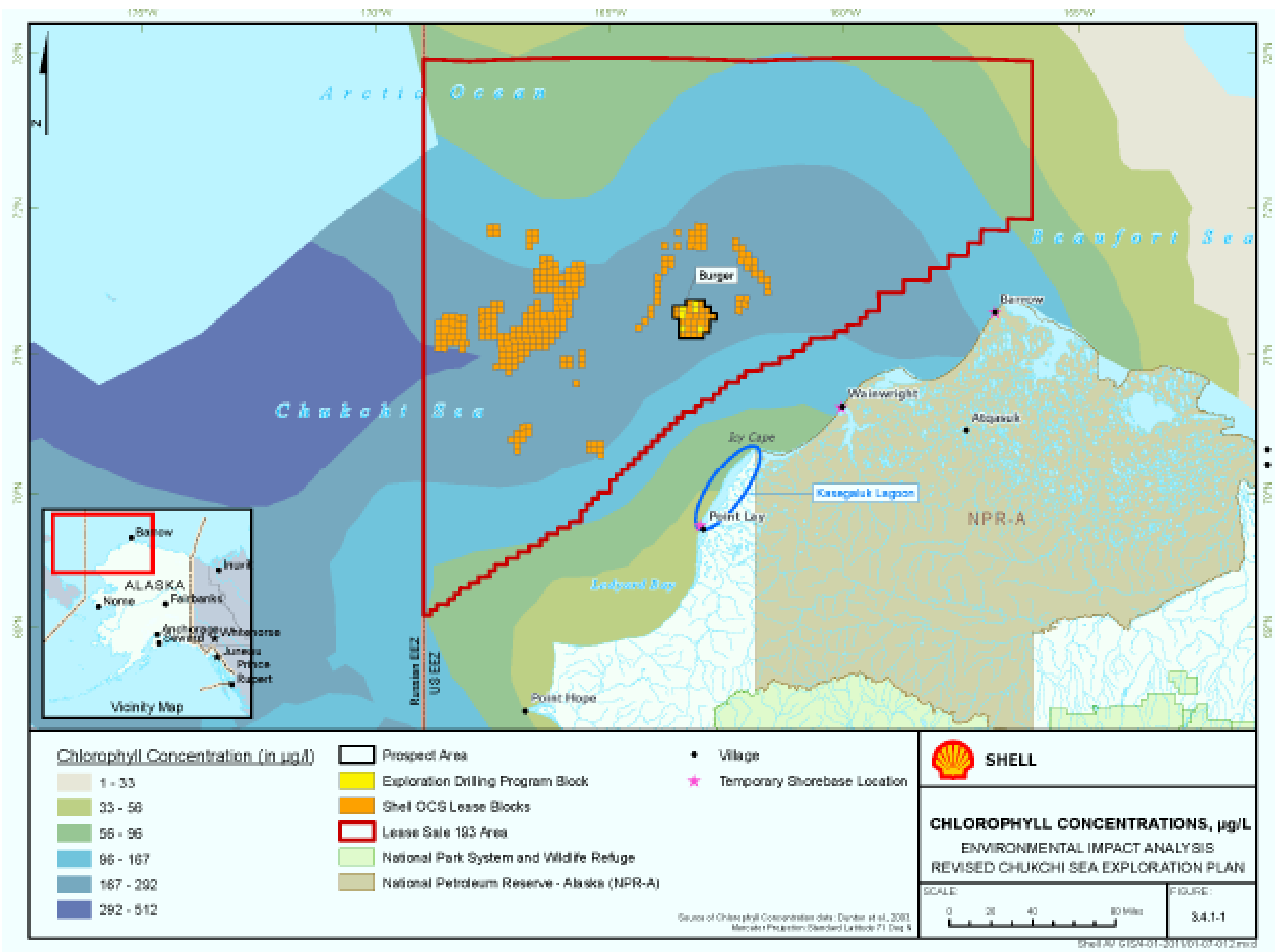

Figure 8. Chlorophyll α concentrations in the Chukchi Sea shown in µg/L (Source: Shell, 2011d).

Samples collected near Camden Bay at depths less than 656 ft (200 m) near Shell's prospects yielded groups of zooplankton (Griffith et al., 2002). These groups included copepods (the most abundant species collected in the sampling), ctenophores, cnidarians, chaetognaths, mysids, and fish larvae (Griffith et al., 2002). Because the two prospects are in close proximity to each other on the nearshore shelf of the Beaufort Sea, where the physical characteristics of one area along the shelf are essentially the same as another, it is reasonably assumed that zooplankton populations in the vicinities of the prospects are representative of the areas studied.

Planktonic communities were sampled at 25 stations in the 34 x 34 mi (55 x 55 km) Burger prospect study area, on three cruises in July-October of 2008 and three cruises in August-October of 2009 (Hopcroft et al., 2009, 2010). Observed concentrations of nutrients and chlorophyll indicated that the 2008 surveys took place during the spring phytoplankton bloom. In 2009, low concentrations observed throughout the entire water column indicated that the surveys were conducted post-phytoplankton bloom. The greatest numbers of taxa were observed in the copepods followed by the cnidarians in both 2008 and 2009. Dominant taxa in the 150 µm and 505 µm nets were similar in 2008 and 2009 and are summarized in Table 14.

Table 14. Dominant taxa by abundance and biomass in plankton surveys in the Burger prospect[1].

Year	Net	Abundance	Biomass
2008	150 µm net	The small larvacean *Fritillaria borealis*, followed by the *Pseudocalanus* copepods, barnacle larvae, calanoid copepod nauplii, bivalve larvae, the copepod *Oithona similis*, polychaete larvae, the larvacean *Oikopleura vanhoeffeni*, all averaging more than 100 / m^3	Several of same taxa plus rarer species of larger individual biomass, with barnacle larvae, the copepod *Calanus marshallae*, the chaetognath *Parasagitta elegans*, the *Pseudocalanus* copepod series, followed by polychaete larvae, the cnidarian *Aglantha digitale*, and the larvacean *Oikopleura vanhoeffeni*
	150 µm net	Barnacle larvae, larvacean *Fritillaria borealis*, the *Pseudocalanus* copepods. the larvacean *Oikopleura vanhoeffeni*, the copepod *Calanus marshallae*, polychaete larvae, the chaetognath *Parasagitta elegans*, bivalve larvae, and the cnidarian *Aglantha digitale* all averaging more than 5 / m^3	Substantially different – fish larvae, , the chaetognath *Parasagitta elegans*, the copepod *Calanus marshallae*, the cnidarian *Aglantha digitale, barnacle larvae*, the larvacean *Oikopleura vanhoeffeni, the euphausiid Thysanoessa inermis*, and several *cnidarians*
2009	150 µm net	The larvacean *Fritillaria borealis*, followed by the copepod *Oithona similis*, *Pseudocalanus*, the pteropod *Limacina helicina*, calanoid copepod nauplii, baranacle larvae, bivalve larvae, polychaete larvae, and the larvacean *Oikopleura vanhoeffeni*, all averaging more than 100 / m^3	Several of same taxa plus rarer species of larger individual biomass, with the copepod *Calanus marshallae*, barnacle larvae, the chaetognath *Parasagitta elegans*, the copepod *Oithona similis* followed by the *Pseudocalanus* copepod series followed by the ctenophore *Mertensia ovum* and finally polychaete larvae.
	150 µm net	The larvacean *Fritillaria borealis* was the only species averaging more than 100 / m^3, followed by the copepods *Calanus marshallae/glacialis*, *Eucalanus bungii*, barnacle larvae, and the chaetognath *Parasagitta elegans*, which averaged 3-13/m^3	The copepod *Calanus marshallae*/glacialis , *the* euphausiid *Thysanoessa raschii*, the jellyfish *Aurelia aurita*, and *Cyanea capillata, the ctenophore Mertensia ovum, and the* chaetognath *Parasagitta elegans*

[1] Source: Hopcroft et al. 2010

3.2.1.1.3 Benthic

The shallow continental shelves of the Beaufort and Chukchi Seas are among the largest in the world (Grebmeier et al., 2006). Each possess varying substrates such as fine sands, muds, and silts (BOEMRE, 2010) and each of these substrates is closely tied to the distribution of benthic fauna. For example, in benthic communities, you will find patchily distributed mollusks, polychaete worms, and amphipods in sandy, silty, or muddy sediments (Conlan et al., 2008;

Feder et al., 2007). Among the benthic biota, there are localized areas of abundant and diverse marine life where boulders provide a hard substrate for algae and epibenthic macrofauna, such as kelp, to attach (Dunton et al., 2006). The benthic communities in the Beaufort and Chukchi Seas can be categorized as: benthic microalgae (microscopic plants); macroscopic algae (large seaweeds); and benthic invertebrates (organisms that live on the bottom of a water body).

Benthic Microalgae

Benthic-microalgal assemblages, consisting primarily of diatoms, have been studied in the nearshore area off Barrow (Matheke and Horner, 1974), off Narwhal Island (Horner and Schrader, 1982), and in Stefansson Sound (Horner and Schrader, 1982; Dunton, 1984). The relationship of the species found in sediments with those found in the ice-algal assemblage is unclear, although some species occur in both assemblages. Primary productivity of the benthic microflora in the Chuckchi Sea in the nearshore area off Barrow, as reported by Matheke and Horner (1974), ranged from less than 0.5 mg $C/m^2/hr$ in winter (when the sampling area was covered with ice), to almost 57 mg $C/m^2/hr$ in August. This peak-productivity value was about eight times the peak value for ice-algal production and approximately twice that of the phytoplankton. The productivity of these various assemblages peaked at different times: ice-algal productivity peaked in May; phytoplankton productivity peaked in the first half of June; and productivity of the benthic microalgae peaked during late July and August. Although Matheke and Horner (1974) reported high productivities for benthic microalgae over the summer, Horner and Schrader (1982) and Dunton (1984) estimate that benthic microalgae contribute about 2% of the annual carbon produced in the Stefansson Sound Boulder Patch, with production in the absence of turbid ice figured at about 0.4 g $C/m^2/yr$.

Macroscopic Algae

Although most substrates in the Beaufort and Chukchi Seas are unsuitable for settlement and growth of large algae, some still persist. Hard substrates (such as cobbles and boulders) occur sporadically, allowing for larger kelp communities. The occurrence of such substrates does not always coincide with large algae since ice gouging can prevent its establishment or growth.

Kelp beds are known to fulfill many diverse habitat functions in other regions of the world's coastal oceans, such as providing three-dimensional space, protection, food, and nursery areas for juvenile life stages (Iken, 1999; Iken et al., 1997; Dean et al., 2000; Beck et al., 2003) and as such, often increase the number of associated fauna (Taylor, 1998). In the Boulder Patch, located in the central Alaskan Beaufort Sea, for example, an important portion of carbon channeling through the food web is derived from macroalgae and approximately 60% of the particulate organic matter found in the environment (Dunton and Schell, 1987; Dunton, 1984).

Kelp beds have been found in the Beaufort Sea in Stefansson Sound in the Boulder Patch and in Camden Bay. The Boulder Patch is an isolated macroalgal-dominated rocky bottom habitat within the usually soft-sediment environment of the Beaufort Sea. The Boulder Patch has been studied extensively, and more than 140 species of invertebrates have been identified including sponges, byrozoans, and hydrozoans with the dominant taxa being red and brown algae (Dunton et al., 2007; MMS 2003, 2007c). The biodiversity and community structure patterns vary among different locations within the Boulder Patch, mainly due to differences in light levels and substrate type. Light limits the growth of kelp in the winter when nutrient levels are high, and, in the summer, nutrients limit the growth when light levels are high (Dunton and Schell, 1986). Kelp also has been observed shoreward in an area behind a shoal near Konganevik Point in Camden Bay; although its spatial distribution and density are not known (MMS, 2008).

Although systematic surveys for macroscopic algae, especially kelp beds, have not been undertaken in the northeastern Chukchi Sea, records from a variety of sources indicate the presence of at least two kelp beds along the nearshore coast. One first described by Mohr et al. (1957) and confirmed by Phillips et al. (1982) is located about 12.4 mi (20 km) northeast of Peard Bay, near Skull Cliff. Another was reported by Phillips and Reiss (1985a) approximately 15.5 mi (25 km) southwest of Wainwright in water depths of 36 to 43 ft (11 to 13 m). Even without detailed surveys, it appears that kelp beds are not frequently encountered in the Chukchi Sea. Mohr et al. (1957) remarked that kelp were found at only one of 18 stations sampled by the Arctic Research Lab's LCM William E. Ripley as it traveled from Point Barrow to Wainwright; the one station where it found algae was near Skull Cliff. The predominant alga at this station was the kelp, *Phvllaria dermatodea*. Two other known algae, *Laminaria saccharina* and *Desmarestia viridis*, also were abundant; and seven species of red algae were sampled. Johnson et al. (1993) reported observing very large quantities of green algae (probably *Ulva* and *Enterornorpha*) which were being utilized as a feeding area by brant. Other macroscopic algae have been noted in Peard Bay, as drift algae and when fouling anchors (Truett, 1984). The areal extent and the inherent possibility of variability in areal extent have not been determined. However, no kelp beds are known to occur in Shell's proposed Burger prospect in the Chukchi Sea.

Benthic invertebrates

Benthic invertebrates in the Beaufort and Chukchi Seas can generally be divided into two main categories: epifauna and infauna, based on their relationship with the substrate. Infaunal organisms live within the substrate and, as a result, are often sedentary. Epifaunal organisms, on the other hand, generally live on or near the surface of the substrate (MMS, 1990). Benthic communities offshore can be quite diverse. Organisms commonly found in surveys include echinoderms, sipunculids, mollusks, polychaetes, copepods, and amphipods (Dunton et al., 2009; Rand and Logerwell, 2011).

During the 2008 summer/fall season, Shell commissioned baseline information to be collected regarding biomass and density of the benthos at 45 sites within the Sivulliq prospect. Polychaetes, mollusks, and crustaceans are the primary infaunal animals in the Beaufort Sea near the proposed Sivulliq and Torpedo drill sites (Dunton et al., 2009). Table 15 shows the number of species in groups of benthic organisms found during a study in the Sivulliq prospect. Benthos communities in the prospect areas are assumed representative of the remainder of the Beaufort Sea at depths between 95 and 164 ft (29 and 50 m) deep.

Blanchard et al. (2010) reported that infauna in Burger and Klondike survey areas, associated with the Chukchi Sea Lease Sale 193, are abundant, contain many animals with high biomass, and comprise diverse communities. They found that average abundance, biomass, and number of taxa of infauna were significantly higher in Burger than in Klondike, but macrofaunal communities in both survey areas were similarly diverse. Macrofaunal community structure was found to be correlated with environmental characteristics such as percent sand, salinity, and phaeopigment concentrations, associated with topography, water currents and other related factors within their survey areas. The Lease Sale 126 EIS (MMS, 1991) explains that the area around the Burger Prospect is inhabited by polychaete *Maldane*, brittle star *Ophiura*, sipunclid (peanut worm) *Golfingia*, and bivalve *Astarte*. Ambrose et al. (2001) found that brittle stars were overwhelmingly dominant in some parts of the northeastern Chukchi Sea.

Blanchard et al. (2010) also sampled a gray whale feeding area northwest of Wainwright and found the site to be dominated by amphipods, whereas the faunal communities found in Burger and Klondike were dominated by bivalves and polychaete worms. As with the infauna, Blanchard et al. (2010) reported that the epifaunal communities of Burger and Klondike comprise taxon groups with high abundance and biomass reflecting diverse communities. Immobile fauna such as sponges, encrusting bryozoans, hydroids, soft corals, and tube worms thrive on the rocky and macroalgal substrates (Dunton et al., 2007; Konar and Iken, 2005).

Table 15. Number of species collected from grab samples near the Sivulliq and Torpedo prospects[1].

Groups	Number of Species
Polychaete	41
Bivalve	20
Amphipod	20
Gastropod	11
Cumacea	7
Anemone	3
Bryozoan	3
Holothurian	2
Isopod	2
Nemertean	2
Anthozoan	1
Ascidean	1
Fish	1
Foraminifera	1
Hydrozoan	1
Mysid	1
Porifera	1
Priapulid	1
Sipunculid	1

[1]Source: Dunton et al., 2009

3.2.1.2 Trophic Level Interactions

In the Beaufort and Chukchi Seas, the trophic levels not only interact, but are interdependent (Figure 9). For example, it is believed that incomplete grazing of ice algae may allow a significant portion of the algal-cell population to remain intact, serving as a direct food source for the pelagic level, and if not fully consumed, may enhance the benthic level by sinking as either detritus (dead) or living, photosynthetically active, cells (Alexander and Chapman, 1981; Niebauer et al., 1981; Stoker 1981).

Dynamics within the pelagic community are mostly influenced by transport of nutrients, phytoplankton, and consumers from the Bering Sea, plus the seasonal retreat of ice and subsequent bloom of open-water phytoplankton. Other primary producers such as kelp, benthic microalgae, or ice-algae may be locally or temporally important sources of carbon (the ice algae providing a burst of production before the open-water phytoplankton bloom). Zooplankton in the Chukchi Sea are thought to be similar to those of the middle Bering Sea shelf in species composition and as small, inefficient grazers of phytoplankton. Thus, much of the local production, as well as plankton and detritus transported into the Chukchi Sea, may sink to the ocean floor and support benthic organisms. It has been suggested that the epibenthic (living on the surface of bottom sediments) community is dependent on detritus (Stoker, 1981). Both the epifauna and infauna are important components in the diets of higher-order consumers.

In the spring, the melting and retreating ice edge of the Chukchi Sea leads to a highly productive and estuary-like near shore corridor that serves as the base of the food chain for coastal and marine Arctic species. The Chukchi Sea's shallow and highly productive seafloor also allows benthic species such as crustaceans and mollusks to flourish and create an important food source for wildlife specialized to feed at the ocean floor, such as walrus, seals, gray whales, and deep-diving sea birds (Audubon, 2011).

The benthic faunal biomass is relatively high in the northeastern Chukchi, compared to the central and western Chukchi and compared to the rest of the Arctic seas (Grebmeier and Dunton, 2000). Grebmeier and Dunton (2000) explain that the richness probably is due partly to the inability of Chukchi pelagic fauna to consume all of the primary production, thereby allowing a lot of organic matter to sink to the seafloor. They refer to the situation as weak or loose trophic "coupling," and the Arctic Climate Impact Assessment (ACIA) refers to such loose coupling as "mismatch" between trophic levels (ACIA, 2005).

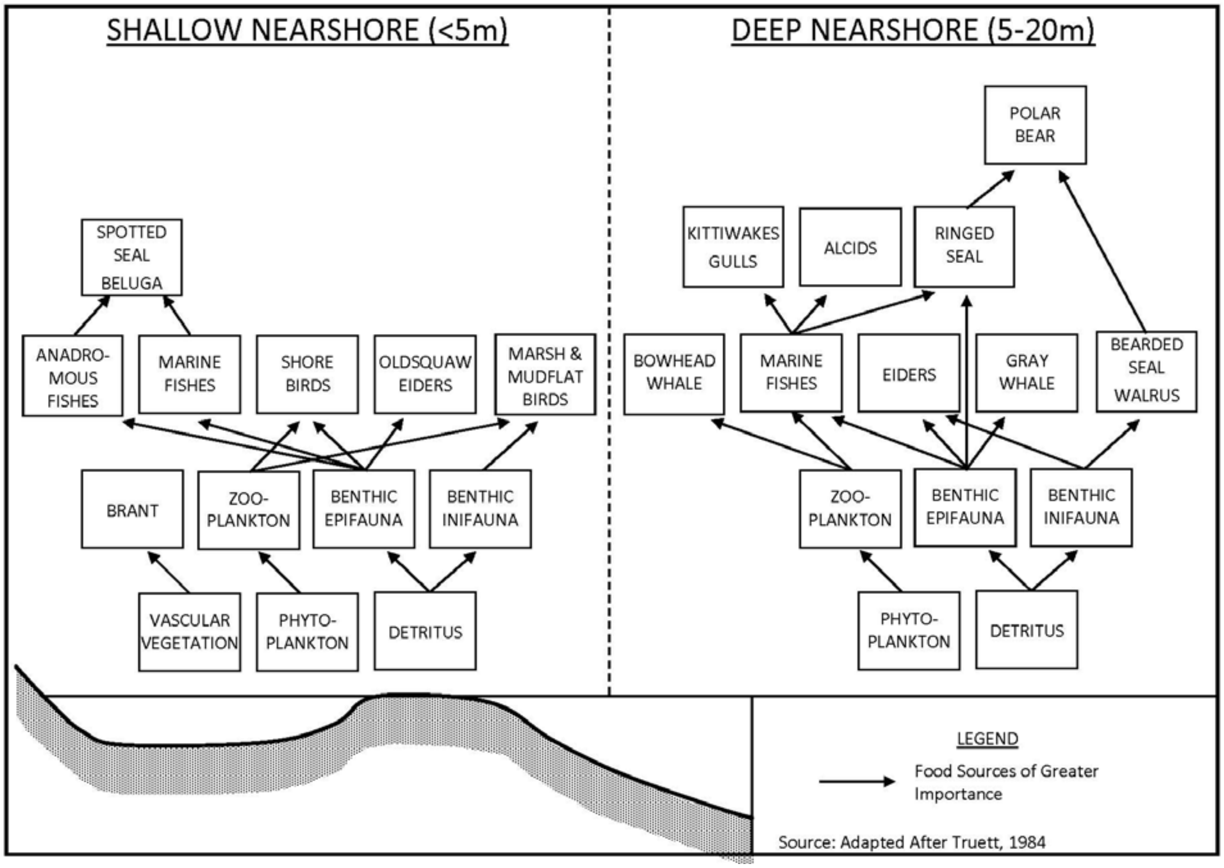

Figure 9. Simplified food web of the Arctic Ocean ecosystem.

3.2.1.3 Influence of Climate Change on Lower Trophic Level Ecology

Global climate change is altering the physical environment in the Arctic. Such changes include warming air and sea temperatures, declining sea ice extent and thickness, salinity changes, rising sea level, increasing precipitation and decreasing snow extent, loss of permafrost, and changes in terrestrial vegetation composition. These changes in the physical environment will precipitate changes on lower trophic level ecology as described here.

The Beaufort and Chukchi Seas are characterized by short, open-water summer periods and long, ice-covered winters. However, the extent of the Arctic sea ice has decreased by approximately 3% over the last decade while the extent of the summer ice has decreased up to 9% during this time period (IPCC, 2007). The 2007 summer ice extent was 39% below long term averages from 1979 to 2000, and changes such as these will likely impact the epontic community, and subsequently, the pelagic and benthic communities (MMS, 2007c).

Information on generation times, life spans, and doubling times are important in any assessment of effects on primary producers or other planktonic organisms. The doubling time for phytoplankton is short, even in the Arctic. Recent studies have shown that plankton growth rates in the Chukchi Sea range from $0.4d^{-1}$ (equivalent to a doubling in 2.5 days) to $0.16d^{-1}$ (equivalent to a doubling in 6.25 days) which results in doubling times of a few days (Grebmeier et al., 2009). In contrast, many Arctic zooplankton reproduce only once per year resulting in generation times of one year (Hopcroft et al., 2010). However, there are studies showing faster growth rates in warmer water (Feder et al., 2005). Therefore, warming ocean temperatures associated with climate change may increase zooplankton growth rates and generation times in the Beaufort and Chukchi Seas.

Atmospheric climate variation and its impact on circulation, heat, salt and nutrient content of shelf waters and sea/shore fast ice formation are central issues in the Arctic seas. It is unlikely that ecosystem change will be understood until more studies examine the Arctic Oscillation-ecosystem interactions (NRC, 2004a). Understanding the proximate and ultimate controlling factors of various trophic level standing stocks and production rates is essential for interpreting ecosystem change occurring presently in the Arctic (Aagaard et al., 1999). The impacts of climate change to the ecosystem are commonly thought to be from the bottom up through the nutrient-phytoplankton-zooplankton sequence, while human impacts are top down (Carmack and Macdonald, 2002). However, the presence of sea ice as habitat for top-level predators such as polar bears means that climate change will directly affect higher trophic levels. An added element of the ecosystem in Arctic seas is shore-fast ice and its attendant phenomena (turbulence under ice, formation of freshwater pools due to blockage of river inflow).

3.2.2 Fish and Essential Fish Habitat

Over 400 fish species are known to inhabit Arctic seas and adjacent waters, which include marine, migratory (mostly anadromous), and freshwater fish species that enter brackish water. The Alaskan Chukchi and western Beaufort Seas support at least 107 fish species, representing 25 families (Mecklenburg et al., 2002; Logerwell and Rand, 2010; Love, 2005; Harris, 1993; Johnson et al., 2010) (see Table 16). Families include lampreys, sleeper sharks, dogfish sharks, herrings, smelts, whitefish, trout and salmon, lanternfish, cods, sticklebacks, greenlings, sculpins, sailfin sculpins, fathead sculpins, poachers, lumpsuckers, snailfish, eelpouts, pricklebacks, gunnels, wolffish, sand lances, and righteye flounders. Forty-nine known species are common to both the Beaufort and Chukchi Seas. A recent study by Logerwell and Rand (2010) discovered five new species formerly unidentified in Arctic waters. Additional species are likely to be found as coastal and offshore waters become more thoroughly surveyed. A similar situation has been reported for waters of the Canadian Arctic where the most recent compilation of marine and anadromous fish has resulted in an updating of the species known to occur in this area (Coad and Reist, 2004). The list currently consists of 189 species comprised of 115 genera in 48 families. Another 83 species occur in waters adjacent to the Canadian Arctic and could be found in Canadian waters during future surveys (Coad and Reist, 2004). Still another 36 species of primarily freshwater taxa occasionally may occur in brackish marine areas (Coad and Reist, 2004).

Freshwater species inhabiting the Arctic coastal plain have been much better described than marine species (Table 16). However, while freshwater habitats and freshwater fish species are important, this section focuses on coastal and marine fish/fishery resources and habitats occurring in nearshore and offshore waters of the Beaufort and Chukchi Seas, as these are the species most likely to occur in the Draft EA proposed project areas. Because freshwater fish species will not occur in the proposed project areas, they are not discussed further in this Draft EA. Few species currently covered by fishery-management plans occur in these waters; however, an Arctic Fishery Management Plan was approved in August 2009 by the North Pacific Fisheries Management Council (NPFMC) to address Arctic fisheries issues. The NPFMC's policy as articulated in that plan is to *"prohibit commercial harvest of all fish resources of the Arctic Management Area until sufficient information is available to support the sustainable management of a commercial fishery"* (NPFMC, 2009). No timeline has been set for such a decision to be made.

Sections III.B.2, 3.2.4.1, and 3.2.4 of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011), respectively, contain additional information on the fish resources of the Beaufort and Chukchi Seas. Section 3.1.2.5 in NMFS' Final EIS for Essential Fish Habitat Identification and Conservation in Alaska (NMFS, 2005) describes EFH in the Draft EA proposed project area. A summary of that information is provided here. These sections of these four NEPA documents are incorporated into this EA by reference.

Table 16. Freshwater, migratory, and marine fish species of the Alaskan Arctic.

Order/Family	*Species Name*	Common name	Primary Assemblage[1]	Source[2]
Petromyzontiformes				
Petromyzontidae	*Lampetra tridentata*	Pacific lamprey	MI	MMT
	Lampetra camtschatica	Arctic lamprey	MI	MMT
Squaliformes				
Dalatiidae	*Somniosus pacificus*	Pacific sleeper shark	MA	MMT
Squalidae	*Squalus acanthias*	spiny dogfish	MA	MMT
Clupeoiformes				
Clupeidae	*Clupea pallasii*	Pacific herring	MA	MMT
Esociformes				
Esocidae	*Esox lucius*	northern pike	FW	
Osmeriformes				
Osmeridae	*Mallotus villosus*	capelin	MA	MMT
	Osmerus mordax	rainbow smelt	MA	MMT
Salmoniformes				
Salmonidae /Coregoninae	*Stenodus leucichthys*	inconnu	MI	MMT
	Coregonus sardinella	least cisco	MI	MMT
	Coregonus autumnalis	Arctic cisco	MI	MMT
	Coregonus laurettae	Bering cisco	MI	MMT
	Coregonus nasus	broad whitefish	MI	MMT
	Coregonus pidschian	humpback whitefish	MI	MMT
	Thymallus arcticus	Arctic grayling	FW	
Salmonidae /Salmoninae	*Salvelinus alpinus*	Arctic char	MI	MMT
	Salvelinus malma	Dolly Varden	MI	MMT
	Oncorhynchus gorbuscha	pink salmon	MI	MMT
	Oncorhynchus kisutch	coho salmon	MI	MMT

Order/Family	*Species Name*	Common name	Primary Assemblage[1]	Source[2]
	Oncorhynchus tshawytscha	Chinook salmon	MI	MMT
	Oncorhynchus keta	chum salmon	MI	MMT
	Oncorhynchus nerka	sockeye salmon	MI	MMT
Myctophiformes				
Myctophidae	*Benthosema glaciale*	glacier lanternfish	MA	MMT
Gadiformes				
Gadidae	*Boreogadus saida*	Arctic cod	MA	MMT
	Arctogadus glacialis	polar cod	MA	MMT
	Arctogadus borisovi	toothed cod	MA	MMT
	Eleginus gracilis	saffron cod	MA	MMT
	Theragra chalcogramma	walleye pollock	MA	MMT
	Gadus macrocephalus	Pacific cod	MA	LR
	Gadus ogac	ogac	MA	MMT
Lotidae	*Lota lota*	burbot	FW	
Gasterosteiformes				
Gasterosteidae	*Gasterosteus aculeatus*	threespine stickleback	FW	MMT
	Pungitius pungitius	ninespine stickleback	FW	MMT
Scorpaeniformes				
Hexagrammidae	*Hexagrammos stelleri*	whitespotted greenling	MA	MMT
Cottidae	*Triglops pingelii*	ribbed sculpin	MA	MMT
	Hemilepidotus papilio	butterfly sculpin	MA	MMT
	Hemilepidotus jordani	yellow Irish lord	MA	MMT
	Icelus spatula	spatulate sculpin	MA	MMT
	Icelus bicornis	twohorn sculpin	MA	MMT
	Gymnocanthus tricuspis	Arctic staghorn sculpin	MA	MMT
	Cottus aleuticus	coastrange sculpin	MA	MMT
	Enophrys diceraus	antlered sculpin	MA	MMT
	Megalocottus platycephalus	belligerent sculpin	MA	MMT
	Myoxocephalus quadricornis	fourhorn sculpin	MA	MMT
	Myoxocephalus scorpius	shorthorn sculpin	MA	MMT
	Myoxocephalus scorpioides	Arctic sculpin	MA	MMT
	Myoxocephalus jaok	plain sculpin	MA	MMT
	Myoxocephalus verrucosus	warty sculpin	MA	LR
	Triglops nybelini	bigeye sculpin	MA	LR
	Microcottus sellaris	brightbelly sculpin	MA	MMT
	Artediellus gomojunovi	spinyhook sculpin	MA	MMT
	Artediellus scaber	hamecon	MA	MMT

Order/Family	*Species Name*	Common name	Primary Assemblage[1]	Source[2]
	Artediellus pacificus	hookhorn sculpin	MA	MMT
	Artediellus ochotensis	Okhotsk hookear sculpin	MA	MMT
	Cottus cognatus	slimy sculpin	FW	
Hemitripteridae	*Blepsias bilobus*	crested sculpin	MA	MMT
	Nautichthys pribilovius	eyeshade sculpin	MA	MMT
Psychrolutidae	*Eurymen gyrinus*	smoothcheek sculpin	MA	MMT
	Cottunculus sadko	Sadko sculpin	MA	MMT
Agonidae	*Hypsagonus quadricornis*	fourhorn poacher	MA	MMT
	Pallasina barbata	tubenose poacher	MA	MMT
	Occella dodecaedron	Bering poacher	MA	MMT
	Leptagonus decagonus	Atlantic poacher	MA	MMT
	Podothecus veternus	veteran poacher	MA	MMT
	Ulcina olrikii	Arctic alligatorfish	MA	MMT
	Aspidophoroides monopterygius	alligatorfish	MA	MMT
Cyclopteridae	*Eumicrotremus derjugini*	leatherfin lumpsucker	MA	MMT
	Eumicrotremus andriashevi	pimpled lumpsucker	MA	MMT
Liparidae	*Liparis gibbus*	variegated snailfish	MA	MMT
	Liparis tunicatus	kelp snailfish	MA	MMT
	Liparis bristolensis	Bristol snailfish	MA	MMT
	Liparis fabricii	gelatinous seasnail	MA	MMT
	Liparis callyodon	spotted snailfish	MA	MMT
	Careproctus sp. cf. rastrinus	salmon snailfish	MA	LR
	Liparis marmoratus	festive snailfish	MA	LR
Perciformes				
Zoarcidae	*Gymnelus hemifasciatus*	halfbarred pout	MA	MMT
	Gymnelus viridis	fish doctor	MA	MMT
	Lycodes seminudus	longear eelpout	MA	MMT
	Lycodes mucosus	saddled eelpout	MA	MMT
	Lycodes turneri	estuarine eelpout	MA	MMT
	Lycodes polaris	polar eelpout	MA	MMT
	Lycodes raridens	marbled eelpout	MA	MMT
	Lycodes rossi	threespot eelpout	MA	MMT
	Lycodes sagittarius	archer eelpout	MA	MMT
	Lycodes palearis	wattled eelpout	MA	MMT
	Lycodes pallidus	pale eelpout	MA	MMT
	Lycodes squamiventer	scalebelly eelpout	MA	MMT
	Lycodes eudipleurostictus	doubleline eelpout	MA	MMT
	Lycodes concolor	ebony eelpout	MA	MMT

Order/Family	*Species Name*	Common name	Primary Assemblage[1]	Source[2]
Stichaeidae	*Eumesogrammus praecisus*	fourline snakeblenny	MA	MMT
	Stichaeus punctatus	Arctic shanny	MA	MMT
	Chirolophis snyderi	bearded warbonnet	MA	MMT
	Leptoclinus maculatus	daubed shanny	MA	MMT
	Anisarchus medius	stout eelblenny	MA	MMT
	Lumpenus fabricii	slender eelblenny	MA	MMT
Pholidae	*Pholis fasciata*	banded gunnel	MA	MMT
Anarhichadidae	*Anarhichas orientalis*	Bering wolffish	MA	MMT
Ammodytidae	*Ammodytes hexapterus*	Pacific sand lance	MA	MMT
Pleuronectiformes				
Pleuronectidae	*Hippoglossus stenolepis*	Pacific halibut	MA	MMT
	Hippoglossoides robustus	Bering flounder	MA	MMT
	Reinhardtius hippoglossoides	Greenland turbot	MA	MMT
	Platichthys stellatus	starry flounder	MA	MMT
	Pleuronectes quadrituberculatus	Alaska plaice	MA	MMT
	Pleuronectes glacialis	Arctic flounder	MA	MMT
	Limanda proboscidea	longhead dab	MA	MMT
	Limanda aspera	yellowfin sole	MA	MMT
	Limanda sakhalinensis	Sakhalin sole	MA	MMT

[1]FW = Freshwater; MI = Migratory; MA = Marine
[2]MMT = Mecklenburg et al., 2002; LR = Logerwell and Rand, 2010

3.2.2.1 Ecology of Alaskan Arctic Fish

Three LMEs encompass coastal and offshore waters of Arctic Alaska. They are the Bering Sea, Chukchi Sea, and Beaufort Sea. Each LME is characterized by distinct hydrographic regimes, submarine topographies, productivity, and trophically-dependent populations. The Chukchi Sea LME represents a transition zone between the fish assemblages of the Beaufort and Bering LMEs. Aspects of all three LMEs are discussed below because they interact and influence each other.

Aquatic systems of the Arctic undergo extended seasonal periods of frigid and harsh environmental conditions. Fish inhabiting such systems must be biologically and ecologically adapted to surviving such conditions so as to produce offspring that eventually do the same. Behavioral strategies of each life stage are evolutionarily timed to coincide with environmental conditions favoring survival to the next life stage. The process of natural selection does not favor individuals or populations that are not adapted to survive such conditions. Important environmental factors that Arctic fish must contend with include reduced light, seasonal darkness, prolonged low temperatures and ice cover, limited fauna and flora, and low seasonal productivity (see McAllister, 1975 for a description of environmental factors relative to Arctic fish).

The lack of sunlight and extensive ice cover in Arctic latitudes during winter months influence primary and secondary productivity, making food resources very scarce during this time; most of a fish's yearly food supply must be acquired during the brief Arctic summer (Craig, 1989). The Chukchi Sea is warmer, more productive, and supports a more diverse fish population than occurs in the western Beaufort Sea (Morris, 1981 as cited in Craig, 1984; Craig and Skvorc, 1982), although Arctic waters support fewer fish species than warmer waters to the south such as the Bering Sea or Gulf of Alaska.

Marine waters of the Chukchi and Beaufort Seas offer the greatest 2- and 3-dimensional area for Arctic fish to exploit; these include nearshore waters and substrates (occurring landward of the continental shelf break, as delimited by the 656-ft [200-m] isobath) and oceanic waters and substrates (occurring seaward of the continental shelf break [>656-ft, 200-m, isobath]). The diverse fish of the eastern Chukchi and western Beaufort Seas use a range of waters and substrates for spawning, breeding, feeding, or growing to maturity (MMS, 2006).

3.2.2.2 Primary Fish Assemblages

Arctic fish of Alaska are classified into primary assemblages by occurrence in basic aquatic systems and by life-history strategies that allow the fish to survive the frigid polar conditions (Craig, 1984; Craig, 1989; Moulton and George, 2000; Gallaway and Fechhelm, 2000). A life-history strategy is a set of co-adapted traits designed by natural selection to solve particular ecological problems (Stearns, 1976 as cited in Craig, 1989).

The primary assemblages of Arctic fish are:

- Freshwater fish that spend their entire life in freshwater systems (although some also might spend brief periods in nearshore brackish waters);
- Marine fish that spend their entire life in marine waters (some also spend brief periods in nearshore brackish waters along the coast); and
- Migratory fish that move between and are able to use fresh, brackish, and/or marine waters due to various biological stimuli or ecological factors.

In the last several decades, biologists have described the fish assemblages occurring in freshwater systems (Moulton and George, 2000) or nearshore brackish waters along the mainland and inner barrier island coasts (Craig, 1984, 1989; Gallaway and Fechhelm, 2000). Far fewer reports are available describing fishes in marine waters, especially those exceeding 6.6 ft (2 m) in depth (e.g., Frost and Lowry, 1983; Jarvela and Thorsteinson, 1999). Scientific information on marine fishes inhabiting waters more than approximately 12.4 mi (20 km) from the Alaskan coastline (excluding barrier islands) is limited.

3.2.2.3 Marine Fishes

Marine fish typically feed and spawn in coastal waters during winter. They spawn during mid-winter with eggs hatching in late winter. They are likely to spawn inside the barrier islands in colder zones with high salinity (November to February) (Craig, 1984; Schmidt et al., 1983). They may also use areas far offshore. A large abundance of select marine fish species were also documented over 100 mi (161 km) offshore during winter (Craig et al., 1982).

Marine fish in the region primarily feed on marine invertebrates and/or fish. They rely heavily on epibenthic and planktonic crustacea such as amphipods, mysids, isopods, and copepods. Because the feeding habits of marine fish in nearshore waters are similar to those of diadromous fish, some marine fish are believed to compete with diadromous fish for the same prey resources (Craig, 1984; Fechhelm et al., 2006). Competition is most likely to occur in the nearshore brackish water ecotone, particularly in or near river deltas. As nearshore ice thickens in winter, marine fish probably continue to feed under the ice but eventually depart the area as ice freezes to the bottom some 6.6 ft (2 m) thick. Seaward of the bottomfast ice, marine fish continue to feed and reproduce in coastal waters all winter (Craig, 1984). Many evidently spawn during winter, some in shallow coastal waters, and others in deeper waters. Arctic cod spawn under the ice between November and February (Craig and Halderson, 1981). Snailfish spawn farther offshore by attaching their adhesive eggs to rock or kelp substrate (MMS, 2008).

Fish distribution and abundance in Camden Bay can be described by the unique migration strategies employed by each species. Instinctual migration strategies of Arctic fish initiate movement to feeding and spawning locations at the optimal time specific to their species. These biological cues ultimately affect fish distribution and abundance in Camden Bay. Marine fish spend their entire life cycle in ocean waters. The more abundant marine fish species are shown in Table 17, and these species are likely to occur in Shell's proposed Sivulliq and Torpedo prospects. The most abundant marine fish species identified in Shell's Camden Bay prospects include arctic cod and fourhorn scupulin.

In February 2011, BOEMRE released a fish population study for a portion of the western Beaufort Sea titled "*Beaufort Sea Marine Fish Monitoring 2008: Pilot Survey and Test of Hypotheses*". The eastern extent of the survey area was approximately longitude 152°W, near the Cape Halkett area west of Nuiqsut, well outside the exploration drilling program area. The prospects are situated approximately 140 mi (225 km) west of the fish survey area. A similar study of the central Beaufort Sea began in summer 2011.

Table 17. Marine fish species documented within Camden Bay.

Common Name	Scientific Name
Arctic cod	*Boreogadus saida*
fourhorn sculpin	*Myoxocephalus quadricornis*
Arctic flounder	*Pleuronectes glacialis*
saffron cod	*Eleginus gracilis*
Capelin	*Mallotus villosus*

Fruge et al. 1989; Thorsteinson et al. 1992

While over 66 fish species have been documented in the Chukchi Sea (Barber et al., 1997), some species occur more frequently than others. Some of the more common species are listed below in Table 18. The distribution of marine fish species in the Chukchi Sea is driven by salinity, water depth, and percent of gravel in the sediments (Barber et al., 1997), and often shifts as seasonal changes occur. Both the number of species and fish biomass found in the northeastern Chukchi Sea are comparable to more southerly locations, but the diversity is much lower due to the predominance of arctic cod, which at many locations approaches or equals 100 percent of the fish fauna (Barber et al., 1997). The most abundant demersal fish species in the assemblages found in Shell's Burger prospect was the arctic cod; most other species were found in very low numbers. Abundant pelagic species in the northeastern Chukchi include Pacific herring and capelin (Craig, 1984). Although capelin is most abundant in nearshore waters (Craig, 1984), it is included here due to its importance as a forage species.

Table 18. Marine fish species found within the northeastern Chukchi Sea[1].

Common Name	Scientific Name
Arctic cod	*Boreogadus saida*
Saffron cod	*Eleginus gracilis*
Sculpin	*Myoxocephalus sp.*
Staghorn sculpin	*Gymnocanthis tricuspis*
Bering flounder	*Hippoglossoides robustus*
Warty sculpin	*Myoxocephalus verrucosus*
Hamecon	*Artediellus scaber*
Walleye pollock	*Theragra chalcogramma*
Ribbed sculpin	*Triglope pingeli*
Capelin	*Mallotus villosis*
Wattled eelpout	*Lycodes polearis*
Pacific herring	*Clupea harengus pallasi*
Slender eelblenny	*Lumpenus fabricii*
Canadian eelpout	*Lycodes polaris*
Eelpout	*Lycodes raridens*
Sturgeon poacher	*Podothecus acipenserinus*
Pacifc cod	*Gadus macrocephalus*
Variegated snailfish	*Liparis gibbus*
Butterfly sculpin	*Hemilepidotus papilio*
Hookear sculpin	*Artediellus sp.*

[1] Source: MMS 1990b, Morris 1981

3.2.2.4 Migratory Fish

Migratory (or diadromous) fish can move between and are able to live in fresh, brackish, and/or marine waters due to various biological stimuli such as feeding or reproduction; or ecological factors such as temperature, oxygen level, or specific spawning-habitat needs. Numerous strategies exist for the use of these different habitats, and as such, different terms are used to define those life histories. The term diadromous is considered the most inclusive category because its definition incorporates all migration types (anadromous and amphidromous) between marine and freshwaters, including single lifetime events, repetitive multiyear events, spawning migrations, feeding migrations, and seasonal movements between environments (Craig, 1989).

Anadromous fish employ a life history pattern involving single or repeated migrations between overwintering sites and coastal waters, followed by a spawning migration into freshwater at maturity. This cycle consists of three broad phases: spawning; freshwater residency (of juveniles); and anadromy (Craig, 1989). The most commonly studied anadromous fish are salmon, of which all five Pacific species are found within the U.S. Arctic Ocean. Chum and pink salmon are found in the Canning River, the closest river to Shell's proposed Camden Bay prospects (i.e., approximately 18 mi [29 km] from the proposed Sivulliq drill sites and approximately 22 mi [35 km] from the Torpedo drill sites).

Amphidromous fish migrate from freshwater to marine waters (or vice-versa) for non-reproductive purposes (Craig, 1989). In the Arctic, amphidromous species live much longer, grow much slower, and become sexually mature much later in life than Arctic anadromous fish. Unlike anadromous Pacific salmon, they do not make one far-ranging ocean migration and return years later to freshwater to spawn and die. Instead, they make many migrations between freshwater and the sea for purposes other than just spawning. Amphidromous Arctic fish spend much more time in brackish coastal waters than they do in marine waters. Additionally, they migrate to freshwater to overwinter. In fact, amphidromous fish typically have multiple migrations to freshwater before reaching spawning age. Even after reaching spawning age, spawning occurs only if their nutritional requirements were met during the brief Arctic summer. When they do spawn, they do not necessarily die; some return years later to spawn again.

