ENVIRONMENTAL ASSESSMENT

FOR THE ISSUANCE OF AN INCIDENTAL HARASSMENT AUTHORIZATION TO TAKE MARINE MAMMALS BY HARASSMENT INCIDENTAL TO CONDUCTING AN IN-ICE SEISMIC SURVEY IN THE BEAUFORT AND CHUKCHI SEAS

September 2012

LEAD AGENCY: USDOC, National Oceanic and Atmospheric Administration
National Marine Fisheries Service, Office of Protected Resources
1315 East West Highway
Silver Spring, MD 20910

RESPONSIBLE OFFICIAL: Helen M. Golde, Acting Director, Office of Protected Resources

FOR INFORMATION CONTACT: Office of Protected Resources
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910
(301) 427-8400

LOCATION: Beaufort and Chukchi Seas

ABSTRACT: The National Marine Fisheries Service proposes to issue an Incidental Harassment Authorization (IHA) to ION Geophysical (ION) for the taking, by harassment, of small numbers of marine mammals incidental to conducting an in-ice seismic survey in the Beaufort and Chukchi Seas, Alaska.

TABLE OF CONTENTS

List of Acronyms, Abbreviations, and Initialisms

0-p	0-to-peak
2D	2-dimensional
3D	3-dimensional
4MP	Marine Mammal Monitoring and Mitigation Plan
AAM	Active Acoustic Monitoring
ABWC	Alaska Beluga Whale Committee
ACMA	Alaska Coastal Management Act
ACMP	Alaska Coastal Management Program
ACP	Arctic Coastal Plain
ADCCED	Alaska Department of Commerce, Community, and Economic Development
ADFG	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AEWC	Alaska Eskimo Whaling Commission
AKRO	NMFS Alaska Regional Office
AM	amplitude-modulated
AMAR	Multi-Channel Acoustic Recorder
ANSC	Alaska Native Science Commission
AQCR	Air Quality Control Regions
ASRC	Arctic Slope Regional Corporation
AURAL	Autonomous Underwater Recorder for Acoustic Listening
AUV	Autonomous Underwater Vehicle
BCB	Bering-Chukchi-Beaufort Seas (stock of bowhead whale)
BOEM	Bureau of Ocean Energy Management, Regulation and Enforcement
BPXA	BP Exploration Alaska
CBD	Center for Biological Diversity
CBS	Chukchi/Bering Seas (stock of polar bear)
CFR	Code of Federal Regulations
CEQ	President's Council on Environmental Quality
CF	correction factor
CI	confidence interval
cm	centimeter
CV	coefficient of variation
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Plan
DASAR	Directional Autonomous Seafloor Acoustic Recorder
dB	decibel
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FM	frequency-modulated
FMP	Fishery Management Plan
FONSI	Finding of No Significant Impact
ft	foot/feet
FR	Federal Register
GPS	Global Positioning System
HZ	hertz

IHA	Incidental Harassment Authorization
IMO	International Maritime Organization
in^3	cubic inch
ION	ION Geophysical
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometer
km^2	square kilometer
kPa	kilopascal
kts	knots
kW	kilowatt
LBCHU	Ledyard Bay Critical Habitat Unit
LME	Large Marine Ecosystem
m	meter
mi	mile
mi^2	square mile
min	minutes
MMO	Marine Mammal Observer
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service, currently the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE)
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
nmi	nautical mile
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
NPR-A	National Petroleum Reserve-Alaska
NRC	National Research Council
NSB	North Slope Borough
NVD	Night-vision Device
NWAB	Northwest Arctic Borough
OBC	Ocean Bottom Cable
OBH	Ocean Bottom Hydrophone
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lease Act
OMB	Office of Management and Budget
OPR	Office of Protected Resources
p-p	peak-to-peak
Pa	pascal
PAM	Passive Acoustic Monitoring
PEA	Programmatic Environmental Assessment
PEIS	Programmatic Environmental Impact Statement
POC	Plan of Cooperation
PR1	NMFS OPR Permits, Conservation, and Education Division
PRF	Pulse Repetition Frequency
PRD	Protected Resources Division