Amphidromous fish inhabit many of the lakes, rivers, streams, interconnecting channels, and coastal waters of the North Slope. Common species include Arctic cisco, least cisco, Bering cisco, rainbow smelt, humpback whitefish, broad whitefish, Dolly Varden char, and inconnu. The highest concentration and diversity of amphidromous fish in the area occurs in river-delta areas, such as the Colville and the Sagavanirktok (Bendock, 1997), while the most common species found in nearshore waters are Arctic and least cisco (Craig, 1984).

With the first signs of spring breakup (typically June 5 to 20), adult migratory fish (and the juveniles of some species) move out of freshwater rivers and streams and into the brackish coastal waters nearshore (Craig, 1989). They disperse in waves parallel to shore, each wave lasting a few weeks or so. Some disperse widely from their streams of origin (e.g. Arctic cisco and some Dolly Varden char). Others, like broad and humpback whitefish and least cisco, do not; they are seldom found anywhere except for near the mainland shore (Craig, 1984).

During the 3-to-4-month open-water season that follows spring breakup, migratory fish accumulate energy reserves for overwintering, and, if sexually mature, they spawn. They prefer the nearshore brackish zone, rather than the colder, more saline waters farther offshore. While their prey is concentrated in the nearshore zone, their preference for this area is believed to be more correlated with its warmer temperature (Craig, 1989; Fechhelm et al., 1993). Migratory fish are more abundant along the mainland and island shorelines, but they also inhabit the central waters of bays and lagoons. Larger fish of the same species are more tolerant of colder water (e.g. Dolly Varden char and Arctic and least cisco) and range farther offshore (Moulton et al., 1985; Thorsteinson et al., 1991). Smaller fish are more abundant in warmer, nearshore waters and the small, freshwater streams draining into the Beaufort Sea (Hemming, 1993).

Within Camden Bay, there are seven commonly occurring migratory fish species (see Table 19), of which Arctic cisco is anticipated to be the most abundant. These species are expected to occur incidentally within Shell's proposed Sivulliq and Torpedo drill sites. Arctic cisco, broad whitefish, and Dolly Varden are important to personal use in Nuiqsut and Kaktovik. Arctic cisco is an important subsistence fish species in Nuiqsut and supports a small commercial harvest on the Colville River. In addition to Arctic cisco, broad whitefish are also an important subsistence species in Nuiqsut. Dolly Varden are targeted for subsistence primarily in Kaktovik.

Diadromous fish are not as abundant in the northeastern Chukchi Sea as they are in either the southern Chukchi Sea or the Beaufort Sea (Craig, 1984). This is likely related to the small stock of these species in the streams in the area, restricted amounts of over-wintering habitat, and cold-water barriers to coastal dispersion (Craig, 1984). Fish surveys also indicate that they are largely restricted to nearshore waters (Craig, 1984); therefore, numbers of these fish would not be expected to occur in Shell's proposed Burger drill sites. Least cisco and rainbow smelt are the principal diadromous species in the northeastern Chukchi Sea (Craig, 1984) along with pink and chum salmon. Tables 20 and 21 list common anadromous and amphidromous fish species found in the northeastern Chukchi Sea.

Table 19. Migratory fish species documented within Camden Bay, Beaufort Sea, Alaska.

Common Name	Scientific Name
Arctic cisco	*Coregonus autumnalis*
Dolly Varden	*Salvelinus malma malma*
pink salmon	*Oncorhynchus gorbuscha*
chum salmon	*Oncorhynchus keta*
broad whitefish	*Coregonus nasus*
least cisco	*Coregonus* sardinella
humpback whitefish	*Coregonus pidschian*

Fruge et al. 1989; Thorsteinson et al. 1992

Table 20. Anadrmous fish species documented in the northeastern Chukchi Sea.

Common Name	Scientific Name
Rainbow smelt	*Osmerus mordax*
Arctic lamprey	*Lampreta japonica*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytscha*
Sockeye salmon	*Oncorhynchus nerka*
Pink salmon	*Oncorhynchus gorbuscha*
Arctic char	*Salvelinus malma*
Arctic cisco	*Coregonus autumnalis*

[1] Source: MMS 1990b; Morris 1981

Table 21. Amphidromous fish species documented in the northeastern Chukchi Sea.

Common Name	Scientific Name
Bering cisco	*Coregonus laurette*
Least cisco	*Coregonus sardinella*
Broad whitefish	*Coregonus nasus*
Humpback whitefish	*Coregonus oidschian*

[1] Source: MMS 1990; Morris 1981

3.2.2.5 Influence of Climate Change on Arctic Fish

Changes in the climate of the Arctic are being documented. While climatic warming is not distributed evenly across the Arctic, the Bering, Chukchi, and Beaufort seas are clearly experiencing a warming trend (ACIA, 2005). This warming is altering the distribution and abundance of marine life in the Arctic. The better known fish resources such as capelin, arctic cod, Pacific sand lance, and Bering flounder can exhibit very large interannual fluctuations in distribution, abundance, and biomass. Climate change experienced in the past and apparently accelerating in Arctic Alaska likely is altering the distribution and abundance of their respective populations from what was known from past surveys.

Climate change can affect fish production at both the individual and population level through a variety of means (Loeng, 2005). Direct effects of temperature on the metabolism, growth, and distribution of fish occur. Food-web effects also occur through changes in lower trophic-level production or in the abundance of predators, but such effects are difficult to predict. Fish-recruitment patterns are strongly influenced by oceanographic processes such as local wind patterns and mixing and by prey availability during early life stages. Recruitment success sometimes is affected by changes in the time of spawning, fecundity rates, survival rate of larvae, and food availability (MMS, 2008). An analysis of the Arctic cisco data in the Colville Delta suggests, for example, that survival of certain age classes is reduced during summers with above average temperature and below average ice concentrations (ABR, Inc. et al., 2007).

For example, a climate shift occurred in the Bering Sea in 1977, abruptly changing from a cool to a warm period (ACIA, 2004, 2005). The warming brought about ecosystem shifts that favored herring stocks and enhanced productivity for Pacific cod, skates, flatfish, and noncrustacean invertebrates. The species composition of seafloor organisms changed from being crab dominated to a more diverse assemblage of echinoderms, sponges, and other sea life. Historically high commercial catches of Pacific salmon occurred. The walleye pollock catch, which was at low levels in the 1960s and 1970s (2 to 6 million metric tons), has increased to levels >10 million metric tons for most years since 1980 (ACIA, 2005). Additional recent climate-related impacts observed in the Bering Sea LME include significant reductions in seabird and marine mammal populations, unusual algal blooms, abnormally high water temperatures, and low harvests of salmon on their return to spawning areas. While the Bering Sea fishery has become one of the world's largest, numbers of salmon have been far below expected levels, fish have been smaller than average, and their traditional migratory patterns appear to have been altered.

Regarding the Beaufort and Chukchi Seas, the Arctic Climate Impact Assessment, published in the mid-2000s (ACIA, 2004, 2005) concluded that the southern limits of distribution for colder water species such as arctic cod, and more southerly species from the Bering Sea, are both anticipated to move northward. Adjustments by one or more fish populations often require adjustments within or among LMEs, influencing the distribution and/or abundance of competitors, prey, and predators. Consequently, it appears reasonable to believe that the composition, distribution, and abundance of fish resources in the Beaufort and Chukchi Seas are changing and are now different from that measured in the surveys conducted 16 to 18 years ago or earlier. Pacific cod, herring, walleye pollock, and some flatfish are likely to move northward and become more abundant, while capelin, arctic cod, and Greenland turbot are expected to have a restricted range and decline in abundance. Recent work supports this, with Logerwell and Rand (2010) concluding that climate change may have resulted in northward expansion of some species' ranges, including commercially valuable species such as pollock and Pacific cod. This survey was also the first to document commercial-sized opilio crab in the U.S. Arctic.

The occurrence of pink and chum salmon in Arctic waters probably is due to their relative tolerance of cold water temperatures and their predominantly marine lifecycle (Salonius, 1973 as cited in Craig and Halderson, 1986). The expansion of chinook, sockeye, and coho salmon into the Arctic appears restricted by cold water temperatures, particularly in freshwater environments (Craig and Halderson, 1986). Babaluk et al. (2000) noted that significant temperature increases in Arctic areas as a result of climate change may result in greater numbers of Pacific salmon in Arctic regions. The recent range extensions of pink, sockeye, and chum salmon in the Canadian Arctic, as described by Babaluk et al. (2000), indicate that some Pacific salmon may be expanding their distribution and abundance in the proposed Draft EA project area.

A period of warming in the region between 1990 and 2007, documented and discussed by Moulton (2010) reviewed a number of biological response by freshwater fish in the Teshekpuk Lake region to warming temperatures, mostly relating to growth and condition. Least cisco showed faster growth rates during the warmer period and lake trout distribution may be influenced by the resulting additional prey distribution.

3.2.2.6 Essential Fish Habitat

The MSFCMA includes provisions concerning the identification and conservation of EFH. The MSFCMA defines EFH as *"those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."* 16 U.S.C. § 1801(10). NMFS and regional Fishery Management Councils must describe and identify EFH in fishery management plans (FMPs), minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH. In Alaska, the NPFMC is the regional council responsible for fisheries management within the Exclusive Economic Zone (EEZ). There are six FMPs that apply to Alaskan waters, and two of these apply to Arctic waters: the *Fishery Management Plan for the Salmon Fisheries in the EEZ off the Coast of Alaska* (Salmon FMP) (NPFMC, 1990) and the *Fishery Management Plan for Fish Resources of the Arctic Management Area* (Arctic FMP) (NPFMC, 2009). The Arctic FMP was completed in 2009 and governs commercial harvests of fish resources in U.S. waters of the Beaufort Sea and Chukchi Sea (NPFMC, 2009). The Salmon FMP governs management of all salmon fisheries that occur within the EEZ, including the Arctic.

Presently, EFH has been described in the Alaskan Arctic for all five species of Pacific salmon, in addition to arctic cod, saffron cod, and opilio (snow) crab (NPFMC, 2009). The vastness of Alaska and the large number of individual fish species managed by FMPs make it challenging to describe EFH by text using static boundaries, and descriptions are therefore often vague. Further, species are likely to have EFH described in the future, as conditions and resources require and allow.

The EFH for Pacific salmon species has been described and mapped by NMFS (2005). Salmon EFH includes all those freshwater streams, lakes, ponds, wetlands, and other water bodies currently or historically accessible to salmon. Marine EFH for the salmon fisheries in Alaska includes all estuarine and marine areas used by Pacific salmon of Alaska origin, extending from the influence of tidewater and tidally submerged habitats to the limits of the EEZ. This habitat includes waters of the continental shelf (to the 656-ft [200-m] isobath). In the deeper waters of the continental slope and ocean basin, salmon occupy the upper water column, generally from the surface to a depth of about 164 ft (50 m). Chinook and chum salmon use deeper layers, generally to about 984 ft (300 m) but on occasion to 1,640 ft (500 m). A more detailed description of marine EFH for salmon found in Arctic Alaska is provided in the *Final EIS for Essential Fish Habitat Identification and Conservation in Alaska* (NMFS, 2005) and is incorporated herein by reference.

3.2.3 Marine and Coastal Birds

Although NMFS does not expect marine and coastal birds would be directly affected from the proposed action (the issuance of IHAs to Shell for the take of marine mammals incidental to conducting exploratory drilling programs in the U.S. Beaufort and Chukchi Seas), they could be indirectly affected by Shell's activities. Therefore, as part of the environmental analysis, the baseline information on marine and coastal birds that could potentially occur in the proposed project area is provided here as part of the affected environment.

Sections III.B.4 and III.B.5 of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), Section 3.2.5 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and Section 3.2.6 of BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011) contain descriptions of marine and coastal birds commonly found in the areas of Shell's proposed 2012 exploratory drilling programs in the U.S. Arctic Ocean. The information contained in those sections is incorporated herein by reference and summarized next.

Several million migratory marine and coastal birds occur in the Beaufort and Chukchi sea regions. Most occur on a seasonal basis related to the availability of open water. These birds occupy offshore and coastal marine, freshwater, and tundra habitats during the summer breeding and summer/fall migration seasons. Spring migrations into the Arctic typically occur from late March into June. Departure times during post-breeding or fall migration vary between species and also by sex within the same species. Most birds will be out of the Beaufort and Chukchi Seas by late fall, typically in September or October, to avoid the formation of sea ice (Divoky, 1987). The Beaufort and Chukchi Seas' coastal lagoons are used by substantial numbers of breeding and post-breeding migratory birds during the short Arctic summer when waters are mostly ice free. The coastal and marine birds found within Shell's proposed Camden Bay, Beaufort Sea, exploration areas are predominantly foraging seabird species, including alcids, gulls, terns, jaegers, loons, sea ducks, and possibly phalaropes. The Chukchi Sea and adjacent onshore areas are important habitat for a wide variety of birds that include a number of species of alcids, gulls, terns, jaegers, loons, waterfowl, and shorebirds. Most of the birds that use the Chukchi Sea are migrants and use the coastal areas for breeding and nesting. Spectacled and Steller's eiders are listed as threatened under the ESA. Kittlitz murrelet and yellow-billed loon are listed as candidate species under the ESA, meaning that they are being considered for listing as endangered or threatened under the ESA.

Figures 10 and 11 identify seabird colonies in 2000 along the Alaskan Beaufort and Chukchi Seas coastlines. These figures indicate that none of the colonies are located in the proposed Camden Bay or Chukchi Sea drill sites. Therefore, numbers of seabirds in the location of the active drilling operations should be lower than along the coasts.

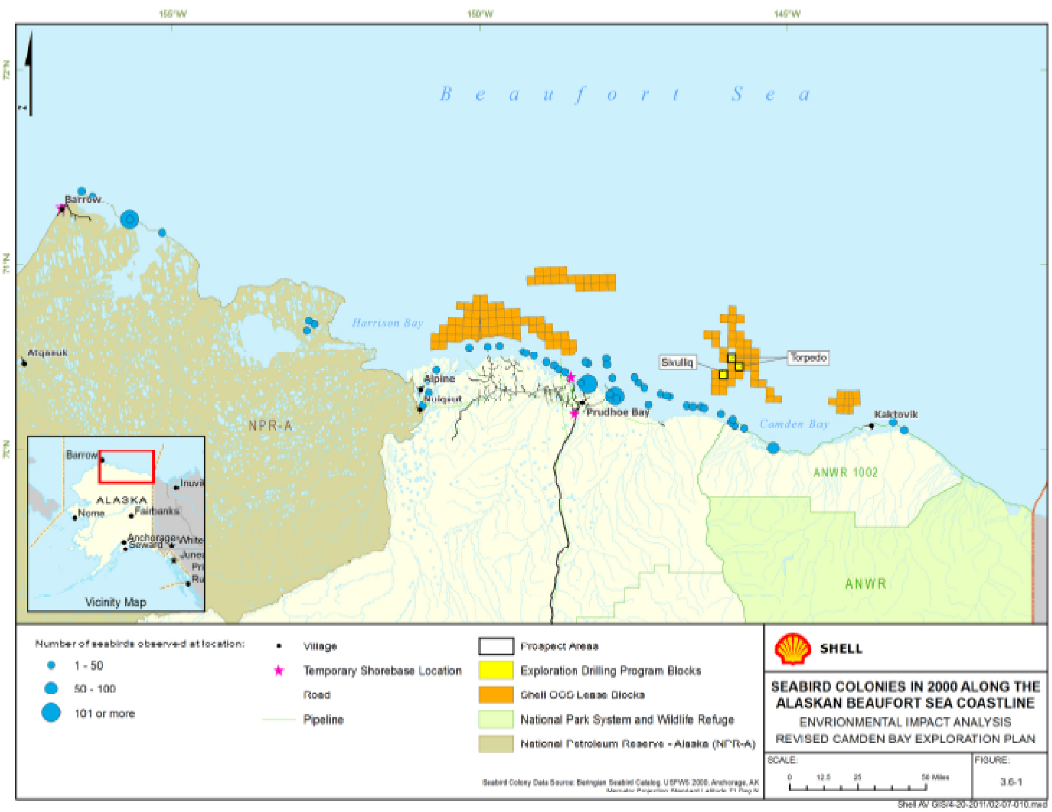

Figure 10. Seabird colonies in 2000 along the Alaskan Beaufort Sea coastline (Source: Shell, 2011c).

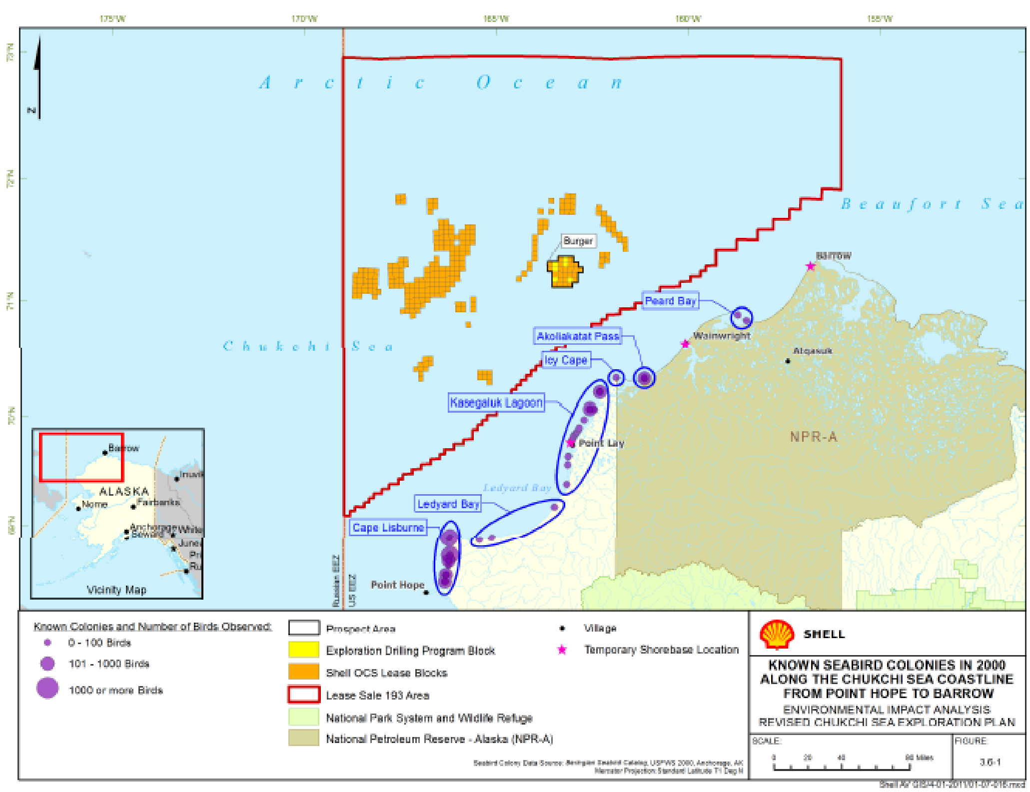

Figure 11. Known seabird colonies in 2000 along the Chukchi Sea coastline from Point Hope to Barrow (Source: Shell, 2011d).

3.2.4 Marine Mammals

Section 3.2.4 of NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011) contains descriptions of the marine mammals that may occur in the proposed project area. The descriptions include information regarding the following: species description; population status and trends; distribution, migration, and habitat use; reproduction and growth; survival and mortality; and hearing and other senses. This information is provided for the following marine mammal species: bowhead whale; humpback whale; fin whale; minke whale; gray whale; beluga whale; narwhal; killer whale; harbor porpoise; ringed seal; spotted seal; ribbon seal; bearded seal; Pacific walrus; and polar bear. There is also a discussion regarding the influence of climate change on marine mammals. That information is incorporated herein by reference and summarized next.

The Beaufort and Chukchi Seas support a diverse assemblage of marine mammals, including: bowhead, gray, beluga, killer, minke, fin, and humpback whales; harbor porpoises; ringed, ribbon, spotted, and bearded seals; narwhal; polar bears; and walruses. The bowhead, fin, and humpback whales and polar bear are listed as "endangered" under the ESA and as depleted under the MMPA. Pacific walrus is a candidate species for listing, and ringed and bearded seals are proposed for listing under the ESA. Additionally, the ribbon seal is considered a "species of concern" under the ESA. On December 13, 2011, NMFS announced initiation of a new status review to determine whether listing the ribbon seal as threatened or endangered under the ESA is warranted (76 FR 77467). Both the walrus and the polar bear are under the jurisdiction of the USFWS; all other marine mammal species are under NMFS jurisdiction. In both the Beaufort and Chukchi Seas proposed project areas, the marine mammal species that is likely to be encountered most widely (in space and time) throughout the period of the proposed drilling programs is the ringed seal. Certain species, such as the bowhead whale, are only anticipated to occur in larger numbers in the proposed drilling areas at certain times during the open-water season but not throughout the entire period of proposed operations. They are more likely to occur in the proposed project area once they begin their fall westward migration through the Beaufort and Chukchi Seas in September and October. Species such as humpback and fin whales and walrus are only anticipated in the Chukchi Sea proposed drilling area and not in the Beaufort Sea proposed drilling area.

Mysticetes (i.e., bowhead, gray, humpback, fin, and minke whales) likely hear in low frequency ranges, with an estimated auditory bandwidth of 7 Hz to 22 kHz (Southall et al., 2007). Beluga whales and narwhals are in the mid-frequency hearing group with an estimated auditory bandwidth of 150 Hz to 160 kHz (Southall et al., 2007). Average hearing thresholds of captive belugas were measured at 65 and 120.6 dB re 1 μPa at frequencies of 8 kHz and 125 Hz, respectively (Awbrey et al., 1988). They have a well-developed sense of hearing and echolocation, and are reported to have acute vision both in and out of water. Killer whales are highly vocal and use sound for social communication and to find and capture prey. The sounds include a variety of clicks, whistles, and pulsed calls (Ford, 2009). Most of the pulsed sound frequencies range from 0.5 to 25 kHz. Harbor porpoise are in the high-frequency functional hearing group, whose estimated auditory bandwidth is 200 Hz to 180 kHz (Southall et al., 2007).

The estimated auditory bandwidth of ringed, spotted, ribbon, and bearded seals and walrus is 75 Hz to 75 kHz in water and 75 Hz to 30 kHz in air (Southall et al., 2007). Seals do not echolocate; however they can hear low-frequency sounds. Call activity by ice seals varies seasonally in the Arctic. For example, bearded seals are extremely vocal during the May breeding season (Hannay et al., 2011) but typically not as much during other times of year. Therefore, sounds produced by Shell's activities should not interfere substantially with vocalizations of ice seals since the primary times for vocalizations by those species fall outside of Shell's proposed operating season. Foraging by seals is believed to integrate vision and tactile senses such that they can see in almost total darkness, having the ability to track moving prey from as far as 100+ ft (30+ m) away using their vibrissae (Schusterman et al., 2004; Riedman, 1990; Wieskotten et al., 2010; Dehnhardt et al., 2001; Schulte-Pelkum et al., 2007).

Polar bears are not known to communicate underwater. Nachtigall et al. (2007) measured the in-air hearing of three polar bears using evoked auditory potentials. Measurements were not obtainable at 1 kHz, and best sensitivity was found in the 11.2 to 22.5 kHz range. Preliminary behavioral testing of hearing indicates that they can hear down to at least 14 Hz and up to 25 kHz (Bowles pers. comm., 2008).

Climate change impacts on the Arctic are of growing concern. The impacts of climate change on marine mammals in the Arctic will likely be profound, but exactly what form these impacts will take is not easy to determine (ACIA, 2005). Direct loss of habitat for feeding, breeding, pupping, and resting is likely, as are changes in prey composition and availability. Loss of sea ice habitat and associated ecosystems will impact access to prey, prey availability, and species composition. Range expansion of sub-Arctic and temperate species into the Beaufort and Chukchi Seas has been observed in recent years and could continue with changing Arctic conditions. The occurrence of humpback whales and fin whales in the northeastern Chukchi Sea appears to be a relatively recent phenomenon (Clarke et al., 2011). Along with range expansion of the more temperate species comes the possibility for competition for resources with Arctic species (ACIA, 2005). Other risks to Arctic marine mammals induced by climate change include increased risk of infection and disease with improved growing conditions for disease vectors and from contact with non-native species, increased pollution through increased precipitation transporting river borne pollution northward, and increased human activity through shipping and offshore development (ACIA, 2005; Huntington, 2009).

3.3 Socioeconomic Environment

Economic activity, broadly defined, is a basic determinant of socioeconomic change and therefore the starting point in assessing change for the affected communities. MMS (now BOEM) EIS documents define a sociocultural system as encompassing social organization, cultural values, and institutional organization of communities (MMS, 2007b,c). The communities that are closest to Shell's proposed Camden Bay, Beaufort Sea, exploratory drilling program include Kaktovik (60 mi [96.6 km] east of the project area) and Nuiqsut (118 mi [190 km] west of the project area and about 20 mi [32 km] inland from the coast along the Colville River). Cross Island, from which Nuiqsut hunters base their bowhead whaling activities, is 47 mi (75.6 km) southwest of the project area. Wainwright (approximately 78 mi [125.5 km] from Shell's Burger prospect) is the village closest to Shell's proposed Chukchi Sea exploratory drilling program. The villages of Barrow, Point Lay, and Point Hope may also potentially be affected and are located approximately 140, 92, and 180 mi (225.3, 148, and 290 km), respectively, from Shell's Burger prospect. Barrow is also located 298 mi (479.6 km) west of

Shell's Camden Bay proposed drill sites. To a lesser extent, the villages of Kivalina and Kotzebue may potentially be impacted by the proposed activities.

3.3.1 Economy

Sections III.C.1, 3.2.9, and 3.2.11 of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011), respectively, contain descriptions of the economy in the EA project area. That information is summarized here and incorporated herein by reference.

Economic activity is measured in the form of revenues, employment, and personal income. Alaska OCS activities contribute to economic activity in the North Slope Borough (NSB), State of Alaska, and Federal government. The tax base in the NSB consists mainly of high-value property owned or leased by the oil industry in the Prudhoe Bay area. NSB oil and gas property tax revenues have exceeded $180 million annually. The State of Alaska's tax base is comprised mostly of revenues from oil and gas production. Federal revenues are generated primarily from income and payroll taxes.

The NSB is the largest employer of permanent residents in the NSB. However, very few North Slope residents have been employed by the oil and gas industry or supporting industries in and near Prudhoe Bay since production started in the 1970s. The oil and gas industry is also extremely important in the State of Alaska generally, accounting for more than 41,000 jobs, 9.4% of employment, and 11.2% of wages in the state.

3.3.2 Sociocultural Systems

Sections III.C.3, 3.2.7, and 3.2.10 of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011), respectively, contain descriptions of the sociocultural systems in the EA project area. That information is summarized here and incorporated herein by reference.

"Sociocultural systems" encompasses three organizing concepts: social organization; cultural values; and institutional organizations of communities. These concepts are interrelated. "Social organization" means how people are divided into social groups and networks. Social organization encompasses households and families but also wider networks of kinship and friends, which, in turn, are embedded in groups that are responsible for acquiring, distributing, and consuming subsistence resources. The fundamental Iñupiat social organization is kin-related groups engaged in subsistence activities.

"Cultural values" means concepts regarding what is desirable that are widely and explicitly or implicitly shared by members of a social group. The Iñupiat culture on the North Slope has strong ties to the natural environment. Cultural values, many of which are rooted in, maintained, and reinforced by the interrelatedness of social organization, include a close relationship with natural resources and an emphasis on kinship, maintenance of the community, cooperation, and sharing.

"Institutional organization" refers to the government and nongovernment entities that provide services to the community. Institutional arrangements focus primarily on the structure of borough, village, and tribal governments, and the Native regional and various village for-profit and not-for-profit corporations. But this could include extended institutional arrangements or voluntary organizations such as Search and Rescue. The government and nongovernmental organizations that make up the institutional organization of the area include the NSB, city governments, Tribal governments, Alaska Native Regional Corporations, village corporations, nonprofit corporations, and nongovernmental organizations, such as the AEWC.

3.3.3 Subsistence Resources and Uses

To the Iñupiat of northern Alaska, subsistence is more than a legal definition or means of providing food; subsistence is life. The Iñupiaq way of life is one that has developed over the course of generations upon generations. Their adaptations to the harsh arctic environment have enabled their people and culture to survive and thrive for thousands of years in a world seen by outsiders as unforgiving and inhospitable. Subsistence requires cooperation on both the family and community level. It promotes sharing and serves to maintain familial and social relationships within and between communities.

Subsistence is an essential part of local economies in the arctic, but it also plays an equally significant role in the spiritual and cultural realms for the people participating in a subsistence lifestyle (Brower, 2004). Traditional stories feature animals that are used as subsistence resources, conveying the importance of subsistence species within Iñupiaq society. These stories are used to pass information pertaining to environmental knowledge, social etiquette, and history between generations, as well as to strengthen social bonds. The Iñupiaq way of life is dependent upon and defined by subsistence.

Subsistence foods have been demonstrated to contain important vitamins and antioxidants that are better for one's health than processed foods purchased at stores. Consumption of subsistence foods can lower rates of diabetes and heart disease and may help to prevent some forms of cancer. Traditional foods in the arctic contain high levels of vitamin A, iron, zinc, copper, and essential fats; and the pursuit of subsistence resources provides exercise, time with family, and a spiritual as well as cultural connection with the land and its resources (Nobmann, 1997).

Subsistence activities in the NSB today are inextricably intertwined with a cash economy. The price of conducting subsistence activities is tied to the price of the boats, snow machines, gas, and other modern necessities required to participate in the subsistence lifestyle of Alaska's North Slope. Many people balance wage employment with seasonal subsistence activities, presenting unique challenges to traditional and cultural values regarding land use and subsistence. Some studies have indicated a correlation between higher household incomes and commitment to, and returns from, the harvesting of natural resources (NRC, 1999). Surveys conducted by the NSB reveal a majority of households continue to participate in subsistence activities and depend on subsistence resources (Shepro et al., 2003).

Quantification of subsistence resources harvested is difficult, and errors are inherent in the data. Some of the problems associated with the collection of subsistence data can be traced to individuals' willingness to share information and the difficulty of conducting subsistence surveys around peak harvest times, as well as cultural and language complexities (SRBA, 1993a; Fuller and George, 1997) . Another issue that comes up when documenting subsistence species harvested is the misidentification of species. Locals often use a colloquial term for a particular resource, which can vary between communities and can be at odds with the classifications of western science. By appearance, some fish species are so comparably similar that they are commonly mistaken for one another, including Dolly Varden, an anadromous species, and Arctic char, which is the closely related, lake-occurring species. Other species often misidentified include burbot, which are commonly referred to as lingcod; least cisco, sometimes called herring; and chum salmon, which can be mistaken for silver salmon. Some species of birds are also misidentified. White-fronted geese are confused with Canada geese, and various species of eiders, especially females, can be confused with each other (Fuller and George, 1997).

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives. The main marine mammal species that are hunted include bowhead and beluga whales, ringed, spotted, and bearded seals, walruses, and polar bears. Fish, migratory waterfowl, and caribou are also important subsistence species in the North Slope communities. The importance of each of these species varies among the communities and is largely based on availability. Table 22 provides an overview of Community Subsistence Harvest by Species Group (percent total harvest by species, total harvest, and pounds per capita). The communities conducting hunts closest to Shell's proposed Camden Bay, Beaufort Sea, drill sites are Kaktovik and Nuiqsut (the Nuiqsut community conducts hunts from Cross Island). The community conducting hunts closest to Shell's proposed Chukchi Sea drill sites is Wainwright. Barrow, Point Hope, and Point Lay also conduct hunts in the U.S. Arctic Ocean. Kivalina and Kotzebue are much farther to the south in the Chukchi Sea from Shell's proposed drill sites. However, Shell will need to transit through the Bering Strait northward through the Chukchi Sea past these communities. Therefore, all of these communities have been included in Table 22.

Summaries of subsistence harvest patterns are provided here. More detailed information can be found in Section 3.3.2 of NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011), as well as in Sections III.C.2, 3.2.8, and 3.2.9 of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011), respectively. That information is incorporated herein by reference.

Table 22. Community Subsistence Harvest by Species Group (percent total harvest by species, total harvest, and pounds per capita).

Species	Kaktovik (1992 – 1993)	Nuiqsut (1993)	Barrow (1987 – 1989)	Wainwright (1988 - 1989)	Point Lay (1987)	Point Hope (1992)	Kivalina (2007)	Kotzebue (1986)
Bowhead whale	63%	29%	38%	35%	-	6.9%	5.1%	-
Beluga whale	-	-	-	1%	64%	40.3%	3.8%	1.9%
Seals	3%	3%	6%	6%	6%	8.3%	24%	24%
Walrus	-	-	9%	27%	4%	16.4%	8.1%	1.1%
Fish	13%	34%	11%	5%	3%	9%	33%	40.5%
Polar bear	1%	-	2%	2%	<1%	-	<1%	<1%
Waterfowl	2%	2%	4%	2%	5%	2.8%	1.4%	1.3%
Caribou	11%	31%	27%	23%	16%	7.7%	18.2%	24.4%
Other terrestrial mammals and vegetation	6%	2%	3%	<1%	2%	-	3.5%	4%
Total Harvest in pounds	170,939	267,818	872,092	351,580	107,321	304,383	255,344	1,067,280
Per capita Harvest in pounds	886	742	289	751	890	487	594	398

Sources:
ADFG 1986, 1988, 1989, 1992, 1993, 2007 accessed on April 28, 2011; Braund and Kruse 2009; MMS 2008

3.3.3.1 Marine Mammals

Whales are harvested for their meat, oil, baleen, and bone. In whaling communities, a special significance is reserved for the bowhead whale. The Iñupiat people see themselves and are known by others as being whalers, and the bowhead whale is symbolic of this pursuit. Of the three communities along the Beaufort Sea coast, Barrow is the only one that currently participates in a spring bowhead whale hunt. The Chukchi Sea villages of Wainwright, Point Hope, and Point Lay also participate in spring bowhead hunts typically from April to June. From 1984-2009, bowhead harvests by the villages of Wainwright, Point Hope, and Point Lay occurred only between April 14 and June 24 and only between April 23 and June 15 in Barrow (George and Tarpley, 1986; George et al., 1987, 1988, 1990, 1992, 1995, 1998, 1999, 2000; Philo et al., 1994; Suydam et al., 1995, 1996, 1997, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010). Because Shell will not mobilize and move into the Chukchi and Beaufort Seas until early July, the spring bowhead whale hunts will not be affected.

All three of the Beaufort Sea communities participate in a fall bowhead whale hunt. In autumn, westward-migrating bowhead whales typically reach the Kaktovik and Cross Island (Nuiqsut hunters) areas by early September, at which points the hunts begin (Kaleak, 1996; Long, 1996; Galginaitis and Koski, 2002; Galginaitis and Funk, 2004, 2005; Koski et al., 2005). The hunting period starts normally in early September and may last as late as mid-October, depending mainly on ice and weather conditions and the success of the hunt. Most of the hunt occurs offshore in waters east, north, and northwest of Cross Island where bowheads migrate and not inside the barrier islands (Galginaitis, 2007). Hunters prefer to take bowheads close to shore to avoid a long tow, but Braund and Moorehead (1995) report that crews may (rarely) pursue whales as far as 50 mi (80 km) offshore. Whaling crews use Kaktovik as their home base, leaving the village and returning on a daily basis. The core whaling area is within 12 mi (19.3 km) of the village with a periphery ranging about 8 mi (13 km) farther, if necessary. The extreme limits of the Kaktovik whaling limit would be the middle of Camden Bay to the west. In recent years, the hunts at Kaktovik and Cross Island have usually ended by mid- to late September. In Barrow, the fall bowhead whale hunt typically occurs in the waters east and northeast of Point Barrow from early to mid-September to mid- to late October. Fall bowhead whaling has not typically occurred in the villages of Wainwright, Point Hope, and Point Lay. However, Wainwright whaling crews harvested one bowhead whale on October 8, 2010, and one bowhead whale on October 28, 2011. Because of changing ice conditions, there is the potential for these villages to resume a fall bowhead harvest. Additionally, residents of Point Lay have not hunted bowhead whales in the recent past, but were selected by the International Whaling Commission (IWC) to receive a bowhead whale quota in 2009, and began bowhead hunting again in 2009. In the more distant past, Point Lay hunters traveled to Barrow, Wainwright, or Point Hope to participate in the bowhead whale harvest activities. Shell's activities overlap temporally with the fall bowhead whale hunts. For the proposed Camden Bay, Beaufort Sea, exploratory drilling program, Shell has agreed to cease operations on August 25, move offsite, and return only after the close of the fall bowhead whale hunts for the communities of Kaktovik and Nuiqsut (Cross Island). Therefore, Shell's activities will not impact these two hunts. For the fall hunts at Barrow and Wainwright, Shell would be operating more than 78 and 140 mi (125.5 and 225.3 km) from Wainwright and Barrow, respectively.

Beluga whales are not a prevailing subsistence resource in the communities of Kaktovik and Nuiqsut. Data presented by Braund and Kruse (2009) indicate that only 1% of Barrow's total harvest between 1962 and 1982 was of beluga whales and that it did not account for any of the harvested animals between 1987 and 1989. There has been minimal harvest of beluga whales in Beaufort Sea villages in recent years. Additionally, if belugas are harvested, it is usually in conjunction with the fall bowhead harvest. Because Shell will cease operating in the Beaufort Sea during the fall bowhead whale hunt, hunting of beluga whales at this time would not be impacted. The Chukchi Sea communities typically hunt belugas in the spring (late March to early June) and then again in July and August. Point Lay has a well established hunt in Kasegaluk Lagoon during this time period. Beluga whales are typically hunted within 10 mi (16 km) of shore. Therefore, Shell's activities are not anticipated to overlap spatially with the summer beluga hunts. Additionally, in BOEM's lease stipulations, there is a requirement that industry operators remain outside of the Ledyard Bay Critical Habitat Unit, thereby reducing further potential impacts to the hunts in Point Lay. The spring hunts will be completed before Shell enters the Chukchi Sea.

Ringed seals are available to subsistence users in the Beaufort Sea year-round, but they are primarily hunted in the winter or spring due to the rich availability of other mammals in the summer. Bearded seals are primarily hunted during July in the Beaufort Sea; however, in 2007, bearded seals were harvested in the months of August and September at the mouth of the Colville River Delta. An annual bearded seal harvest occurs in the vicinity of Thetis Island (which is a considerable distance from Shell's proposed Camden Bay drill sites) in July through August. Approximately 20 bearded seals are harvested annually through this hunt. Spotted seals are harvested by some of the villages in the summer months. Nuiqsut hunters typically hunt spotted seals in the nearshore waters off the Colville River delta, which is more than 100 mi (161 km) from Shell's proposed Camden Bay drill sites. Although there is the potential for some temporal overlap with Shell's proposed Camden Bay activities, ice seals are typically hunted during times when Shell will not be operating in the area.

In the Chukchi Sea, seals are most often taken between May and September by Wainwright residents. Hunters typically stay within 45 mi (72 km) of the shore. Ringed and bearded seals are harvested all year by Point Lay hunters. Ringed seals are hunted 20 mi (32.2 km) north of Point Lay, as far as 25 mi (40 km) offshore. Hunters travel up to 30 mi (48 km) north of the community for bearded seals, which are concentrated in the Solivik Island area. Seals are harvested throughout most of the year by the Point Hope community, although they tend to be taken in the greatest numbers in the winter and spring months. The exception is the bearded seal hunt, which peaks later in the spring and into the summer (Fuller and George, 1997; MMS, 2007a). Species of seals harvested by Point Hope hunters include ringed, spotted, and bearded. Seals are hunted on the ice (Fuller and George, 1997). It is unlikely that sealing activities will overlap with Shell's proposed Chukchi Sea exploratory drilling program.

Walrus are harvested for their meat, hides, and ivory tusks. Most villages conduct walrus hunts during the summer (June-August); however, some communities may begin hunting for walrus as early as April or as late as September.

Polar bears are hunted for both their meat and pelts (AES, 2009). Local harvest of polar bears has declined since 1972, when the State and the Federal government passed legislation protecting polar bears. Alaska Natives are still permitted to hunt polar bears, but the sale of polar bear hides is prohibited (BLM, 2003). The villages of Point Lay, Wainwright, Barrow, Nuiqsut, and Kaktovik conduct polar bear hunts. Most villages hunt polar bears within the October through April/May timeframe. Shell's activities will not overlap with the polar bear hunts.

3.3.3.2 Birds and Waterfowl

Birds and waterfowl compose a relatively small percentage of the total annual subsistence harvest, but the harvest of birds, ducks, and geese is traditionally rooted and culturally significant. Perhaps just as important, birds are valued for their taste, and they have a special place in holiday feasts and important celebrations (MMS, 2008). Additionally, bird eggs are an important subsistence food source (BLM, 2003). NMFS' proposed action of issuing IHAs for the take of marine mammals incidental to the specified activities will not impact subsistence hunts of birds and waterfowl or the harvesting of their eggs. Therefore, this resource is not discussed further in this EA.

3.3.3.3 Fish

Fish are a substantial and significant supplemental subsistence resource for North Slope communities. More than 25 species are harvested, and the wide variety in species available for the affected communities allows for their harvest all year long (Fuller and George, 1997; Jones, 2006). The role that fishing has played in the subsistence economy has changed over time and can vary from year to year. Historically, during some years, a familiy might concentrate specifically on fishing and other years might not fish at all (SRBA, 1993a). Marine, anadromous, and freshwater species are all harvested as subsistence species.

3.3.3.4 Terrestrial Mammals

In addition to being an important food resource, caribou have traditionally been prized for their hides, which were used to make clothing. Every part of the caribou was utilized. Caribou continue to be a substantial resource in the study area, providing the majority of meat harvested from terrestrial mammals each year (Fuller and George, 1997). Other terrestrial resources are also harvested, including bear, wolf, wolverine, rabbits, Dall sheep, moose, and squirrels (Fuller and George, 1997). Small furbearing animals are used to make modern parkas, and the soft fur of the wolf or wolverine is used for the parka ruff (Irene Itta in Panikpak Edwardsen, 1993). NMFS' proposed action of issuing IHAs for the take of marine mammals incidental to the specified activities will not impact terrestrial hunts that occur on land. Therefore, this resource is not discussed further in this EA.

3.3.3.5 Influence of Climate Change on Subsistence Resources and Uses

While the potential impacts of climate change on subsistence resources and harvests are impossible to predict, Arctic residents have observed some trends that are anticipated to continue. Changes that have been observed in the Arctic by residents include: changes in thickness of sea-ice; increased snowfall; drier summers and falls; forest decline; reduced river and lake ice; permafrost degradation; increased storms and coastal erosion; cooling in the Labrador Sea (associated with increased sea-ice melt); and ozone depletion (MMS, 2008). The communities of the Beaufort and Chukchi Seas have voiced increasing concern about the potential for adverse effects on subsistence harvest patterns and subsistence resources from habitat and alterations due to the effects of global climate change. Indigenous peoples have settled in particular locations because of their proximity to important subsistence resources and dependable sources of water, shelter, and fuel. As voiced by Edna Ahmaogk at the March 9, 2010, public scoping meeting in Wainwright for NMFS' EIS on the Effects of Oil and Gas Activities in the Arctic Ocean:

> *[T]here is nowhere else in the world where people are still living as lively as we are, subsistence-wise, and we're not exploiting our natural resources as in most countries. You know, we're doing it for our living. And I don't want to lose that.*

MMS (2008) described how the indigenous communities and their traditional subsistence practices will be stressed to the extent that the following observed changes continue:

- villages and settlements are threatened by sea-ice melt, permafrost loss, and sea-level rise;
- traditional hunting locations are altered;
- traditional storage practices are altered due to melting in ice cellars;
- subsistence travel and access difficulties increase on land and on water; and
- resource patterns shift and their seasonal availability changes.

Changes in sea ice could have dramatic effects on sea mammal-migration routes which could impact the harvest patterns of coastal subsistence communities and increase the danger of hunting on sea ice (Callaway et al., 1999; Bielawski, 1997).

Subsistence hunters have already noted such changes:

> *We realize the ecosystem we are in is very healthy and productive. However, the access, due to changing patterns in ice and weather, has affected our ability to access resources. The changes aren't all bad, because in 1990 Savoonga and Gambell started harvesting bowheads in the dead of winter. As a consequence, 40 percent of our harvests are now occurring in winter (November/December timeframe). We have begun to take steps to conduct spring whaling activities earlier so we can adjust to the changes that are now occurring in migration patterns of marine mammals, specifically the bowhead whales.* - George Noongwook, AEWC Vice Chair and representing Savoonga/St Lawrence March 2011 - Open Water Meeting, Anchorage, AK.

In addition, changes in ice conditions have influenced the spring bowhead hunt in the Chukchi Sea communities. Due to worsening ice conditions that are considered to be too dangerous and difficult for captains and their crews during the spring season, whaling crews from Wainwright, Point Hope, and Point Lay have recently been conducting fall hunts to provide for their communities and meet allotted quotas (Comstock, 2011).

Social organization is underlain by subsistence in the communities of the Beaufort and Chukchi Seas. Disruption of the subsistence cycle by climate change could also change the way social groups are organized and affect rates of harvest and sharing. Widespread changes in patterns of subsistence harvest, particularly serious declines in productivity, would likely result in stresses within a community or between communities.

Populations of subsistence resources of marine and terrestrial animals could be particularly vulnerable to changes in sea ice, snow cover, and changes in habitat and food sources brought on by climate change. The thawing of permafrost and sea-ice melting will continue to threaten and change important subsistence habitats and species. The reduction of sea ice would result in the loss of habitat for marine mammals, including polar bear, ringed and bearded seals, walrus, and beluga whales.

Every community in the Arctic potentially is affected by the anticipated climactic shift (MMS, 2008). It is likely that the reduction, regulation, and/or loss of subsistence resources would have severe effects on the way of life for residents of coastal communities in the Beaufort and Chukchi Seas who depend on subsistence resources. Shore erosion in communities such as Shishmaref, Kivalina, Wainwright, Barrow, Kaktovik, the Yukon-Kuskokwim Delta in Alaska, and in Tuktoyaktuk at the mouth of the Mackenzie River in Canada has become increasingly severe in recent years, as sea-ice formation occurs later, allowing wave action from storms to cause greater damage to the shoreline and change the usage pattern of local and regional subsistence use areas (MMS, 2008).

3.3.4 Coastal and Marine Use

3.3.4.1 Shipping and Boating

Other than vessels associated with the proposed exploratory drilling programs, vessel transit in the project area is expected to be limited. The Beaufort and Chukchi Seas do not support an extensive fishing, maritime, or tourist industry between major ports. The main reason there is limited vessel movement is that the Beaufort and Chukchi Seas are ice-covered for most of the year. With the exception of research vessels, most vessels are expected to transit the Beaufort and Chukchi Seas area within 12.4 mi (20 km) off the coast. Sport fishing is not known to occur offshore in the Beaufort and Chukchi Seas, and little if any sport fishing takes place in rivers flowing into the Beaufort and Chukchi Seas. Local boating occurs in coastal areas as part of normal subsistence fishing and whaling activities for the coastal villages of Barrow, Kaktovik, Wainwright, Point Hope, and Point Lay.

During ice-free months (June–October), barges are used for supplying the local communities and the North Slope oil industry complex at Prudhoe Bay. On average, marine shipping to the villages of the NSB occurs only during these four months of the year. Usually, one large fuel barge and one supply barge visit the North Slope coastal villages per year, and one barge per year traverses the Arctic Ocean to the Canadian Beaufort Sea.

The International Maritime Organization (IMO) approved guidelines for ships operating in arctic, ice-covered waters in December 2002; and revised guidelines were drafted and approved by the IMO in late 2009 (IMO, 2010). These guidelines recognize the difficulty inherent in arctic travel, such as the lack of good charts, navigational aids, and communications systems, and extreme weather conditions. In addition, the Arctic Marine Shipping Assessment developed a set of scenarios projected from 2009 – 2050 to aid in future arctic maritime operations (Arctic Council, 2009).

With few ports and shallow, storm-driven seas, tourist vessels are still minimal in the Beaufort and Chukchi Seas. In the event, however, that vessel transit increased in the summer, the USCG is attending to more of the region and considering basing some types of response units seasonally in Kotzebue, Barrow, or Nome (Littlejohn, 2009). The port city of Nome provides safe harbor for oceangoing vessels such as bulk carriers, cruise ships, tugboats, fuel barges, and large fishing vessels. The Port of Nome hosted 234 dockings in 2008, a sharp rise from 34 dockings in 1990 (Yanchunas, 2009).

Regarding the Northwest Passage, most of the cruises stay within Canadian waters, and there is little or no cruise vessel movement expected to occur in the proposed exploratory drilling program areas in 2012. Two cruise ships, the Hanseatic and the Bremen, traveled in the Chukchi during the summer of 2009, with stops in Barrow, Point Hope, and Nome (AES, 2009).

3.3.4.2 Military Activities

The USCG has jurisdictional responsibility for the protection of the public, the environment, and U.S. economic and security interests in international waters and America's coasts, ports, and inland waterways. As a part of their commitment to protect ecologically rich and sensitive marine environments, their presence is nationwide and more recently increasing in the extreme areas like the Arctic. The USCG has conducted limited activities in the Chukchi Sea. They are planning to extend operations in northern Alaska and the Arctic region (Bonk, 2009; USCG, 2008a).

Issues with changing climate, receding ice pack, and economic activity appear to be influencing the expansion of operations north to the Arctic (NRC, 2005). Figure 12 shows the activity of the USCG *Cutter Healy* (WAGB-20) during the period 2000 – 2009 (NSF, 2009). Since 2002, the *Healy* has supported scientific research in the arctic waters off Alaska's coast. As a Coast Guard cutter, the *Healy* is also a capable platform for supporting other potential missions in the polar regions, including logistics, search and rescue, ship escort, environmental protection, and enforcement of laws and treaties. The *Healy* was also deployed in August and September 2010, to conduct a marine geophysical (seismic reflection/refraction) and bathymetric survey in the Arctic Ocean.

There is interest in international boundary claims and future international maritime Arctic shipping routes (USCG, 2008b). This would increase activities for both marine vessels and aircraft. The USCG District 17 has stated "all Coast Guard missions in southern Alaska must be expanded to northern Alaska" (USCG, 2008b). In 2007, the USCG initiated its first air mission in northern Alaska by flying from Barrow to the North Pole. This became known as the Arctic Domain Awareness mission, with planned deployment of C130 aircraft to a Forward Operation Location in Nome, Alaska, to conduct a series of cold weather tests.

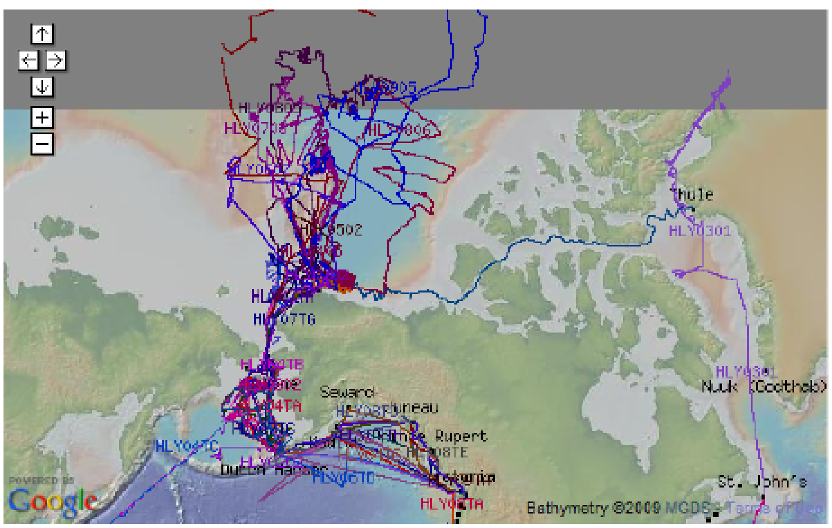

Figure 12. Cruise activity catalog of the USCG Cutter *Healy* (WAGB-20), 2000 - 2009. (Adopted from NSF (2009)).

3.3.4.3 Commercial Fishing

There is no known commercial fishing presently in the Beaufort and Chukchi Seas in the vicinity of the proposed exploratory drilling program areas. The nearest commercial fisheries are in Kotzebue Sound and include all waters from Cape Prince of Wales to Point Hope and the Colville River Delta (Gray, 2005). No regulatory authority for commercial fishing exists in the NSB. The Arctic Fishery Management Plan has been implemented since December 3, 2009 (NPFMC, 2009). This plan closes the U.S. Arctic to commercial fishing within the EEZ or that area from 3 nm (6 km) offshore the coast of Alaska to 200 nm (370 km) seaward (see Figure 13;

NPFMC, 2009). Enforcement for the area will be the responsibility of USCG and NOAA's Office of Law Enforcement. The plan does not affect arctic subsistence fishing or hunting.

Figure 13. Map showing the Arctic Management Area (Adopted from NPFMC (2009)).

3.3.5 Environmental Justice

The Environmental Justice EO requires each Federal agency to make the consideration of environmental justice part of its mission. The EO requires an evaluation in an EIS or EA as to whether the proposed project would have "disproportionately high adverse human health (i.e., community health) and environmental effects…on minority populations and low income populations." Alaska Iñupiat Natives, a recognized minority, are the predominant residents of the North Slope and the Northwest Arctic Boroughs, the area potentially affected by survey activities. The ethnic composition of Kaktovik, Nuiqsut, Barrow, Wainwright, Point Hope, Point Lay, Kivalina, and Kotzebue demonstrates that all of these communities would be classed as minority communities on the basis of their proportional American Indian and Alaskan Native membership. The Statewide population is 15.4% American Indian and Alaskan Native. On this basis, an evaluation of disproportionate impacts is required. Alaska Natives are the only minority population allowed to hunt for marine mammals in the U.S. Beaufort and Chukchi Seas region. There are not substantial numbers of "other minorities" in potentially affected Iñupiat communities. Negative effects to members of these communities could occur because OCS activities may negatively affect the subsistence resources, subsistence harvest practices, and sociocultural systems that members of North Slope and Northwest Arctic communities rely upon.

Chapter 4 ENVIRONMENTAL CONSEQUENCES

This chapter outlines the effects or impacts to the aforementioned resources in the Beaufort and Chukchi Seas from the proposed action and alternatives. Significance of those effects is determined by considering the context in which the action will occur and the intensity of the action. The context in which the action will occur includes the specific resources, ecosystem, and the human environment affected. The intensity of the action includes the type of impact (beneficial versus adverse), duration of impact (short versus long term), magnitude of impact (minor versus major), and degree of risk (high versus low level of probability of an impact occurring).

This chapter also includes a separate discussion and analysis of potential environmental impacts resulting from a large oil spill within the Draft EA project area. A large or very large oil spill is not considered part of the proposed action for any alternative because the occurrence of an oil spill is a highly unlikely event. Additionally, an oil spill is an illegal activity and would only occur accidentally. Therefore, it is not part of the specified activity for which Shell has requested IHAs from NMFS. However, if a large or very large spill were to occur, it could result in adverse impacts on the aforementioned resources. For this reason, it is discussed and analyzed separately in Section 4.5 of this Draft EA. As noted in Section 4.5, the full analysis of the potentials for and possibly impacts from large and very large oil spills are analyzed in several recent BOEM NEPA documents, which are incorporated herein by reference.

Effects include ecological, aesthetical, historical, cultural, economic, social, or health impacts, whether indirect, direct, or cumulative. The terms "effects" and "impacts" are used interchangeably in preparing these analyses. The CEQ's regulations for implementing the procedural provisions of NEPA, also state, "Effects and impacts as used in these regulations are synonymous" (40 CFR §1508.8). The terms "positive" and "beneficial", or "negative" and "adverse" are likewise used interchangeably in this analysis to indicate direction of intensity in significance determination.

The following terms are used throughout this document to discuss impacts:

- **Direct Impacts** – caused by the action and occur at the same time and place (40 CFR §1508.8). "Place" in this sense refers to the spatial dimension of impacts and generally, would be analyzed on the basis of the project area. The spatial dimension of direct impacts may not be the same for all resources, and will be defined on a resource by resource basis;
- **Indirect Impacts** – defined as effects which are "*caused by an action and are later in time or farther removed in distance but are still reasonably likely. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems*" (40 CFR §1508.8). Indirect impacts are caused by the project, but do not occur at the same time or place as the direct impacts;
- **Cumulative Impacts** – additive or interactive effects that would result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions (40 CFR §1508.7). Interactive impacts may be either countervailing – where the net cumulative impact is less than the sum of the individual impacts; or synergistic –

where the net cumulative impact is greater than the sum of the individual impacts. Direct impacts are limited to the proposed action and alternatives only, while cumulative impacts pertain to the additive or interactive effects that would result from the incremental impact of the proposed action and alternatives when added to other past, present, and reasonably foreseeable future actions; and

- **Reasonably Foreseeable Future Actions** – this term is used in concert with the CEQ definitions of indirect and cumulative impacts, but the term itself is not further defined. Most regulations that refer to "reasonably foreseeable" do not define the meaning of the words but do provide guidance on the term. For this analysis, reasonably foreseeable future actions are those that are likely (or reasonably certain) to occur, and although they may be uncertain, they are not purely speculative. Typically, they are based on documents such as existing plans and permit applications.

4.1 Effects of Alternative 1—No Action Alternative

Under the No Action Alternative, NMFS would not issue IHAs to Shell for the proposed exploratory drilling programs in the Beaufort and Chukchi Seas. Therefore, the No Action Alternative would effectively preclude Shell from engaging in drilling operations as approval of the exploration plans by BOEM is contingent upon Shell receiving IHAs from NMFS. If this alternative were selected, the impact on the environment and to Shell from not conducting the proposed exploratory drilling programs in 2012 means that:

1) Adverse impacts on marine mammals, principally bowhead whales, would not be expected as the associated noise generated by the drilling, support, and ZVSP activities that have the potential to result in Level B (behavioral) harassment would not exist;
2) Adverse impacts on the Inupiat subsistence hunts would not occur as marine mammals would not be affected and would not have cause to deflect further from shore (other than the natural variation due to heavy and low ice years);
3) Adverse impacts on the marine habitat would not occur as the drilling vessels and associated support vessels would not be conducting drilling activities within the U.S. Beaufort and Chukchi Seas; and
4) A cessation or delay in offshore drilling activities by Shell will result either in unrecoverable costs with the potential for an increased level of activity in future years in an attempt to recover costs or in the displacement of activities and potential impacts to other offshore locations.

4.2 Effects of Alternative 2

Under this alternative, NMFS would issue IHAs to Shell for the proposed exploratory drilling programs in the Beaufort and Chukchi Seas during the 2012 Arctic open-water season with required mitigation, monitoring, and reporting requirements as discussed in Chapter 5 of this Draft EA. As part of NMFS' action, the mitigation and monitoring described later in this EA would be undertaken as required by the MMPA, and, as a result, no serious injury or mortality of marine mammals is expected and correspondingly no impact on the reproductive or survival ability of affected species would occur. Potentially affected marine mammal species under NMFS' jurisdiction include: bowhead, beluga, killer, gray, minke, fin, and humpback whales; harbor porpoise; and bearded, spotted, ringed, and ribbon seals. Three of these species (i.e., bowhead, humpback, and fin whales) are listed as endangered under the ESA.

4.2.1 Effects on the Physical Environment

Although NMFS does not expect the physical environment would be directly affected from the proposed action (i.e., the issuance of IHAs for the take of marine mammals incidental to the specified activities), it could be indirectly affected by the proposed exploratory drilling programs. Therefore, the effects on the physical environment are analyzed as part of the environmental consequences analysis.

4.2.1.1 Physical Oceanography

Effects on the physical oceanography of the Draft EA project area would be minimal. The activities described under Alternative 2 would be temporary in nature and would have only a seasonal presence of extremely limited size and geographic distribution, and would not affect tides or water levels within the proposed EA project area. Effects on water depth and general circulation resulting from the activities described under Alternative 2 would be restricted to changes in bathymetry that would result from deposition of material discharged to the seafloor during the exploratory drilling programs. Certain permitted materials, including drill cuttings and drilling fluids, would be discharged to the water in the vicinity of the drilling activity. The discharged cuttings and drilling fluids would be composed of a slurry of particles with wide ranges of grain sizes and densities, ranging from liquids and neutrally-buoyant colloids to gravel (Neff, 2005). Most cuttings solids would have densities between 2.3 to 2.65 g cm^{-3}, whereas barite (a common component of drilling muds) has a density of 4.3 g cm^{-3} (Neff, 2005). As a result of the physical and chemical heterogeneity of typical drill cuttings and drilling fluids, the mixture would undergo rapid fractionation (separate into various components) as it is discharged to the ocean. The larger particles, which represent about 90% of the mass of drilling mud solids, would settle rapidly out of solution, whereas the remaining 10% of the mass of the mud solids consisting of fine-grained particles would drift with prevailing currents away from the drilling site (NRC, 1983; Neff, 2005). The fine-grained particles would disperse into the water column and settle slowly over a large area of the seafloor, whereas coarser and denser particles would be deposited on the seafloor within several hundred meters of the point of discharge, forming a mud/cuttings pile that would affect water depths near the drilling site (Figure 21) (NRC, 1983; Neff, 2005).

A working definition of a cuttings pile is taken to be "a discrete accumulation of material clearly identifiable as resulting from material discharged from drilling activities, and forming a topographic feature distinct from the surrounding seabed" (adapted from Gerrard et al., 1999). The distance traveled by discharged particles, and thus, the spatial extent and depth of the cuttings pile would depend not only upon the attributes of the discharged material but also upon the rate and duration of the discharge, the distance between the discharge point and the seafloor, lateral transport of discharged material in the water, turbulence, and local current speeds (MMS, 2002; Neff, 2005). Modeled distribution and loading of material on the seafloor following discharges of drill cuttings to offshore waters suggests that maximum loading of the seafloor from drilling waste solids would be 64 kg m^{-2}, equating to a depth of about 1.6 in (4 cm), in an area adjacent to a platform (Smith et al., 2004; Neff, 2005). However, cuttings pile heights measured in the North Sea under conditions different from those used in the model are 49 to 62 ft (15 to 19 m) for cuttings piles with volumes of 40,000 to 45,000 m^3 (251,592 to 283,041 bbl) (Gerrard et al., 1999; Koh and The, 2011). Exploratory wells are estimated to discharge about 1,000 m^3 (6290 bbl) of dry solids over the life of the well (NRC, 1983).

The overall effect of material discharged from exploration wells on water depth in the proposed action area would depend on the characteristics of the discharged material, the rate and duration of the discharge, the distance between the discharge point and the seafloor, lateral transport of discharged material in the water, turbulence, and local current speeds (MMS, 2002; Neff, 2005). Changes in water depth from discharged material would have only minor effects on the physical resource character of the proposed action area. Additionally, Shell has agreed to collect certain discharge streams and cuttings and dispose of them at an onshore facility. Therefore, impacts to the physical oceanography in the Camden Bay, Beaufort Sea, are will be reduced even further.

4.2.1.2 Sea Ice

The proposed exploratory drilling programs are anticipated to have little to no impact on sea ice. Shell has designed the programs to occur during the open-water season (i.e., July through October). However, Shell recognizes that the drilling program is located in an area that is characterized by active sea ice movement, ice scouring, and storm surges. In anticipation of potential ice hazards that may be encountered, Shell has developed and will implement an Ice Management Plan to ensure real-time ice and weather forecasting is conducted in order to identify conditions that might put operations at risk and will modify its activities accordingly. The IMP also contains ice threat classification levels depending on the time available to suspend drilling operations, secure the well, and escape from advancing hazardous ice. Real-time ice and weather forecasting will be available to operations personnel for planning purposes and to alert the fleet of impending hazardous ice and weather conditions.

As mentioned previously in this document (Section 1.5), drift ice will be actively managed by ice management vessels. Ice management for safe operation of Shell's planned exploration drilling program will occur far out in the OCS, remote from the vicinities of any routine marine vessel traffic in the Beaufort or Chukchi Seas causing no threat to public safety or services that occurs near to shore. Shell vessels will also communicate movements and activities through the 2012 North Slope Communications Centers. Management of ice by ice management vessels will occur during a drilling season predominated by open water and thus is not expected to contribute to ice hazards, such as ridging, override, or pileup in an offshore or nearshore environment.

It is anticipated that the ice management vessels will be managing ice for 38% of the time for each program. The ice floe frequency and intensity are unpredictable and could range from no ice to ice sufficiently dense that the fleet has insufficient capacity to continue operating, and the drillship would need to disconnect from its anchors and move off site. If ice is present, ice management activities may be necessary in early July and towards the end of operations in late October, but it is not expected to be needed throughout the proposed drilling season. Shell has indicated that when ice is present at the drill site, ice disturbance will be limited to the minimum needed to allow drilling to continue. First-year ice (i.e., ice that formed in the most recent autumn-winter period) will be the type most likely to be encountered. The ice management vessels will be tasked with managing the ice so that it will flow easily around and past the drillships without building up in front of or around it. This type of ice is managed by the ice management vessel continually moving back and forth across the drift line, directly up-drift of the drillship and making turns at both ends. During ice management, the vessel's propeller is rotating at approximately 15-20% of the vessel's propeller rotation capacity. Ice management occurs with slow movements of the vessel using lower power and therefore slower propeller rotation speed (i.e., lower cavitation), allowing for fewer repositions of the vessel, thereby reducing cavitation effects in the water. Occasionally, there may be multi-year ice (i.e., ice that has survived at least one summer melt season) ridges that would be managed at a much slower speed than that used to manage first-year ice. Such activities are not anticipated to reduce sea ice or impact its formation.

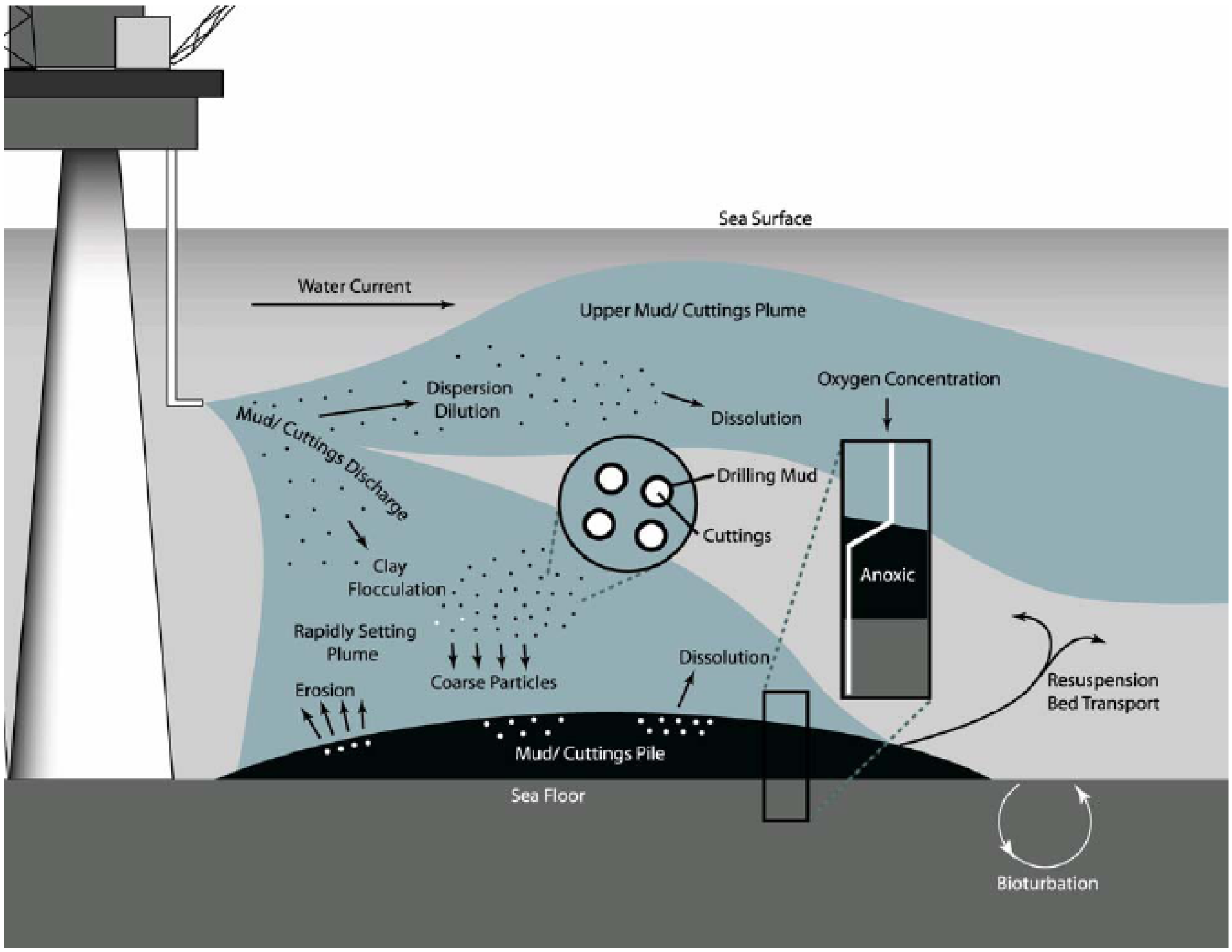

Figure 14. Dispersion and fate of water-based drill cuttings and drilling fluids discharged to the ocean. About 90% of the discharged solids settle rapidly and form a mud/cuttings pile within several hundred meters of the point of discharge. This mud/cuttings pile would affect water depths near the drilling activity. The remaining 10% of the discharged solids remain suspended and drift with prevailing currents away from the drilling site. (Source: Neff, 2005)

During exploration drilling operations, Shell has indicated that they do not intend to conduct any icebreaking activities; rather, Shell would deploy its support vessels to manage ice as described here. As detailed in Shell's IMP (Shell, 2011a,b), actual breaking of ice would occur only in the unlikely event that ice conditions in the immediate vicinity of operations create a safety hazard for the drilling vessel. In such a circumstance, operations personnel will follow the guidelines established in the IMP to evaluate ice conditions and make the formal designation of a hazardous, ice alert condition, which would trigger the procedures that govern any actual icebreaking operations. Historical data relative to ice conditions in the Beaufort and Chukchi

Seas in the vicinity of Shell's planned operations, and during the timeframe for those operations, establish that there is a very low probability (e.g., minimal) for the type of hazardous ice conditions that might necessitate icebreaking (e.g., records of the National Naval Ice Center archives). This probability could be greater at the shoulders of the drilling season (early July or late October); therefore, for purposes of evaluating possible impacts of the planned activities, Shell has assumed limited icebreaking activities for a very limited period of time. If icebreaking activities are necessary, the impacts to sea ice formation would be minimal.

4.2.1.3 Air Quality

The condition of local air quality could be affected by the introduction of additional emissions from the drillships and associated support vessels and aircraft. While NMFS' proposed action would not impact air quality, the drillships and vessels proposed for use by Shell would emit pollutants into the air. Section 4.2.1 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b) contains an analysis of the direct and indirect impacts of Shell's exploratory drilling program on the Camden Bay environment. BOEMRE's EA includes analysis of both the *Kulluk* and the *Discoverer*, as either drillship could be used in the Beaufort Sea. Only the *Discoverer* is contemplated for use by Shell in the Chukchi Sea. That information is summarized next and incorporated herein by reference.

The EPA also conducted analyses on the use of the *Kulluk* in the Beaufort Sea and the use of the *Discoverer* in both the Beaufort and Chukchi Seas. Information contained in the following reports is summarized here and incorporated herein by reference:

- Technical Support Document Review of Shell's Supplemental Air Quality Impact Analysis for the Discoverer OCS Permit Applications in the Beaufort and Chukchi Seas;
- Supplemental Statement of Basis for Proposed Outer Continental Shelf Prevention of Significant Deterioration Permits Noble Discoverer Drillship; and
- Technical Support Document Review of Shell's Ambient Air Quality Impact Analysis for the Kulluk OCS Permit Application Permit No. R10OCS030000.

Shell prepared an emission inventory, which included the use of Best Available Control Technology (BACT) and owner-requested restrictions (ORR) to lower emissions, particularly emissions of nitrogen oxides and carbon monoxide from drilling operations. The total projected annual emissions from the *Kulluk* and the *Discoverer* are given in Tables 10 and 11, respectively, in BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b). Values provided in those tables represent emissions after the application of reduction strategies, such as, BACT and other ORR. For the drillship *Kulluk*, emissions of NO_X, and CO, and SO_2 were greater than the threshold of 250 tons per year before application of the reduction strategies but were reduced to less than 250 tons per year when the emission reduction strategies were applied, defining the *Kulluk* as a minor source. Emissions of NO_X for the *Discoverer* remained above the threshold even after emission reduction strategies were applied, defining the *Discoverer* as a major source. Using either the *Kulluk* or *Discoverer* would not cause emissions that would result in pollutant concentrations that would equal or exceed the NAAQS or the AAAQS. Emissions of black carbon would be reduced to the greatest extent possible. Movement of the drillship will decrease short-term impacts of all pollutants, especially in the near-field where high modeled concentrations occur, if averaging were performed over multiple years. The assumption of a fixed drilling location for the entire 120 day OCS period produces a conservative analysis (i.e., the predicted modeled impacts are larger than what would likely be realized with a moving ship with averaging over a longer period of time). Modeled impacts generally decrease as the distance from the 1,640 ft (500 m) assumed ambient air boundary increases, and on average there is a rapid decrease in concentrations as the distance from the *Kulluk* or *Discoverer* increases. Modeled impacts at all onshore locations are well below the NAAQS. The proposed action is not anticipated to have more than a minor impact on air quality in the Draft EA project area.

4.2.1.4 Acoustic Environment

Potential effects on the marine acoustic environment within the Draft EA project area from Shell's proposed 2012 exploratory drilling programs in the Beaufort and Chukchi Seas include sound generated by the drillship, support vessels, and the ZVSP airgun. Sections 1.5.1.3 and 1.5.2.3 in this Draft EA describe the sound characteristics of the sources proposed to be used during Shell's programs. The drillships and support vessels emit low-level continuous sound into the marine environment. The airgun to be used for short periods of time (i.e., a maximum of 28 hours in the Beaufort Sea and a maximum of 56 hours in the Chukchi Sea) for the ZVSP surveys would emit impulse sounds into the marine environment. These sounds are anticipated to be more intense than those produced by the drillships or support vessels. However, these effects are expected to be localized to the project areas and temporary, occurring only during active operations.

As discussed in Section 3.1.4, the ambient noise environment in the Arctic is complex and variable due to the seasonal changes in ice cover and sea state. Much research has been conducted in characterizing ambient noise in relation to sea ice coverage in the Arctic (e.g., Milne and Ganton, 1964; Diachok and Winoker, 1974; Lewis and Denner, 1987, 1988), however, none of these studies provide the broadband ambient noise levels in time and space that can be used in comparison to the broadband received noise levels from the proposed activities. Nevertheless, frequency band specific analysis showed that ambient levels reach to about 90 dB re 1 μPa at certain 1/3-octave band under 100 Hz near the ice edge (Diachok and Winoker 1974; Lewis and Denner 1987, 1988). Therefore, it is possible that at certain times and/or locations, such as near the ice margins or in open ocean with high sea state, natural ambient noise levels in the Arctic could reach or exceed 120 dB re 1 μPa, although the extent of these situations is unknown. The sounds introduced by Shell's activities are not anticipated to have a significant effect on the acoustic environment of the arctic.

Source levels from the drillship, support vessels, and the ZVSP airgun would be empirically measured before the start of operations (see mitigation measures in Chapter 5 of this Draft EA).

4.2.1.5 Water Quality

Impacts to water quality are possible from vessel mooring, mudline cellar (MLC) construction, discharge of drill cuttings, mud, and other permitted discharges, and from small fuel spills (<1,000 bbl) during fuel transfers. (Potential impacts from a very large oil spill are discussed later in this document in Section 4.5). While NMFS' proposed action is not anticipated to have impacts on water quality, Shell's activities could potentially impact water quality in the project area.

The exploratory drilling proposed in Camden Bay and the Chukchi Sea would be conducted under NPDES General Permit AK280000 (Offshore Oil and Gas Exploration Facilities in Alaska) as authorized by EPA. The type and degree of effects on water quality from discharges into the marine environment are influenced by several physical factors including: rate of discharge; depth of discharge; concentration of contaminants; currents; bathymetry; density layers; oxygen concentration; and water temperature. These factors would be considered by EPA under its NPDES permitting process.

There is a possibility of some seafloor disturbance or temporary increased turbidity in the seabed sediments during anchoring and excavation of the MLCs. The amount and duration of disturbed or turbid conditions will depend on sediment material and consolidation of specific activity. Placement and retrieval of the anchors will disturb seafloor sediments and some sediment will be resuspended in the water column during these operations. These increased sediment loads would be restricted to a very small area and would be expected to remain suspended for a very short time. Any such impacts to water quality would be negligible and temporary lasting only minutes to a few hours at most after the activity is complete.

In the Beaufort Sea, Shell proposes to drill two wells per season. For the *Kulluk*, construction of each MLC, 36-in (91.4-cm) hole section and 26-in (66-cm) hole section would result in a range of displaced material from approximately 5,184 bbl (824 m^3) for Sivulliq G to 5,335 bbl (848 m^3) for Torpedo J. For the *Discoverer*, the range of displaced volume of material ranges from 3,851 bbl (612 m^3) for Sivulliq G to 4,002 bbl (636 m^3) for Torpedo J. The larger displaced volume for the *Kulluk* is due to the larger diameter MLC construction in using the *Kulluk*. These sediments would be discharged to the seafloor. A portion of the sediments would be suspended in the water column, resulting in a temporary plume with increased total suspended solids (TSS), turbidity, and biochemical oxygen demand (BOD). In the Chukchi Sea, Shell proposes to drill three wells and a partial fourth well during the open-water season. Each well will generate about 4,100 bbl (652 m^3) of cuttings from the MLC and two upper well sections. Seawater will be used to drill these upper hole sections. These sediments totaling approximately 24,700 bbl (3,927 m^3) will be discharged on the surface of the seafloor and a portion of the sediments would be suspended in the water column resulting in a plume with increased TSS, turbidity, and BOD. Mooring would displace about 120,124 bbl (19,098 m^3) and would result in some additional suspension of solids in the water column. TSS loading in the plume is expected to be less than 1,000 ppm and could be less than 300 ppm (LaSalle et al., 1991). Previous construction work in the Beaufort Sea resulted in incremental TSS loads of 200-600 ppm (Slaney, 1977; Envirocon, 1977), but these loads were reduced to 14-100 ppm within about 1,640 ft (500 m) from the discharge point. Water quality effects of MLC construction and drilling the 36-in (91.4-cm) and 26-in (66-cm) diameter hole sections in the Beaufort will be localized and temporary, lasting only about as long as the MLC construction is ongoing.

The release of drill cuttings and drilling muds associated with exploratory drilling activity would also result in increased turbidity and concentrations of total suspended solids in the water column. Drill cuttings and water-based drilling fluids are comprised of a slurry of particles with a wide range of grain sizes and densities, and various fluid additives may be water soluble, colloidal, or particulate in nature (Neff, 1981; Neff, 2005). Drill cuttings are particles of sediment and rock extracted from the bore hole as the drill bit penetrates the earth. Water-based drilling fluids consist of water mixed with a weighting agent (usually barium sulfate [$BaSO_4$]) and various additives to modify the properties of the mud (Neff, 2005).

As a result of the physical and chemical heterogeneity of typical drill cuttings and drilling fluids, the mixture would undergo fractionation (separate into various components) as it is discharged to the ocean. The larger particles, which represent about 90% of the mass of drilling mud solids, would settle rapidly out of solution, whereas the remaining 10% of the mass of the mud solids consists of fine-grained particles that would drift with prevailing currents away from the drilling site (NRC, 1983; Neff, 2005). The fine-grained particles would disperse into the water column and settle slowly over a large area of the seafloor. Models, lab-scale simulations, and field studies suggest that discharged drilling muds and cuttings would be rapidly diluted to very low concentrations, and that suspended particulate matter concentrations would drop below effluent limitation guidelines within several meters of the discharge (Nedwed et al., 2004; Smith et al., 2004; Neff, 2005). In well-mixed waters, particles discharged to the ocean from drilling activities are typically diluted by 100-fold within 33 ft (10 m) of the discharge and by 1,000-fold after a transport time of about 10 minutes at a distance of about 328 ft (100 m) from the platform (Neff, 2005). Therefore, effects on water quality resulting from turbidity from discharged drill cuttings and drilling fluids are expected to be temporary, localized to the vicinity of the discharge.

Discharge of drill cuttings and drilling fluids from exploratory drilling programs could result in elevated levels of metals in the water (Neff, 1981; NRC, 1983). Chromium, copper, mercury, lead, and zinc are the metals of greatest concern resulting from the discharge of drill cuttings and drilling fluids (Neff, 1981). Arsenic, nickel, vanadium, and manganese may also be present at elevated concentrations in some drill cuttings and drilling fluids. Barium, as $BaSO_4$, is usually present at high concentrations in drilling fluids, but due to its low solubility in seawater and low reactivity, barium sulfate would settle to the seafloor as it is discharged, and would not be expected to have any effects on water quality (DHHS, 2007). Some metals are present in additives that may be mixed with the drilling mud to improve the physical and chemical properties of the mud, while other metals may be contaminants of major mud ingredients or may be present in drill cuttings (Neff, 1981). Additives such as drill pipe dope, which contains 15% copper and seven percent lead, and drill collar dope, which can contain 35% zinc, 20% lead, and seven percent copper, may also contribute trace metals to discharges of drill cuttings and drilling fluids (EPA, 2006). Lignosulfonate compounds that are commonly added to drilling fluids as deflocculants and thinners are another source of metals in discharges from exploratory drilling programs. A detailed discussion related to the environmental distribution of trace metals from exploratory drilling activities is available in the *Final Ocean Discharge Criteria Evaluation of the Arctic NPDES General Permit for Oil and Gas Exploration (Permit No.: AKG280000). Expired: 26 June 2011* (EPA, 2006), and is incorporated here by reference.

Most of the discharged drill cuttings and drilling fluids would rapidly sink to the bottom near the discharge location (Neff, 2005). The actual distance traveled by the discharge would depend on the water depth, lateral transport, particle size and the density of the discharged material (NRC, 2003). A smaller fraction of the discharge plume, consisting of soluble components and fine-grained particles, is likely to remain in the water column longer, and may be transported considerable distances from the discharge site. Depending on the composition of the discharged drill cuttings and drilling fluids, as well as the rate of discharge, lateral transport, and dilution rates, concentrations of soluble metals may exceed EPA marine water quality criteria for dissolved metals within a small area around the site of discharge. Effects on water quality would be local and would generally be restricted to the areas within 328 ft (100 m) of the activity (NRC, 1983; Neff, 2005).

Indirect effects could result from resuspension of deposited sediments with elevated concentrations of trace metals. Metals from resuspended sediments could contribute to elevated concentrations of metals dissolved in the water. The magnitude of effects on water quality resulting from elevation of metal concentrations would depend on the composition of the sediments, concentrations of certain metal ions in the water column, and the uses of the affected water. Concentrations of certain dissolved metals above the established threshold values would result in adverse effects on water quality within the proposed EA project area (EPA, 2009). These effects could occur indirectly (i.e. at a later time than the proposed action) if deposited sediments with elevated concentrations of soluble metals were resuspended by tides, waves, or other natural or unnatural events. The magnitude of such indirect effects on water quality would depend on the composition of the deposited sediments, as well as other factors. Based on analysis of sediments discharged from oil and gas operations (NRC, 1983) and chemical assessment of sediments in the Sivulliq prospect around Hammerhead drillsite (Trefry and Trocine, 2009), concentrations of metals dissolved from resuspended sediments are unlikely to exceed the EPA Water Quality Criteria (EPA, 2009). If such indirect effects were to occur, the effects on water quality in the proposed project area under Alternative 2 are expected to be of low intensity and temporary and local in nature.

Non-contact cooling water is comprised of seawater that would be pumped continuously to provide cooling for certain pieces of machinery associated with exploratory drilling activities. Heat transferred from the machinery to the water is expected to raise the temperature of the seawater in the system by about 1º Celsius (MMS, 2002). Chlorine, as calcium hypochlorite, or a similar biocide, would be added to the non-contact cooling water to reduce biofouling and would contribute to the overall salinity of the waste stream. Before discharge, water from the cooling system would generally be mixed with other discharges. After mixing, sodium metabisulfate may be added to the effluent to reduce total residual chlorine concentration to comply with regulatory limits (MMS, 2002; EPA, 2006). Discharged waters would be slightly warmer and would contain higher concentrations of dissolved salts relative to the ambient waters of the Beaufort and Chukchi Seas. Therefore, discharged waters would increase the temperature and salinity of the seawater in the immediate vicinity of the discharge.

For the Camden Bay proposed exploration drilling program, Shell has committed to not discharge various waste streams during routine drilling operations. Shell has agreed to not discharge any of the following liquid waste streams that are generated by the drilling vessel: treated sanitary waste (black water); domestic waste (gray water); bilge water; or ballast water. Shell will not discharge drilling mud or cuttings that are generated below the depth at which the 20-in. (51-cm) diameter casing is set in each well. The mud and cuttings collected will be transferred to an OSV then to the deck or waste barge. Either barge will hold collected mud, cuttings, and wastewater for transport and disposal at an approved and licensed onshore facility.

Because Shell has agreed to these measures as part of its Camden Bay exploratory drilling program, impacts to water quality in the EA project area will be reduced even further. Shell has not agreed to make this part of the Chukchi Sea exploratory drilling program. However, for the reasons described here, impacts to water quality would be temporary and localized.

There is a potential for fuel spills during fuel transfers. A fuel spill would introduce hydrocarbons and temporary toxicity effects to the surface water. The effects of a fuel spill would be limited by required deployment of booming equipment during fuel transfers and automatic shutdown of fuel lines triggered by decreased pressure. Additional information is described and analyzed in Section 4.2.2.1 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b) and Section 4.2.2 of BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011). That information is incorporated herein by reference.

Aircraft traffic and sound generation in the water would have no effects on water quality in the EA project area. Overall, impacts to water quality in the Draft EA proposed project area are anticipated to be low given the fact that turbidity will only be increased for a short period of time in close proximity to the actual activities and discharged waste streams would be diluted within close proximity to the vessel.

4.2.2 Effects on the Biological Environment

4.2.2.1 Effects on Lower Trophic Organisms

Direct and indirect effects on the lower trophic resources include the sediments displaced during anchoring of drilling rigs, construction of the MLC, and early drilling phases, permitted water discharges through the EPA NPDES permit, potential of invasive species introduction, and potential liquid hydrocarbon spills. Although the effects on lower trophic populations include past and future deposition of mercury, barium, and hydrogen sulfide on surface sediments due to sediment disruption, problems with the mechanical turbation of benthic environments due to ice gouging and ice melt, or a paucity of life cycle information on many invertebrate species (USGS, 2011), these factors would not be a factor during the time period analyzed within this analysis. There are no known sensitive or unique biological communities in the vicinity of the proposed exploration drill sites in the Beaufort and Chukchi Seas that would be affected by these activities.

Vessel mooring and MLC construction would result in increased suspended sediment in the water column that could result in lethal effects on some phytoplankton and zooplankton by reducing the amount of light that can penetrate into the water column. However, compared to the overall population of phytoplankton and zooplankton and the localized nature of effects, any mortality that may occur would not be considered significant. Due to fast regeneration periods of such organisms, populations are expected to recover quickly.

Many species of benthic organisms are sedentary and have little or no mobility and are therefore sensitive to habitat disturbance. Benthic organisms within the area directly affected by MLC excavation and anchor mooring would likely be killed due to the weight and force of the anchors and MLC drill bit or subsequent displacement. Deposition of the re-suspended sediments to depths of 1 in (2.5 cm) or more may also smother and kill benthic organisms in the area near the MLC. For the Burger prospect in the Chukchi Sea, modeling indicates that the benthic organisms within an additional 1.6 acres (38,892 m^2) of seafloor adjacent to the directly disturbed area at each drill site totaling 9.6 ac (38,850 m^2) for up to six wells, would be indirectly affected by re-deposition of the approximately 4,100 bbl (652 m^3) of sediments and cuttings re-suspended during construction of each MLC and drilling of the upper well sections (Shell, 2011d). In the Beaufort Sea, using the *Kulluk*, construction of each MLC will directly disturb an approximate area of 452 ft^2 (42 m^2) on the seafloor, and using the *Discoverer* an approximate area of 314 ft^2 (29.2 m^2) would be disturbed (Shell, 2011c). This area is quite small relative to the sizes of the Beaufort and Chukchi Seas where these organisms reside. Additionally, there are no sensitive benthic communities at the Burger, Sivulliq, or Torpedo prospects. Seafloor severely disturbed by ice gouging in the high Arctic have been found to be largely re-colonized within eight to nine years (MMS, 2007b).

The generation of sound from the drillship, during ice management/icebreaking, or the airguns could have some direct impacts on phytoplankton, zooplankton, and benthic organisms. Studies of sound energy produced by seismic operations at distances greater than 3 ft (0.9 m) concluded that such sound energy had no effect on phytoplankton (Kosheleva, 1992 as cited in Turnpenny and Nedwell, 1994). The sound energy resulting from the drillship and associated ice management/icebreaking activities will be at lower levels than the sound energy produced by seismic survey sound sources. Therefore, sound energy resulting from the drilling operations and associated ice management/icebreaking activities are not anticipated to have adverse impacts on phytoplankton.

Reactions of zooplankton to sound are, for the most part, not known. Their ability to move significant distances is limited or nil, depending on the type of zooplankton. Behavior of zooplankters is not expected to be affected by the exploratory drilling activities. These animals have exoskeletons and no air bladders. Many crustaceans can make sounds, and some crustacea and other invertebrates have some type of sound receptor. A reaction by zooplankton to sounds produced by the exploratory drilling program would only be relevant to whales if it caused concentrations of zooplankton to scatter. Pressure changes of sufficient magnitude to cause that type of reaction would probably occur only very close to the sound source, if any would occur at all due to the low energy sounds produced by the drillship. 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 Shell's proposed operations is insignificant as compared to the naturally occurring reproductive and mortality rates of these species. This is consistent with previous conclusions that crustaceans are not particularly sensitive to sound produced by seismic sounds (Wiese, 1996). Impact from sound energy generated by an icebreaker, other marine vessels, and drillships would have less impact, as these activities produce lower sound energy levels (Burns et al., 1993). Historical sound propagation studies performed on the *Kulluk* by Hall et al. (1994) also indicate the *Kulluk* and similar drilling vessels would have lower sound energy output than 3-D seismic sound sources (Burns et al., 1993). The *Discoverer* will emit sounds at a lower level than the *Kulluk,* and, therefore, the impacts due to drilling sounds would be even lower than the *Kulluk*. Therefore, zooplankton organisms would not likely be affected by sound energy levels by the vessels to be used during Shell's proposed exploration drilling activities.