PSD	Prevention of Significant Deterioration
PSO	Protected Species Observer
psi	pounds per square inch
PTS	Permanent Threshold Shift
rms	root-mean-square
s	second
SBS	Southern Beaufort Sea (stock of polar bear)
SEA	Supplemental Environmental Assessment
SEL	Sound Exposure Level
SPL	Sound Pressure Level
SPLASH	Populations, Levels of Abundance, and Status of Humpbacks
SSV	Sound Source Verification
TEK	Traditional Ecological Knowledge
TGS	TGS-NOPEC Geophysical Company
TK	Traditional Knowledge
TS	Threshold Shift
TTS	Temporary Threshold Shift
U.S.C.	United States Code
USCG	United States Coast Guard
USDOI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
Y-K Delta	Yukon-Kuskokwim Delta
μPa	micro pascal

CHAPTER 1 PURPOSE AND NEED FOR ACTION

1.1 Description of Action

In response to receipt of a request from ION Geophysical (ION), NMFS proposes to issue an incidental harassment authorization (IHA) that authorizes takes[1] by harassment of marine mammals in the wild pursuant to section 101(a)(5)(D) of the Marine Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1631 *et seq*.), and the regulations governing the taking and importing of marine mammals (50 Code of Federal Regulations (CFR) Part 216).

This Environmental Assessment (EA), titled "*Environmental Assessment for the Issuance of an Incidental Harassment Authorization to Take Marine Mammals by Harassment Incidental to Conducting an In-ice Seismic Survey in the Beaufort and Chukchi Seas,*" (hereinafter, EA) addresses the impacts on the human environment that would result from the issuance of the IHA.

1.1.1 BACKGROUND

On March 1, 2012, NMFS received an application from ION for the taking, by harassment, of marine mammals incidental to an in-ice 2-dimensional (2D) marine seismic survey in the Beaufort and Chukchi Seas, Alaska, during October through December 2012. After addressing comments from NMFS, ION modified its application and submitted a revised application on June 11, 2012. The June 11, 2012, application is considered a complete application by NMFS. ION also submitted IHA applications for essentially the same in-ice seismic survey activity in 2010 and 2011. However, in both years ION withdrew its applications due to logistical issues with carrying out such activities before NMFS published a proposed IHA for public comments.

To comply with the MMPA, ION has submitted the IHA application due to the presence of marine mammal species in the vicinity of its proposed in-ice marine seismic survey areas. Marine mammals under NMFS' jurisdiction that could be affected by the proposed marine and seismic survey are:

- Beluga whale (*Delphinapterus leucas*)
- Harbor porpoise (*Phocoena phocoena*)
- Bowhead whale (*Balaena mysticetus*)
- Gray whale (*Eschrichtius robustus*)
- Minke whale (*B. acutorostrata*)
- Bearded seal (*Erignathus barbatus*)
- Ringed seal (*Phoca hispida*)
- Ribbon seal (*P. fasciata*)
- Spotted seal (*P. largha*)

[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).

1.1.2 PURPOSE AND NEED

The purpose and need of the proposed action is to ensure compliance with the MMPA and its implementing regulations in association with ION's proposed in-ice seismic survey in the Beaufort and Chukchi Seas. The MMPA prohibits takes of all marine mammals with certain exceptions.

In response to the receipt of the IHA application from ION, NMFS proposes to issue an IHA pursuant to the MMPA §101(a)(5)(D). The primary purpose of the IHA is to provide an exception from the take prohibitions under the MMPA to authorize "takes" by "harassment" of marine mammals, including endangered species, incidental to the proposed in-ice 2-D seismic survey in the Beaufort and Chukchi Seas by ION. The need for the issuance of the IHA is related to NMFS' mandates under the MMPA. Specifically the MMPA prohibits takes of marine mammals, with specific exceptions, including the incidental, but not intentional, taking of marine mammals, for periods of not more than one year, by United States citizens who engage in a specified activity (other than commercial fishing).

IHA issuance criteria require that the taking authorized by an IHA will have a negligible impact on the species or stock(s); and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses. In addition, the IHA must set forth the permissible methods of taking, other means of effecting the least practicable adverse impact on the species or stock and its habitat, and requirements for monitoring and reporting of such takings.