Again, because of the lower levels of sound produced during drilling operations, impacts are not anticipated to the benthos in the proposed drilling areas. Bodies of marine invertebrates are generally the same density as the surrounding water so that sudden changes in pressure, such as that caused by sudden loud sound, are unlikely to cause physical damage. Some research has been done evaluating potential effects of sound energy generated by larger airguns associated with seismic surveys on marine invertebrates (e.g. crabs and bivalves) and other marine organisms (e.g. sea sponges and polychaetes). Studies on brown shrimp in the Wadden Sea (Webb and Kempf, 1998) have revealed no particular sensitivity to sounds generated by airguns used in seismic activities with sound levels of 190 dB at 3.3 ft (1 m) in water depths of 6.6 ft (2 m). According to reviews by Thomson and Davis (2001) and Moriyasu et al. (2004), seismic survey sound pulses have limited effect on benthic invertebrates, and observed effects are typically restricted to animals within a few meters of the sound source. A recent Canadian government review of the impacts of seismic sound on invertebrates and other organisms (CDFO, 2004) 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 sublethal effects (e.g. reduced growth, behavioral changes) were noted (CDFO, 2004). However, no adverse impact on planktonic or benthic populations would be expected due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations.

Vessel and aircraft transits will not have any direct or indirect impacts on lower level trophic organisms. If a small oil spill were to occur, there could be lethal effects to planktonic and benthic organisms. The effects of a small spill on lower trophic level organisms are dependent upon seasonality, duration, and weather conditions during and following the event. Shell has implemented several procedures to reduce the potential for such spills from occurring. That information is described in detail in the exploration plans (Shell, 2011c,d). That information and the analysis of impacts from a small liquid hydrocarbon spill are hereby incorporated by reference.

For its Camden Bay, Beaufort Sea, proposed exploratory drilling program, Shell has agreed to collect several discharges and dispose of them on land. Therefore, none of those discharges would impact lower trophic organisms in the Camden Bay area. However, Shell has not agreed to do this in the Chukchi Sea, and other permitted discharge streams would still be discharged into the ocean environment at both locations. Such discharges could lead to a loss of physical habitat or increase turbidity or TSS in the vicinity of the discharge. The NPDES General Permit issued by the EPA establishes discharge limits. The dilution rate is strongly affected by the discharge rate; the NPDES General Permit limits the discharge of cuttings and fluids to 750 bbl/hr. For example, the EPA modeled hypothetical 750 bbl/hr discharges of drilling fluids in water depths of 66 ft (20 m) in the Beaufort and Chukchi Seas and predicted a minimum dilution of 1,326:1 at 330 ft (100 m). Modeling of similar discharges offshore of Sakhalin Island predicted a 1,000-fold dilution within 10 minutes and 330 ft (100 m) of the discharge. In a field study (O’Reilly et al., 1989) of a drilling waste discharge offshore of California, a 270 bbl discharge of drilling fluids was found to be diluted 183-fold at 33 ft (10 m) and 1,049-fold at 330 ft (100 m). Neff (2005) concluded that concentrations of discharged drilling fluids drop to levels that would have no effect within about two minutes of discharge and within 16 ft (5 m) of the discharge location.

Studies by the EPA (2006) and Neff (2005) indicate that although planktonic organisms are extremely sensitive to environmental conditions (e.g., temperature, light, availability of nutrients, and water quality), there is little or no evidence of effects from drilling mud and cuttings discharges on plankton. More than 30 OCS well sites have been drilled in the Beaufort Sea. The Warthog well was drilled in Camden Bay in 35 ft (11 m) of water (Thurston et al., 1999). BOEM routinely monitored that well site for contaminants and found that it had no accumulated petroleum hydrocarbons or heavy metals (Brown et al., 2001). Effects on zooplankton present within a few meters of the discharge point would be expected, primarily due to sedimentation. However, zooplankton and benthic animals are not likely to have long-term exposures to drilling mud and cuttings because of the episodic nature of discharges (typically only a few hours in duration). Results of a recent study on a historical drill site in Camden Bay (HH-2) showed that movement of drilling mud and cuttings were restricted to within 330 ft (100 m) of the discharge site (Trefry and Trocine, 2009).

Fine-grained particulates and other solids in drilling mud and cuttings could cause sublethal effects to organisms in the water column. The responses observed following exposure to drilling mud include alteration of respiration and filtration rates and altered behavior. Zooplankton in the immediate area of discharge from exploration drilling operations could potentially be adversely impacted by sediments in the water column, which could clog respiratory and feeding structures, and they could suffer abrasions. However, because of the close proximity that is required to endure such effects, impacts are anticipated to be inconsequential. Studies in the 1980s, 1999, 2000, and 2002 (Brown et al., 2001 as cited in MMS, 2003) also found that benthic organisms near drilling sites in the Beaufort have accumulated neither petroleum hydrocarbon nor heavy metals. In 2008, Shell investigated the benthic communities (Dunton et al., 2009) and sediments (Trefry and Trocine, 2009) around the Sivulliq Prospect, including the location of the historical Hammerhead drill site that was drilled in 1985. Benthic communities at the historical Hammerhead drill site were found not to differ statistically in abundance, community structure, or diversity, from benthic communities elsewhere in this portion of the Beaufort Sea, indicating that there was no long term effect. Because discharges from drilling mud and cuttings are composed of seawater, impacts to benthic organisms are anticipated to be inconsequential and restricted to a very small area of the seafloor in the Beaufort and Chukchi Seas. Overall, impacts to lower trophic level organisms are anticipated to be negligible to minor.

4.2.2.2 Effects on Fish and Essential Fish Habitat

Fish and EFH in the Draft EA project area would be affected by several aspects of the proposed exploration drilling activities including: vessel traffic; vessel noise; and vessel anchoring; MLC construction; drilling noise and drill cuttings; permitted waste stream discharges; water withdrawals; small refueling spills; and oil spills from vessel accidental spills or well releases. Section 4.2.5 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b) analyzes potential impacts to fish and EFH from an exploratory drilling program. That information is incorporated herein by reference. That information is summarized below along with additional information.

Impacts on fish resulting from suspended sediments would be dependent upon the life stage of the fish (e.g., eggs, larvae, juveniles, or adults), the concentration of the suspended sediments, the type of sediment, and the duration of exposure (IMG Golder, 2004). Eggs and larvae have been found to exhibit greater sensitivity to suspended sediments (Wilber and Clarke, 2001) and other stresses, which is thought to be related to their relative lack of motility (Auld and Schubel, 1978). Sedimentation could affect fish by causing egg morbidity of demersal fish feeding near or on the ocean floor (Wilber and Clarke, 2001). Surficial membranes are especially susceptible to abrasion (Cairns and Scheier, 1968). Adhesive demersal eggs could be exposed to the sediments as long as the excavation activity continues, while exposure of pelagic eggs would be much shorter as they move with ocean currents (Wilber and Clarke, 2001). Most of the offshore demersal marine fish species in the northeastern Chukchi Sea and the central Beaufort Sea spawn under the ice during the winter and therefore would not be affected by redeposition of sediments on the seafloor due to MLC construction since Shell has not scheduled any exploration drilling activities during the winter months.

Most diadromous fish species expected to be present in the area of Shell's drilling operations lay their eggs in freshwater or coastal estuaries. Therefore, only those eggs carried into the marine environment by winds and current would be affected by these operations. Because Shell's proposed drill sites occur 65 and 78 mi (105 and 125.5 km) from the Chukchi coast, the statistical probability of diadromous fish eggs being present in the vicinity of Shell's proposed operations is infinitesimally small. Shell's proposed Camden Bay drill sites occur between 16.2 and 23.1 mi (26.1 and 37.2 km) from shore, also making it highly unlikely that diadromous fish eggs would be present in the vicinity of the proposed Camden Bay drill sites. Thus, impacts on diadromous fish eggs due to abrasion, puncture, burial, or other effects associated with anchoring or MLC construction would be slight. Further, since most diadromous fish species produce eggs prolifically, even if a small number of eggs were impacted by these activities, the total species population would not be expected to be impacted.

Suspended sediments, resulting from vessel mooring and MLC excavation, are not expected to result in permanent damage to habitats used by the marine mammal species in the proposed project area or on the food sources that they utilize. Rather, NMFS considers that such impacts will be temporary in nature and concentrated in the areas directly surrounding vessel mooring and MLC excavation activities—areas which are very small relative to the overall Beaufort and Chukchi Seas region. Less than 0.0000001 percent of the fish habitat in the LS 193 area would be directly affected by the mooring and excavation activity.

Fish are known to hear and react to sounds and to use sound to communicate (Tavolga et al., 1981) and possibly avoid predators (Wilson and Dill, 2002). Experiments have shown that fish can sense both the strength and direction of sound (Hawkins, 1981). Primary factors determining whether a fish can sense a sound signal, and potentially react to it, are the frequency of the signal and the strength of the signal in relation to the natural background noise level.

Fishes produce sounds that are associated with behaviors that include territoriality, mate search, courtship, and aggression. It has also been speculated that sound production may provide the means for long distance communication and communication under poor underwater visibility conditions (Zelick et al., 1999), although the fact that fish communicate at low-frequency sound levels where the masking effects of ambient noise are naturally highest suggests that very long distance communication would rarely be possible. Fishes have evolved a diversity of sound generating organs and acoustic signals of various temporal and spectral contents. Fish sounds vary in structure, depending on the mechanism used to produce them (Hawkins, 1993). Generally, fish sounds are predominantly composed of low frequencies (less than 3 kHz).

Since objects in the water scatter sound, fish are able to detect these objects through monitoring the ambient noise. Therefore, fish are probably able to detect prey, predators, conspecifics, and physical features by listening to environmental sounds (Hawkins, 1981). There are two sensory systems that enable fish to monitor the vibration-based information of their surroundings. The two sensory systems, the inner ear and the lateral line, constitute the acoustico-lateralis system.

Although the hearing sensitivities of very few fish species have been studied to date, it is becoming obvious that the intra- and inter-specific variability is considerable (Coombs, 1981). Nedwell et al. (2004) compiled and published available fish audiogram information. A noninvasive electrophysiological recording method known as auditory brainstem response is now commonly used in the production of fish audiograms (Yan, 2004). Generally, most fish have their best hearing in the low-frequency range (i.e., less than 1 kHz). Even though some fish are able to detect sounds in the ultrasonic frequency range, the thresholds at these higher frequencies tend to be considerably higher than those at the lower end of the auditory frequency range.

Literature relating to the impacts of sound on marine fish species can be divided into the following categories: (1) pathological effects; (2) physiological effects; and (3) behavioral effects. Pathological effects include lethal and sub-lethal physical damage to fish; physiological effects include primary and secondary stress responses; and behavioral effects include changes in exhibited behaviors of fish. Behavioral changes might be a direct reaction to a detected sound or a result of the anthropogenic sound masking natural sounds that the fish normally detect and to which they respond. The three types of effects are often interrelated in complex ways. For example, some physiological and behavioral effects could potentially lead to the ultimate pathological effect of mortality. Hastings and Popper (2005) reviewed what is known about the effects of sound on fishes and identified studies needed to address areas of uncertainty relative to measurement of sound and the responses of fishes. Popper et al. (2003/2004) also published a paper that reviews the effects of anthropogenic sound on the behavior and physiology of fishes.

Potential effects of exposure to continuous sound on marine fish include temporary threshold shift (TTS), physical damage to the ear region, physiological stress responses, and behavioral responses such as startle response, alarm response, avoidance, and perhaps lack of response due to masking of acoustic cues. Most of these effects appear to be either temporary or intermittent and therefore probably do not significantly impact the fish at a population level. The studies that resulted in physical damage to the fish ears used noise exposure levels and durations that were far more extreme than would be encountered under conditions similar to those expected during Shell's proposed exploratory drilling activities.

The level of sound at which a fish will react or alter its behavior is usually well above the detection level. Fish have been found to react to sounds when the sound level increased to about

20 dB above the detection level of 120 dB (Ona, 1988); however, the response threshold can depend on the time of year and the fish's physiological condition (Engas et al., 1993). In general, fish react more strongly to pulses of sound rather than a continuous signal (Blaxter et al., 1981), such as the type of sound that will be produced by the drillship, and a quicker alarm response is elicited when the sound signal intensity rises rapidly compared to sound rising more slowly to the same level.

Investigations of fish behavior in relation to vessel noise (Olsen et al., 1983; Ona, 1988; Ona and Godo, 1990) have shown that fish react when the sound from the engines and propeller exceeds a certain level. Avoidance reactions have been observed in fish such as cod and herring when vessels approached close enough that received sound levels are 110 dB to 130 dB (Nakken, 1992; Olsen, 1979; Ona and Godo, 1990; Ona and Toresen, 1988). However, other researchers have found that fish such as polar cod, herring, and capeline are often attracted to vessels (apparently by the noise) and swim toward the vessel (Rostad et al., 2006). Typical sound source levels of vessel noise in the audible range for fish are 150 dB to 170 dB (Richardson et al., 1995a). (Based on models, the 160 dB radius for the *Discoverer* would extend approximately 33 ft [10 m] and the 160 dB radius for the *Kulluk* would extend approximately 180 ft [55 m]; therefore, fish would need to be in close proximity to the drillship for the noise to be audible). In calm weather, ambient noise levels in audible parts of the spectrum lie between 60 dB to 100 dB.

Sound will also occur in the marine environment from the various support vessels. Reported source levels for vessels during ice management have ranged from 175 dB to 185 dB (Brewer et al., 1993; Hall et al., 1994). However, ice management or icebreaking activities are not expected to be necessary throughout the entire drilling season, so impacts from that activity would occur less frequently than sound from the drillship. Sound pressures generated by drilling vessels during active drilling operations have been measured during past exploration in the Beaufort and Chukchi Seas. Sounds generated by drilling and ice management/icebreaking are generally low frequency and within the frequency range detectable by most fish.

Shell also proposes to conduct seismic surveys with an airgun array for a short period of time during the drilling season (a total of approximately 20-28 hours and 30-56 hours over the course of the entire proposed Beaufort Sea and Chukchi Sea drilling programs, respectively). Airguns produce impulsive sounds as opposed to continuous sounds at the source. Short, sharp sounds can cause overt or subtle changes in fish behavior. Chapman and Hawkins (1969) tested the reactions of whiting (hake) in the field to an airgun. When the airgun was fired, the fish dove from 82 to 180 ft (25 to 55 m) depth and formed a compact layer. The whiting dove when received sound levels were higher than 178 dB re 1 μPa (Pearson et al., 1992).

Pearson et al. (1992) conducted a controlled experiment to determine effects of strong noise pulses on several species of rockfish off the California coast. They used an airgun with a source level of 223 dB re 1 μPa. They noted:

- Startle responses at received levels of 200–205 dB re 1 μPa and above for two sensitive species, but not for two other species exposed to levels up to 207 dB;
- Alarm responses at 177–180 dB for the two sensitive species, and at 186 to 199 dB for other species;
- An overall threshold for the above behavioral response at about 180 dB;

- An extrapolated threshold of about 161 dB for subtle changes in the behavior of rockfish; and
- A return to pre-exposure behaviors within the 20-60 minute exposure period.

In summary, fish often react to sounds, especially strong and/or intermittent sounds of low frequency. Sound pulses at received levels of 160 dB re 1 μPa may cause subtle changes in behavior. Pulses at levels of 180 dB may cause noticeable changes in behavior (Chapman and Hawkins, 1969; Pearson et al., 1992; Skalski et al., 1992). It also appears that fish often habituate to repeated strong sounds rather rapidly, on time scales of minutes to an hour. However, the habituation does not endure, and resumption of the strong sound source may again elicit disturbance responses from the same fish. Underwater sound levels from the drillship and other vessels produce sounds lower than the response threshold reported by Pearson et al. (1992), and are not likely to result in major effects to fish near the proposed drill sites.

Based on a sound level of approximately 140 dB, there may be some avoidance by fish of the area near the drillship while drilling, around ice management vessels in transit and during ice management, and around other support and supply vessels when underway. Any reactions by fish to these sounds will last only minutes (Mitson and Knudsen, 2003; Ona et al., 2007) longer than the vessel is operating at that location or the drillship is drilling. Any potential reactions by fish would be limited to a relatively small area within about 0.21 mi (0.34 km) of the drillship during drilling (JASCO, 2007). Avoidance by some fish or fish species could occur within portions of this area. No important spawning habitats are known to occur at or near the drilling locations. Pressure changes of sufficient magnitude to cause fish to vacate the area would probably occur only very close to the sound source, if any would occur at all due to the low energy sounds produced by the majority of equipment proposed for use. Impacts on fish behavior are predicted to be inconsequential.

Vessel and aircraft transits will not have any direct or indirect impacts on fish or EFH. Additionally, ice management and icebreaking activities are not anticipated to have impacts on fish in the project area. If a small oil spill were to occur, there could be lethal effects to some fish. The effects of a small spill on fish are dependent upon seasonality, duration, and weather conditions during and following the event. Shell has implemented several procedures to reduce the potential for such spills from occurring. That information is described in detail in the exploration plans (Shell, 2011c,d). That information and the analysis of impacts from a small liquid hydrocarbon spill are hereby incorporated by reference. Impacts from a very large oil spill are discussed later in this document in Section 4.5.

As discussed in Section 4.2.2.1 above, for its Camden Bay, Beaufort Sea, proposed exploratory drilling program, Shell has agreed to collect several discharges and dispose of them on land. Therefore, none of those discharges would impact fish or EFH in the Camden Bay area. However, Shell has not agreed to do this in the Chukchi Sea, and other permitted discharge streams would still be discharged into the ocean environment at both locations. Such discharges could lead to a loss of physical habitat or increase turbidity or TSS in the vicinity of the discharge. As described above, discharges are expected to dilute within close proximity of the drilling area.

Discharges and drill cuttings could impact fish by displacing them from the affected area. Additionally, sedimentation could impact fish, as demersal fish eggs could be smothered if discharges occur in a spawning area during the period of egg production. However, this is unlikely in deeper offshore locations, and no specific demersal fish spawning locations have been identified at the Burger well locations. The most abundant and trophically important marine fish, the Arctic cod, spawns with planktonic eggs and larvae under the sea ice during winter and will therefore have little exposure to discharges. Based on this information, drilling muds and cutting wastes are not anticipated to have long-term impacts to fish or EFH in the project area. Overall, impacts to fish as a result of the proposed action are anticipated to be minor.

4.2.2.3 Effects on Marine and Coastal Birds

While NMFS' proposed action of issuing IHAs for the take of marine mammals incidental to conducting an offshore exploratory drilling program will not impact marine and coastal birds, Shell's activities may have direct or indirect effects on these species. Such impacts include the potential for disturbance from vessels and aircraft, injury or mortality from collisions with vessels or structures, and habitat changes/contamination. Four of the species that are likely to occur in the EA project area are listed as threatened or candidate species under the ESA. They are: Steller's eider; spectacled eider; Kittlitz's murrelet; and yellow-billed loon.

Sections IV.C.8. and IV.C.9 of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a), Section 4.2.6 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and Section 4.5.2 of BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011) describe potential impacts to marine and coastal birds from oil and gas exploration activities. That information is summarized here and incorporated into this EA by reference.

Birds' responses to disturbance vary according to the species, physiological and reproductive status of the individual, distance from the disturbance, and the type/intensity/duration of the disturbance. The vessels which would be used during Shell's proposed programs would not create noise intense enough to have a significant impact on marine and coastal birds. Evans et al. (1993) evaluated marine birds from operating seismic vessels in the North Sea and found no observable difference in bird behavior. Studies in the Canadian Arctic (Webb and Kempf, 1998) and Wadden Sea (Stemp, 1985) found no statistical differences in bird distribution between on-going seismic surveys. Therefore, sounds from seismic surveys and lower-intensity sounds from drilling, ice management, and icebreaking activities are anticipated to have only negligible to minor impacts on marine and coastal birds. If there were a small liquid hydrocarbon spill in the vicinity of Shell's proposed drill sites, bird mortality could occur through direct contact with the oil. Indirect effects of oil include a reduction in egg productivity, decreased survival of embryos and chicks, poor chick growth, delayed maturation of ovaries, altered hormone levels, and abandonment of nests by adults (Burger and Fry, 1993). While there is the potential for a small liquid hydrocarbon spill, effects would be minor with respect to overall bird populations in the vicinity and restricted to small areas. Shell has several measures in place to reduce the occurrence of an oil spill, and the likelihood of such effects is low. Shell's Chukchi Sea programs occur more than 70 mi (113 km) from shore, away from onshore nesting and breeding colonies. In the Beaufort Sea, Shell's proposed activities occur between approximately 16 and 23 mi (25.8 and 37 km) from the coast. It is expected that birds would flush from areas where aircraft are traveling. BOEM typically requires several mitigation measures in its permits to oil and gas industry operators in order to reduce impacts to birds, especially in important areas such as the Ledyard Bay Critical Habitat Unit. Implementation of such measures is anticipated to reduce impacts to marine and coastal birds even further. Overall, impacts are anticipated to be minor.

4.2.2.4 Effects on Marine Mammals

Noise exposure, habitat degradation, and vessel activity, which could possibly lead to ship strikes, are the primary mechanisms by which activities associated with exploratory drilling programs in the Beaufort and Chukchi Seas could directly or indirectly affect marine mammals. The potential effects are primarily those associated with noise exposure, habitat degradation, and vessel activity, which although unlikely, could possibly lead to ship strikes. The impacts of anthropogenic noise on marine mammals has been summarized in numerous articles and reports including Richardson et al. (1995), Cato et al. (2004), NRC (2003, 2005), Southall et al. (2007), Nowacek et al. (2007), and Weilgart (2007). Because the occurrence of a large oil spill is a highly unlikely event, it is not part of the proposed action for any alternative. However, in the highly unlikely event a large spill were to occur, it could result in adverse impacts on marine mammals. The oil spill analysis is not contained in the sections that analyze direct and indirect effects of the alternatives on marine mammals; rather, it is discussed and analyzed separately in Section 4.5 of this EA since an oil spill is not a component of the proposed action.

4.2.2.4.1 Effects of Noise on Marine Mammals

Marine mammals use hearing and sound transmission to perform vital life functions. Sound (hearing and vocalization/echolocation) serves four primary functions for marine mammals, including: (1) providing information about their environment; (2) communication; (3) prey detection; and (4) predator detection. Introducing sound into the ocean environment could disrupt those functions. The distance from oil and gas exploration activities at which noises are audible depends upon source levels, frequency, ambient noise levels, the propagation characteristics of the environment, and sensitivity of the receptor (Richardson et al., 1995; Nowacek et al., 2007). Impacts to marine mammals are expected to primarily be acoustic in nature. Potential acoustic effects on marine mammals relate to sound produced by drilling activity, vessels, and aircraft, as well as the ZVSP airgun array.

In assessing potential effects of noise, Richardson et al. (1995) suggested four criteria for defining zones of influence:

- ***Zone of audibility*** – the area within which the marine mammal might hear the noise. Marine mammals as a group have functional hearing ranges of 10 Hz to 180 kHz, with best thresholds near 40 dB (Ketten, 1998; Kastak et al., 2005; Southall et al., 2007). These data show reasonably consistent patterns of hearing sensitivity within each of four groups: small odontocetes (such as harbor porpoise); medium-sized odontocetes (such as beluga and killer whales); large cetaceans (such as bowhead whales); and pinnipeds.
- ***Zone of responsiveness*** – the area within which the animal reacts behaviorally or physiologically. The behavioral responses of marine mammals to sound depend on: 1)

the acoustic characteristics of the noise source; 2) the physical and behavioral state of animals at time of exposure; 3) the ambient acoustic and ecological characteristics of the environment; and 4) the context of the sound (e.g. whether it sounds similar to a predator) (Richardson et al., 1995; Southall et al., 2007). Temporary behavioral effects, however, often merely show that an animal heard a sound and may not indicate lasting consequences for exposed individuals (Southall et al., 2007).

- ***Zone of masking*** – the area within which the noise may interfere with detection of other sounds, including communication calls, prey sounds, or other environmental sounds.
- ***Zone of hearing loss, discomfort, or injury*** – the area within which the received sound level is potentially high enough to cause discomfort or tissue damage to auditory or other systems. This includes temporary threshold shifts (TTS, temporary loss in hearing) or permanent threshold shifts (PTS, permanent loss in hearing at specific frequencies or deafness). Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage.

Tolerance

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. Numerous studies have also shown that marine mammals at distances more than a few kilometers away often show no apparent response 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. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to underwater sound such as airgun pulses or vessels under some conditions, at other times mammals of all three types have shown no overt reactions (e.g., Malme et al., 1986; Richardson et al., 1995; Madsen and Mohl, 2000; Croll et al., 2001; Jacobs and Terhune, 2002; Madsen et al., 2002; Miller et al., 2005). 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). In general, pinnipeds and small odontocetes seem to be more tolerant of exposure to some types of underwater sound than are baleen whales. Richardson et al. (1995a) found that vessel noise does not seem to strongly affect pinnipeds that are already in the water. Richardson et al. (1995a) went on to explain that seals on haul-outs sometimes respond strongly to the presence of vessels and at other times appear to show considerable tolerance of vessels, and Brueggeman et al. (1992, cited in Richardson et al., 1995a) observed ringed seals hauled out on ice pans displaying short-term escape reactions when a ship approached within 0.25-0.5 mi (0.4-0.8 km).

Masking

Masking is the obscuring of sounds of interest by other sounds, often at similar frequencies. Marine mammals are highly dependent on sound, and their ability to recognize sound signals amid other noise is important in communication, predator and prey detection, and, in the case of toothed whales, echolocation. Even in the absence of manmade sounds, the sea is usually noisy. Background ambient noise often interferes with or masks the ability of an animal to detect a sound signal even when that signal is above its absolute hearing threshold. Natural ambient noise includes contributions from wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal noise resulting from molecular agitation (Richardson et al., 1995a). Background noise also can include sounds from human activities. Masking of natural sounds can result when human activities produce high levels of background noise. Conversely, if the background level of underwater noise is high (e.g., on a day with strong wind and high waves), an anthropogenic noise source will not be detectable as far away as would be possible under quieter conditions and will itself be masked.

Although some degree of masking is inevitable when high levels of manmade broadband sounds are introduced into the sea, marine mammals have evolved systems and behavior that function to reduce the impacts of masking. Structured signals, such as the echolocation click sequences of small toothed whales, may be readily detected even in the presence of strong background noise because their frequency content and temporal features usually differ strongly from those of the background noise (Au and Moore, 1988, 1990). The components of background noise that are similar in frequency to the sound signal in question primarily determine the degree of masking of that signal.

Redundancy and context can also facilitate detection of weak signals. These phenomena may help marine mammals detect weak sounds in the presence of natural or manmade noise. Most masking studies in marine mammals present the test signal and the masking noise from the same direction. 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., 1995a). The dominant background noise may be highly directional if it comes from a particular anthropogenic source such as a ship or industrial site. Directional hearing may significantly reduce the masking effects of these noises by improving the effective signal-to-noise ratio. In the cases of high-frequency hearing by the bottlenose dolphin, beluga whale, and killer whale, empirical evidence confirms that masking depends strongly on the relative directions of arrival of sound signals and the masking noise (Penner et al., 1986; Dubrovskiy, 1990; Bain et al., 1993; Bain and Dahlheim, 1994). Toothed marine mammals, and probably other marine mammals as well, have additional capabilities besides directional hearing that can facilitate detection of sounds in the presence of background noise. There is evidence that some toothed marine mammals can shift the dominant frequencies of their echolocation signals from a frequency range with a lot of ambient noise toward frequencies with less noise (Au et al., 1974, 1985; Moore and Pawloski, 1990; Thomas and Turl, 1990; Romanenko and Kitain, 1992; Lesage et al., 1999). A few marine mammal species are known to increase the source levels or alter the frequency of their calls in the presence of elevated sound levels (Dahlheim, 1987; Au, 1993; Lesage et al., 1993, 1999; Terhune, 1999; Foote et al., 2004; Parks et al., 2007, 2009; Di Iorio and Clark, 2009; Holt et al., 2009).

These data demonstrating adaptations for reduced masking pertain mainly to the very high frequency echolocation signals of toothed whales. There is less information about the existence of corresponding mechanisms at moderate or low frequencies or in other types of marine mammals. For example, Zaitseva et al. (1980) found that, for the bottlenose dolphin, the angular separation between a sound source and a masking noise source had little effect on the degree of masking when the sound frequency was 18 kHz, in contrast to the pronounced effect at higher frequencies. Directional hearing has been demonstrated at frequencies as low as 0.5-2 kHz in several marine mammals, including killer whales (Richardson et al., 1995a). This ability may be useful in reducing masking at these frequencies. In summary, high levels of noise generated by anthropogenic activities may act to mask the detection of weaker biologically important sounds by some marine mammals. This masking may be more prominent for lower frequencies. For higher frequencies, such as that used in echolocation by toothed whales, several mechanisms are available that may allow them to reduce the effects of such masking.

Masking effects of underwater sounds from Shell's proposed activities on marine mammal calls and other natural sounds are expected to be limited. For example, beluga whales primarily use high-frequency sounds to communicate and locate prey; therefore, masking by low-frequency sounds associated with drilling activities is not expected to occur (Gales, 1982, as cited in Shell, 2011a). If the distance between communicating whales does not exceed their distance from the drilling activity, the likelihood of potential impacts from masking would be low (Gales, 1982, as cited in Shell, 2011a). At distances greater than 660-1,300 ft (200-400 m), recorded sounds from drilling activities did not affect behavior of beluga whales, even though the sound energy level and frequency were such that it could be heard several kilometers away (Richardson et al., 1995b). This exposure resulted in whales being deflected from the sound energy and changing behavior. These minor changes are not expected to affect the beluga whale population (Richardson et al., 1991; Richard et al., 1998).

There is evidence of other marine mammal species continuing to call in the presence of industrial activity. Annual acoustical monitoring near BP's Northstar production facility during the fall bowhead migration westward through the Beaufort Sea has recorded thousands of calls each year (for examples, see Richardson et al., 2007; Aerts and Richardson, 2008). Construction, maintenance, and operational activities have been occurring from this facility for over 10 years. To compensate and reduce masking, some mysticetes may alter the frequencies of their communication sounds (Richardson et al., 1995a; Parks et al., 2007). Masking processes in baleen whales are not amenable to laboratory study, and no direct measurements on hearing sensitivity are available for these species. It is not currently possible to determine with precision the potential consequences of temporary or local background noise levels. However, Parks et al. (2007) found that right whales (a species closely related to the bowhead whale) altered their vocalizations, possibly in response to background noise levels. For species that can hear over a relatively broad frequency range, as is presumed to be the case for mysticetes, a narrow band source may only cause partial masking. Richardson et al. (1995a) note that a bowhead whale 12.4 mi (20 km) from a human sound source, such as that produced during oil and gas industry activities, might hear strong calls from other whales within approximately 12.4 mi (20 km), and a whale 3.1 mi (5 km) from the source might hear strong calls from whales within approximately 3.1 mi (5 km). Additionally, masking is more likely to occur closer to a sound source, and distant anthropogenic sound is less likely to mask short-distance acoustic communication (Richardson et al., 1995a).

McDonald et al. (1995) heard blue and fin whale calls between seismic pulses in the Pacific. Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al., 1994), a more recent study reported that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al., 2002). Similar results were also reported during work in the Gulf of Mexico (Tyack et al., 2003). Bowhead whale calls are frequently detected in the presence of seismic pulses, although the numbers of calls detected may sometimes be reduced (Richardson et al., 1986; Greene et al., 1999; Blackwell et al., 2009a). Bowhead whales in the Beaufort Sea may decrease their call rates in response to seismic operations, although movement out of the area might also have contributed to the lower call detection rate (Blackwell et al., 2009a,b). Additionally, there is increasing evidence that, at times, there is enough reverberation between airgun pulses such that detection range of calls may be significantly reduced. In contrast, Di Iorio and Clark (2009) found evidence of increased calling by blue whales during operations by a lower-energy seismic source, a sparker.

Although some masking by marine mammal species in the area may occur, the extent of the masking interference will depend on the spatial relationship of the animal and Shell's activity. Almost all energy in the sounds emitted by drilling and other operational activities is at low frequencies, predominantly below 250 Hz with another peak centered around 1,000 Hz. Most energy in the sounds from the vessels and aircraft to be used during this project is below 1 kHz (Moore et al., 1984; Greene and Moore, 1995; Blackwell et al., 2004a; Blackwell and Greene, 2006). These frequencies are mainly used by mysticetes but not by odontocetes. Therefore, masking effects would potentially be more pronounced in the bowhead and gray whales that might occur in the proposed project area.

Again, there is little concern regarding masking due to the brief duration of these pulses and relatively longer silence between airgun shots (9 – 12 seconds) near the sound source. However, at long distances (over tens of kilometers away) in deep water, due to multipath propagation and reverberation, the durations of airgun pulses can be "stretched" to seconds with long decays (Madsen et al., 2006; Clark and Gagnon, 2006). Therefore it 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., 2009a,b) and cause increased stress levels (e.g., Foote et al., 2004; Holt et al., 2009). Nevertheless, the intensity of the noise is also greatly reduced at long distances. Therefore, masking effects are anticipated to be limited, especially in the case of odontocetes, given that they typically communicate at frequencies higher than those of the airguns.

Behavioral Disturbance Reactions

Behavioral responses to sound are highly variable and context-specific. Many different variables can influence an animal's perception of and response to (in both nature and magnitude) an acoustic event. An animal's prior experience with a sound or sound source affects whether it is less likely (habituation) or more likely (sensitization) to respond to certain sounds in the future (animals can also be innately pre-disposed to respond to certain sounds in certain ways; Southall et al., 2007). Related to the sound itself, the perceived nearness of the sound, bearing of the sound (approaching vs. retreating), similarity of a sound to biologically relevant sounds in the animal's environment (i.e., calls of predators, prey, or conspecifics), and familiarity of the sound may affect the way an animal responds to the sound (Southall et al., 2007). Individuals (of different age, gender, reproductive status, etc.) among most populations will have variable hearing capabilities and differing behavioral sensitivities to sounds that will be affected by prior conditioning, experience, and current activities of those individuals. Often, specific acoustic features of the sound and contextual variables (i.e., proximity, duration, or recurrence of the sound or the current behavior that the marine mammal is engaged in or its prior experience), as well as entirely separate factors such as the physical presence of a nearby vessel, may be more relevant to the animal's response than the received level alone.

Exposure of marine mammals to sound sources can result in (but is not limited to) no response or any of the following observable responses: increased alertness; orientation or attraction to a sound source; vocal modifications; cessation of feeding; cessation of social interaction; alteration of movement or diving behavior; avoidance; habitat abandonment (temporary or permanent); and, in severe cases, panic, flight, stampede, or stranding, potentially resulting in death (Southall et al., 2007). On a related note, many animals perform vital functions, such as feeding, resting, traveling, and socializing, on a diel cycle (24-hr cycle). Behavioral reactions to noise exposure (such as disruption of critical life functions, displacement, or avoidance of important habitat) are more likely to be significant if they last more than one diel cycle or recur on subsequent days (Southall et al., 2007). Consequently, a behavioral response lasting less than one day and not recurring on subsequent days is not considered particularly severe unless it could directly affect reproduction or survival (Southall et al., 2007).

Detailed studies regarding responses to anthropogenic sound have been conducted on humpback, gray, and bowhead whales and ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, small toothed whales, and sea otters. Examples of behavioral responses that provide an idea of the variability in behavioral responses that would be expected given the different sensitivities of marine mammal species to sound are provided next.

Baleen Whales: Baleen whale responses to pulsed sound (e.g., seismic airguns) have been studied more thoroughly than responses to continuous sound (e.g., drillships). Studies identifying baleen whale reactions to both pulsed and continuous sounds sources, as well as aircraft, are described here. Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much greater distances (Miller et al., 2005). However, baleen whales exposed to strong noise pulses often react by deviating from their normal migration route (Richardson et al., 1999). Migrating gray and bowhead whales were observed avoiding the sound source by displacing their migration route to varying degrees but within the natural boundaries of the migration corridors (Schick and Urban, 2000; Richardson et al., 1999; Malme et al., 1983). Baleen whale responses to pulsed sound however may depend on the type of activity in which the whales are engaged. Some evidence suggests that feeding bowhead whales may be more tolerant of underwater sound than migrating bowheads (Miller et al., 2005; Lyons et al., 2009; Christie et al., 2010).

Results of studies of gray, bowhead, 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. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 2.8-9 mi (4.5-14.5 km) from the source. For the much smaller airgun array used during the ZVSP survey (total discharge volume of 760 in^3), distances to received levels in the 170-160 dB re 1 µPa rms range are estimated to be 1.44-2.28 mi (2.31-3.67 km). Baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and recent studies have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 µPa rms. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with avoidance occurring out to distances of 12.4-18.6 mi (20-30 km) from a medium-sized airgun source (Miller et al., 1999; Richardson et al., 1999). However, more recent research on bowhead whales (Miller et al., 2005) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. In summer, bowheads typically begin to show avoidance reactions at a received level of about 160–170 dB re 1 µPa rms (Richardson et al., 1986; Ljungblad et al., 1988; Miller et al., 2005).

Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 µPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast and on observations of the distribution of feeding Western Pacific gray whales off Sakhalin Island, Russia, during a seismic survey (Yazvenko et al., 2007).

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. While it is not certain whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years, certain species have continued to use areas ensonified by airguns and have continued to increase in number despite successive years of anthropogenic activity in the area. Gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A in Malme et al., 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al., 1987). Populations of both gray whales and bowhead whales grew substantially during this time. Bowhead whales have increased by approximately 3.4% per year for the last 10 years in the Beaufort Sea (Allen and Angliss, 2011). Many animals perform vital functions, such as feeding, resting, traveling, and socializing, on a diel cycle (24-hr cycle). Behavioral reactions to noise exposure (such as disruption of critical life functions, displacement, or avoidance of important habitat) are more likely to be significant if they last more than one diel cycle or recur on subsequent days (Southall et al., 2007). Consequently, a behavioral response lasting less than one day and not recurring on subsequent days is not considered particularly severe unless it could directly affect reproduction or survival (Southall et al., 2007). Therefore, the brief exposures to sound pulses from the proposed airgun source (the airguns will only be fired for a period of 10-14 hours for each well, with the potential for up to two wells in the Beaufort Sea and three wells and a partial fourth well in the Chukchi Sea) are highly unlikely to result in prolonged effects.

Richardson et al. (1995b) reported changes in surfacing and respiration behavior and the occurrence of turns during surfacing in bowhead whales exposed to playback of underwater sound from drilling activities. These behavioral effects were localized and occurred at distances up to 1.2-2.5 mi (2-4 km).

Some bowheads appeared to divert from their migratory path after exposure to projected icebreaker sounds. Other bowheads however, tolerated projected icebreaker sound at levels 20 dB and more above ambient sound levels. The source level of the projected sound however, was much less than that of an actual icebreaker, and reaction distances to actual icebreaking may be much greater than those reported here for projected sounds. However, it should be noted that Shell does not intend to actively break ice unless it is necessary to protect the equipment or for reasons of human safety. If icebreaking were to occur, it would be for a very limited amount of time in order to free the drillship and move it offsite.

Brewer et al. (1993) and Hall et al. (1994) reported numerous sightings of marine mammals including bowhead whales in the vicinity of offshore drilling operations in the Beaufort Sea. One bowhead whale sighting was reported within approximately 1,312 ft (400 m) of the *Kulluk* drilling vessel although most other bowhead sightings were at much greater distances. Few bowheads were recorded near industrial activities by aerial observers. After controlling for spatial autocorrelation in aerial survey data from Hall et al. (1994) using a Mantel test, Schick and Urban (2000) found that the variable describing straight line distance between the rig and bowhead whale sightings was not significant but that a variable describing threshold distances between sightings and the rig was significant. Thus, although the aerial survey results suggested substantial avoidance of the operations by bowhead whales, observations by vessel-based observers indicate that at least some bowheads may have been closer to industrial activities than was suggested by results of aerial observations.

Richardson et al. (2008) reported a slight change in the distribution of bowhead whale calls in response to operational sounds on BP's Northstar Island. The southern edge of the call distribution ranged from 0.47 to 1.46 mi (0.76 to 2.35 km) farther offshore, apparently in response to industrial sound levels. This result however, was only achieved after intensive statistical analyses, and it is not clear that this represented a biologically significant effect.

Patenaude et al. (2002) reported fewer behavioral responses to aircraft overflights by bowhead compared to beluga whales. Behaviors classified as reactions consisted of short surfacings, immediate dives or turns, changes in behavior state, vigorous swimming, and breaching. Most bowhead reaction resulted from exposure to helicopter activity and little response to fixed-wing aircraft was observed. Most reactions occurred when the helicopter was at altitudes ≤492 ft (150 m) and lateral distances ≤820 ft (250 m; Nowacek et al., 2007).

During their study, Patenaude et al. (2002) observed one bowhead whale cow-calf pair during four passes totaling 2.8 hours of the helicopter and two pairs during Twin Otter overflights. All of the helicopter passes were at altitudes of 49-98 ft (15-30 m). The mother dove both times she was at the surface, and the calf dove once out of the four times it was at the surface. For the cow-calf pair sightings during Twin Otter overflights, the authors did not note any behaviors specific to those pairs. Rather, the reactions of the cow-calf pairs were lumped with the reactions of other groups that did not consist of calves.

Richardson et al. (1995b) and Moore and Clarke (2002) reviewed a few studies that observed responses of gray whales to aircraft. Cow-calf pairs were quite sensitive to a turboprop survey flown at 1,000 ft (305 m) altitude on the Alaskan summering grounds. In that survey, adults were seen swimming over the calf, or the calf swam under the adult (Ljungblad et al., 1983 as cited in Richardson et al., 1995b and Moore and Clarke, 2002). However, when the same aircraft circled for more than 10 minutes at 1,050 ft (320 m) altitude over a group of mating gray whales, no reactions were observed (Ljungblad et al., 1987 as cited in Moore and Clarke, 2002). Malme et al. (1984 as cited in Richardson et al., 1995b and Moore and Clarke, 2002) conducted playback experiments on migrating gray whales. They exposed the animals to underwater noise recorded from a Bell 212 helicopter (estimated altitude=328 ft [100 m]), at an average of three simulated passes per minute. The authors observed that whales changed their swimming course and sometimes slowed down in response to the playback sound but proceeded to migrate past the transducer. Migrating gray whales did not react overtly to a Bell 212 helicopter at greater than 1,394 ft (425 m) altitude, occasionally reacted when the helicopter was at 1,000-1,198 ft (305-365 m), and usually reacted when it was below 825 ft (250 m; Southwest Research Associates, 1988 as cited in Richardson et al., 1995b and Moore and Clarke, 2002). Reactions noted in that study included abrupt turns or dives or both. Green et al. (1992 as cited in Richardson et al., 1995b) observed that migrating gray whales rarely exhibited noticeable reactions to a straight-line overflight by a Twin Otter at 197 ft (60 m) altitude. Restrictions on aircraft altitude will be part of the proposed mitigation measures (described in Chapter 5 of this EA) during the proposed drilling activities, and overflights are likely to have little or no disturbance effects on baleen whales. Any disturbance that may occur would likely be temporary and localized.

Southall et al. (2007, Appendix C) reviewed a number of papers describing the responses of marine mammals to non-pulsed sound, such as that produced during exploratory drilling operations. In general, little or no response was observed in animals exposed at received levels from 90-120 dB re 1 μPa (rms). Probability of avoidance and other behavioral effects increased when received levels were from 120-160 dB re 1 μPa (rms). Some of the relevant reviews contained in Southall et al. (2007) are summarized next.

Baker et al. (1982) reported some avoidance by humpback whales to vessel noise when received levels were 110-120 dB (rms) and clear avoidance at 120-140 dB (sound measurements were not provided by Baker but were based on measurements of identical vessels by Miles and Malme, 1983).

Malme et al. (1983, 1984) used playbacks of sounds from helicopter overflight and drilling rigs and platforms to study behavioral effects on migrating gray whales. Received levels exceeding 120 dB induced avoidance reactions. Malme et al. (1984) calculated 10%, 50%, and 90% probabilities of gray whale avoidance reactions at received levels of 110, 120, and 130 dB, respectively. Malme et al. (1986) observed the behavior of feeding gray whales during four experimental playbacks of drilling sounds (50 to 315 Hz; 21- min overall duration and 10% duty cycle; source levels of 156-162 dB). In two cases for received levels of 100-110 dB, no behavioral reaction was observed. However, avoidance behavior was observed in two cases where received levels were 110-120 dB.

Richardson et al. (1990) performed 12 playback experiments in which bowhead whales in the Alaskan Arctic were exposed to drilling sounds. Whales generally did not respond to exposures in the 100 to 130 dB range, although there was some indication of minor behavioral changes in several instances.

McCauley et al. (1996) reported several cases of humpback whales responding to vessels in Hervey Bay, Australia. Results indicated clear avoidance at received levels between 118 to 124 dB in three cases for which response and received levels were observed/measured.

Palka and Hammond (2001) analyzed line transect census data in which the orientation and distance off transect line were reported for large numbers of minke whales. The authors developed a method to account for effects of animal movement in response to sighting platforms. Minor changes in locomotion speed, direction, and/or diving profile were reported at ranges from 1,847 to 2,352 ft (563 to 717 m) at received levels of 110 to 120 dB.

Biassoni et al. (2000) and Miller et al. (2000) reported behavioral observations for humpback whales exposed to a low-frequency sonar stimulus (160- to 330-Hz frequency band; 42-s tonal signal repeated every 6 min; source levels 170 to 200 dB) during playback experiments. Exposure to measured received levels ranging from 120 to 150 dB resulted in variability in humpback singing behavior. Croll et al. (2001) investigated responses of foraging fin and blue whales to the same low frequency active sonar stimulus off southern California. Playbacks and control intervals with no transmission were used to investigate behavior and distribution on time scales of several weeks and spatial scales of tens of kilometers. The general conclusion was that whales remained feeding within a region for which 12 to 30% of exposures exceeded 140 dB.

Frankel and Clark (1998) conducted playback experiments with wintering humpback whales using a single speaker producing a low-frequency "M-sequence" (sine wave with multiple-phase reversals) signal in the 60 to 90 Hz band with output of 172 dB at 1 m. For 11 playbacks, exposures were between 120 and 130 dB re 1 µPa (rms) and included sufficient information regarding individual responses. During eight of the trials, there were no measurable differences in tracks or bearings relative to control conditions, whereas on three occasions, whales either moved slightly away from (n = 1) or towards (n = 2) the playback speaker during exposure. The presence of the source vessel itself had a greater effect than did the M-sequence playback.

Finally, Nowacek et al. (2004) used controlled exposures to demonstrate behavioral reactions of northern right whales to various non-pulse sounds. Playback stimuli included ship noise, social sounds of conspecifics, and a complex, 18-min "alert" sound consisting of repetitions of three different artificial signals. Ten whales were tagged with calibrated instruments that measured received sound characteristics and concurrent animal movements in three dimensions. Five out of six exposed whales reacted strongly to alert signals at measured received levels between 130 and 150 dB (i.e., ceased foraging and swam rapidly to the surface). Two of these individuals were not exposed to ship noise, and the other four were exposed to both stimuli. These whales reacted mildly to conspecific signals. Seven whales, including the four exposed to the alert stimulus, had no measurable response to either ship sounds or actual vessel noise.

Toothed Whales: Most toothed whales have the greatest hearing sensitivity at frequencies much higher than that of baleen whales and may be less responsive to low-frequency sound commonly associated with oil and gas industry exploratory drilling activities. Richardson et al. (1995b) reported that beluga whales did not show any apparent reaction to playback of underwater drilling sounds at distances greater than 656-1,312 ft (200-400 m). Reactions included slowing down, milling, or reversal of course after which the whales continued past the projector, sometimes within 164-328 ft (50-100 m). The authors concluded (based on a small sample size) that the playback of drilling sounds had no biologically significant effects on migration routes of beluga whales migrating through pack ice and along the seaward side of the nearshore lead east of Point Barrow in spring.

At least six of 17 groups of beluga whales appeared to alter their migration path in response to underwater playbacks of icebreaker sound (Richardson et al., 1995b). Received levels from the icebreaker playback were estimated at 78-84 dB in the 1/3-octave band centered at 5,000 Hz, or 8-14 dB above ambient. If beluga whales reacted to an actual icebreaker at received levels of 80 dB, reactions would be expected to occur at distances on the order of 6.2 mi (10 km). Finley et al. (1990) also reported beluga avoidance of icebreaker activities in the Canadian High Arctic at distances of 22-31 mi (35-50 km). In addition to avoidance, changes in dive behavior and pod integrity were also noted.

Seismic operators and marine mammal observers sometimes see dolphins and other small toothed whales near operating airgun arrays, but, in general, there seems to be a tendency for most delphinids to show some limited avoidance of seismic vessels operating large airgun systems. However, some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing. Nonetheless, there have been indications that small toothed whales sometimes move away or maintain a somewhat greater distance from the vessel when a large array of airguns is operating than when it is silent (e.g., Goold, 1996a,b,c; Calambokidis and Osmek, 1998; Stone, 2003). The beluga may be a species that (at least at times) shows long-distance avoidance of seismic vessels. Aerial surveys during seismic operations in the southeastern Beaufort Sea recorded much lower sighting rates of beluga whales within 6.2-12.4 mi (10–20 km) of an active seismic vessel. These results were consistent with the low number of beluga sightings reported by observers aboard the seismic vessel, suggesting that some belugas might be avoiding the seismic operations at distances of 6.2-12.4 mi (10–20 km) (Miller et al., 2005).

Captive bottlenose dolphins and (of more relevance in this project) beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al., 2002, 2005). However, the animals tolerated high received levels of sound (pk–pk level >200 dB re 1 μPa) before exhibiting aversive behaviors.

Reactions of toothed whales to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for mysticetes. However, based on the limited existing evidence, belugas should not be grouped with delphinids in the "less responsive" category.

Patenaude et al. (2002) reported that beluga whales appeared to be more responsive to aircraft overflights than bowhead whales. Changes were observed in diving and respiration behavior, and some whales veered away when a helicopter passed at ≤820 ft (250 m) lateral distance at altitudes up to 492 ft (150 m). However, some belugas showed no reaction to the helicopter. Belugas appeared to show less response to fixed-wing aircraft than to helicopter overflights.

In reviewing responses of cetaceans with best hearing in mid-frequency ranges, which includes toothed whales, Southall et al. (2007) reported that combined field and laboratory data for mid-frequency cetaceans exposed to non-pulse sounds did not lead to a clear conclusion about received levels coincident with various behavioral responses. In some settings, individuals in the field showed profound (significant) behavioral responses to exposures from 90-120 dB, while others failed to exhibit such responses for exposure to received levels from 120-150 dB. Contextual variables other than exposure received level, and probable species differences, are the likely reasons for this variability. Context, including the fact that captive subjects were often directly reinforced with food for tolerating noise exposure, may also explain why there was great disparity in results from field and laboratory conditions—exposures in captive settings generally exceeded 170 dB before inducing behavioral responses. A summary of some of the relevant material reviewed by Southall et al. (2007) is next.

LGL and Greeneridge (1986) and Finley et al. (1990) documented belugas and narwhals congregated near ice edges reacting to the approach and passage of icebreaking ships. Beluga whales responded to oncoming vessels by (1) fleeing at speeds of up to 12.4 mi/hr (20 km/hr) from distances of 12.4-50 mi (20-80 km), (2) abandoning normal pod structure, and (3) modifying vocal behavior and/or emitting alarm calls. Narwhals, in contrast, generally demonstrated a "freeze" response, lying motionless or swimming slowly away (as far as 23 mi [37 km] down the ice edge), huddling in groups, and ceasing sound production. There was some evidence of habituation and reduced avoidance 2 to 3 days after onset.

The 1982 season observations by LGL and Greeneridge (1986) involved a single passage of an icebreaker with both ice-based and aerial measurements on June 28, 1982. Four groups of narwhals (n = 9 to 10, 7, 7, and 6) responded when the ship was 4 mi (6.4 km) away (received levels of approximately 100 dB in the 150- to 1,150-Hz band). At a later point, observers sighted belugas moving away from the source at more than 12.4 mi (20 km; received levels of approximately 90 dB in the 150- to 1,150-Hz band). The total number of animals observed fleeing was about 300, suggesting approximately 100 independent groups (of three individuals each). No whales were sighted the following day, but some were sighted on June 30, with ship noise audible at spectrum levels of approximately 55 dB/Hz (up to 4 kHz).

Observations during 1983 (LGL and Greeneridge, 1986) involved two icebreaking ships with aerial survey and ice-based observations during seven sampling periods. Narwhals and belugas generally reacted at received levels ranging from 101 to 121 dB in the 20- to 1,000-Hz band and at a distance of up to 40.4 mi (65 km). Large numbers (100s) of beluga whales moved out of the area at higher received levels. As noise levels from icebreaking operations diminished, a total of

45 narwhals returned to the area and engaged in diving and foraging behavior. During the final sampling period, following an 8-h quiet interval, no reactions were seen from 28 narwhals and 17 belugas (at received levels ranging up to 115 dB).

The final season (1984) reported in LGL and Greeneridge (1986) involved aerial surveys before, during, and after the passage of two icebreaking ships. During operations, no belugas and few narwhals were observed in an area approximately 16.8 mi (27 km) ahead of the vessels, and all whales sighted over 12.4-50 mi (20-80 km) from the ships were swimming strongly away. Additional observations confirmed the spatial extent of avoidance reactions to this sound source in this context.

Buckstaff (2004) reported elevated dolphin whistle rates with received levels from oncoming vessels in the 110 to 120 dB range in Sarasota Bay, Florida. These hearing thresholds were apparently lower than those reported by a researcher listening with towed hydrophones. Morisaka et al. (2005) compared whistles from three populations of Indo-Pacific bottlenose dolphins. One population was exposed to vessel noise with spectrum levels of approximately 85 dB/Hz in the 1- to 22-kHz band (broadband received levels approximately 128 dB) as opposed to approximately 65 dB/Hz in the same band (broadband received levels approximately 108 dB) for the other two sites. Dolphin whistles in the noisier environment had lower fundamental frequencies and less frequency modulation, suggesting a shift in sound parameters as a result of increased ambient noise.

Morton and Symonds (2002) used census data on killer whales in British Columbia to evaluate avoidance of non-pulse acoustic harassment devices (AHDs). Avoidance ranges were about 2.5 mi (4 km). Also, there was a dramatic reduction in the number of days "resident" killer whales were sighted during AHD-active periods compared to pre- and post-exposure periods and a nearby control site.

Monteiro-Neto et al. (2004) studied avoidance responses of tucuxi (*Sotalia fluviatilis*) to Dukane® Netmark acoustic deterrent devices. In a total of 30 exposure trials, approximately five groups each demonstrated significant avoidance compared to 20 pinger off and 55 no-pinger control trials over two quadrats of about 0.19 mi^2 (0.5 km^2). Estimated exposure received levels were approximately 115 dB.

Awbrey and Stewart (1983) played back semi-submersible drillship sounds (source level: 163 dB) to belugas in Alaska. They reported avoidance reactions at 984 and 4,921 ft (300 and 1,500 m) and approach by groups at a distance of 2.2 mi (3.5 km; received levels were approximately 110 to 145 dB over these ranges assuming a 15 log R transmission loss). Similarly, Richardson et al. (1990) played back drilling platform sounds (source level: 163 dB) to belugas in Alaska. They conducted aerial observations of eight individuals among approximately 100 spread over an area several hundred meters to several kilometers from the sound source and found no obvious reactions. Moderate changes in movement were noted for three groups swimming within 656 ft (200 m) of the sound projector.

Two studies deal with issues related to changes in marine mammal vocal behavior as a function of variable background noise levels. Foote et al. (2004) found increases in the duration of killer whale calls over the period 1977 to 2003, during which time vessel traffic in Puget Sound, and particularly whale-watching boats around the animals, increased dramatically. Scheifele et al. (2005) demonstrated that belugas in the St. Lawrence River increased the levels of their vocalizations as a function of the background noise level (the "Lombard Effect").

Several researchers conducting laboratory experiments on hearing and the effects of non-pulse sounds on hearing in mid-frequency cetaceans have reported concurrent behavioral responses. Nachtigall et al. (2003) reported that noise exposures up to 179 dB and 55-min duration affected the trained behaviors of a bottlenose dolphin participating in a TTS experiment. Finneran and Schlundt (2004) provided a detailed, comprehensive analysis of the behavioral responses of belugas and bottlenose dolphins to 1-s tones (received levels 160 to 202 dB) in the context of TTS experiments. Romano et al. (2004) investigated the physiological responses of a bottlenose dolphin and a beluga exposed to these tonal exposures and demonstrated a decrease in blood cortisol levels during a series of exposures between 130 and 201 dB. Collectively, the laboratory observations suggested the onset of a behavioral response at higher received levels than did field studies. The differences were likely related to the very different conditions and contextual variables between untrained, free-ranging individuals vs. laboratory subjects that were rewarded with food for tolerating noise exposure.

Pinnipeds: Pinnipeds generally seem to be less responsive to exposure to industrial sound than most cetaceans. Pinniped responses to underwater sound from some types of industrial activities such as seismic exploration appear to be temporary and localized (Harris et al., 2001; Reiser et al., 2009).

Blackwell et al. (2004b) reported little or no reaction of ringed seals in response to pile-driving activities during construction of a man-made island in the Beaufort Sea. Ringed seals were observed swimming as close as 151 ft (46 m) from the island and may have been habituated to the sounds which were likely audible at distances <9,842 ft (3,000 m) underwater and 0.3 mi (0.5 km) in air. Moulton et al. (2003) reported that ringed seal densities on ice in the vicinity of a man-made island in the Beaufort Sea did not change significantly before and after construction and drilling activities.

Pinnipeds are not likely to show a strong avoidance reaction to the airgun sources proposed for use. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. 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). Monitoring work in the Alaskan Beaufort Sea during 1996–2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al., 2001; Moulton and Lawson, 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes of 560 to 1,500 in^3. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating than when they were not (Moulton and Lawson, 2002). However, these avoidance movements were relatively small, on the order of 328 ft (100 m) to a few hundreds of meters, and many seals remained within 328–656 ft (100–200 m) of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997. Similarly, seals are often very tolerant of pulsed sounds from seal-scaring devices (Mate and Harvey, 1987; Jefferson and Curry, 1994; Richardson et al., 1995a). However, initial telemetry work suggests that avoidance and other behavioral reactions by two other species of seals to small airgun sources may at times be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson et al., 1998). Even if reactions of the species occurring in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations. Additionally, the airguns are only proposed to be used for a short time during the exploration drilling program (approximately 10-14 hours for each well, for a total of 20-28 hours in the Beaufort Sea and 40-56 hours in the Chukchi Sea, and more likely to be 30-42 hours if the fourth well is not completed, over the entire open-water season, which lasts for approximately 4 months).

Southall et al. (2007) reviewed literature describing responses of pinnipeds to non-pulsed sound and reported that the limited data suggest exposures between approximately 90 and 140 dB generally do not appear to induce strong behavioral responses in pinnipeds exposed to non-pulse sounds in water; no data exist regarding exposures at higher levels. It is important to note that among these studies, 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.

Jacobs and Terhune (2002) observed harbor seal reactions to AHDs (source level in this study was 172 dB) deployed around aquaculture sites. Seals were generally unresponsive to sounds from the AHDs. During two specific events, individuals came within 141 and 144 ft (43 and 44 m) of active AHDs and failed to demonstrate any measurable behavioral response; estimated received levels based on the measures given were approximately 120 to 130 dB.

Costa et al. (2003) measured received noise levels from an Acoustic Thermometry of Ocean Climate (ATOC) program sound source off northern California using acoustic data loggers placed on translocated elephant seals. Subjects were captured on land, transported to sea, instrumented with archival acoustic tags, and released such that their transit would lead them near an active ATOC source (at 939-m depth; 75-Hz signal with 37.5- Hz bandwidth; 195 dB maximum source level, ramped up from 165 dB over 20 min) on their return to a haul-out site. Received exposure levels of the ATOC source for experimental subjects averaged 128 dB (range 118 to 137) in the 60- to 90-Hz band. None of the instrumented animals terminated dives or radically altered behavior upon exposure, but some statistically significant changes in diving parameters were documented in nine individuals. Translocated northern elephant seals exposed to this particular non-pulse source began to demonstrate subtle behavioral changes at exposure to received levels of approximately 120 to 140 dB.

Kastelein et al. (2006) exposed nine captive harbor seals in an approximately 82 × 98 ft (25 × 30 m) enclosure to non-pulse sounds used in underwater data communication systems (similar to acoustic modems). Test signals were frequency modulated tones, sweeps, and bands of noise with fundamental frequencies between 8 and 16 kHz; 128 to 130 [± 3] dB source levels; 1- to 2-s duration [60-80 percent duty cycle]; or 100 percent duty cycle. They recorded seal positions and the mean number of individual surfacing behaviors during control periods (no exposure), before exposure, and in 15-min experimental sessions (n = 7 exposures for each sound type). Seals generally swam away from each source at received levels of approximately 107 dB, avoiding it by approximately 16 ft (5 m), although they did not haul out of the water or change surfacing behavior. Seal reactions did not appear to wane over repeated exposure (i.e., there was no obvious habituation), and the colony of seals generally returned to baseline conditions following exposure. The seals were not reinforced with food for remaining in the sound field.

Potential effects to pinnipeds from aircraft activity could involve both acoustic and non-acoustic effects. It is uncertain if the seals react to the sound of the helicopter or to its physical presence flying overhead. Typical reactions of hauled out pinnipeds to aircraft that have been observed include looking up at the aircraft, moving on the ice or land, entering a breathing hole or crack in the ice, or entering the water. Ice seals hauled out on the ice have been observed diving into the water when approached by a low-flying aircraft or helicopter (Burns and Harbo, 1972, cited in Richardson et al., 1995a; Burns and Frost, 1979, cited in Richardson et al., 1995a). Richardson et al. (1995a) note that responses can vary based on differences in aircraft type, altitude, and flight pattern. Additionally, a study conducted by Born et al. (1999) found that wind chill was also a factor in level of response of ringed seals hauled out on ice, as well as time of day and relative wind direction.

Blackwell et al. (2004b) observed 12 ringed seals during low-altitude overflights of a Bell 212 helicopter at Northstar in June and July 2000 (9 observations took place concurrent with pipe-driving activities). One seal showed no reaction to the aircraft while the remaining 11 (92%) reacted, either by looking at the helicopter (n=10) or by departing from their basking site (n=1). Blackwell et al. (2004b) concluded that none of the reactions to helicopters were strong or long lasting, and that seals near Northstar in June and July 2000 probably had habituated to industrial sounds and visible activities that had occurred often during the preceding winter and spring. There have been few systematic studies of pinniped reactions to aircraft overflights, and most of the available data concern pinnipeds hauled out on land or ice rather than pinnipeds in the water (Richardson et al., 1995a; Born et al., 1999).

Born et al. (1999) determined that 49% of ringed seals escaped (i.e., left the ice) as a response to a helicopter flying at 492 ft (150 m) altitude. Seals entered the water when the helicopter was 4,101 ft (1,250 m) away if the seal was in front of the helicopter and at 1,640 ft (500 m) away if the seal was to the side of the helicopter. The authors noted that more seals reacted to helicopters than to fixed-wing aircraft. The study concluded that the risk of scaring ringed seals by small-type helicopters could be substantially reduced if they do not approach closer than 4,921 ft (1,500 m).

Spotted seals hauled out on land in summer are unusually sensitive to aircraft overflights compared to other species. They often rush into the water when an aircraft flies by at altitudes up to 984–2,461 ft (300–750 m). They occasionally react to aircraft flying as high as 4,495 ft (1,370 m) and at lateral distances as far as 1.2 mi (2 km) or more (Frost and Lowry, 1990; Rugh et al., 1997).

Hearing Impairment
Animals exposed to intense sound may experience reduced hearing sensitivity for some period of time following exposure. This increased hearing threshold is known as noise induced threshold shift (TS). The amount of TS incurred is influenced by amplitude, duration, frequency content, temporal pattern, and energy distribution of the noise (Kryter, 1985; Richardson et al., 1995; Southall et al., 2007). It is also influenced by characteristics of the animal, such as behavior, age, history of noise exposure, and health. The magnitude of TS generally decreases over time after noise exposure and if it eventually returns to zero, it is known as TTS. If TS does not return to zero after some time, it is known as PTS. Sound levels associated with TTS onset are generally considered to be below the levels that will cause PTS, which is considered to be auditory injury.

Temporary Threshold Shift: TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter, 1985). While experiencing TTS, the hearing threshold rises, and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days, can be limited to a particular frequency range, and can be in varying degrees (i.e., a loss of a certain number of dBs of sensitivity). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends. Few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

Marine mammal hearing plays a critical role in communication with conspecifics and in interpretation of environmental cues for purposes such as predator avoidance and prey capture. Depending on the degree (elevation of threshold in dB), duration (i.e., recovery time), and frequency range of TTS and the context in which it is experienced, TTS can have effects on marine mammals ranging from discountable to serious. For example, a marine mammal may be able to readily compensate for a brief, relatively small amount of TTS in a non-critical frequency range that takes place during a time when the animal is traveling through the open ocean, where ambient noise is lower and there are not as many competing sounds present. Alternatively, a larger amount and longer duration of TTS sustained during a time when communication is critical for successful mother/calf interactions could have more serious impacts if it were in the same frequency band as the necessary vocalizations and of a severity that it impeded communication. The fact that animals exposed to levels and durations of sound that would be expected to result in this physiological response would also be expected to have behavioral responses of a comparatively more severe or sustained nature is also notable and potentially of more importance than the simple existence of a TTS.

Researchers have derived TTS information for odontocetes from studies on the bottlenose dolphin and beluga. For the one harbor porpoise tested, the received level of airgun sound that elicited onset of TTS was lower (Lucke et al., 2009). If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (cf. Southall et al., 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. The frequencies to which baleen whales are most sensitive are assumed to be lower than those to which odontocetes are most sensitive, and natural background noise levels at those low frequencies tend to be higher. As a result, auditory thresholds of baleen whales within their frequency band of best hearing are believed to be higher (less sensitive) than are those of odontocetes at their best frequencies (Clark and Ellison, 2004), meaning that baleen whales require sounds to be louder (i.e., higher dB levels) than odontocetes in the frequency ranges at which each group hears the best. From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales (Southall et al., 2007). Since current NMFS practice assumes the same thresholds for the onset of hearing impairment in both odontocetes and mysticetes, NMFS' onset of TTS threshold is likely conservative for mysticetes. For this proposed activity, Shell expects no cases of TTS given the strong likelihood that baleen whales would avoid the airguns before being exposed to levels high enough for TTS to occur. The source levels of the drillship are far lower than those of the airguns.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. However, systematic TTS studies on captive pinnipeds have been conducted (Bowles et al., 1999; Kastak et al., 1999, 2005, 2007; Schusterman et al., 2000; Finneran et al., 2003; Southall et al., 2007). Initial evidence from more prolonged (non-pulse) exposures suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al., 1999, 2005; Ketten et al., 2001; cf. Au et al., 2000). The TTS threshold for pulsed sounds has been indirectly estimated as being a sound exposure level (SEL) of approximately 171 dB re 1 μPa2•s (Southall et al., 2007) which would be equivalent to a single pulse with a received level of approximately 181 to 186 dB re 1 μPa (rms), or a series of pulses for which the highest rms values are a few dB lower. Corresponding values for California sea lions and northern elephant seals are likely to be higher (Kastak et al., 2005). For harbor seal, which is closely related to the ringed seal, TTS onset apparently occurs at somewhat lower received energy levels than for odonotocetes. The sound level necessary to cause TTS in pinnipeds depends on exposure duration, as in other mammals; with longer exposure, the level necessary to elicit TTS is reduced (Schusterman et al., 2000; Kastak et al., 2005, 2007). For very short exposures (e.g., to a single sound pulse), the level necessary to cause TTS is very high (Finneran et al., 2003). For pinnipeds exposed to in-air sounds, auditory fatigue has been measured in response to single pulses and to non-pulse noise (Southall et al., 2007), although high exposure levels were required to induce TTS-onset (SEL: 129 dB re: 20 μPa2.s; Bowles et al., unpub. data).

NMFS has established acoustic thresholds that identify the received sound levels above which hearing impairment or other injury could potentially occur, which are 180 and 190 dB re 1 μPa (rms) for cetaceans and pinnipeds, respectively (NMFS 1995, 2000). The established 180- and 190-dB re 1 μPa (rms) criteria are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before additional TTS measurements for marine mammals became available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. TTS is considered by NMFS to be a type of Level B (non-injurious) harassment. The 180- and 190-dB levels are shutdown criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000) and are used to establish exclusion zones, as appropriate. Additionally, based on the summary provided here and the fact that modeling indicates the back-propagated source level for the *Discoverer* to be between 177 and 185 dB re 1 μPa at 1 m (Austin and Warner, 2010), TTS is not expected to occur in any marine mammal species that may occur in the proposed drilling area since the source level will not reach levels thought to induce even mild TTS. While the source level of the airgun is higher than the 190-dB threshold level, an animal would have to be in very close proximity to be exposed to such levels. Additionally, the 180- and 190-dB radii for the airgun are 0.8 mi (1.24 km) and 0.3 mi (524 m), respectively, from the source. Because of the short duration that the airguns will be used (no more than 20-28 or 30-56 hours throughout the entire open-water season in the Beaufort and Chukchi Seas, respectively) hearing impairment is not anticipated. Additionally, the mitigation and monitoring measures described later in this EA are intended to reduce even further any possibility of hearing impairment in marine mammals.

Permanent Threshold Shift: When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges (Kryter, 1985).

There is no specific evidence that exposure to underwater industrial sound associated with oil exploration can cause PTS in any marine mammal (see Southall et al., 2007). However, given the possibility that mammals might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to such activities might incur PTS (e.g., Richardson et al., 1995, p. 372ff; Gedamke et al., 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals (Southall et al., 2007; Le Prell, in press). PTS might occur at a received sound level at least several decibels above that inducing mild TTS. Based on data from terrestrial mammals, a precautionary assumption is that the PTS threshold for impulse sounds (such as airgun pulses as received close to the source) is at least 6 dB higher than the TTS threshold on a peak-pressure basis and probably greater than 6 dB (Southall et al., 2007).

It is highly unlikely that marine mammals could receive sounds strong enough (and over a sufficient duration) to cause PTS during the proposed exploratory drilling programs. The source levels of the drillship are not considered strong enough to cause even mild TTS. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, as noted above, based on the modeled source levels for the drillship, the levels immediately adjacent to the drillship will not reach those thought to induce even mild TTS even if the animals remain in the immediate vicinity of the activity. Based on this, the likelihood of PTS occurring is even more remote. Because the source levels do not reach the threshold of 190 dB currently used for pinnipeds and is at the 180 dB threshold currently used for cetaceans, it is highly unlikely that any type of hearing impairment, temporary or permanent, would occur as a result of either of the exploration drilling activities. Additionally, Southall et al. (2007) proposed that the thresholds for injury of marine mammals exposed to "discrete" noise events (either single or multiple exposures over a 24-hr period) are higher than the 180- and 190-dB re 1 μPa (rms) in-water threshold currently used by NMFS. Table 23 summarizes the SPL and SEL levels thought to cause auditory injury to cetaceans and pinnipeds in-water. For more information, please refer to Southall et al. (2007).

Table 23. Proposed injury criteria for cetaceans and pinnipeds exposed to "discrete" noise events (either single pulses, multiple pulses, or non-pulses within a 24-hr period; Southall et al., 2007).

	Single pulses	**Multiple pulses**	**Non pulses**
Low-frequency cetaceans			
Sound pressure level	230 dB re 1 μPa (peak) (flat)	230 dB re 1 μPa (peak) (flat)	230 dB re 1 μPa (peak) (flat)
Sound exposure level	198 dB re 1 μPa^2-s (M_{lf})	198 dB re 1 μPa^2-s (M_{lf})	215 dB re 1 μPa^2-s (M_{lf})
Mid-frequency cetaceans			
Sound pressure level	230 dB re 1 μPa (peak) (flat)	230 dB re 1 μPa (peak) (flat)	230 dB re 1 μPa (peak) (flat)
Sound exposure level	198 dB re 1 μPa^2-s (M_{lf})	198 dB re 1 μPa^2-s (M_{lf})	215 dB re 1 μPa^2-s (M_{lf})
High-frequency cetaceans			
Sound pressure level	230 dB re 1 μPa (peak) (flat)	230 dB re 1 μPa (peak) (flat)	230 dB re 1 μPa (peak) (flat)
Sound exposure level	198 dB re 1 μPa^2-s (M_{lf})	198 dB re 1 μPa^2-s (M_{lf})	215 dB re 1 μPa^2-s (M_{lf})
Pinnipeds (in water)			
Sound pressure level	218 dB re 1 μPa (peak) (flat)	218 dB re 1 μPa (peak) (flat)	218 dB re 1 μPa (peak) (flat)
Sound exposure level	186 dB re 1 μPa^2-s (M_{pw})	186 dB re 1 μPa^2-s (M_{pw})	203 dB re 1 μPa^2-s (M_{pw})

Non-auditory Physiological Effects

Non-auditory physiological effects or injuries could include stress, neurological effects, bubble formation, and other types of organ or tissue damage (Cox et al., 2006; Southall et al., 2007). If any such effects do occur, they may be limited to unusual situations when animals might be exposed at close range for unusually long periods. Issues that may arise from stress responses over a period of time include accelerated aging, sickness-like symptoms, and suppression of reproduction (physiologically and behaviorally) (Wright et al., 2008).

There are times during an animal's life when they have lower reserves and are more vulnerable to impacts from stressors. For example, if a mammal is stressed at the end of a feeding season just prior to a long distance migration, it may have sufficient energy reserves to cope with the stress. If stress occurs at the end of a long migration or fasting period, energy reserves may not be sufficient to adequately cope with the stress (Tyack, 2008; McEwen and Wingfield, 2003; Romano et al., 2004).

Young animals (and fetuses) are sensitive to neurological consequences of the stress response and can suffer permanent neurological alterations, therefore, deep diving marine mammals may be sensitive to noise as a stressor since they live so closely to their physiological limits (Wright et al., 2008).

In an examination of beaked whales that were stranded in association with military exercises involving sonar (psychological stressor), intracellular globules composed of acute phase proteins were found in cells in six out of eight livers examined, therefore, there is some indication that a stress response was partly involved (Wright et al., 2008). Hypoxia may also pose an issue for marine mammals being exposed to stressors at depth, due to increases in heart rate, which in turn causes an increase in oxygen consumption. This added oxygen demand could push the whales over the physiological edge. The combination of both the psychological stressor and the physiological stressor may have detrimental consequences (Wright et al., 2008). Classic stress responses begin when an animal's central nervous system perceives a potential threat to its homeostasis. That perception triggers stress responses regardless of whether a stimulus actually threatens the animal; the mere perception of a threat is sufficient to trigger a stress response (Moberg, 2000; Sapolsky et al., 2000; Seyle, 1950). Once an animal's central nervous system perceives a threat, it mounts a biological response or defense that consists of a combination of the four general biological defense responses: behavioral responses; autonomic nervous system responses; neuroendocrine responses; or immune responses.

In the case of many stressors, an animal's first and most economical (in terms of biotic costs) response is behavioral avoidance of the potential stressor or avoidance of continued exposure to a stressor. An animal's second line of defense to stressors involves the sympathetic part of the autonomic nervous system and the classical "fight or flight" response which includes the cardiovascular system, the gastrointestinal system, the exocrine glands, and the adrenal medulla to produce changes in heart rate, blood pressure, and gastrointestinal activity that humans commonly associate with "stress." These responses have a relatively short duration and may or may not have significant long-term effect on an animal's welfare. Baker et al. (1983) described two avoidance techniques whales used in response to vessels: horizontal avoidance (faster swimming, and fewer long dives) and vertical avoidance (swimming more slowly but remaining submerged more frequently. Watkins et al. (1981) found that humpback and fin whales appeared startled and increased their swimming speed to move away from the approaching vessel. Johada 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. 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 (Frid and Dill, 2002; Sapolsky, 2000). All of these responses to stressors can cause an abandonment of an area, reduction in reproductive success, and even death (Mullner et al., 2004; Daan et al., 1996).

An animal's third line of defense to stressors involves its neuroendocrine or sympathetic nervous systems; the system that has received the most study has been the hypothalmus-pituitary-adrenal system (also known as the HPA axis in mammals or the hypothalamus-pituitary-interrenal axis in fish and some reptiles). Unlike stress responses associated with the autonomic nervous system, virtually all neuro-endocrine functions that are affected by stress – including immune competence, reproduction, metabolism, and behavior – are regulated by pituitary hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Moberg, 1987; Rivier, 1995), altered metabolism (Elasser et al., 2000), reduced immune competence (Blecha, 2000), and behavioral disturbance. Increases in the circulation of glucocorticosteroids (cortisol, corticosterone, and aldosterone in marine mammals; see Romano et al., 2004) have been equated with stress for many years.

The primary distinction between stress (which is adaptive and does not normally place an animal at risk) and distress is the biotic cost of the response. During a stress response, an animal uses glycogen stores that can be quickly replenished once the stress is alleviated. In such circumstances, the cost of the stress response would not pose a risk to the animal's welfare. However, when an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other biotic functions, which impair those functions that experience the diversion. For example, when mounting a stress response diverts energy away from growth in young animals, those animals may experience stunted growth. When mounting a stress response diverts energy from a fetus, an animal's reproductive success and fitness will suffer. In these cases, the animals will have entered a pre-pathological or pathological state which is called "distress" (sensu Seyle, 1950) or "allostatic loading" (sensu McEwen and Wingfield, 2003). This pathological state will last until the animal replenishes its biotic reserves sufficient to restore normal function. Note that these examples involved a long-term (days or weeks) stress response exposure to stimuli.

Relationships between these physiological mechanisms, animal behavior, and the costs of stress responses have also been documented fairly well through controlled experiment; because this physiology exists in every vertebrate that has been studied, it is not surprising that stress responses and their costs have been documented in both laboratory and free-living animals (for examples see, Holberton et al., 1996; Hood et al., 1998; Jessop et al., 2003; Krausman et al., 2004; Lankford et al., 2005; Reneerkens et al., 2002; Thompson and Hamer, 2000). Although no information has been collected on the physiological responses of marine mammals to anthropogenic sound exposure, studies of other marine animals and terrestrial animals would lead one to expect some marine mammals to experience physiological stress responses and, perhaps, physiological responses that would be classified as "distress" upon exposure to anthropogenic sounds.

For example, Jansen (1998) reported on the relationship between acoustic exposures and physiological responses that are indicative of stress responses in humans (e.g. elevated respiration and increased heart rates). Jones (1998) reported on reductions in human performance when faced with acute, repetitive exposures to acoustic disturbance. Trimper et al. (1998) reported on the physiological stress responses of osprey to low-level aircraft noise, while Krausman et al. (2004) reported on the auditory and physiology stress responses of endangered Sonoran pronghorn to military overflights. Smith et al. (2004a,b) identified noise-induced physiological transient stress responses in hearing-specialist fish (i.e. goldfish) that accompanied short- and long-term hearing losses. Welch and Welch (1970) reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Hearing is one of the primary senses marine mammals use to gather information about their environment and communicate with conspecifics. Although empirical information on the relationship between sensory impairment (TTS, PTS, and acoustic masking) on marine mammals remains limited, it is reasonable to assume that reducing an animal's ability to gather information about its environment and to communicate with other members of its species would be stressful for animals that use hearing as their primary sensory mechanism. Therefore, NMFS assumes that acoustic exposures sufficient to trigger onset PTS or TTS would be accompanied by physiological stress responses because terrestrial animals exhibit those responses under similar conditions (NRC, 2003). More importantly, marine mammals might experience stress responses at received levels lower than those necessary to trigger onset TTS. Based on empirical studies of the time required to recover from stress responses (Moberg, 2000), NMFS also assumes that stress responses could persist beyond the time interval required for animals to recover from TTS and might result in pathological and pre-pathological states that would be as significant as behavioral responses to TTS.

There is little information available on sound-induced stress in marine mammals or on its potential to affect the long-term health or reproductive success of marine mammals (Fair and Becker, 2000; Hildebrand, 2005; Wright et al., 2007a,b). Potential long-term effects, if they occur, would be mainly associated with chronic noise exposure (Nieukirk et al., 2009). Disruption in feeding, especially within small populations could have impacts on whales, their reproductive success and even the survival of the species (NRC, 2005).

The USA National Research Council (NRC) developed a model; [the population consequences of acoustic disturbance] (NRC, 2005); which describes several stages to relate acoustic disturbance effects on marine mammal populations. This model defines potential effects ranging from life functions and behavioral and vital rate level effects. The model is based on an analysis of energy changes during foraging trips by northern and southern elephant seals and the effects this change had on pup survival (Walmsley, 2007). Anthropogenic noise, by itself or in combination with other stressors, can reduce fitness of individuals and decrease the viability of some marine mammal populations (Wright et al., 2008).

Available data on potential stress-related impacts of anthropogenic noise on marine mammals are limited; research on the stress responses of marine mammals and the technologies for measuring hormonal, neuroendocrinological, cardiological, and biochemical indicators of stress in marine mammals are in the early stages of development (ONR, 2009). Obtaining samples from free-ranging marine mammals is complicated by the brief periods of time most are visible while either hauled-out or at the surface to breath, by home ranges that may include expansive and inaccessible areas of ocean which limits the potential for continued or repeated monitoring, and many species cannot be easily captured or sampled using traditional methods (ONR, 2009). Blood sampling is not currently possible for large, free-swimming whales. Conducting stress research on marine mammals, therefore, requires novel approaches to obtaining physiologic data and samples. Real time measurement of existing stress hormones and biomarkers are further limited by the invasive nature of many of the sampling methods (e.g., chase, restraint), which may, themselves, be stressors that could mask the physiological signal of interest (ONR, 2009).

Recent novel, non-invasive approaches developed for collecting corticosteroid and hormone samples from free-swimming large whales include fecal sampling (Hunt et al., 2006) and sampling whale blows (Hogg et al., 2009; NEA, 2011). Both techniques have been used to collect samples from North Atlantic right whales and show promise. The former, however, is limited by the frequency with which feces are encountered. Methods for sampling whale blows, obtaining sufficiently large samples, and measuring stress hormones were being developed and tested by the New England Aquarium during 2011 (NEA, 2011). These methods are still being developed and their practicability and viability have not been tested on Arctic species.

Stranding and Mortality

Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al., 1993; Ketten, 1995). However, explosives are no longer used for marine waters for commercial seismic surveys; they have been replaced entirely by airguns or related non-explosive pulse generators. Underwater sound from drilling, support activities, and airgun arrays is less energetic and has slower rise times, and there is no proof that they can cause serious injury, death, or stranding, even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises involving mid-frequency active sonar, and, in one case, a Lamont-Doherty Earth Observatory (L-DEO) seismic survey (Malakoff, 2002; Cox et al., 2006), has raised the possibility that beaked whales exposed to strong pulsed sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding (e.g., Hildebrand, 2005; Southall et al., 2007).

Specific sound-related processes that lead to strandings and mortality are not well documented, but may include:

(1) Swimming in avoidance of a sound into shallow water;

(2) A change in behavior (such as a change in diving behavior) that might contribute to tissue damage, gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive hemorrhage or other forms of trauma;

(3) A physiological change, such as a vestibular response leading to a behavioral change or stress-induced hemorrhagic diathesis, leading in turn to tissue damage; and

(4) Tissue damage directly from sound exposure, such as through acoustically-mediated bubble formation and growth or acoustic resonance of tissues.

Some of these mechanisms are unlikely to apply in the case of impulse sounds. However, there are indications that gas-bubble disease (analogous to "the bends"), induced in supersaturated tissue by a behavioral response to acoustic exposure, could be a pathologic mechanism for the strandings and mortality of some deep-diving cetaceans exposed to sonar. However, the evidence for this remains circumstantial and is associated with exposure to naval mid-frequency sonar, not seismic surveys or exploratory drilling programs (Cox et al., 2006; Southall et al., 2007).

Both seismic pulses and continuous drillship sounds are quite different from mid-frequency sonar signals, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses or drillships. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz, and the low-energy continuous sounds produced by drillships have most of the energy between 20 and 1,000 Hz. Additionally, the non-impulsive, continuous sounds produced by the drillship proposed to be used by Shell do not have rapid rise times. Rise time is the fluctuation in sound levels of the source. The type of sound that would be produced during the proposed drilling program will be constant and will not exhibit any sudden fluctuations or changes. Typical military mid-frequency sonar emits non-impulse sounds at frequencies of 2-10 kHz, generally with a relatively narrow bandwidth at any one time. A further difference between them is that naval exercises can involve sound sources on more than one vessel. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and oil and gas industry operations on marine mammals. However, evidence that sonar signals can, in special circumstances, lead (at least indirectly) to physical damage and mortality (e.g., Balcomb and Claridge, 2001; NOAA and USN, 2001; Jepson et al., 2003; Fernández et al., 2004, 2005; Hildebrand, 2005; Cox et al., 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity "pulsed" sound.

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al., 2004) were not well founded (IAGC, 2004; IWC, 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel R/V *Maurice Ewing* was operating a 20 airgun (8,490 in^3) array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth, 2002; Yoder, 2002). Nonetheless, the Gulf of California incident, plus the beaked whale strandings near naval exercises involving use of mid-frequency sonar, suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand, 2005). It should also be noted that while marine mammal strandings have occurred in U.S. Arctic waters over the decades, none of those strandings have been linked to oil and gas industry seismic surveys or offshore exploratory drilling operations. No injuries of beaked whales are anticipated during the proposed exploratory drilling programs because none occur in the proposed area. Additionally, strandings or mortalities of marine mammals as a result of the sounds produced during the exploratory drilling programs are highly unlikely.

4.2.2.4.2 Effects of Vessel Activity on Marine Mammals

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. 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., 1989; Richardson et al., 1995; Heide-Jorgensen et al., 2003). 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. In places where boat traffic is heavy, there have been cases where seals have habituated to vessel disturbance (e.g. Bonner, 1982; Jansen et al., 2006).

Collisions with vessels are possible but highly unlikely. Ship strikes of marine mammals can lead to death by massive trauma, hemorrhaging, broken bones, or propeller wounds (Knowlton and Kraus, 2001). Massive propeller wounds can be immediately fatal. If more superficial, whales may be able to survive the collisions (Silber et al., 2009). Vessel speed is a key factor in determining the frequency and severity of ship strikes, with the potential for collision increasing at ship speeds of 15 knots and greater (Laist et al., 2001; Vanderlaan and Taggart, 2007). Shell has agreed to travel at slower speeds. In the Beaufort Sea, Shell has agreed not to operate vessels at speeds greater than 9 knots.

Incidence of injury caused by vessel collisions appears to be low in the Arctic. Less than 1% of bowhead whales have scars indicative of vessel collision. This could be due to either collisions resulting in death (and not accounted for) or a low incidence of co-occurrence of ships and bowhead whales (George et al., 1994).

4.2.2.4.3 Effects of Drill Cuttings, Drilling Muds, and Other Discharges on Marine Mammals

Discharging drill cuttings or other liquid waste streams generated by the drilling vessel could potentially affect marine mammal habitat. Toxins could persist in the water column, which could have an impact on marine mammal prey species. However, despite a considerable amount of investment in research of exposures of marine mammals to organochlorines or other toxins, there have been no marine mammal deaths in the wild that can be conclusively linked to the direct exposure to such substances (O'Shea, 1999). Information regarding potential impacts of such discharges on marine mammal prey is discussed earlier in this EA in Sections 4.2.2.1 and 4.2.2.2.

All of the marine mammal species that may occur in the proposed EA project area prey on either other marine mammals, fish, or invertebrates. If there were significant impacts to marine fish and/or invertebrates from such discharges, that could in turn lead to potentially significant impacts on marine mammals. However, based on the information presented earlier in this EA, such discharges are not anticipated to have more than minor impacts on marine fish and invertebrates. Therefore, only minor impacts to marine mammals are anticipated. Additionally, for the Camden Bay, Beaufort Sea, exploratory drilling program, Shell has agreed to collect several discharge streams and dispose of them at onshore facilities. Therefore, those discharge streams would have no impacts on marine mammals that may occur in the vicinity of Shell's proposed Camden Bay exploratory drilling program.

Many of the contaminants of concern, including organic contaminants such as organochlorine compounds and PAHs, as well as metals such as chromium and mercury, have the potential to accumulate in marine mammals. Indirect effects to marine mammals could result from exposure to contaminants of concern through the food web and the relevant pathway of exposure would involve trophic transfers of contaminants rather than direct exposure. Monitoring conducted as part of the ANIMIDA and cANIMIDA projects has shown that oil and gas developments in the Alaskan Beaufort Sea "are not contributing ecologically important amounts of petroleum hydrocarbons and metals to the near-shore marine food web of the area" (Neff, 2010). Additionally, Shell has agreed to recycle drilling muds to the extent operationally practical in both the Beaufort and Chukchi Seas. This will help to further reduce impacts to marine mammals.

4.2.2.4.4 Effects of a Small Liquid Hydrocarbon Spill on Marine Mammals

There is a small potential for a fuel spill during the proposed activities. Shell has developed oil spill prevention plans for both drilling programs to help reduce further the possibility of an oil spill of any size from occurring. If marine mammals were to come into contact with spilled oil, some of the potential effects include:

- For cetaceans, skin irritation, baleen fouling (which might reduce feeding efficiency), respiratory distress from inhalation of hydrocarbon vapors, consumption of some contaminated prey items, and temporary displacement from contaminated feeding areas; and
- For pinnipeds, eye irritation, increased stress, consumption of contaminated prey items, temporary displacement from contaminated feeding areas, and death of seal pups due to hypothermia.

The probability of a large or very large oil spill occurring in either the Beaufort Sea or the Chukchi Sea drilling areas is remote. Based on modeling conducted by Bercha (2008), the predicted frequency of an exploration well oil spill in waters similar to those in the Beaufort Sea and Chukchi Sea, Alaska, is 0.000612 per well for a blowout sized between 10,000 barrels (bbl) to 149,000 bbl and 0.000354 per well for a blowout greater than 150,000 bbl. Additional information on large or very large oil spills, including the potential impacts of a large or very large oil spill on marine mammals and other resources in the EA proposed project area is contained in Section 4.5 of this EA.

4.2.2.4.5 Conclusion of Effects on Marine Mammals

Based on the discussion of potential impacts to marine mammals from the proposed action, the most likely impacts could be behavioral disturbance reactions from the introduction of noise into the marine environment and vessel and aircraft activity. There is also a potential for some acoustic masking in baleen whales, as the frequencies of their hearing and vocalizations overlap with the frequencies of much of the equipment to be used during the exploratory drilling operations. It is less likely that masking would occur in odonotocetes and pinnipeds because of the higher frequencies of their hearing and vocalizations. Impacts from drill cuttings, drilling muds, and other discharges are likely to be minor, if they occur at all. Additionally, impacts from small fuel spills are anticipated to be minor.

Several of the marine mammal species that may occur in the EA proposed project area are migratory and could therefore occur in both the Beaufort and Chukchi Seas. The two species that are most likely to be migrating through the area (i.e., both the Beaufort and the Chukchi Seas) during the time frame of Shell’s proposed operations are the bowhead whale and the beluga whale. The spring migrations for these species will be completed prior to the beginning of Shell’s operations. While some animals of both species remain in the Beaufort and Chukchi Seas during the summer months, the majority of these species occur in the area in the fall. These species typically migrate from the Canadian Beaufort Sea into U.S. waters in September and October. Gray whales also conduct long annual migrations from Mexico to the Arctic (Rugh et al., 1999), moving northward from mid-February to May and returning south out of the Chukchi

Sea in October and November (Rice et al., 1984). However, while in the Chukchi Sea, gray whales are not migrating. Instead, these are their summer feeding grounds. While it is possible for large numbers of gray whales to occur in the Chukchi Sea during the majority of Shell's proposed operations, the majority are seen within 31.1 mi (50 km) of shore (i.e., closer to shore than Shell's proposed operations). Gray whales are uncommon in the area of Camden Bay.

In the Beaufort Sea, Shell has agreed to cease operations on August 25 and will not resume until the communities of Kaktovik and Nuiqsut have completed their fall bowhead whale hunts (which typically occurs around September 15). Therefore, animals that migrate past the area of Shell's proposed Camden Bay, Beaufort Sea, exploratory drilling sites in late August through early to mid-September will not be impacted, as operations will not be conducted at that time, and the vessels will not be in the area. Therefore, these early migrating animals could only potentially be impacted by operations in the Chukchi Sea. This further reduces the overall cumulative impacts that these simultaneous operations may have on marine mammals in the region. Overall, impacts to marine mammals are anticipated to have minor to moderate effects. Impacts would only occur during the time that the animals are in the ensonified areas and are expected to be short-term in duration and limited to behavioral disturbance. Lastly, the two proposed exploratory drilling programs are located more than 400 mi (644 km) apart. As noted in Table 6, the *Kulluk* has the largest 120 dB radius, which is modeled at 8.24 mi (13.27 km). The *Discoverer*, which is the only drillship proposed for use in the Chukchi Sea has a modeled 120 dB radius of 0.81 mi (1.31 km) in the Chukchi Sea. Additionally, the modeled 120 dB radius for the airgun array (the same array is proposed for use in both locations) is 6.5 mi (10.5 km). Based on this information, there would not be overlap in the sound fields between the two programs. Additionally, there would be hundreds of miles between the two sound fields for the two programs. Therefore, animals would not occur within ensonified zones for long periods of time. Additional information concerning the potential effects from these activities on marine mammals is contained in the Notices of Proposed IHAs. *See* 76 FR 68974 (November 7, 2011) and 76 FR 69958 (November 9, 2011).

4.2.3 Effects on the Socioeconomic Environment

4.2.3.1 Economy

Information on the potential direct and indirect effects on the economy is provided in Section 4.2.10 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b) and Section 4.10 of BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011). That information is summarized here and incorporated herein by reference. Activities conducted by Shell for its two 2012 proposed exploratory drilling programs are only expected to generate economic effects at the local level. Therefore impacts are not analyzed at a State or Federal level. Shell's offshore exploration plans promise to provide some specific benefits to local residents in and around Barrow, Nuiqsut, Kaktovik, Wainwright, Point Hope, and Point Lay. Local residents could obtain jobs as protected species observers (formerly marine mammal observers), subsistence advisors, or communication call center staff. Even with the potential employment and related personal income associated with the proposed activities, it appears that employment opportunities for local residents, especially Alaskan Natives, would remain comparatively low in oil industry-related jobs on the North Slope. The proposed exploration activities will not result in additional onshore oil and gas infrastructure from which the NSB and State of Alaska would receive property tax revenues. Based on this, the proposed action is anticipated to have a negligible impact on the economy of the NSB.

4.2.3.2 Sociocultural Systems

Information on the potential direct and indirect effects on the sociocultural systems in the EA proposed project area is provided in Section 4.2.8 of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b) and Section 4.9 of BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011). That information is summarized here and incorporated herein by reference. BOEM, which is the agency with the authority to allow offshore oil and gas exploration activities to occur, only permits offshore oil and gas exploration activities to occur in Arctic waters if such activities are conducted in a way that minimizes impacts to subsistence resources. Potential impacts to subsistence activities in the region are discussed in Section 4.2.3.3 of this EA. Based on the fact that impacts to subsistence activities are anticipated to be minor, impacts to sociocultural systems would be minor to negligible.

4.2.3.3 Subsistence

Subsistence use by the communities of Kaktovik, Nuiqsut, Barrow, Wainwright, Point Lay, Point Hope, Kivalina, and Kotzebue, including information on which species are hunted and when, is provided in Section 3.3.3 of this EA. This section describes the potential direct and indirect effects of Alternative 2 on subsistence within these communities.

4.2.3.3.1 Marine Mammals

NMFS has defined "unmitigable adverse impact" in 50 CFR 216.103 as:

> …an impact resulting from the specified activity: (1) That is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by: (i) Causing the marine mammals to abandon or avoid hunting areas; (ii) Directly displacing subsistence users; or (iii) Placing physical barriers between the marine mammals and the subsistence hunters; and (2) That cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

Noise and general activity during Shell's proposed drilling programs have the potential to impact marine mammals hunted by Native Alaskans. In the case of cetaceans, the most common reaction to anthropogenic sounds (as noted previously in this document) is avoidance of the ensonified area. In the case of bowhead whales, this often means that the animals divert from their normal migratory path by several kilometers. Helicopter activity also has the potential to disturb cetaceans and pinnipeds by causing them to vacate the area. Additionally, general vessel presence in the vicinity of traditional hunting areas could negatively impact a hunt. Native knowledge indicates that bowhead whales become increasingly "skittish" in the presence of seismic noise. Whales are more wary around the hunters and tend to expose a much smaller portion of their back when surfacing (which makes harvesting more difficult). Additionally, natives report that bowheads exhibit angry behaviors in the presence of seismic sound, such as tail-slapping, which translate to danger for nearby subsistence harvesters.

In the case of subsistence hunts for bowhead whales in the Beaufort Sea, there could be an adverse impact on the hunt if the whales were deflected seaward (further from shore) in traditional hunting areas. The impact would be that whaling crews would have to travel greater distances to intercept westward migrating whales, thereby creating a safety hazard for whaling crews and/or limiting chances of successfully striking and landing bowheads.

Bowhead Whales

Shell's proposed exploratory drilling programs will not commence prior to completion of the spring bowhead whale hunts in the Chukchi and Beaufort Sea communities. Therefore, there will be no impacts to spring bowhead whale hunting.

The two communities closest to Shell's proposed Camden Bay, Beaufort Sea, exploratory drilling program are Kaktovik and Nuiqsut (who conducts their bowhead hunts from Cross Island). Both communities hunt bowhead whales in the fall. Traditionally, these communities begin preparing for the hunt in late August and typically conduct the hunt during the first couple of weeks of September. Shell has agreed to cease activities in Camden Bay on August 25 to allow the communities of Kaktovik and Nuiqsut to prepare for the fall bowhead hunts, will move the drillship and all support vessels out of the hunting area so that there are no physical barriers between the marine mammals and the hunters, and will not recommence activities until the close of both communities' hunts. Shell has stated that they will move the vessels to a location that is agreed to by the AEWC.

Barrow also conducts a fall bowhead whale hunt and is located approximately 298 mi (479.6 km) west of Shell's proposed Camden Bay drill sites and approximately 140 mi (225 km) east of Shell's proposed Chukchi Sea drill sites. Although fall hunting can begin as early as late August, the fall bowhead whale hunt in Barrow typically occurs in September and October. Fall whaling occurs east or northeast of Cape Simpson on Smith Bay in an area that extends 10 mi (16 km) west of Barrow to 30 mi (48 km) north of Barrow and southeast 30 mi (48 km) off Cooper Island with an eastern boundary on the east side of Dease Inlet. Because of the distance of Barrow from both proposed drill sites, Shell's activities will not displace the hunters. Additionally, when Shell moves its drillship and support vessels out of Camden Bay, the vessels will not be moved into an area that would disrupt the Barrow fall bowhead whale hunt. Moreover, hunters from the northwest Arctic villages prefer to harvest whales within 50 mi (80 km) of the coast so as to avoid long tows back to shore. Because of the considerable distance from shore of Shell's proposed Chukchi Sea drill sites, there is not a potential for overlap in areas where active hunting is occurring. Shell will have several support vessels that will transit between the drill site and shore. Shell will use the Communication Call Centers. These Call Centers are designed to inform Shell about the timing and location of active subsistence hunts so that Shell can avoid those areas and avoid impacting active hunts.

The Chukchi Sea coastal communities have occasionally taken bowhead whales during fall hunts in recent years; however, the total number has been small. With the shifts in ice patterns, these communities have indicated the importance of resuming their fall bowhead whale hunts. The communities of Wainwright, Point Hope, and Point Lay have been allocated a quota that they may use for the fall hunt by the AEWC. In October 2010, Wainwright landed its first fall whale in more than 90 years and landed another whale during the fall 2011 bowhead whale hunt.

Bering Sea communities hunt for bowhead whales later in the season (typically late November/early December). Shell will begin transiting out of the Beaufort and Chukchi Seas on October 31. This will provide ample time for Shell's vessels to transit through the Bering Strait and past these communities prior to commencement of late season bowhead whale hunting.

The proposed activities will have no effect on spring bowhead whale hunts. There will not be an overlap in active drilling operations in the Beaufort Sea with the fall bowhead hunts in Kaktovik and Nuiqsut (conducted from Cross Island), as Shell has agreed to shutdown activities during the hunts by those two communities. Based on this, there will be no effect on the bowhead hunts in these two communities. Barrow lies a considerable distance from both operations, as do the Chukchi Sea communities. Although there will be a temporal overlap between the drilling operations and fall hunts, based on the distance between the two activities and the mitigation measures (described more in Chapter 5) developed by Shell, there will be only a negligible impact to the hunts, and there will not be an unmitigable adverse impact on the availability of bowheads for subsistence uses.

Beluga Whales

Beluga whales are not a prevailing subsistence resource in the communities of Kaktovik, Nuiqsut, or Barrow. Thus, given the location and timing of Shell's activities in the Beaufort or Chukchi Seas, any such behavioral response by beluga to these activities would have no significant effect on them as a subsistence resource.

Beluga whales are a prevailing subsistence resource in the Chukchi Sea community of Point Lay. The Point Lay beluga hunt is concentrated in the first two weeks of July (but sometimes continues into August), when belugas are herded by hunters with boats into Kasegaluk Lagoon and harvested in shallow waters. Although Shell may begin transiting through the Chukchi Sea prior to the completion of this hunt, all transit activity will be coordinated via the nearest Communication Call Centers operating in the Chukchi Sea. Shell will enter the Chukchi Sea far offshore, outside of the areas where the beluga hunt occurs. Additionally, in BOEM's lease stipulations, there is a requirement that industry operators remain outside of the Ledyard Bay Critical Habitat Unit, thereby reducing further potential impacts to the hunts in Point Lay. It is possible, but unlikely, that accessibility to belugas during the subsistence hunt could be impaired during the exploratory drilling activities. Therefore, the proposed exploratory drilling programs in the Beaufort and Chukchi Seas are not expected to have significant or unmitigable impacts to beluga whale subsistence harvests.

Ice Seals

Seals are an important subsistence resource and ringed seals make up the bulk of the seal harvest of both Kaktovik and Nuiqsut. Seals can be hunted year-round, but are taken in highest numbers in the summer months in the Beaufort Sea. In Kaktovik, most seals are hunted during the open-water season in July, August, and sometimes into September when basking on ice floes (SRBA, 2010). Although there is a temporal overlap between sealing and Shell's proposed Camden Bay operations, Kaktovik is located 60 mi (96.6 km) to the east of Shell's proposed drill sites. Seal-hunting trips can take Nuiqsut hunters several miles offshore; however, the majority of seal hunting takes place closer to shore. The mouth of the Colville River is considered a productive seal hunting area (AES, 2009), as well as the edge of the sea ice. Shell's proposed Camden Bay drill sites are located more than 100 mi (161 km) from the mouth of the Colville River, so there is little chance Shell's activities will impact subsistence hunting for seals. It is assumed that effects on subsistence seal harvests would be negligible given the distances between Shell's proposed drill sites and the subsistence seal hunting areas of the Beaufort Sea communities.

Seals are an important subsistence resource in the Chukchi Sea community of Wainwright. Ringed seals make up the bulk of the seal harvest. Most ringed and bearded seals are harvested in the winter or in the spring (May-July), but some harvest continues into the open water period. Hunting that does occur during the open-water season generally occurs within 10 mi (16 km) of the coastline (AES 2009), while Shell's drilling program will occur more than 65 mi (105 km) offshore. Timing of activities will be coordinated via the nearest communication and call centers operating in the Chukchi Sea. It is assumed that effects on subsistence seal harvests would be negligible given the timing and distances between Shell's proposed drill sites and the subsistence seal hunting areas of the Chukchi Sea communities. Therefore, the proposed exploratory drilling programs in the Beaufort and Chukchi Seas are not expected to have significant or unmitigable impacts to ice seal subsistence harvests.

Walrus and Polar Bears

It is unlikely that the proposed activities would impact subsistence hunts of walrus and polar bear in the communities. The communities that do hunt walrus typically do so close to shore. Hunts are more common in the Chukchi Sea. Peak hunting months for walrus tend to be May through July. While the latter part of the hunting season for walrus overlaps temporally with Shell's proposed activities, because of the distance between Shell's drill sites and typical hunting grounds impacts would be negligible. Polar bears are also hunted nearshore. Therefore, Shell's activities would have a negligible impact on polar bear subsistence hunts.

4.2.3.3.2 Fish

Temporally, subsistence fishing activities will co-occur with Shell's proposed drilling activities in all of the communities. Freshwater fishing occurs in rivers. Therefore, the proposed activities will not affect freshwater fishing activities. Fishing that occurs near the Colville River Delta is located more than 100 mi (161 km) from Shell's proposed Camden Bay drill sites. Subsistence fishing for marine fishes occurs close to shore near the communities. Shell's proposed Camden Bay drill sites are located more than 20 mi (32.2 km) offshore, and Shell's proposed Chukchi Sea drill sites are located more than 65 mi (105 km) offshore. Although support and supply vessels will be operating closer into shore, use of the communication and call centers will reduce interference with subsistence fishing activities. Based on these factors, Shell's proposed exploratory drilling programs would have a negligible impact on subsistence fishing.

4.2.3.4 Coastal and Marine Use

The proposed Shell exploratory drilling programs in the Beaufort and Chukchi Seas are not anticipated to have any effect on the coastal and marine uses or the recreational and visual resources in the project areas. All proposed project activities are expected to be conducted in areas that would not conflict with marine activities such as military activities, commercial shipping, commercial fishing, and recreational boating.

Currently, shipping and vessel transit occurs at low levels in the U.S. Arctic Ocean. This is not expected to change over the term of this proposed action. While each of the two exploratory drilling programs would require a fleet of approximately 8-11 vessels, the presence of these vessels in the areas of Shell's prospects will not have a significant effect on current levels of cruise or recreational vessels over the span of the proposed exploratory drilling programs. The proposed exploratory drilling programs will have no effect on commercial fishing, recreational fishing, or mariculture, as none of these is known to exist in the Beaufort and Chukchi Seas. Therefore, it is anticipated that the proposed exploratory drilling programs will not have effects on coastal and marine uses.

4.2.3.5 Environmental Justice

This EA analyzes impacts to subsistence resources, subsistence harvest practices, and sociocultural systems that members of North Slope and Northwest Arctic communities rely upon as factors that would most affect environmental justice. Because the analyses above conclude that the proposed action would result in negligible direct and indirect effects to these resources, it follows that the proposed action would have non-existent to negligible direct and indirect effects on environmental justice.

4.3 Effects of Alternative 3

Under this alternative, NMFS would issue IHAs to Shell for the proposed exploratory drilling programs in the Beaufort and Chukchi Seas during the 2012 Arctic open-water season with required mitigation, monitoring, and reporting requirements as discussed in Chapter 5 of this Draft EA. However, under this alternative activities in the Chukchi Sea would cease at the end of September instead of the end of October (as under Alternative 2). There are no other differences between Alternatives 2 and 3. As part of NMFS' action, the mitigation and monitoring described later in this EA would be undertaken as required by the MMPA, and, as a result, no serious injury or mortality of marine mammals is expected and correspondingly no impact on the reproductive or survival ability of affected species would occur. Potentially affected marine mammal species under NMFS' jurisdiction include: bowhead, beluga, killer, gray, minke, fin, and humpback whales; harbor porpoise; and bearded, spotted, ringed, and ribbon seals.

4.3.1 Effects on the Physical Environment

Although NMFS does not expect the physical environment would be directly affected from the proposed action (i.e., the issuance of IHAs for the take of marine mammals incidental to the specified activities), it could be indirectly affected by the proposed exploratory drilling programs. Effects on the physical oceanography, sea ice, air quality, acoustic environment, and water quality would generally be the same as those described above in Section 4.2.1 for Alternative 2, which are mostly temporary in nature. However, because the Chukchi Sea exploratory drilling program would operate for approximately 30 days less under this alternative, the length of time that certain impacts would persist would be reduced.

Sound from Shell's activities would only propagate into the marine environment for approximately three months instead of four months in the Chukchi Sea, thereby reducing impacts to the acoustic environment by about 25%. Additionally, the chances of impacting sea ice would be reduced even further under this alternative, as Shell would have ceased operations and left the area long before sea ice typically begins to form in the area.

Because operations for the proposed Camden Bay, Beaufort Sea,, exploratory drilling program would occur in exactly the same manner and for the same amount of time evaluated under Atlernative 2, there would be no differences in effects in the Beaufort Sea proposed project area between the two alternatives.

4.3.2 Effects on the Biological Environment

4.3.2.1 Effects on Lower Trophic Organisms

No additional effects beyond those described above in Section 4.2.2.1 for Alternative 2 would be expected on lower trophic orgranisms under Alternative 3. In the Chukchi Sea, impacts would likely be less than those described for Atlernative 2, as the operating season would be reduced by about 25%.

4.3.2.2 Effects on Fish and Essential Fish Habitat

No additional effects beyond those described above in Section 4.2.2.2 for Alternative 2 would be expected on fish or EFH under Alternative 3. In the Chukchi Sea, impacts would likely be less than those described for Alternative 2, as the operating season would be reduced by about 25%.

4.3.2.3 Effects on Marine and Coastal Birds

While NMFS' proposed action of issuing IHAs for the take of marine mammals incidental to conducting offshore exploratory drilling programs will not impact marine and coastal birds, Shell's activities may have direct or indirect effects on these species. No additional effects beyond those described above in Section 4.2.2.3 for Alternative 2 would be expected on marine and coastal birds under Alternative 3. In the Chukchi Sea, impacts would likely be less than those described for Alternative 2, as the operating season would be reduced by about 25%.

4.3.2.4 Effects on Marine Mammals

As with Alternative 2, noise exposure, habitat degradation, and vessel activity, which could possibly lead to ship strikes, are the primary mechanisms by which activities associated with exploratory drilling programs in the Beaufort and Chukchi Seas could directly or indirectly affect marine mammals under Alternative 3. Potential impacts from noise exposure, habitat degradation, and vessel activity would be the same as described above in Section 4.2.2.4, and that discussion is not repeated here.

The primary difference regarding potential impacts to marine mammals under Atlernative 3 is the numbers and types of species that would be exposed to activities in the Chukchi Sea. Additionally, impacts to certain marine mammal species migrating across both the Beaufort and Chukchi Seas would be reduced.

Bowhead whales migrate westward from the Canadian Beaufort Sea through the U.S. Beaufort and Chukchi Seas in September and October. Although some individuals have been sighted in the northeastern Chukchi Sea during summer months (Clarke et al., 2011; Ireland et al., 2008), bowheads are typically not found in U.S. waters until late August or early September in the fall. Bowhead whales increased in the Chukchi Offshore Monitoring in Drilling Area (COMIDA) in September and October 2008 through 2010, with sighting rates highest in October (Clarke et al., 2011). This was similar to the previously observed distribution during surveys conducted from 1989 through 1991 (Clarke et al., 2011). Under Alternative 3, Shell would be required to cease operations in the Chukchi Sea by the end of September. Therefore, fewer bowhead whales would be impacted by the proposed Chukchi Sea exploratory drilling program because Shell would stop operating before the majority of the population reaches the Chukchi Sea Lease Sale 193 area. Temporal segregation by size and sex class occurs during the spring and fall migrations. In the spring, the first wave consists of sub-adults, the second of larger whales, and the third is comprised of even larger whales and cows with calves (NMFS, 2008b; Rugh, 1990; Suydam and George, 2004). The reverse order is seen in the fall throughout the migration corridor (Koski and Miller, 2009; Noongwook et al., 2007); however, the cows with calves typically occur later in the migration in the fall as well. Therefore, fewer cows with calves would be impacted, as operations would cease before that portion of the population reaches the Chukchi Sea Lease Sale 193 area.

Beluga whales from both the Beaufort Sea and eastern Chukchi Sea stocks overwinter in the Bering Sea and then migrate to coastal estuaries, bays, and rivers in the spring (Allen and Angliss, 2010). Although individuals from both stocks can be found in U.S. Beaufort and Chukchi Seas waters during the summer, open-water period, they are typically found further north than Shell's proposed exploratory drill sites in waters around 79-80º North latitude. Beluga whales from both stocks have been noted migrating westward back through the Beaufort and Chukchi Seas in September and October southward to the Bering Sea. Therefore, as with the bowhead whales, if Chukchi Sea operations cease at the end of September instead of the end of October, fewer beluga whales would be exposed to activities associated with the exploratory drilling program in the Chukchi Sea.

Under Alternative 3, impacts to both bowhead and beluga whales would be reduced further, as it is less likely that they would travel through areas with active exploratory drilling operations twice. In the Beaufort Sea, Shell has agreed to cease operations on August 25 and will not resume until the communities of Kaktovik and Nuiqsut have completed their fall bowhead whale hunts (which typically occurs around September 15). Therefore, animals that migrate past the area of Shell's proposed Camden Bay, Beaufort Sea, exploratory drilling sites in late August through early to mid-September will not be impacted, as operations will not be conducted at that time, and the vessels will not be in the area. Therefore, these early migrating animals will only potentially be impacted by operations in the Chukchi Sea. However, they would only be impacted in the Chukchi Sea if they reach the Chukchi Sea Lease Sale 193 area prior to the end of September. Additionally, individuals that begin their westward migrations later in the season once the Beaufort Sea operations have resumed would only be impacted in the Beaufort Sea, as the Chukchi Sea program would have ended prior to those individuals reaching the Chukchi Sea. This further reduces the overall cumulative impacts that these simultaneous operations may have on marine mammals in the region.

Impacts to other cetacean species and to ice seals would be the same under Alternative 3 as for Alternative 2 in the Beaufort Sea. In the Chukchi Sea, the types of impacts that could potentially occur under Alternative 2 could also potentially occur under Alternative 3. However, the duration of those impacts would be lessened under Alternative 3, as Shell would cease operations in the Chukchi Sea at the end of September instead of the end of October. Overall, impacts to marine mammals are anticipated to have minor to moderate effects. Impacts would only occur during the time that the animals are in the ensonified areas and are not anticipated to persist for long periods of time. Also, the two proposed exploratory drilling programs are located more than 400 mi (644 km) apart, so there would not be overlap in the sound fields between the two programs. Additionally, there would be hundreds of miles between the two sound fields for the two programs. Therefore, animals would not occur within ensonified zones for long periods of time. Lastly, individuals that begin the migrations early or late in the fall season would only be impacted in one of the two proposed operating areas.

4.3.3 Effects on the Socioeconomic Environment

No additional effects beyond those described above in Section 4.2.3 for Alternative 2 would be expected on the economy, sociocultural systems, coastal and marine use, and environmental justice under Alternative 3. There would also be no additional effects to subsistence activites in the Beaufort Sea under Alternative 3. However, there would likely be a reduction in possible impacts to subsistence activities in the Chukchi Sea communities of Wainwright, Point Hope, Point Lay, Kivalina, and Kotzebue. If Shell ceases operations at the end of September instead of the end of October, there would be no temporal overlap with fall whaling activities. Although, as described above in Section 4.2.3.3 under Alternative 2, the likelihood of Shell's Chukchi Sea exploratory drilling program affecting fall whaling in the Chukchi Sea is small, those impacts would be reduced even further under Alternative 3.

4.4 Estimation of Takes

For purposes of evaluating the potential significance of the "takes" by harassment, estimations of the number of potential takes are discussed in terms of the populations present. The specific number of takes considered for the authorizations is developed via the MMPA process, and the analysis in this EA provides a summary of the anticipated numbers that would be authorized to give a relative sense of the nature of impact of NMFS' proposed action. The methods to estimate take by harassment and present estimates of the numbers of marine mammals that might be affected during Shell's proposed exploratory drilling programs are described in detail in Shell's IHA applications and the *Federal Register* notices of proposed IHAs, which were published in the *Federal Register* on November 7, 2011 (76 FR 68974) for the Beaufort Sea program and on November 9, 2011 (76 FR 69958) for the Chukchi Sea program.

The marine mammal species NMFS determined likely to be taken by Level B harassment incidental to Shell's Beaufort Sea program are: bowhead, gray, and beluga whales; harbor porpoise; and ringed, bearded, spotted, and ribbon seals. The marine mammal species NMFS determined likely to be taken by Level B harassment incidental to Shell's Chukchi Sea program are: bowhead, beluga, killer, fin, gray, humpback, and minke whales; harbor porpoise; and bearded, ribbon, ringed, and spotted seals. Any takes that occur are anticipated to result from noise propagation from the drillship, ice management/icebreaking activities, and the airguns used for the ZVSP surveys and would take the form of Level B behavioral harassment. Table 24 presents the number of each species that might be affected by use of the *Kulluk* in the Beaufort Sea, by use of the *Discoverer* in the Chukchi Sea, the total number of each species that might be affected in both seas, and the percentage of the populations or stocks. Although Shell presented take estimates for both the *Kulluk* and the *Discoverer* in the Beaufort Sea, only one of the two drillships would be used in the Beaufort Sea. Beacause Shell has also proposed to use the *Discoverer* in the Chukchi Sea, if it is in fact used for that program, it cannot also be used in the Beaufort Sea. Therefore, NMFS presents in this EA the most likely scenario. Additional information regarding the "take" estimates and population sizes that were used to determine the percentages of a stock and population that might potentially be taken can be found in the Notices of Proposed IHAs. *See* 76 FR 68974 (November 7, 2011) and 76 FR 69958 (November 9, 2011).

Table 24. Numbers of marine mammals estimated to be taken from each program and both programs combined and the total percentage of the population or stock from both programs combined.

Species	Total Proposed Level B Take with the Kulluk[1]	Total Proposed Level B Take with the Discoverer[2]	Total Proposed Level B Take from both Programs	Percentage of Stock or Population
Bowhead Whale	5,608	53	5,661	37.2
Gray Whale	15	46	61	0.34
Beluga Whale	38	15	53	0.14
Killer Whale	0	15	15	2.3
Fin Whale	0	15	15	0.26
Humpback Whale	0	15	15	0.53
Minke Whale	0	15	15	1.22-1.85
Harbor Porpoise	15	15	30	0.06
Ringed Seal	1,069	814	1,883	0.76
Bearded Seal	55	36	91	0.04-0.06
Spotted Seal	7	21	28	0.05
Ribbon Seal	5	15	20	0.04

[1]This includes take from operation of the Kulluk, ice management/icebreaking, and the airguns
[2]This includes take from operation of the Discoverer, ice management/icebreaking, and the airguns

4.5 Large and Very Large Oil Spill Analysis

An oil spill is not part of the proposed action (i.e., issuance of IHAs for the take of marine mammals incidental to conducting exploratory drilling programs) nor is it part of the specified activities considered by NMFS. Therefore, an oil spill is neither a direct nor an indirect effect of the proposed action. Additionally, the likelihood of a large or very large oil spill occurring at either of the two proposed program sites is extremely remote. The likelihood of a large or very large (i.e. ≥1,000 barrels or ≥150,000 barrels, respectively) oil spill occurring during Shell's proposed programs has been estimated to be low. A total of 35 exploration wells have been drilled between 1982 and 2003 in the Chukchi and Beaufort Seas, and there have been no incidents of loss of well control or a blowout resulting from the loss of well control. In addition, no blowouts resulting from a loss of well control have occurred from the approximately 98 exploration wells drilled within the Alaskan OCS (MMS, 2007a; BOEMRE, 2011). Additional information regarding the probability of a spill occurring is contained in Shell's IHA applications to NMFS, BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf

Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b), and BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011), and that information is hereby incorporated by reference. Based on modeling conducted by Bercha (2008), the predicted frequency of an exploration well oil spill in waters similar to those in Camden Bay, Beaufort Sea, and the Chukchi Sea, Alaska, is 0.000612 per well for a blowout sized between 10,000 bbl to 149,000 bbl and 0.000354 per well for a blowout greater than 150,000 bbl.

Although the probability of such an event is discountable, NMFS nonetheless acknowledges this is a potential issue and describes the potential environmental effects associated with a large or very large oil spill. Potential impacts to marine mammals is included herein, while impacts to other resources (e.g., physical, fish, birds, socioeconomic, etc.) can be found in the BOEM documents mentioned below, and that information is incorporated herein by reference. An analysis of the potential impacts of an oil spill on the physical, biological, and socioeconomic environments is also included in NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011). That information is incorporated herein by reference.

Additionally, Shell has implemented several design and operational measures to reduce further the potential for an oil spill. That information is summarized here and is described in more detail in the BOEM documents mentioned in the next paragraph. Shell has implemented several design standards and practices to reduce the already low probability of an oil spill occurring as part of its operations. The wells proposed to be drilled in the Arctic are exploratory and will not be converted to production wells; thus, production casing will not be installed, and the well will be permanently plugged and abandoned once exploration drilling is complete. Shell has also developed and will implement the following plans and protocols: Shell's Critical Operations Curtailment Plan; IMP; Well Control Plan; and Fuel Transfer Plan. Many of these safety measures are required by the Department of the Interior's interim final rule implementing certain measures to improve the safety of oil and gas exploration and development on the Outer Continental Shelf in light of the Deepwater Horizon event (see 75 FR 63346, October 14, 2010). Operationally, Shell has committed to the following to help prevent an oil spill from occurring in the Beaufort and Chukchi Seas:

- Shell's Blow Out Preventer (BOP) was inspected and tested by an independent third party specialist;
- Further inspection and testing of the BOP have been performed to ensure the reliability of the BOP and that all functions will be performed as necessary, including shearing the drill pipe;
- Subsea BOP hydrostatic tests will be increased from once every 14 days to once every 7 days;
- A second set of blind/shear rams will be installed in the BOP stack;
- Full string casings will typically not be installed through high pressure zones;
- Liners will be installed and cemented, which allows for installation of a liner top packer;
- Testing of liners prior to installing a tieback string of casing back to the wellhead;
- Utilizing a two-barrier policy; and
- Testing of all casing hangers to ensure that they have two independent, validated barriers at all times.

Recent BOEM NEPA documents contain additional information and evaluations of effects from oil and the potential from oil spills from these activities on physical, biological, and socioecnomic resources. Those documents also explain key differences between the Macondo incident in the Gulf of Mexico in April 2010 and the locations proposed by Shell in the Arctic for exploratory drilling. Some of the more notable differences include the water depth and total pressure (both of which are lower in the Arctic). The information contained in those documents is hereby incorporated by reference. That information can be found in Sections IV.D and IV.E of BOEMRE's Final Supplemental EIS for the Lease Sale 193 Chukchi Sea Planning Area (BOEMRE, 2011a) and Section 5 BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b).

4.5.1 Potential Effects on Cetaceans

The specific effects an oil spill would have on cetaceans are not well known. While mortality is unlikely, exposure to spilled oil could lead to skin irritation, baleen fouling (which might reduce feeding efficiency), respiratory distress from inhalation of hydrocarbon vapors, consumption of some contaminated prey items, and temporary displacement from contaminated feeding areas. Geraci and St. Aubin (1990) summarize effects of oil on marine mammals, and Bratton et al. (1993) provides a synthesis of knowledge of oil effects on bowhead whales. The number of cetaceans that might be contacted by a spill would depend on the size, timing, and duration of the spill and where the oil is in relation to the animals. Whales may not avoid oil spills, and some have been observed feeding within oil slicks (Goodale et al., 1981). These topics are discussed in more detail next.

In the case of an oil spill occurring during migration periods, disturbance of the migrating cetaceans from cleanup activities may have more of an impact than the oil itself. Human activity associated with cleanup efforts could deflect whales away from the path of the oil. However, noise created from cleanup activities likely will be short term and localized. In fact, whale avoidance of clean-up activities may benefit whales by displacing them from the oil spill area.

There is no direct evidence that oil spills, including the much studied Santa Barbara Channel and Exxon Valdez spills, have caused any deaths of cetaceans (Geraci, 1990; Brownell, 1971; Harvey and Dahlheim, 1994). It is suspected that some individually identified killer whales that disappeared from Prince William Sound during the time of the Exxon Valdez spill were casualties of that spill. However, no clear cause and effect relationship between the spill and the disappearance could be established (Dahlheim and Matkin, 1994). The AT-1 pod of transient killer whales that sometimes inhabits Prince William Sound has continued to decline after the Exxon Valdez oil spill (EVOS). Matkin et al. (2008) tracked the AB resident pod and the AT-1 transient group of killer whales from 1984 to 2005. The results of their photographic surveillance indicate a much higher than usual mortality rate for both populations the year following the spill (33% for AB Pod and 41% for AT-1 Group) and lower than average rates of increase in the 16 years after the spill (annual increase of about 1.6% for AB Pod compared to an annual increase of about 3.2% for other Alaska killer whale pods). In killer whale pods, mortality rates are usually higher for non-reproductive animals and very low for reproductive animals and adolescents (Olesiuk et al., 1990, 2005; Matkin et al., 2005). No effects on humpback whales in Prince William Sound were evident after the EVOS (von Ziegesar et al., 1994). There was some temporary displacement of humpback whales out of Prince William Sound, but this could have been caused by oil contamination, boat and aircraft disturbance, displacement of food sources, or other causes.

Migrating gray whales were apparently not greatly affected by the Santa Barbara spill of 1969. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill represented increased survey effort and therefore cannot be conclusively linked to the spill itself (Brownell, 1971; Geraci, 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci, 1990).

4.5.1.1 Oiling of External Surfaces

Whales rely on a layer of blubber for insulation, so oil would have little if any effect on thermoregulation by whales. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's health (Geraci, 1990). Histological data and ultrastructural studies by Geraci and St. Aubin (1990) showed that exposures of skin to crude oil for up to 45 minutes in four species of toothed whales had no effect. They switched to gasoline and applied the sponge up to 75 minutes. This produced transient damage to epidermal cells in whales. Subtle changes were evident only at the cell level. In each case, the skin damage healed within a week. They concluded that a cetacean's skin is an effective barrier to the noxious substances in petroleum. These substances normally damage skin by getting between cells and dissolving protective lipids. In cetacean skin, however, tight intercellular bridges, vital surface cells, and the extraordinary thickness of the epidermis impeded the damage. The authors could not detect a change in lipid concentration between and within cells after exposing skin from a white-sided dolphin to gasoline for 16 hours in vitro.

Bratton et al. (1993) synthesized studies on the potential effects of contaminants on bowhead whales. They concluded that no published data proved oil fouling of the skin of any free-living whales, and conclude that bowhead whales contacting fresh or weathered petroleum are unlikely to suffer harm. Although oil is unlikely to adhere to smooth skin, it may stick to rough areas on the surface (Henk and Mullan, 1997). Haldiman et al. (1985) found the epidermal layer to be as much as seven to eight times thicker than that found on most whales. They also found that little or no crude oil adhered to preserved bowhead skin that was dipped into oil up to three times, as long as a water film stayed on the skin's surface. Oil adhered in small patches to the surface and vibrissae (stiff, hairlike structures), once it made enough contact with the skin. The amount of oil sticking to the surrounding skin and epidermal depression appeared to be in proportion to the number of exposures and the roughness of the skin's surface. It can be assumed that if oil contacted the eyes, effects would be similar to those observed in ringed seals; continued exposure of the eyes to oil could cause permanent damage (St. Aubin, 1990).

4.5.1.2 Ingestion

Whales could ingest oil if their food is contaminated, or oil could also be absorbed through the respiratory tract. Some of the ingested oil is voided in vomit or feces but some is absorbed and could cause toxic effects (Geraci, 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt, 1978, 1982). Oil ingestion can decrease food assimilation of prey eaten (St. Aubin, 1988). Cetaceans may swallow some oil-contaminated prey, but it likely would be only a small part of their food. It is not known if whales would leave a feeding area where prey was abundant following a spill. Some zooplankton eaten by bowheads and gray whales consume oil particles and bioaccumulation can result. Tissue studies by Geraci and St. Aubin (1990) revealed low levels of naphthalene in the livers and blubber of baleen whales. This result suggests that prey have low concentrations in their tissues, or that baleen whales may be able to metabolize and excrete certain petroleum hydrocarbons. Whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin, 1980, 1982) and this kind of damage has not been reported (Geraci, 1990).

4.5.1.3 Fouling of Baleen

Baleen itself is not damaged by exposure to oil and is resistant to effects of oil (St. Aubin et al., 1984). Crude oil could coat the baleen and reduce filtration efficiency; however, effects may be temporary (Braithwaite, 1983; St. Aubin et al., 1984). If baleen is coated in oil for long periods, it could cause the animal to be unable to feed, which could lead to malnutrition or even death. Most of the oil that would coat the baleen is removed after 30 min, and less than 5% would remain after 24 hr (Bratton et al., 1993). Effects of oiling of the baleen on feeding efficiency appear to be minor (Geraci, 1990). However, a study conducted by Lambertsen et al. (2005) concluded that their results highlight the uncertainty about how rapidly oil would depurate at the near zero temperatures in arctic waters and whether baleen function would be restored after oiling.

4.5.1.4 Avoidance

Some cetaceans can detect oil and sometimes avoid it, but others enter and swim through slicks without apparent effects (Geraci, 1990; Harvey and Dahlheim, 1994). Bottlenose dolphins in the Gulf of Mexico apparently could detect and avoid slicks and mousse but did not avoid light sheens on the surface (Smultea and Wursig, 1995). After the Regal Sword spill in 1979, various species of baleen and toothed whales were observed swimming and feeding in areas containing spilled oil southeast of Cape Cod, MA (Goodale et al., 1981). For months following EVOS, there were numerous observations of gray whales, harbor porpoises, Dall's porpoises, and killer whales swimming through light-to-heavy crude-oil sheens (Harvey and Dalheim, 1994, cited in Matkin et al., 2008). However, if some of the animals avoid the area because of the oil, then the effects of the oiling would be less severe on those individuals.

4.5.1.5 Factors Affecting the Severity of Effects

Effects of oil on cetaceans in open water are likely to be minimal, but there could be effects on cetaceans where both the oil and the whales are at least partly confined in leads or at ice edges (Geraci, 1990). In spring, bowhead and beluga whales migrate through leads in the ice. At this time, the migration can be concentrated in narrow corridors defined by the leads, thereby creating a greater risk to animals caught in the spring lead system should oil enter the leads. This situation would only occur if there were an oil spill late in the season and Shell could not complete cleanup efforts prior to ice covering the area. The oil would likely then be trapped in the ice until it began to thaw in the spring.

In fall, the migration route of bowheads can be close to shore (Blackwell et al., 2009c). If fall migrants were moving through leads in the pack ice or were concentrated in nearshore waters, some bowhead whales might not be able to avoid oil slicks and could be subject to prolonged contamination. However, the autumn migration through the Chukchi and Beaufort Seas extends over several weeks, and some of the whales travel along routes north or inland of the area, thereby reducing the number of whales that could approach patches of spilled oil. Additionally, vessel activity associated with spill cleanup efforts may deflect whales traveling near the Burger prospect in the Chukchi Sea, or the Camden Bay prospects in the Beaufort Sea, thereby reducing the likelihood of contact with spilled oil.

Bowhead and beluga whales overwinter in the Bering Sea (mainly from November to March). In the summer, the majority of the bowhead whales are found in the Canadian Beaufort Sea, although some have recently been observed in the U.S. Beaufort and Chukchi Seas during the summer months (June to August). Data from the Barrow-based boat surveys in 2009 (George and Sheffield, 2009) showed that bowheads were observed almost continuously in the waters near Barrow, including feeding groups in the Chukchi Sea at the beginning of July. The majority of belugas in the Beaufort stock migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July (Braham et al., 1984; Ljungblad et al., 1984; Richardson et al., 1995a). Therefore, a spill in summer would not be expected to have major impacts on these species. Additionally, humpback and fin whales are only sighted in the Chukchi Sea in small numbers in the summer, as this is thought to be the extreme northern edge of their range. Although harbor porpoises and gray whales are common in the Chukchi Sea, impacts are anticipated to be similar to belugas and bowheads. Bowhead and beluga whales are the most common cetacean species in the Camden Bay area; therefore, impacts to other cetaceans are not expected from the proposed Camden Bay program. Therefore, impacts to these species from an oil spill would be extremely limited.

4.5.2 Potential Effects on Pinnipeds

Ice seals are present in open-water areas during summer and early autumn. Externally oiled phocid seals often survive and become clean, but heavily oiled seal pups and adults may die, depending on the extent of oiling and characteristics of the oil. Prolonged exposure could occur if fuel or crude oil was spilled in or reached nearshore waters, was spilled in a lead used by seals, or was spilled under the ice when seals have limited mobility (NMFS, 2000). Adult seals may suffer some temporary adverse effects, such as eye and skin irritation, with possible infection (MMS, 1996). Such effects may increase stress, which could contribute to the death of some individuals. Ringed seals may ingest oil-contaminated foods, but there is little evidence that oiled seals will ingest enough oil to cause lethal internal effects. There is a likelihood that newborn seal pups, if contacted by oil, would die from oiling through loss of insulation and resulting hypothermia. These potential effects are addressed in more detail in subsequent paragraphs.

Reports of the effects of oil spills have shown that some mortality of seals may have occurred as a result of oil fouling; however, large scale mortality had not been observed prior to the EVOS (St. Aubin, 1990). Effects of oil on marine mammals were not well studied at most spills because of lack of baseline data and/or the brevity of the post-spill surveys. The largest documented impact of a spill, prior to EVOS, was on young seals in January in the Gulf of St. Lawrence (St. Aubin, 1990). Brownell and Le Boeuf (1971) found no marked effects of oil from the Santa Barbara oil spill on California sea lions or on the mortality rates of newborn pups.

Intensive and long-term studies were conducted after the EVOS in Alaska. There may have been a long-term decline of 36% in numbers of molting harbor seals at oiled haul-out sites in Prince William Sound following EVOS (Frost et al., 1994a). However, in a reanalysis of those data and additional years of surveys, along with an examination of assumptions and biases associated with the original data, Hoover-Miller et al. (2001) concluded that the EVOS effect had been overestimated. The decline in attendance at some oiled sites was more likely a continuation of the general decline in harbor seal abundance in Prince William Sound documented since 1984 (Frost et al., 1999) rather than a result of EVOS. The results from Hoover-Miller et al. (2001) indicate that the effects of EVOS were largely indistinguishable from natural decline by 1992. However, while Frost et al. (2004) concluded that there was no evidence that seals were displaced from oiled sites, they did find that aerial counts indicated 26% fewer pups were produced at oiled locations in 1989 than would have been expected without the oil spill. Harbor seal pup mortality at oiled beaches was 23% to 26%, which may have been higher than natural mortality, although no baseline data for pup mortality existed prior to EVOS (Frost et al., 1994a). There was no conclusive evidence of spill effects on Steller sea lions (Calkins et al., 1994). Oil did not persist on sea lions themselves (as it did on harbor seals), nor did it persist on sea lion haul-out sites and rookeries (Calkins et al., 1994). Sea lion rookeries and haul out sites, unlike those used by harbor seals, have steep sides and are subject to high wave energy (Calkins et al., 1994).

4.5.2.1 Oiling of External Surfaces

Adult seals rely on a layer of blubber for insulation, and oiling of the external surface does not appear to have adverse thermoregulatory effects (Kooyman et al., 1976, 1977; St. Aubin, 1990). Contact with oil on the external surfaces can potentially cause increased stress and irritation of the eyes of ringed seals (Geraci and Smith, 1976; St. Aubin, 1990). These effects seemed to be temporary and reversible, but continued exposure of eyes to oil could cause permanent damage (St. Aubin, 1990). Corneal ulcers and abrasions, conjunctivitis, and swollen nictitating membranes were observed in captive ringed seals placed in crude oil-covered water (Geraci and Smith, 1976) and in seals in the Antarctic after an oil spill (Lillie, 1954).

Newborn seal pups rely on their fur for insulation. Newborn ringed seal pups in lairs on the ice could be contaminated through contact with oiled mothers. There is the potential that newborn ringed seal pups that were contaminated with oil could die from hypothermia.

4.5.2.2 Ingestion

Marine mammals can ingest oil if their food is contaminated. Oil can also be absorbed through the respiratory tract (Geraci and Smith, 1976; Engelhardt et al., 1977). Some of the ingested oil is voided in vomit or feces but some is absorbed and could cause toxic effects (Engelhardt, 1981). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt, 1978, 1982, 1985). In addition, seals exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin, 1980, 1982).

4.5.2.3 Avoidance and Behavioral Effects

Although seals may have the capability to detect and avoid oil, they apparently do so only to a limited extent (St. Aubin, 1990). Seals may abandon the area of an oil spill because of human disturbance associated with cleanup efforts, but they are most likely to remain in the area of the spill. One notable behavioral reaction to oiling is that oiled seals are reluctant to enter the water, even when intense cleanup activities are conducted nearby (St. Aubin, 1990; Frost et al., 1994b, 2004).

4.5.2.4 Factors Affecting the Severity of Effects

Seals that are under natural stress, such as lack of food or a heavy infestation by parasites, could potentially die because of the additional stress of oiling (Geraci and Smith, 1976; St. Aubin, 1990; Spraker et al., 1994). Female seals that are nursing young would be under natural stress, as would molting seals. In both cases, the seals would have reduced food stores and may be less resistant to effects of oil than seals that are not under some type of natural stress. Seals that are not under natural stress (e.g., fasting, molting) would be more likely to survive oiling.
In general, seals do not exhibit large behavioral or physiological reactions to limited surface oiling or incidental exposure to contaminated food or vapors (St. Aubin, 1990; Williams et al., 1994). Effects could be severe if seals surface in heavy oil slicks in leads or if oil accumulates near haul-out sites (St. Aubin, 1990). An oil spill in open-water is less likely to impact seals.

4.6 Cumulative Effects

Cumulative effect is defined as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions” (40 CFR §1508.7). Cumulative impacts may occur when there is a relationship between a proposed action and other actions expected to occur in a similar location or during a similar time period, or when past or future actions may result in impacts that would additively or synergistically affect a resource of concern. In other words, the analysis takes into account the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions (40 CFR §1508.7). These relationships may or may not be obvious. Actions overlapping within close proximity to the proposed action can reasonably be expected to have more potential for cumulative effects on “shared resources” than actions that may be geographically separated. Similarly, actions that coincide temporally will tend to offer a higher potential for cumulative effects.

Actions that might permanently remove a resource would be expected to have a potential to act additively or synergistically if they affected the same population, even if the effects were separated geographically or temporally. Note that the proposed action considered here would not be expected to result in the removal of individual cetaceans or pinnipeds from the population or to result in harassment levels that might cause animals to permanently abandon preferred feeding areas or other habitat locations, so concerns related to removal of viable members of the populations are not implicated by the proposed action. This cumulative effects analysis considers these potential impacts, but more appropriately focuses on those activities that may temporally or geographically overlap with the proposed activity such that repeat harassment effects warrant consideration for potential cumulative impacts to the potentially affected 12 marine mammal species and their habitats.

Cumulative effects may result in significant effects even when the Federal action under review is insignificant when considered by itself. The CEQ guidelines recognize that it is not practical to analyze the cumulative effects of an action on the universe but to focus on those effects that are truly meaningful. This section analyzes the addition of the effects of the proposed action (i.e., the issuance of IHAs to Shell for the take of marine mammals incidental to conducting offshore exploratory drilling programs in the U.S. Beaufort and Chukchi Seas) to the potential direct and indirect effects of other factors that may, in combination with the proposed action, result in greater effects on the environment than those resulting solely from the proposed action. Cumulative effects on affected resources that may result from the following activities—seismic survey activities, vessel and air traffic, oil and gas exploration and development in Federal and state waters, subsistence harvest activities, military activities, industrial development, community development, and climate change—within the proposed EA project area are discussed in the following subsections.

4.6.1 Past Commercial Whaling

Commercial hunting between 1848 and 1915 caused severe depletion of the bowhead population(s) that inhabits the Bering, Chukchi, and Beaufort (BCB) Seas. This hunting is no longer occurring and is not expected to occur again. Woody and Botkin (1993) estimated that the historic abundance of bowheads in this population was between 10,400 and 23,000 whales in 1848, before the advent of commercial whaling. Woody and Botkin (1993) estimated between 1,000 and 3,000 animals remained in 1914, near the end of the commercial-whaling period. Data indicate that what is currently referred to as the BCB Seas stock of bowheads is increasing in abundance.

Similar to bowhead whales, most stocks of fin whales were depleted by commercial whaling (Reeves et al., 1998) beginning in the second half of the mid-1800s (Schmitt et al., 1980; Reeves and Barto, 1985). In the 1900s, hunting for fin whales continued in all oceans for about 75 years (Reeves et al., 1998) until it was legally ended in the North Pacific in 1976. Commercial hunting for humpback whales resulted in the depletion and endangerment of this species. Prior to commercial hunting, humpback whales in the North Pacific may have numbered approximately 15,000 individuals (Rice, 1978). Unregulated hunting legally ended in the North Pacific in 1966.

None of the alternatives considered would have a direct or indirect effect on the historical whaling that previously impacted bowhead, fin, and humpback whales. None of the alternatives would authorize lethal takes or serious injury of any marine mammal species, and none of the activities or action alternatives are expected to lead to future commercial harvesting of whales. Therefore, there is no potential for there to be additive or cumulative effects with the proposed action.

4.6.2 Subsistence Hunting

4.6.2.1.1 Bowhead Whales

Indigenous peoples of the Arctic and Subarctic have been hunting bowhead whales for at least 2,000 years (Stoker and Krupnik, 1993). Thus, subsistence hunting is not a new contributor to cumulative effects on this population. There is no indication that, prior to commercial whaling, subsistence whaling caused significant adverse effects at the population level. However, modern technology has changed the potential for any lethal hunting of this whale to cause population-level adverse effects if unregulated. Under the authority of the IWC, the subsistence take from this population has been regulated by a quota system since 1977. Federal authority for cooperative management of the Eskimo subsistence hunt is shared with the AEWC through a cooperative agreement between the AEWC and NMFS.

The sustainable take of bowhead whales by indigenous hunters represents the largest known human-related cause of mortality in this population at the present time. Available information suggests that it is likely to remain so for the foreseeable future. While other potential effectors primarily have the potential to cause, or to be related to, behavioral or sublethal adverse effects to this population, or to cause the deaths of a small number of individuals, little or no evidence exists of other common human-related causes of mortality. Subsistence take, which all available evidence indicates is sustainable, is monitored, managed, and regulated, and helps to determine the resilience of the population to other effecters that could potentially cause lethal takes. The sustained growth of the BCB Seas bowhead population indicates that the level of subsistence take has been sustainable. Because the quota for the hunt is tied to the population size and population parameters (IWC, 2003; NMFS, 2003), it is unlikely this source of mortality will contribute to a significant adverse effect on the recovery and long-term viability of this population.

Currently, Native Alaskan hunters from 11 communities harvest bowheads for subsistence and cultural purposes under a quota authorized by the IWC. Chukotkan Native whalers from Russia also are authorized to harvest bowhead whales under the same authorized quota. Bowheads are hunted at Gambell and Savoonga on St. Lawrence Island, and along the Chukotkan coast. On the northward spring migration, harvests may occur by the villages of Wales, Little Diomede, Kivalina, Point Lay, Point Hope, Wainwright, and Barrow. During their westward migration in autumn, whales are harvested by Kaktovik, Nuiqsut, and Barrow. At St. Lawrence Island, fall migrants can be hunted as late as December (IWC, 2004). The status of the population is closely monitored, and these activities are closely regulated.

There are adverse impacts of the hunting to bowhead whales in addition to the death of animals that are successfully hunted and the serious injury of animals that are struck but not immediately killed. Available evidence indicates that subsistence hunting causes disturbance to the other whales, changes in their behavior, and sometimes temporary effects on habitat use, including migration paths. Modern subsistence hunting represents a source of noise and disturbance to the whales during the following periods and in the following areas: during their northward spring migration in the Bering Sea, the Chukchi Sea in the spring lead system, and in the Beaufort Sea spring lead system near Barrow; their fall westward migration in subsistence hunting areas associated with hunting from Kaktovik, Cross Island, and Barrow; hunting along the Chukotka coast; and hunting in wintering areas near St. Lawrence Island. Lowry et al. (2004) reported that indigenous hunters in the Beaufort Sea sometimes hunt in areas where whales are aggregated for feeding. When a subsistence hunt is successful, it results in the death of a bowhead. Data on strike and harvested levels indicate that whales are not always immediately killed when struck, and some whales are struck but cannot be harvested. Whales in the vicinity of the struck whale could be disturbed by the sound of the explosive harpoon used in the hunt, the boat motors, and any sounds made by the injured whale.

Noise and disturbance from subsistence hunting serves as a seasonally and geographically predictable source of noise and disturbance to which other noise and disturbance sources, such as shipping and oil and gas-related activities, add. To the extent such activities occur in the same habitats during the period of whale migration, even if the activities (for example, hunting and shipping) themselves do not occur simultaneously, cumulative effects from all noise and disturbance could affect whale habitat use. Subsistence hunting attaches a strong adverse association to human noise for any whale that has been in the vicinity when other whales were struck.

4.6.2.2 Beluga Whales

The subsistence take of beluga whales within U.S. waters is reported by the Alaska Beluga Whale Committee (ABWC). The annual subsistence take of the Beaufort Sea stock of beluga whales by Alaska Natives averaged 25 belugas during the 5-year period from 2002-2006 (Allen and Angliss, 2011). The annual subsistence take of Eastern Chukchi Sea stock of beluga whales by Alaska Natives averaged 59 belugas landed during the 5-year period 2002-2006 based on reports from ABWC representatives and on-site harvest monitoring. Data on beluga that were struck and lost have not been quantified and are not included in these estimates (Allen and Angliss, 2011). As with bowhead whale subsistence hunts, noise during the hunts may disturb other animals not struck and taken for subsistence purposes. Again, the disturbance occurs during specific time periods in specific locations to which other activities could add. To the extent such activities occur in the same habitats during the period of whale migration, even if the activities (for example, hunting and shipping) themselves do not occur simultaneously, cumulative effects from all noise and disturbance could affect whale habitat use. Subsistence hunting attaches a strong adverse association to human noise for any whale that has been in the vicinity when other whales were struck.

4.6.2.3 Ice Seals

The Division of Subsistence, Alaska Department of Fish and Game (ADF&G) maintains a database that provides additional information on the subsistence harvest of ice seals in different regions of Alaska (ADF&G 2000a,b). Information on subsistence harvest of bearded seals has been 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. As of August 2000, the subsistence harvest database indicated that the estimated number of bearded, ribbon, ringed, and spotted seals harvested for subsistence use per year are 6,788, 193, 9,567, and 244, respectively (Allen and Angliss, 2011).

At this time, there are no efforts to quantify the current level of harvest of bearded seals by all Alaska communities. However, the USFWS collects information on the level of ice seal harvest in five villages during their Walrus Harvest Monitoring Program. Results from this program indicate that an average of 239 bearded seals were harvested annually in Little Diomede, Gambell, Savoonga, Shishmaref, and Wales from 2000 to 2004, 13 ribbon seals from 1999 to 2003, and 47 ringed seals from 1998 to 2003 (Allen and Angliss, 2010). Since 2005, harvest data are only available from St. Lawrence Island (Gambell and Savoonga) due to lack of walrus harvest monitoring in areas previously monitored. There were 21 bearded seals harvested during the walrus harvest monitoring period on St. Lawrence Island in 2005, 41 in 2006, and 82 in 2007. There were no ringed seals harvested on St. Lawrence Island in 2005, 1 in 2006, and 1 in

2007. The mean annual subsistence harvest of spotted seals in north Bristol Bay from this stock over the 5-year period from 2002 through 2006 was 166 seals per year. No ribbon seal was harvested between 2005 and 2007 (Allen and Angliss, 2010).

4.6.2.4 Contributions of the Alternatives to Cumulative Effects of Subsistence Hunting

Alternative 1 would not contribute any additional effects beyond those already analyzed to the cumulative effects from subsistence hunting, as the IHAs would not be issued. Alternatives 2 and 3 would allow for the issuance of IHAs for the take of marine mammals incidental to conducting exploratory drilling programs in the Beaufort and Chukchi Seas during the open-water season. However, Shell would shutdown prior to the fall whaling at Kaktovik and Nuiqsut and not operate until the hunts were completed, thus avoiding concurrent impacts. Additionally, the proposed action is not anticipated to result in serious injury or mortality of any marine mammals; therefore, there would not be additional deaths beyond those from subsistence hunting activities. While both activities (i.e., the proposed action and subsistence hunting) can disturb marine mammals, NMFS considers the contribution of such disturbance to overall cumulative effects to be minimal because of the mitigation measures that would be required under the IHA, which are included to reduce impacts to the lowest level practicable (see Chapter 5).

4.6.3 Climate Change

Section 3.1.4.4 in NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011) describes changes to climate in the Arctic environment. That information is summarized here and incorporated herein by reference. Evidence of climate change in the Arctic has been identified and appear to generally agree with climate modeling scenarios of greenhouse gas warming. Such evidence suggests (NSIDC, 2011a):

- Air temperatures in the Arctic are increasing at an accelerated rate;
- Year-round sea ice extent and thickness has continually decreased over the past three decades;
- Water temperatures in the Arctic Ocean have increased;
- Changes have occurred to the salinity in the Arctic Ocean;
- Rising sea levels;
- Retreating glaciers;
- Increases in terrestrial precipitation;
- Warming permafrost in Alaska; and
- Northward migration of the treeline.

Concurrent with climate change is a change in ocean chemistry known as ocean acidification. This phenomenon is described in the IPCC Fourth Assessment Report (IPCC, 2007a), a 2005 synthesis report by members of the Royal Society of London (Raven et al., 2005), and an ongoing BOEM-funded study (Mathis, 2011). The greatest degree of ocean acidification worldwide is predicted to occur in the Arctic Ocean. This amplified scenario in the Arctic is due to the effects of increased freshwater input from melting snow and ice and from increased CO_2 uptake by the sea as a result of ice retreat (Fabry et al., 2009). Measurements in the Canada Basin of the Arctic Ocean demonstrate that over 11 years, melting sea ice forced changes in pH and the inorganic carbon equilibrium, resulting in decreased saturation of calcium carbonate in the seawater (Yamamoto-Kawai, 2009). Bates et al. (2009) showed the effects of decreasing pH on the saturation states of inorganic carbonate in the Chukchi and Beaufort Seas, and the interaction of carbonate states with primary productivity.

Bowhead and other Arctic whales are associated with and well adapted to ice-covered seas with leads, polynyas, open water areas, or thin ice that the whales can break through to breathe. Arctic coastal peoples have hunted bowheads for thousands of years, but the distribution of bowheads in relation to climate change and sea ice cover in the distant past is not known. It has been suggested that a cold period 500 years ago resulted in less ice-free water near Greenland, forcing bowheads to abandon the range, and that this in turn led to the disappearance of the Thule culture (McGhee, 1984; Aagaard and Carmack, 1994 as cited in Tynan and DeMaster, 1997). However, it is not clear if larger expanses and longer periods of ice-free water would be beneficial to bowheads. The effect of warmer ocean temperatures on bowheads may depend more on how such climate changes affect the abundance and distribution of their planktonic prey rather than the bowheads' need for ice habitat itself (Tynan and DeMaster, 1997).

Climate change associated with Arctic warming may also result in regime change of the Arctic Ocean ecosystem. Sighting of humpback whales in the Chukchi Sea during the 2007 Shell seismic surveys (Funk et al., 2008), 2009 COMIDA aerial survey (Clarke et al., 2011), and south of Point Hope in 2009 while transiting to Nome (Brueggeman, 2010) may indicate the expansion of habitat by this species as a result of ecosystem regime shift in the Arctic. These species, in addition to minke and killer whales, and four pinniped species (harp, hooded, ribbon, and spotted seals) that seasonally occupy Arctic and subarctic habitats may be poised to encroach into more northern latitudes and to remain there longer, thereby competing with extant Arctic species (Moore and Huntington, 2008).

In the past decade, geographic displacement of marine mammal population distributions has coincided with a reduction in sea ice and an increase in air and ocean temperatures in the Bering Sea (Grebmeier et al., 2006). Continued warming is likely to increase the occurrence and resident times of subarctic species such as spotted seals and bearded seals in the Beaufort Sea. The result of global warming would significantly reduce the extent of sea ice in at least some regions of the Arctic (ACIA, 2004; Johannessen et al., 2004).

Ringed seals, which are true Arctic species, depend on sea ice for their life functions, and give birth to and care for their pups on stable shorefast ice. The reductions in the extent and persistence of ice in the Beaufort Sea almost certainly could reduce their productivity (Ferguson et al., 2005; NRC, 2003b), but at the current stage, there are insufficient data to make reliable predictions of the effects of Arctic climate change on the Alaska ringed seal stock (Allen and Angliss, 2010). In addition, spotted seals and bearded seals would also be vulnerable to reductions in sea ice, although insufficient data exist to make reliable predictions of the effects of Arctic climate change on these two species (Allen and Angliss, 2010).

The implications of the trends of a changing climate for bowheads and other Arctic cetaceans are uncertain, but they may be beneficial, in contrast to affects on ice-obligate species such as ice seals, polar bears, and walrus (ACIA, 2004). There will be more open water and longer ice-free seasons in the arctic seas, which may allow them to expand their range as the population continues to recover from commercial whaling. However, this potential for beneficial effects on bowheads and other whales will depend on their ability to locate sufficient concentrations of planktonic crustaceans to allow efficient foraging. Since phytoplankton blooms may occur earlier or at different times of the season, or in different locations, the timing of zooplankton availability may also change from past patterns (Arrigo and van Dijken, 2004). Hence, the ability of bowheads to use these food sources may depend on their flexibility to adjust the timing of their own movements and to find food sources in different places (ACIA, 2004). In addition, it is hypothesized that some of the indirect effects of climate change on marine mammal health would likely include alterations in pathogen transmission due to a variety of factors, effects on body condition due to shifts in the prey base/food web, changes in toxicant exposures, and factors associated with increased human habitation in the Arctic (Burek et al., 2008).

With the large uncertainty of the degree of impact of climate change to Arctic marine mammals, NMFS recognizes that warming of this region which results in the diminishing of ice could be a concern to ice dependent seals, walrus, and polar bears. Nonetheless, NMFS considers the effects of the proposed action and the specified activity proposed by Shell during 2012 on climate change are too remote and speculative at this time to conclude definitively that the issuance of MMPA IHAs for the 2012 proposed exploratory drilling programs would contribute to climate change, and therefore a reduction in Arctic sea ice coverage. More research is needed to determine the magnitude of the impact, if any, of global warming to marine mammal species in the Arctic and subarctic regions. Finally, any future oil and gas activities that may arise as a result of this year's open-water exploratory drilling programs would likely need to undergo separate permit reviews and analyses.

4.6.4 Oil and Gas Exploration and Development

Section 4.10.2.1 of NMFS' Draft EIS on the Effects of Oil and Gas Activities in the Arctic Ocean (NMFS, 2011) outlines past, present, and future oil and gas exploration, development, and production projects in the U.S. Arctic, as well as in Russian and Canadian waters. Additionally, Section 4.5.4 of NMFS' EA for the Issuance of Incidental Harassment Authorizations to Take Marine Mammals by Harassment Incidental to Conducting Open Water Seismic and Marine Surveys in the Chukchi and Beaufort Seas (NMFS, 2010) summarizes recent oil and gas industry geophysical and exploration activity in the U.S. Beaufort and Chukchi Seas. That information is incorporated herein by reference.

In addition to the projects listed in those NEPA documents, there is the potential for several projects to be occurring concurrently in the U.S. Arctic in 2012 with the two proposed exploratory drilling programs analyzed in this EA. As in recent years, ION has proposed to conduct a late season seismic survey in the ice in the Beaufort Sea. There is the potential for about one month of overlap with Shell's proposed activities. Additionally, BP has proposed a seismic survey to occur in the area of Simpson Lagoon in the Beaufort Sea from approximately early July to October. Potential impacts to marine mammals from these activities include disturbance from the noise of the airguns and vessels. Injury and mortality are not anticipated as a result of these two proposed surveys.

The same species that would potentially be present during Shell's proposed exploratory drilling programs would also potentially be present during these other operations, especially those that occur in offshore waters during the open-water season. Alternative 1 would not contribute any additional effects beyond those already analyzed to the cumulative effects from oil and gas exploration and development, as the IHAs would not be issued to Shell for the two proposed programs.

Alternatives 2 and 3 could potentially add to the cumulative effects to the marine environment and to marine mammal species in particular. For example, as bowhead whales migrate from Canadian waters to Russian waters, they could potentially be exposed to activities conducted by all three countries. However, proponents conducting activities in U.S. waters typically request authorization under the MMPA to legally take marine mammals. Those authorizations, if issued, contain measures to lessen impacts on marine mammals. NMFS has proposed to include a suite of mitigation measures in the two Shell IHAs for the two exploratory drilling programs as well. Implementation of such measures is to ensure that impacts are at the lowest level practicable. Certain mitigation measures help to reduce the likelihood of cumulative impacts. Under both Alernatives 2 and 3, Shell would be required to shutdown for approximately three weeks in the Beaufort Sea during the fall bowhead whale hunts at Kaktovik and Cross Island (Nuiqsut). This will allow whales to migrate through the area without being exposed to the operations, thus reducing the likelihood that the animals would be exposed to that operation as well as others farther west in the Beaufort Sea. Additionally, ION's proposed seismic survey would start later in the season, after the majority of the whales would have already migrated through the U.S. Beaufort Sea and close to the end of Shell's operating season. Alternative 3 would reduce the likelihood of overlap with these other operations as well by requiring an end to operations in the Chukchi Sea by the end of September. Therefore, if Alternative 3 were selected, there is the potential for many of the migrating bowhead whales not to be exposed to either operation. The same could potentially be true for some migrating beluga whales as well. Although the majority of pinnipeds would likely not be exposed to both operations, reducing the operating seasons decreases the likelihood even further. The additive effects are not likely to result in significant cumulative impacts to the environment.

4.6.5 Vessel Traffic and Movement

Increasing vessel traffic in the Northwest Passage increases the risks of oil and fuel spills and vessel strikes of marine mammals. The proposed exploratory drilling programs are not expected to contribute substantially to these risks, as exploration will occur in ice-free seas and because most marine mammals are likely to actively avoid close proximity to the operations.

Vessel traffic in the Alaskan Arctic generally occurs within 12.4 mi (20 km) of the coast and usually is associated with fishing, hunting, cruise ships, icebreakers, Coast Guard activities, and supply ships and barges. No extensive maritime industry exists for transporting goods. Traffic in the Beaufort and Chukchi Seas, at present, is limited primarily to late spring, summer, and early autumn.

For cetaceans, the main potential for effects from vessel traffic is through vessel strikes and acoustic disturbance. Regarding sound produced from vessels, it is generally expected to be less in shallow waters (i.e., background noise only by 6.2 mi [10 km] away from vessel) and greater in deeper waters (traffic noise up to 2,480 mi [4,000 km] away may contribute to background noise levels) (Richardson et al., 1995). Aside from the drillships and other vessels associated with the drilling programs, seismic-survey vessels, barging associated with activities such as onshore and limited offshore oil and gas activities, fuel and supply shipments, and other activities contribute to overall ambient noise levels in some regions of the Beaufort and Chukchi Seas. Whaling boats (usually aluminum skiffs with outboard motors) contribute noise during the fall whaling periods in the Alaskan Beaufort Sea. Fishing boats in coastal regions also contribute sound to the overall ambient noise. Sound produced by these smaller boats typically is at a higher frequency, around 300 Hz (Richardson et al., 1995).

Overall, the level of vessel traffic in the Alaskan Arctic, either from oil and gas-related activities or other industrial, military, or subsistence activities, is expected to be greater than in the recent past.

Ships using the newly opened waters in the Arctic likely will use leads and polynyas to avoid icebreaking and to reduce transit time. Leads and polynyas are important habitat for polar bears and belugas, especially during winter and spring, and heavy shipping traffic could disturb polar bears and belugas during these times.

Alternative 1 would not contribute any additional effects beyond those already analyzed to the cumulative effects from vessel traffic and movement, as the IHAs would not be issued to Shell for the two proposed programs. Alternatives 2 and 3 would increase the number of vessels in the Beaufort and Chukchi Seas for approximately four months, as each program will require approximately 8-12 vessels, including the drillships, icebreakers, and other support vessels. However, because of the overall low level of vessel traffic in the Alaskan Arctic, the proposed action is not anticipated to add significantly to the cumulative effects from vessel traffic and movement in the region.

4.6.6 Conclusion

Based on the analyses provided in this section, NMFS has determined that the proposed Shell exploratory drilling programs in the Beaufort and Chukchi Seas during the 2012 open-water season would not be expected to add significant impacts to overall cumulative effects on marine mammals from past, present, and future activities. The potential impacts to marine mammals and their habitat are expected to be minimal based on the limited noise footprint. Although it is not a component of the proposed action or Shell’s specified activities, NMFS has also determined that there is a very low likelihood of a large or very large oil spill event occurring as a result of the proposed programs. In addition, mitigation and monitoring measures described in Chapter 5 are expected to further reduce any potential adverse effects.

Chapter 5 MITIGATION, MONITORING, AND REPORTING

As required under the MMPA, NMFS considered mitigation to effect the least practicable impact on marine mammals and has developed a series of mitigation measures, as well as monitoring and reporting procedures, that would be required under the two IHAs (if issued) for the proposed exploratory drilling programs described earlier in this EA. Mitigation measures have been proposed by Shell for the 2012 open-water exploratory drilling programs. Additional measures have also been considered by NMFS pursuant to its authority under the MMPA to ensure that the proposed activities will result in the least practicable impact on marine mammal species or stocks in the Beaufort and Chukchi Seas. The mitigation requirements contained in the MMPA IHAs will help to ensure that takings result in the least practicable impact to affected marine mammal species or stocks and minimize the number of species or stocks exposed, ensuring that any impacts to marine mammals will be negligible, and that there will be no unmitigable adverse impacts to subsistence uses of the affected species or stocks. If issued, all mitigation measures contained in the IHAs must be followed. Sections 5.3 and 5.4 describe the monitoring and reporting conditions that would be contained in any issued IHAs. These measures would be applicable under both Alternatives 2 and 3.

5.1 Mitigation Measures

Shell submitted a marine mammal monitoring and mitigation plan (4MP) as part of its MMPA IHA applications submitted to NMFS (see Attachment C in Shell, 2011a and Attachment C in Shell, 2011b). Shell's planned offshore drilling programs incorporate both design features and operational procedures for minimizing potential impacts on marine mammals and on subsistence hunts. Survey design features include:

- Timing and locating drilling and support activities to avoid interference with the annual subsistence hunts by the peoples of the Beaufort and Chukchi Seas communities;
- Identifying transit routes and timing to avoid other subsistence use areas and communicating with coastal communities before operating in or passing through these areas; and
- Conducting pre-season sound propagation modeling to establish the appropriate exclusion and behavioral radii.

The potential disturbance of cetaceans and pinnipeds during operations would be minimized through implementation of the mitigation measures discussed here. The mitigation measures presented in this section would be implemented under Alternatives 2 and 3. Unless otherwise specified, the measures would be required for both proposed programs. The measures are summarized here and are explained further in Shell's MMPA IHA applications (Shell, 2011a,b). Those further explanations are incorporated herein by reference.

5.1.1 Sound Source Verification and Characterization

Shell intends to verify sound levels of already measured vessels and sound sources and to characterized sound levels of vessels and sound sources not yet measured during the operating season. Drilling sounds are expected to vary significantly with time due to variations in the level of operations and the different types of equipment used at different times onboard the *Kulluk* or *Discoverer*. The objectives of these measurements are: (1) to quantify the absolute sound levels produced by drilling and to monitor their variations with time, distance, and direction from the drilling vessel; (2) to measure the sound levels produced by vessels operating in support of exploration drilling operations. These vessels will include crew change vessels, tugs, icebreakers, and OSRVs; and (3) to measure the sound levels produced by an end-of-hole ZVSP survey, using a stationary sound source.

The drillship (*Kulluk* or *Discoverer*), support vessels, and ZVSP sound measurements will be performed using one of two methods, both of which involve real-time monitoring. The first method would involve use of bottom-founded hydrophones cabled back to the drillship. These hydrophones would be positioned between 1,640 ft (500 m) and 3,281 ft (1,000 m) from the *Kulluk* or *Discoverer*, depending on the final positions of the anchors used to hold the *Kulluk* or *Discoverer* in place. Hydrophone cables would be fed to real-time digitization systems onboard. In addition to the cabled system, a separate set of bottom-founded hydrophones may be deployed at various distances from the exploration drilling operation for storage of acoustic data to be retrieved and processed at a later date.

As an alternative to the cabled hydrophone system (and possible inclusion of separate bottom-founded hydrophones), the second (or alternative) monitoring method would involve a radio buoy approach deploying four sparbuoys 4-5 mi (6-8 km) from the drillship. Additional hydrophones may be deployed closer to the drillship, if necessary, to better determine sound source levels. Monitoring personnel and recording/receiving equipment would be onboard one of the support vessels with 24-hr monitoring capacity. The system would allow for collection and processing of real-time data similar to that provided by the cabled system but from a wider range of locations.

Sound level monitoring with either method will occur on a continuous basis throughout all exploration drilling activities. Both types of systems will be set to record digital acoustic data at a sample rate of 32 kHz, providing useful acoustic bandwidth to at least 15 kHz. These systems are capable of measuring absolute broadband sound levels between 90 and 180 dB re 1 μPa. The long duration recordings will capture many different operations performed from the drillship. Retrieval of these systems will occur following completion of the exploration drilling activities.

These recorders will provide a capability to examine sound levels produced by different drilling activities and practices. This system will not have the capability to locate calling marine mammals and will indicate only relative proximity. The system will be evaluated during operations for its potential to improve protected species observer (PSO; formerly marine mammal observer, MMO) observations through notification of PSOs on vessel and aircraft of high levels of call detections and their general locations.

The deployment of drilling sound monitoring equipment will occur as soon as possible once the drillship is on site. Activity logs of exploration drilling operations and nearby vessel activities will be maintained to correlate with these acoustic measurements. This equipment will also be used to take measurements of the support vessels and airguns. Additional details can be found in Shell's 4MPs (Shell, 2011a,b). Sound source verification and characterization tests are an important mitigation tool. Such tests aid in understanding the propagation and sound levels of the various vessels and equipment used so that other mitigation measures to protect marine mammals can be properly implemented. Previous implemtation of this measure has indicated that it is both practical and effective at determining sound isopleths.

5.1.2 Exclusion and Disturbance Zones

Exclusion radii for marine mammals around sound sources are customarily defined as the distances within which received sound levels are greater than or equal to 180 dB re 1 μPa (rms) for cetaceans and greater than or equal to 190 dB re 1 μPa (rms) for pinnipeds. These exclusion criteria are based on an assumption that sounds at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels might have such effects. It should be understood that marine mammals inside these exclusion zones will not necessarily be injured, as the received sound thresholds which determine these zones were established prior to the current understanding that significantly higher levels of sound would be required before injury could occur (see Southall et al., 2007). With respect to Level B harassment, NMFS' practice has been to apply the 120 dB re 1 μPa (rms) received level threshold for underwater continuous sound levels and the 160 dB re 1 μPa (rms) received level threshold for underwater impulsive sound levels. In the case of the two proposed exploratory drilling programs by Shell considered in this EA, the 120 dB Level B criterion will be applied to the drillships and icebreakers actively involved in ice management/icebreaking activities, and the 160 dB Level B criterion will be applied to the airguns used during the ZVSP surveys.

Shell proposes to monitor the various radii in order to implement any mitigation measures that may be necessary. Initial radii for the sound levels produced by the *Kulluk* and *Discoverer*, the icebreaker, and the airguns have been modeled. Measurements taken by Greene (1987a) indicated a broadband source level of 185.5 dB re 1 μPa rms for the *Kulluk*. Measurements taken by Austin and Warner (2010) indicated broadband source levels between 177 and 185 dB re 1 μPa rms for the *Discoverer*. Measurements of the icebreaking supply ship *Robert Lemeur* pushing and breaking ice during exploration drilling operations in the Beaufort Sea in 1986 resulted in an estimated broadband source level of 193 dB re 1 μPa rms (Greene, 1987a; Richardson et al., 1995a). Based on a similar airgun array used in the shallow waters of the Beaufort Sea in 2008 by BP, the source level of the airgun is predicted to be 241.4 dB re 1 μPa rms. Once on location in Camden Bay, Shell will conduct sound source verification and characterization tests to establish exclusion zones for the previously mentioned sound level criteria. Upon completion of the sound source tests, the new radii, if necessary, will be established and monitored, and mitigation measures will be implemented in accordance with Shell's 4MP. Additional information on the sound source verification and characterization tests is contained in Section 5.1.1 of this EA.

Based on the best available scientific literature, the source levels noted earlier in this document and in Shell's 4MP for the drillships are not high enough to cause a temporary reduction in hearing sensitivity or permanent hearing damage to marine mammals. Consequently, Shell believes that mitigation as described for seismic activities including ramp ups, power downs, and shutdowns should not be necessary for drilling activities. NMFS has also determined that these types of mitigation measures, traditionally required for seismic survey operations, are not practical or necessary for this proposed drilling activity, except when the airguns are in use during the ZVSP surveys. Seismic airgun arrays can be turned on slowly (i.e., only turning on one or some guns at a time) and powered down quickly. The types of sound sources used for exploratory drilling have different properties and are unable to be "powered down" like airgun arrays or shutdown instantaneously without posing other risks to operational and human safety. However, Shell plans to use PSOs onboard the drillship and the various support vessels to monitor marine mammals and their responses to industry activities and to initiate mitigation measures should in-field measurements of the operations indicate that such measures are necessary.

Vessel-based monitoring for marine mammals will be done by trained PSOs throughout the period of drilling operations on all vessels. PSOs will monitor the occurrence and behavior of marine mammals near the drillship during all daylight periods during operation and during most daylight periods when drilling operations are not occurring. PSO duties will include watching for and identifying marine mammals, recording their numbers, distances, and reactions to the drilling operations. A sufficient number of PSOs will be required onboard each vessel to meet the following criteria: (1) 100% monitoring coverage during all periods of drilling operations in daylight; (2) maximum of 4 consecutive hours on watch per PSO; and (3) maximum of 12 hours of watch time per day per PSO. Shell anticipates that there will be provision for crew rotation at least every 3-6 weeks to avoid observer fatigue.

Biologist-observers will have previous marine mammal observation experience, and field crew leaders will be highly experienced with previous vessel-based marine mammal monitoring projects. Resumes for those individuals will be provided to NMFS so that NMFS can review and accept their qualifications. Inupiat observers will be experienced in the region, familiar with the marine mammals of the area, and complete a NMFS approved observer training course designed to familiarize individuals with monitoring and data collection procedures. A handbook, adapted for the specifics of the planned Shell drilling program, will be prepared and distributed beforehand to all PSOs.

PSOs will watch for marine mammals from the best available vantage point on the drillship and support vessels. PSOs will scan systematically with the unaided eye and 7 x 50 reticle binoculars, supplemented with "Big-eye" binoculars and night-vision equipment when needed. Personnel on the bridge will assist the PSOs in watching for marine mammals. New or inexperienced PSOs will be paired with an experienced PSO or experienced field biologist so that the quality of marine mammal observations and data recording is kept consistent. Information to be recorded by PSOs will include the same types of information that were recorded during recent monitoring programs associated with industry activity in the Arctic (e.g., Ireland et al., 2009). The recording will include information about the animal sighted, environmental and operational information, and the position of other vessels in the vicinity of the sighting. The ship's position, speed of support vessels, and water temperature, water depth, sea state, ice cover, visibility, and sun glare will also be recorded at the start and end of each observation watch, every 30 minutes during a watch, and whenever there is a change in any of those variables.

Distances to nearby marine mammals will be estimated with binoculars (Fujinon 7 x 50 binoculars) containing a reticle to measure the vertical angle of the line of sight to the animal relative to the horizon. PSOs may use a laser rangefinder to test and improve their abilities for visually estimating distances to objects in the water. However, previous experience showed that a Class 1 eye-safe device was not able to measure distances to seals more than about 230 ft (70 m) away. The device was very useful in improving the distance estimation abilities of the observers at distances up to about 1,968 ft (600 m)—the maximum range at which the device could measure distances to highly reflective objects such as other vessels. Humans observing objects of more-or-less known size via a standard observation protocol, in this case from a standard height above water, quickly become able to estimate distances within about ±20% when given immediate feedback about actual distances during training.

The purpose of requiring the establishment of exclusion and disturbance radii and that PSOs monitor those zones is to ensure that marine mammals are not exposed to sound levels that could potential cause hearing impairment or injury and to monitor a subset of the animals to estimate the level of take and note reactions to the activities. Sound levels during exploratory drilling operations are not high enough to cause injury to marine mammals. The airguns have louder source levels than the drillships; therefore, the PSOs will be used to monitor the 180 and 190-dB radii so that power-downs and shutdowns can be implemented as necessary during airgun operations. PSOs have been used in all open-water seismic survey operations for which an IHA was sought, and this measure has proven to be practical for implementation in the past.

5.1.3 Airgun Power-downs and Shutdowns

It is standard practice that during activities requiring airguns, certain mitigation measures are implemented. Two such measures include powering down and/or shutting down the airguns if marine mammals are sighted approaching or within the exclusion zones mentioned above. However, unlike a traditional seismic survey where the source vessel is constantly moving, towing the airguns behind the vessel, in this particular case, the airguns used for the ZVSP survey will be done so from a stationary source.

A power down is the immediate reduction in the number of operating energy sources from all firing to some smaller number. A shutdown is the immediate cessation of firing of all energy sources. The arrays will be immediately powered down whenever a marine mammal is sighted approaching close to or within the applicable exclusion zone of the full arrays but is outside the applicable exclusion zone of the single source. If a marine mammal is sighted within the applicable exclusion zone of the single energy source, the entire array will be shutdown (i.e., no sources firing). Following a power-down or shutdown, operation of the airgun array will not resume until the marine mammal has cleared the applicable exclusion zone. The animal will be considered to have cleared the exclusion zone if it:

- Is visually observed to have left the exclusion zone;
- Has not been seen within the zone for 15 min in the case of small odontocetes and pinnipeds; or
- Has not been seen within the zone for 30 min in the case of mysticetes.

The effectiveness of a power-down or shutdown is directly related to the effectiveness of the PSOs. Therefore, these measures are sometimes more difficult to implement in darkness or poor visibility situations. Power down and shut down procedures are currently used during exploration activities in the Beaufort and Chukchi Seas. Frequency of implementation varies but appears generally higher for pinnipeds (190 dB radius) than cetaceans. In 2008, 41 of 44 power-downs requested during seismic surveys in the Beaufort Sea were for pinnipeds; the remainder was for one bowhead whale and two unidentified mysticetes (Ireland et al., 2009).

Despite observer effort to mitigate exposure to sounds ≥180 dB re 1 μPa rms, some cetaceans may enter within the exclusion radii. In the Chukchi Sea in 2006 to 2007, 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., 2010b). Injury criteria for low-frequency cetaceans noted by Southall et al. (2007; see Table 23 earlier in this EA), which includes bowhead whales, is well above the 180 dB exposure threshold upon which this mitigation measure is based. Acoustic impairment or injury is, therefore, unlikely for the cetaceans that briefly enter within the 180 dB exclusion radius before the mitigation measure can be implemented.

NMFS is confident that power-down and shutdown of airgun arrays protect marine mammals from Level A and B harassment from seismic noise sources (75 FR 49760, August 13, 2010). Shutting down removes the noise source and potential for exposure, and powering down the acoustic source reduces the size of the exclusion zones. Marine mammals that were in the original zones would then be outside the zones ensonified by a smaller airgun source (75 FR 49760, August 13, 2010). These measures are practical to implement, as seismic survey IHA holders have been successfully implementing power-downs and shutdowns for several years.

5.1.4 Ramp-ups

As with power-downs and shutdowns, ramp-ups are a standard mitigation measure included in seismic survey authorizations. A ramp up of an airgun array provides a gradual increase in sound levels and involves a step-wise increase in the number and total volume of airguns firing until the full volume is achieved. The purpose of a ramp up (or “soft start”) is to “warn” cetaceans and pinnipeds in the vicinity of the airguns and to provide the time for them to leave the area and thus avoid any potential injury or impairment of their hearing abilities.

During the proposed ZVSP surveys, Shell will ramp up the airgun arrays slowly. Full ramp ups (i.e., from a cold start when no airguns have been firing) will begin by firing a single airgun in the array. A full ramp up will not begin until there has been a minimum of 30 minutes of observation of the 180-dB and 190-dB exclusion zones for cetaceans and pinnipeds, respectively, by PSOs to assure that no marine mammals are present. The entire exclusion zone must be visible during the 30-minutes lead-in to a full ramp up. If the entire exclusion zone is not visible, then ramp up from a cold start cannot begin. If a marine mammal(s) is sighted within the exclusion zone during the 30-minutes watch prior to ramp up, ramp up will be delayed until the marine mammal(s) is sighted outside of the applicable exclusion zone or the animal(s) is not sighted for at least 15 minutes for small odontocetes and pinnipeds or 30 minutes for mysticetes.

The rationale for this measure is that using the ramp-up (soft-start) procedure when starting airgun operations gives marine mammals near the source the opportunity to move away before being exposed to sound levels that might be strong enough to cause TTS. The means by which this mitigates hearing impairment or injury is by causing deflection from or avoidance of the sound source so, in effect, causing disturbance to mitigate potential harm. There have been no documented cases where cetaceans or pinnipeds have been observed to move away from a survey vessel during ramp-up. Efficacy is assumed based on studies of effects of airgun sounds on marine mammals, although the degree to which ramp-up protects marine mammals from exposure to intense noises is unknown (75 FR 49760, August 13, 2010). Data collected during activities will aid in understanding the effectiveness of ramp-up. However, because the purpose is to conduct ramp-up when marine mammals are not present within the area, sample sizes are extremely small.

5.1.5 Vessel and Aircraft Operational Measures

It is proposed that Shell will implement several mitigation measures related to the operation of vessels and aircraft that are part of the exploratory drilling programs. These measures include reducing speed in inclement weather and when near marine mammals. Additionally, Shell will avoid multiple changes in direction when within 300 yards (274 m) of whales. Vessels will also remain anchored when approached by marine mammals in order to avoid the potential for avoidance reactions by marine mammals. Regarding aircraft to be used in support of the proposed exploratory drilling operations, all aircraft will maintain a 1,500 ft (457 m) altitude (except during take-offs and landings or during emergency situations). As noted earlier in this EA, marine mammals tend to react to aircraft flying overhead when done so at lower altitudes. Therefore, requiring a 1,500 ft altitude during routine flights will aid in reducing potential behavioral disturbance reactions of marine mammals to aircraft flying overhead. Additionally, the measures requiring vessels to reduce speed in inclement weather and when near marine mammals will aid in reducing the potential for vessel strikes. Even if a marine mammal is struck at the slower speeds, the risk for injury or death is reduced at slower speeds (see Laist et al., 2001; Vanderlaan and Taggart, 2007). All of these measures are fairly practical for implementation.

5.1.6 Oil Spill Response Plan

In accordance with BSEE regulations, Shell has developed Oil Spill Response Plans for both the Camden Bay and Chukchi Sea proposed exploratory drilling programs. Appendix A of BOEMRE's EA for the Shell Offshore Inc. 2012 Revised Outer Continental Shelf Lease Exploration Plan Camden Bay, Beaufort Sea, Alaska (BOEMRE, 2011b) and Appendix A of BOEM's EA for the Shell Gulf of Mexico Inc. 2012 Revised Outer Continental Shelf Lease Lease Exploration Plan Chukchi Sea Planning Area (BOEM, 2011) describe oil spill prevention plans and analysis of potential oil spills for Shell's proposed Beaufort Sea and Chukchi Sea programs, respectively. That information is incorporated herein by reference. BSEE approved Shell's Chukchi Sea Oil Spill Response Plan in February 2012. Approval of Shell's Beaufort Sea Oil Spill Response Plan is still pending.

5.1.7 Emergency Shutdown

In the unanticipated and unlikely event that the drilling program operation clearly causes the take of a marine mammal in a manner prohibited by the IHA, such as an injury (Level A harassment), serious injury or mortality (e.g., ship-strike, gear interaction, and/or entanglement), Shell will be required to immediately cease operations and immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, by phone or email and the Alaska Regional Stranding Coordinators. The report must include the following information: time, date, and location (latitude/longitude) of the incident; the name and type of vessel involved; the vessel's speed during and leading up to the incident; description of the incident; status of all sound source use in the 24 hours preceding the incident; water depth; environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility); description of marine mammal observations in the 24 hours preceding the incident; species identification or description of the animal(s) involved; the fate of the animal(s); 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 Shell to determine what is necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. Shell may not resume their activities until notified by NMFS via letter, email, or telephone.

In the event that Shell discovers an injured or dead marine mammal, and the lead PSO determines that the cause of the injury or death is unknown and the death is relatively recent (i.e., in less than a moderate state of decomposition as described in the next paragraph), Shell will immediately report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, by phone or email and the NMFS Alaska Stranding Hotline and/or by email to the Alaska Regional Stranding Coordinators. The report must include the same information identified in the previous paragraph. Activities may continue while NMFS reviews the circumstances of the incident. NMFS will work with Shell to determine whether modifications in the activities are appropriate.

In the event that Shell discovers an injured or dead marine mammal, and the lead PSO determines that the injury or death is not associated with or related to the specified activities authorized for the taking of marine mammals in the IHA (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), Shell shall report the incident to the Chief of the Permits and Conservation Division, Office of Protected Resources, NMFS, by phone or email and the NMFS Alaska Stranding Hotline and/or by email to the Alaska Regional Stranding Coordinators, within 24 hours of the discovery. Shell shall provide photographs or video footage (if available) or other documentation of the stranded animal sighting to NMFS and the Marine Mammal Stranding Network. Activities may continue while NMFS reviews the circumstances of the incident.

The purpose of this measure is to collect information on any injured or dead marine mammals that are discovered during the activities. Additionally, if the specified activities caused the injury or death of marine mammals, the collected information will aid in revising protocols to help ensure that such incidents do not occur again.

5.1.8 Collection of Muds, Cuttings, and Discharge Streams

In Camden Bay during its Beaufort Sea exploratory drilling program, Shell has proposed to the following measures regarding collection of wastes generated during the operations. Shell will collect all drilling mud and cuttings with adhered mud from all well sections below the 26-inch (20-inch casing) section, as well as treated sanitary waste water, domestic wastes, bilge water, and ballast water and transport them outside the Arctic for proper disposal in an EPA licensed treatment/disposal site. These waste streams shall not be discharged into the ocean. Additionally, drilling mud shall be cooled to mitigate any potential permafrost thawing or thermal dissociation of any methane hydrates encountered during exploration drilling if such materials are present at the drill site. Lastly, Shell will recycle drilling mud to the extent practicable based on operational considerations (e.g., whether mud properties have deteriorated to the point where they cannot be used further) so that the volume of the mud disposed of at the end of the drilling season is reduced.

During its Chukchi Sea exploratory drilling program, Shell has proposed to recycle drilling muds (e.g., use those muds on multiple wells), to the extent practicable based on operational considerations (e.g., whether mud properties have deteriorated to the point where they cannot be used further) in order to reduce discharges from its operations. At the end of the season excess water base fluid will be pre-diluted to a 30:1 ratio with seawater and then discharged. These measures will help in reducing pollution to the marine environment and will lessen impacts to water quality, which will in turn reduce impacts to marine mammals and their habitats.

5.2 Subsistence Mitigation Measures

The following subsistence mitigation measures, plans, and programs are aimed to mitigate any adverse effects that could potentially affect subsistence groups and communities. These measures, plans, and programs have been effective in past seasons of work in the Arctic and were developed in past consultations with these communities. These measures, plans, and programs will be implemented by Shell during the 2012 exploratory drilling programs in the Beaufort and Chukchi Seas to monitor and mitigate potential impacts to subsistence users and resources.

In addition, regulations at 50 CFR 216.104(a)(12) require IHA applicants for activities that take place in Arctic waters to provide a Plan of Cooperation (POC) or information that identifies what measures have been taken and/or will be taken to minimize adverse effects on the availability of marine mammals for subsistence uses. The POCs developed by Shell are also discussed here.

The following measures to ensure no unmitigable adverse impacts to marine mammals for subsistence uses apply to both proposed programs, unless otherwise stated. The drillships and support vessels will transit through the Chukchi Sea (but not before July 1) along a route that lies offshore of the polynya zone. In the event the transit outside of the polynya zone results in Shell having to break ice (as opposed to managing ice by pushing it out of the way), the drillship and support vessels will enter into the polynya zone far enough so that ice breaking is not necessary. If it is necessary to move into the polynya zone, Shell will notify the local communities of the change in the transit route through the Com Centers.

Shell has developed a Communication Plan and will implement the plan before initiating exploration drilling operations to coordinate activities with local subsistence users as well as Village Whaling Associations in order to minimize the risk of interfering with subsistence hunting activities and keep current as to the timing and status of the bowhead whale migration, as well as the timing and status of other subsistence hunts. The Communication Plan includes procedures for coordination with Com and Call Centers to be located in coastal villages along the Chukchi and Beaufort Seas during Shell's proposed activities in 2012.

Shell will employ local Subsistence Advisors from the Beaufort and Chukchi Sea villages to provide consultation and guidance regarding the whale migration and subsistence hunt. There will be a total of nine subsistence advisor-liaison positions (one per village), to work approximately 8-hours per day and 40-hour weeks through Shell's 2012 exploration project. The subsistence advisor will use local knowledge (Traditional Knowledge) to gather data on subsistence lifestyle within the community and advise on ways to minimize and mitigate potential impacts to subsistence resources during the drilling season. Responsibilities include: reporting any subsistence concerns or conflicts; coordinating with subsistence users; reporting subsistence-related comments, concerns, and information; and advising how to avoid subsistence conflicts. A subsistence advisor handbook will be developed prior to the operational season to specify position work tasks in more detail.

Shell will implement flight restrictions prohibiting aircraft from flying within 1,000 ft (305 m) of marine mammals or below 1,500 ft (457 m) altitude (except during takeoffs and landings or in emergency situations) while over land or sea. Additionally, the drilling support fleets will avoid known fragile ecosystems, including the Ledyard Bay Critical Habitat Unit and will include coordination through the Com Centers. In the Beaufort Sea, all vessels will not exceed a cruising speed of 9 knots.

As part of its Camden Bay, Beaufort Sea, proposed exploratory drilling program, Shell will suspend drilling activities on August 25, 2012, prior to the start of the Kaktovik and Cross Island (Nuiqsut) bowhead whale hunting season. The drillship and associated vessels will remain outside of the Camden Bay area during the hunt. Shell will resume drilling operations after the conclusion of the hunt and, depending on ice and weather conditions, continue its exploration activities through October 31, 2012.

Regulations at 50 CFR 216.104(a)(12) require IHA applicants for activities that take place in Arctic waters to provide a POC or information that identifies what measures have been taken and/or will be taken to minimize adverse effects on the availability of marine mammals for subsistence purposes. Shell has developed Draft POCs for the 2012 Camden Bay, Beaufort Sea, Alaska, and the 2012 Chukchi Sea, Alaska, exploration drilling programs to minimize any adverse impacts on the availability of marine mammals for subsistence uses. A copy of the Draft POCs were provided to NMFS with the IHA Applications. Meetings with potentially affected subsistence users began in 2009 and continued into 2010 and 2011. During these meetings, Shell focused on lessons learned from prior years' activities and presented mitigation measures for avoiding potential conflicts, which are outlined in the 2012 POCs and this EA. For the 2012 Camden Bay drilling program, Shell's POC with Chukchi Sea villages primarily addresses the issue of transit of vessels, whereas the POC with Beaufort Sea villages addresses vessel transit, drilling, and associated activities. Communities that were consulted regarding Shell's 2012 Arctic Ocean operations include: Barrow, Kaktovik, Wainwright, Kotzebue, Kivalina, Point Lay, Point Hope, Kiana, Gambell, Savoonga, and Shishmaref.

Beginning in early January 2009 and continuing into 2011, Shell held one-on-one meetings with representatives from the NSB and Northwest Arctic Borough (NWAB), subsistence-user group leadership, and Village Whaling Captain Association representatives. Shell's primary purpose in holding individual meetings was to inform and prepare key leaders, prior to the public meetings, so that they would be prepared to give appropriate feedback on planned activities.

Shell presented the proposed project to the NWAB Assembly on January 27, 2009, to the NSB Assembly on February 2, 2009, and to the NSB and NWAB Planning Commissions in a joint meeting on March 25, 2009. Meetings were also scheduled with representatives from the AEWC, and presentations on proposed activities were given to the Inupiat Community of the Arctic Slope, and the Native Village of Barrow. On December 8, 2009, Shell held consultation meetings with representatives from the various marine mammal commissions. Prior to drilling in 2012, Shell will also hold additional consultation meetings with the affected communities and subsistence user groups, NSB, and NWAB to discuss the mitigation measures included in the POC. Shell also attended the 2011 Conflict Avoidance Agreement (CAA) negotiation meetings in support of a limited program of marine environmental baseline activities in 2011 taking place in the Beaufort and Chukchi seas. Shell has stated that it is committed to a CAA process and will demonstrate this by making a good-faith effort to negotiate a CAA every year it has planned activities.

The mitigation measures, plans, and programs mentioned in this section are integral to the POC and were developed during consultation with potentially affected subsistence groups and communities. These measures, plans, and programs will be implemented by Shell during its 2012 exploration drilling operations in both the Beaufort and Chukchi Seas to monitor and mitigate potential impacts to subsistence users and resources. The mitigation measures Shell has adopted and will implement during its 2012 Camden Bay and Chukchi Sea exploration drilling operations have been described above. The most recent version of Shell's planned mitigation measures was presented to community leaders and subsistence user groups starting in January of 2009 and has evolved since in response to information learned during the consultation process.

5.3 Monitoring Measures

In order to issue an IHA for an activity, Section 101(a)(5)(D) of the MMPA states that NMFS must, where applicable, set forth "requirements pertaining to the monitoring and reporting of such taking". The MMPA implementing regulations at 50 CFR 216.104 (a)(13) indicate that requests for IHAs must include the suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species and of the level of taking or impacts on populations of marine mammals that are expected to be present in the proposed action area. The measures noted in this section of the EA would be required under both Alternatives 2 and 3. While Shell has proposed vessel-based, aerial, and acoustic monitoring programs in both seas, the methods and objectives are different for both programs. Therefore, the two proposed monitoring programs are described and discussed separately in this EA.

5.3.1 Beaufort Sea Monitoring Plan

A full description of Shell's Beaufort Sea 4MP can be found in the IHA application (Shell, 2011a). The primary components of the plan are summarized here. The full descriptions and protocols are hereby incorporated by reference.

5.3.1.1 Vessel-based Monitoring

Vessel-based monitoring for marine mammals will be done by trained PSOs throughout the period of drilling operations on all vessels. PSOs will monitor the occurrence and behavior of marine mammals near the drillship during all daylight periods during operation and during most daylight periods when drilling operations are not occurring. PSO duties will include watching for and identifying marine mammals, recording their numbers, distances, and reactions to the drilling operations. A sufficient number of PSOs will be required onboard each vessel to meet the following criteria: (1) 100% monitoring coverage during all periods of drilling operations in daylight; (2) maximum of 4 consecutive hours on watch per PSO; and (3) maximum of 12 hours of watch time per day per PSO. Shell anticipates that there will be provision for crew rotation at least every 3-6 weeks to avoid observer fatigue. Additional details on the PSO program can be found in Section 5.1.2 of this EA.

5.3.1.2 Aerial Survey Program

Shell proposes to conduct an aerial survey program in support of the drilling program in the Beaufort Sea during the summer and fall of 2012. Shell's objectives for this program include to:

- Advise operating vessels as to the presence of marine mammals (primarily cetaceans) in the general area of operation;
- Collect and report data on the distribution, numbers, movement and behavior of marine mammals near the drilling operations with special emphasis on migrating bowhead whales;
- Support regulatory reporting related to the estimation of impacts of drilling operations on marine mammals;
- Investigate potential deflection of bowhead whales during migration by documenting how far east of drilling operations a deflection may occur and where whales return to normal migration patterns west of the operations; and
- Monitor the accessibility of bowhead whales to Inupiat hunters.

Aerial survey flights will begin 5 to 7 days before operations at the exploration well sites get underway. Surveys will be flown daily throughout drilling operations, weather and flight conditions permitting, and continue for 5 to 7 days after all activities at the site have ended.

The aerial survey procedures will be generally consistent with those used during earlier industry studies (Davis et al., 1985; Johnson et al., 1986; Evans et al., 1987; Miller et al., 1997, 1998, 1999, 2002; Patterson, 2007). This will facilitate comparison and pooling of data where appropriate. However, the specific survey grids will be tailored to Shell's operations. During the 2012 drilling season, Shell will coordinate and cooperate with the aerial surveys conducted by BOEM/NMFS and any other groups conducting surveys in the same region.

For marine mammal monitoring flights, aircraft will be flown at approximately 120 knots (138 mph) ground speed and usually at an altitude of 1,000 ft (305 m). Surveys in the Beaufort Sea are directed at bowhead whales, and an altitude of 900-1,000 ft (274-305 m) is the lowest survey altitude that can normally be flown without concern about potential aircraft disturbance. Aerial surveys at an altitude of 1,000 ft (305 m) do not provide much information about seals but are suitable for both bowhead and beluga whales. The need for a 900-1000+ (374-305 m) ft cloud ceiling will limit the dates and times when surveys can be flown.

Two primary observers will be seated at bubble windows on either side of the aircraft, and a third observer will observe part time and record data the rest of the time. All observers need bubble windows to facilitate downward viewing. For each marine mammal sighting, the observer will dictate the species, number, size/age/sex class when determinable, activity, heading, swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading to the marine mammal into a digital recorder. The inclinometer reading will be taken when the animal's location is 90° to the side of the aircraft track, allowing calculation of lateral distance from the aircraft trackline.

Transect information, sighting data and environmental data will be entered into a GPS-linked computer by the third observer and simultaneously recorded on digital voice recorders for backup and validation. At the start of each transect, the observer recording data will record the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction (°T) and outside air temperature (°C). In addition, each observer will record the time, visibility (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, moderate, severe) at the start and end of each transect, and at 2 min intervals along the transect. The data logger will automatically record time and aircraft position (latitude and longitude) for sightings and transect waypoints, and at pre-selected intervals along the transects. Ice observations during aerial surveys will be recorded and satellite imagery may be used, where available, during post-season analysis to determine ice conditions adjacent to the survey area. These are standard practices for surveys of this type and are necessary in order to interpret factors responsible for variations in sighting rates.

During the late summer and fall, the bowhead whale is the primary species of concern, but belugas and gray whales are also present. To address concerns regarding deflection of bowheads at greater distances, the survey pattern around drilling operations has been designed to document whale distribution from about 25 mi (40 km) east of the drilling operations to about 37 mi (60 km) west of operations (see Figure 15).

Bowhead whale movements during the late summer/autumn are generally from east to west, and transects should be designed to intercept rather than parallel whale movements. The transect lines in the grid will be oriented north-south, equally spaced at 5 mi (8 km) and randomly shifted in the east-west direction for each survey by no more than the transect spacing. The survey grid will total about 808 mi (1,300 km) in length, requiring approximately 6 hours to survey at a speed of 120 knots (138 mph), plus ferry time. Exact lengths and durations will vary somewhat depending on the position of the drilling operation and thus of the grid, the sequence in which lines are flown (often affected by weather), and the number of refueling/rest stops.

Weather permitting, transects making up the grid in the Beaufort Sea will be flown in sequence from west to east. This decreases difficulties associated with double counting of whales that are (predominantly) migrating westward. The survey sequence around the drilling operation is designed to monitor the distribution of whales around the drilling operation. Shell's 4MP provides an explanation about the importance of statistical power in the sampling design and how the aerial survey data will be analyzed. Please refer to the Beaufort Sea 4MP for that information (Shell, 2011a).

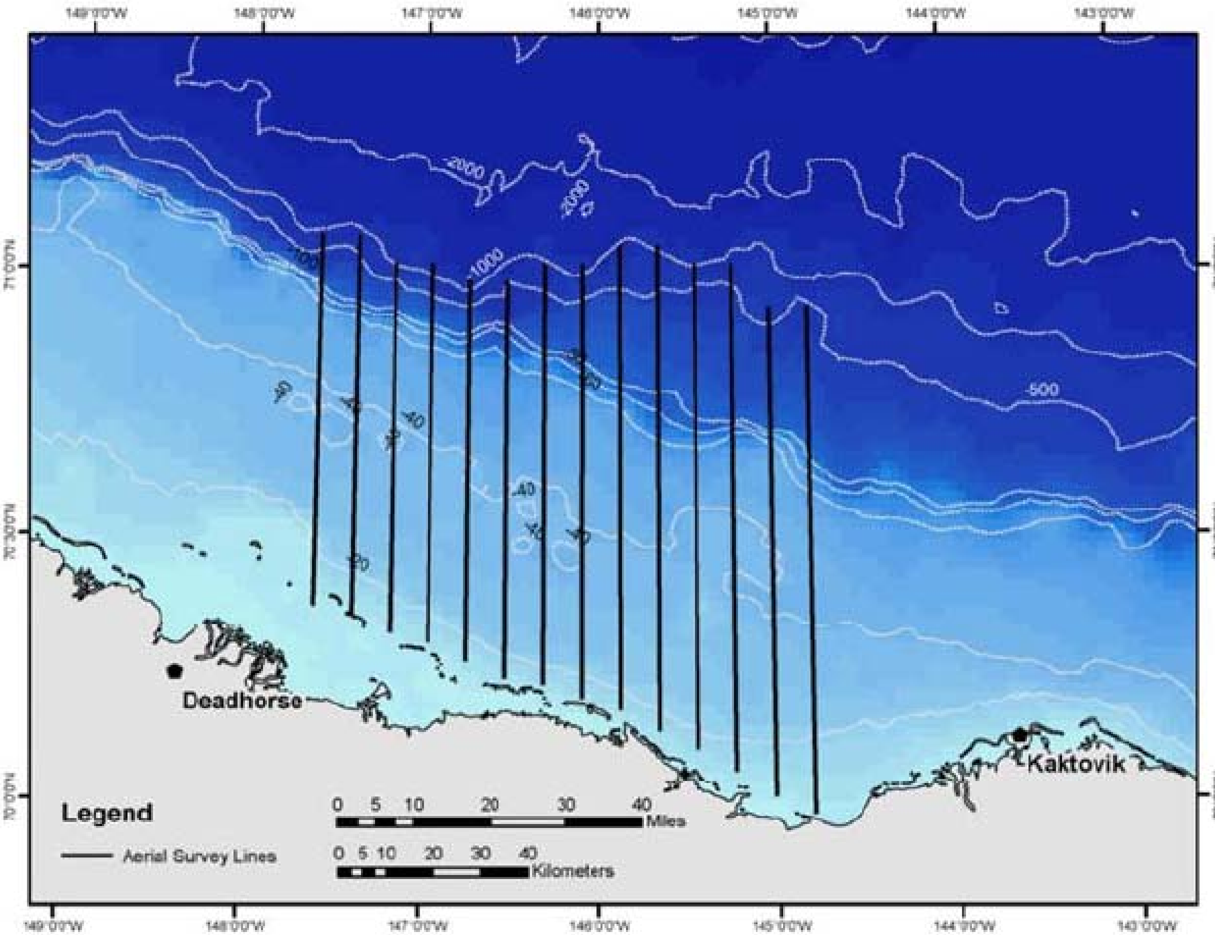

Figure 15. Central Alaskan Beaufort Sea showing a representative aerial survey pattern flown daily during late summer and fall. The survey grid will be moved east or west depending on the precise location of the drillship, and lines will be shifted slightly within the grid for each survey in order to randomize their location and meet sampling size objectives.

5.3.1.3 Acoustic Monitoring Program

In the Beaufort Sea, Shell has proposed to conduct two different and distinct activities regarding acoustic monitoring. The first is sound source verification and characterization of the equipment proposed to be used during the exploratory drilling program. That information is described in Section 5.1.1 of this EA. The second part of the acoustic monitoring program will be conducted to collect calls of migrating bowhead whales.

Shell plans to deploy arrays of acoustic recorders in the Beaufort Sea in 2012, similar to that which was done in 2007 through 2010 using Directional Autonomous Seafloor Acoustic Recorders (DASARs). These directional acoustic systems permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document sound characteristics and propagation resulting from vessel-based drilling operations that may have the potential to cause deflections of bowhead whales from their migratory pathway. Of particular interest will be the east-west extent of deflection, if any (i.e., how far east of a sound source do bowheads begin to deflect and how far to the west beyond the sound source does deflection persist). Of additional interest will be the extent of offshore (or towards shore) deflection that might occur.

In previous work around seismic and drillship operations in the Alaskan Beaufort Sea, the primary method for studying this question has been aerial surveys. Acoustic localization methods will provide supplementary information for addressing the whale deflection question. Compared to aerial surveys, acoustic methods have the advantage of providing a vastly larger number of whale detections, and can operate day or night, independent of visibility, and to some degree independent of ice conditions and sea state—all of which prevent or impair aerial surveys. However, acoustic methods depend on the animals to call, and to some extent, assume that calling rate is unaffected by exposure to industrial noise. Bowheads call frequently in fall, but there is some evidence that their calling rate may be reduced upon exposure to industrial sounds, complicating interpretation. The combined use of acoustic and aerial survey methods will provide a suite of information that should be useful in assessing the potential effects of drilling operations on migrating bowhead whales.

Using passive acoustics with directional autonomous recorders, the locations of calling whales will be observed for a 6- to 10-week continuous monitoring period at five coastal sites (subject to favorable ice and weather conditions). Essential to achieving this objective is the continuous measurement of sound levels near the drillship.

Shell plans to conduct the whale migration monitoring using the passive acoustics techniques developed and used successfully since 2001 for monitoring the migration past Northstar production island northwest of Prudhoe Bay and from Kaktovik to Harrison Bay during the 2007 through 2011 migrations. Those techniques involve using DASARs to measure the arrival angles of bowhead calls at known locations, then triangulating to locate the calling whale.

In attempting to assess the responses of bowhead whales to the planned industrial operations, it will be essential to monitor whale locations at sites both near and far from industry activities. Shell plans to monitor at five sites along the Alaskan Beaufort coast as shown in Figure 16. The eastern-most site (#5 in Figure 16) will be just east of Kaktovik (approximately 62 mi [100 km] west of the Sivulliq drilling area) and the western-most site will be in the vicinity of Harrison Bay (approximately 109 mi [175 km] west of Sivulliq). Site 2 will be located west of Prudhoe Bay (approximately 68 mi [110 km] west of Sivulliq). Site 4 will be approximately 6.2 mi (10 km) east of the Sivulliq drilling area, and site 3 will be approximately 15.5 mi (25 km) west of Sivulliq. These five sites will provide information on possible migration deflection well in advance of whales encountering an industry operation and on "recovery" after passing such operations should a deflection occur.

The proposed geometry of DASARs at each site is comprised of seven DASARs oriented in a north-south pattern so that five equilateral triangles with 4.3-mi (7-km) element spacing is achieved. DASARs will be installed at planned locations using a GPS. However, each DASAR's orientation once it settles on the bottom is unknown and must be determined to know how to reference the call angles measured to the whales. Also, the internal clocks used to sample the acoustic data typically drift slightly, but linearly, by an amount up to a few seconds after 6 weeks of autonomous operation. Knowing the time differences within a second or two between DASARs is essential for identifying identical whale calls received on two or more DASARs.

Bowhead migration begins in late August with the whales moving westward from their feeding sites in the Canadian Beaufort Sea. It continues through September and well into October. However, because of the drilling schedule, Shell will attempt to install the 21 DASARs at three sites (3, 4 and 5) in early August. The remaining 14 DASARs will be installed at sites 1 and 2 in late August. Thus, Shell proposes to be monitoring for whale calls from before August 15 until sometime before October 15.

At the end of the season, the fourth DASAR in each array will be refurbished, recalibrated, and redeployed to collect data through the winter. The other DASARs in the arrays will be recovered. The redeployed DASARs will be programmed to record 35 min every 3 hours with a disk capacity of 10 months at that recording rate. This should be ample space to allow over-wintering from approximately mid-October 2012, through mid-July 2013.

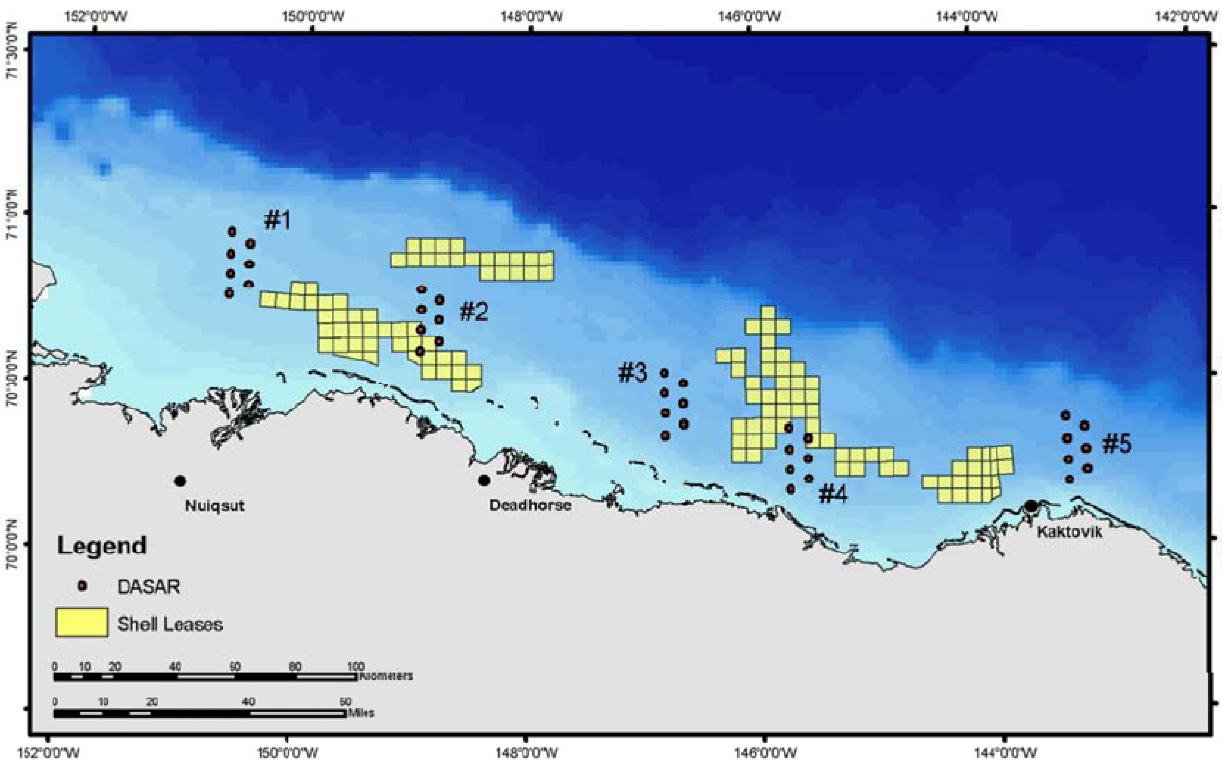

Figure 16. The Alaskan Beaufort Sea coast showing DASAR site locations for whale call location studies.

5.3.2 Chukchi Sea Monitoring Plan

A full description of Shell's Chukchi Sea 4MP can be found in the IHA application (Shell, 2011b). The primary components of the plan are summarized here. The full descriptions and protocols are hereby incorporated by reference.

5.3.2.1 Vessel-based Monitoring

The vessel-based monitoring program proposed for Shell's Chukchi Sea exploratory drilling program is identical to that described for the proposed Beaufort Sea program. Please refer to Section 5.3.1.1 in this EA for that information.

5.3.2.2 Aerial Survey Program

Recent aerial surveys of marine mammals in the Chukchi Sea were conducted over coastal areas to approximately 23 mi (37 km) offshore in 2006-2008 and 2010 in support of Shell's summer seismic exploration activities. These surveys were designed to provide data on the distribution and abundance of marine mammals in nearshore waters of the Chukchi Sea. Shell proposes to conduct an aerial survey program in the Chukchi Sea in 2012 that would be similar to the previous programs.

The current aerial survey program will be designed to collect data on cetaceans but will be limited in its ability to collect similar data on pinnipeds. Shell's objectives for this program include to:

- Collect data on the distribution and abundance of marine mammals in coastal areas of the eastern Chukchi Sea; and
- Collect and report data on the distribution, numbers, orientation and behavior of marine mammals, particularly beluga whales, near traditional hunting areas in the eastern Chukchi Sea.

With agreement from hunters in the coastal villages, aerial surveys of coastal areas to approximately 23 mi (37 km) offshore between Point Hope and Point Barrow will begin in early to mid-July and will continue until drilling operations in the Chukchi Sea are completed. Weather and equipment permitting, surveys will be conducted twice per week during this time period. In addition, during the 2012 drilling season, aerial surveys will be coordinated in cooperation with the aerial surveys funded by BOEM and conducted by NMFS and any other groups conducting surveys in the region. A full description of Shell's survey procedures can be found in the 4MP of Shell's application (Shell, 2011b). A summary follows next.

Transects will be flown in a saw-toothed pattern between the shore and 23 mi (37 km) offshore, as well as along the coast from Point Barrow to Point Hope (Figure 17). This design will permit completion of the survey in one to two days and will provide representative coverage of the nearshore region. The surveyed area will include waters where belugas are normally available to subsistence hunters. Survey altitude will be at least 1,000 ft (305 m) with an average survey speed of 110–120 knots. As with past surveys of the Chukchi Sea coast, coordination with coastal villages to avoid disturbance of the beluga whale subsistence hunt will be extremely important. "No-fly" zones around coastal villages or other hunting areas established during communications with village representatives will be in place until the end of the hunting season.

Aerial surveys at an altitude of 1,000 ft (305 m) do not provide much information about seals but are suitable for bowhead, beluga, and gray whales. The need for a 1,000+ ft (305+ m) cloud ceiling will limit the dates and times when surveys can be flown. Selection of a higher altitude for surveys would result in a significant reduction in the number of days during which surveys would be possible, impairing the ability of the aerial program to meet its objectives. If large concentrations of belugas are encountered during the survey, the survey may be interrupted to photograph the groups to obtain better counts of the number of animals present. If whales are photographed in lagoons or other shallow-water concentration areas, the aircraft will climb to approximately 10,000 ft (3,050 m) altitude to avoid disturbing the whales and causing them to leave the area. If whales are in offshore areas, the aircraft will climb high enough to include all whales within a single photograph; typically about 3,000 ft (914 m) altitude.

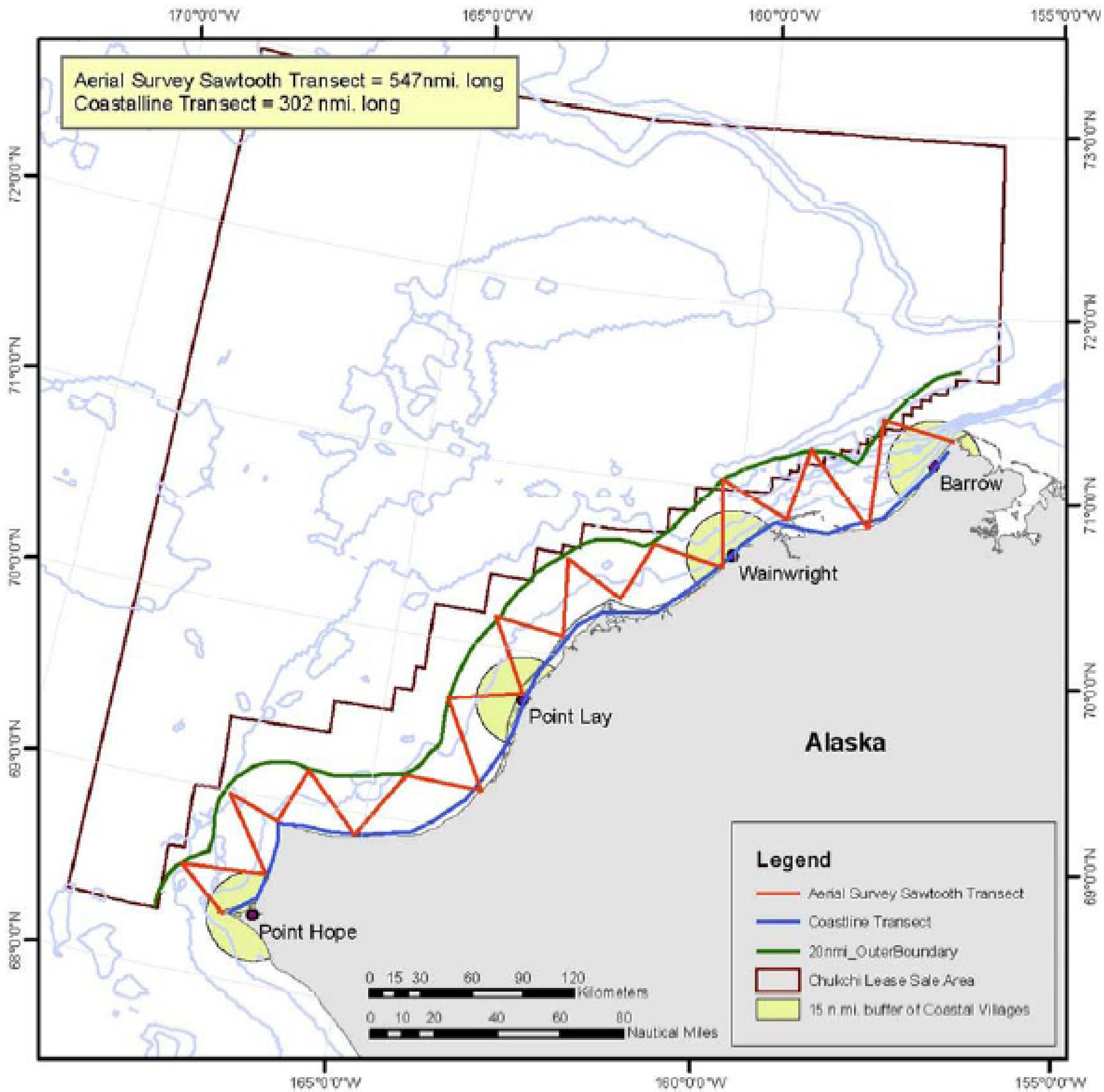

Figure 17. Aerial survey transects location and general pattern for the eastern Chukchi Sea, 2012. Specific transect start-/end-points will be altered randomly from survey to survey, and hunting areas will be avoided when hunting is occurring.

Three PSOs will be aboard the aircraft during surveys. Two primary observers will be looking for marine mammals; one each at bubble windows on either side of the aircraft. The third person will record data. For each marine mammal sighting, the observer will dictate the species, number, size/age/sex class when determinable, activity, heading, swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading to the marine mammal into a digital recorder. The inclinometer reading will be taken when the animal's location is 90° to the side of the aircraft track, allowing calculation of lateral distance from the aircraft trackline.

Transect information, sighting data and environmental data will be entered into a GPS-linked computer by the third observer and simultaneously recorded on digital voice recorders for backup and validation. At the start of each transect, the observer recording data will record the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction (°T) and outside air temperature (°C). In addition, each observer will record the time, visibility (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, moderate, severe) at the start and end of each transect, and at 2 min intervals along the transect. The data logger will automatically record time and aircraft position (latitude and longitude) for sightings and transect waypoints, and at pre-selected intervals along the transects.

5.3.2.3 Acoustic Monitoring Program

In the Chukchi Sea, Shell has proposed to conduct two different and distinct activities regarding acoustic monitoring. The first is sound source verification and characterization of the equipment proposed to be used during the exploratory drilling program. That information is described in Section 5.1.1 of this EA. The second part of the acoustic monitoring program involves the use of an acoustic "net"array.

The acoustic "net" array used by Shell during the 2006-2010 field seasons is proposed for 2012. The array was designed to accomplish two main objectives:

- To collect information on the occurrence and distribution of marine mammals that may be available to subsistence hunters near villages located on the Chukchi Sea coast and to document their relative abundance, habitat use, and migratory patterns; and
- To measure the ambient soundscape throughout the eastern Chukchi Sea and to record received levels of sound from industry and other activities further offshore in the Chukchi Sea.

The net array configuration used in 2007–2010 is again proposed for 2012. The basic components of this effort consist of 30 hydrophone systems placed widely across the U.S. Chukchi Sea and a prospect specific array of 12 hydrophones capable of localization of marine mammal calls. The net array configuration will include hydrophone systems distributed at each of the four primary transect locations: Cape Lisburne; Point Hope; Wainwright; and Barrow. The systems comprising the regional array will be placed at locations shown in Figure 18. These offshore systems will capture exploration drilling sounds, if present, over large distances to help characterize the sound transmission properties in the Chukchi Sea and will also provide a large amount of information related to marine mammals in the Chukchi Sea.

The regional acoustic monitoring program will be augmented in 2012 by an array of additional acoustic recorders to be deployed on a grid pattern over a 7.2 mi (12 km) by 10.8 mi (18 km) area extending over several of Shell's lease blocks near locations of highest interest for exploration drilling in 2012. The cluster array will operate at a sampling frequency of 16 kHz, which is sufficient to capture vocalizations from bowhead, beluga, gray, fin, humpback, and killer whales, and most other marine mammals known to be present in the Chukchi Sea. The cluster deployment configuration was defined to allow tracking of vocalizing animals that pass through the immediate area of these lease blocks. Maximum separation between adjacent recorders is 3.6 mi (5.8 km). At this spacing, Shell expects that individual whale calls will be detected on at least three different recorders when the calling animals are within the boundary of the deployment pattern. Bowhead and other mysticete calls should be detectable simultaneously on more than three recorders due to their relatively higher sound source levels compared to other marine mammals. In calm weather conditions, when ambient underwater sound levels are low, Shell expects to detect most other marine mammal calls on more than three recorders. The goal of simultaneous detection on multiple recorders is to allow for triangulation of the call positions, which also requires accurate time synchronization of the recorders. When small numbers of whales are vocalizing, Shell hopes to be able to identify and track the movements of specific individuals within the deployment area. It will not be possible to track individual whales if many whales are calling due to abundant overlapping calls. In this case, analyses will show the general distribution of calls in the vicinity of the recorders.

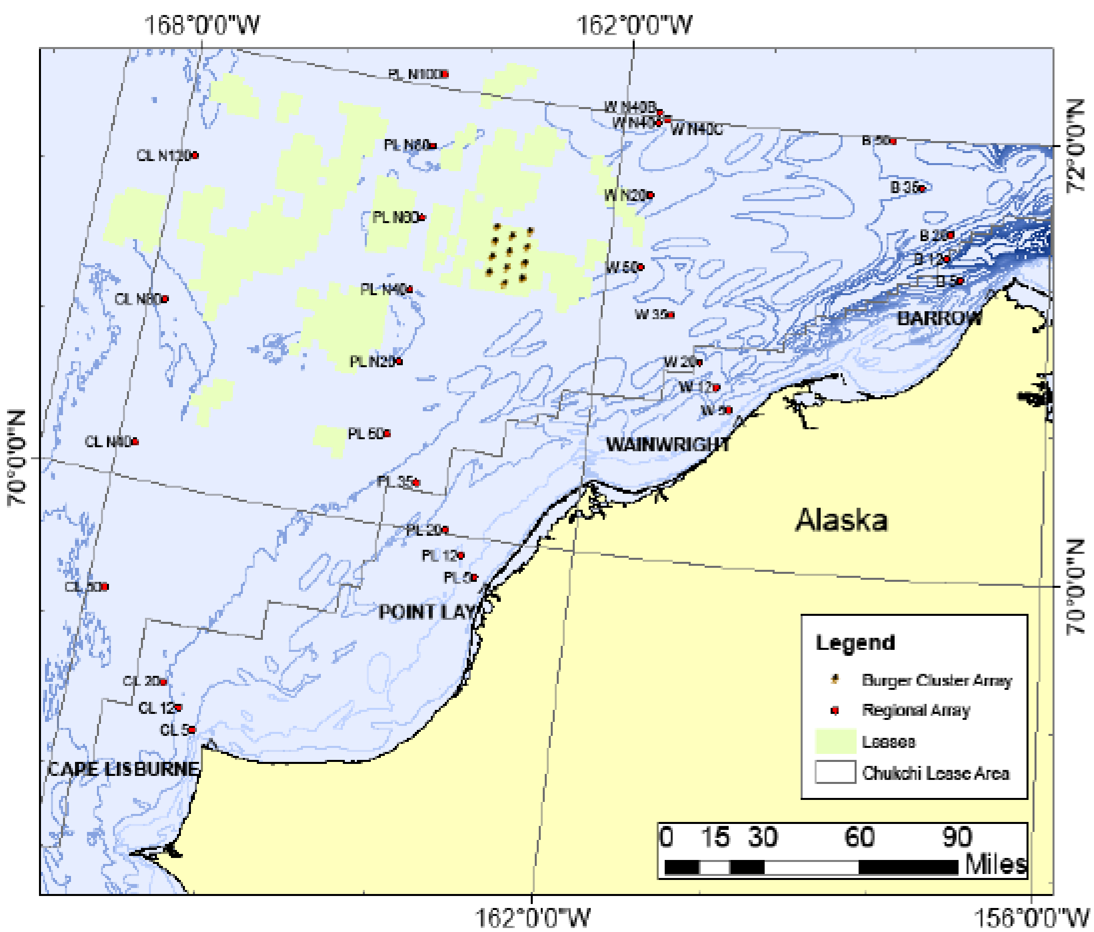

Figure 18. Deployment locations of hydrophones in acoustic arrays in the eastern Chukchi Sea, Alaska, 2012. Depiction of hydrophone at Burger is not scaled correctly based on description above (7.2 mi [12 km] by 10.8 mi [18 km]).

5.3.3 Monitoring Plan Peer Review

The MMPA requires that monitoring plans be independently peer reviewed "where the proposed activity may affect the availability of a species or stock for taking for subsistence uses" (16 U.S.C. 1371(a)(5)(D)(ii)(III)). Regarding this requirement, NMFS' implementing regulations state, "Upon receipt of a complete monitoring plan, and at its discretion, [NMFS] will either submit the plan to members of a peer review panel for review or within 60 days of receipt of the proposed monitoring plan, schedule a workshop to review the plan" (50 CFR 216.108(d)).

NMFS established an independent peer review panel to review Shell's 4MP for Exploration Drilling of Selected Lease Areas in the Alaskan Beaufort Sea in 2012 and Shell's 4MP for Exploration Drilling of Selected Lease Areas in the Alaskan Chukchi Sea in 2012. The panel met in early January 2012 and provided comments to NMFS shortly thereafter. NMFS is currently considering the recommendations made by the panel and is working with Shell to incorporate appropriate changes into the monitoring requirements of the IHA (if issued). Any changes that are incorporated will be included in a revised 4MP for the appropriate program. NMFS will publish the panel's findings and recommendations in the final IHA notice of issuance or denial document.

5.4 Reporting Requirements

The reporting requirements noted here would be required for both the Beaufort and Chukchi Sea programs and would be required under both Alternatives 2 and 3.

5.4.1 Sound Source Verification and Characterization Reports

A report on the preliminary results of the acoustic verification and characterization measurements, including as a minimum the measured 190-, 180-, 160-, and 120-dB (rms) radii of the drillship, support vessels, and airgun array will be submitted within 120 hr after collection and analysis of those measurements at the start of the field season or in the case of the airgun once that part of the program is implemented. This report will specify the distances of the exclusion zones that were adopted for the exploratory drilling program. Prior to completion of these measurements, Shell will use the radii outlined in their application and elsewhere in this EA.

5.4.2 Technical Reports

The results of Shell's 2012 Camden Bay, Beaufort Sea, and Chukchi Sea exploratory drilling monitoring programs (i.e., vessel-based, aerial, and acoustic) will be presented in the "90-day" and Final Technical reports, as required by NMFS under the proposed IHAs. Shell proposes that the Technical Reports for each program regarding the vessel-based and aerial monitoring programs will include:

- Summaries of monitoring effort (e.g., total hours, total distances, and marine mammal distribution through study period, accounting for sea state and other factors affecting visibility and detectability of marine mammals);
- Analyses of the effects of various factors influencing detectability of marine mammals (e.g., sea state, number of observers, and fog/glare);

- Species composition, occurrence, and distribution of marine mammal sightings, including date, water depth, numbers, age/size/gender categories (if determinable), group sizes, and ice cover;
- Sighting rates of marine mammals during periods with and without drilling activities (and other variables that could affect detectability);
- Initial sighting distances versus drilling state;
- Closest point of approach versus drilling state;
- Observed behaviors and types of movements versus drilling state;
- Numbers of sightings/individuals seen versus drilling state;
- Distribution around the drillship and support vessels versus drilling state; and
- Estimates of take by harassment.

Analysis of all acoustic data will be prioritized to address the primary questions, which are to:

- Determine when, where, and what species of animals are acoustically detected on each DASAR;
- Analyze data as a whole to determine offshore bowhead distributions as a function of time;
- Quantify spatial and temporal variability in the ambient noise; and
- Measure received levels of drillship activities.

The bowhead detection data will be used to develop spatial and temporal animal distributions. Statistical analyses will be used to test for changes in animal detections and distributions as a function of different variables (e.g., time of day, time of season, environmental conditions, ambient noise, vessel type, operation conditions).

The initial technical reports are due to NMFS within 90 days of the completion of Shell's exploratory drilling programs. The "90-day" reports will be subject to review and comment by NMFS. Any recommendations made by NMFS must be addressed in the final report prior to acceptance by NMFS.

5.4.3 Comprehensive Report

Following the 2012 drilling season, a comprehensive report describing the vessel-based, aerial, and acoustic monitoring programs in both seas will be prepared. The comprehensive report will describe the methods, results, conclusions and limitations of each of the individual data sets in detail. The report will also integrate (to the extent possible) the studies into a broad based assessment of industry activities, and other activities that occur in the Beaufort and/or Chukchi Seas, and their impacts on marine mammals during 2012. The report will help to establish long-term data sets that can assist with the evaluation of changes in the Chukchi and Beaufort Sea ecosystems. The report will attempt to provide a regional synthesis of available data on industry activity in offshore areas of northern Alaska that may influence marine mammal density, distribution, and behavior.

5.5 Conclusion

The inclusion of the mitigation and monitoring requirements in the IHAs will ensure that Shell's activities and the proposed mitigation measures under Alternatives 2 and3 are sufficient to minimize any potential adverse impacts to the human environment, particularly marine mammal species or stocks and their habitat. With the inclusion of the required mitigation and monitoring requirements, NMFS has determined that the proposed activities (described in Section 1.5 of this EA) by Shell and NMFS' proposed issuance of IHAs to Shell will result at worst in a temporary modification of behavior (Level B harassment) of some individuals of 12 species of marine mammals in the Beaufort and Chukchi Seas. In addition, no take by injury, serious injury, and/or death is anticipated, and the potential for temporary or permanent hearing impairment will be avoided through the incorporation of the mitigation and monitoring measures described earlier in this document.

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