Issuance of an IHA is a federal agency action. For purposes of section 7 of the Endangered Species Act of 1973 (ESA; 16 U.S.C. 1531 et seq), NMFS Office of Protected Resources (OPR) Permits and Conservation Division (PR1) must consult with NMFS endangered species biologists to ensure that its action is not likely to jeopardize the continued existence of any federally-listed species or result in the destruction or adverse modification of critical habitat.

In addition, this EA is prepared in accordance with the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. 4321 *et seq*.) for the analysis of the potential environmental impacts as the result of the NMFS proposed issuance of the IHA.

1.2 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 identify and eliminate from detailed study the issues that are not significant or that have been covered by prior environmental review. An additional purpose of the scoping process is to identify the concerns of the affected public and Federal agencies, states, 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 or a proposed IHA in the *Federal Register* (50 CFR §216.104(b)(1)). The notice summarizes the purpose of the requested IHA and invites interested parties to submit written comments concerning the application.

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.

1.2.1 Comments on Application and EA

On August 17, 2012, NMFS published a notice of a proposed IHA for in-ice 2D marine seismic surveys in the Beaufort and Chukchi Seas in the *Federal Register* (77 FR 49922), which announced the availability of ION's IHA application for public comment for 30 days. The public comment period for the proposed IHA afforded the public the opportunity to provide input on environmental impacts, many of which are highlighted in this EA. In addition, NMFS will post the final EA and the Finding of No Significant Impact, if applicable, on http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications.

During the public comment periods, NMFS received written comments on the proposed IHAs from the following:

- Marine Mammal Commission
- North Slope Borough
- Ocean Conservancy
- PEW Environment Group
- Ocean Conservation Research
- Oceana
- Alaska Wilderness League, Audubon Alaska, Center for Biological Diversity, Earthjustice, Natural Resources Defense Council, Northern Alaska Environmental Center, Ocean Conservation Research, Pacific Environment, Sierra Club, and World Wildlife Fund

The comments focused on concerns of NMFS proposed issuance of Level A takes, small number issues under the MMPA, uncertainty of marine mammal distribution and density in the winter months, and limited monitoring and mitigation measures during low light hours. All these issues have been analyzed in this EA, and all relevant comments will be addressed and included in the *Federal Register* notice if NMFS decides to issue the IHA(s).

1.2.2 Issues within the Scope of this EA

The EA addresses NMFS' proposal to issue the IHA under Section 101(a)(5)(D) of the MMPA, the alternatives to the proposed action, and the associated environmental impacts. The IHA, if issued, would authorize the harassment of small numbers of nine species of marine mammals incidental to the proposed in-ice 2D marine seismic survey in the Beaufort and Chukchi Seas by ION.

NMFS identified the following issues as relevant to the actions and appropriate for detailed evaluation: (1) disturbance of marine mammals from noises generated by seismic airguns and other active acoustic sources; (2) disturbance of marine mammals from noises generated by icebreaking activities; and (3) disturbance of marine mammals related to the presence of survey and support vessels.

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

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

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

This section summarizes federal, state, and local permits, licenses, approvals, and consultation requirements necessary to implement the proposed actions, as well as who is responsible for obtaining them.

1.3.1 National Environmental Policy Act

Issuance of an IHA is subject to environmental review under NEPA. NMFS may prepare an EA, an EIS, or determine that the action is categorically excluded from further review. While NEPA does not dictate substantive requirements for an IHA, 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. NAO 216-6 specifies that issuance of an IHA under the MMPA and ESA is among a category of actions that require further environmental review. 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. The EA is prepared in accordance with NEPA, CEQ's implementing regulations, and NAO 216-6.

1.3.2 Endangered Species Act

Section 7 of the ESA 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, or USFWS) for federal actions that "may affect" a listed species or critical habitat. NMFS' issuance of an IHA 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.

The NMFS OPR Permits and Conservation Division is required to consult with the NMFS Alaska Regional Office (AKRO) Protected Resources Division (PRD) on the issuance of the IHA under Section 101(a)(5)(D) of the MMPA. PR1 is required to consult with PRD because the action of issuing an IHA may affect threatened and endangered species under NMFS' jurisdiction.

1.3.3 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 by harassment of small numbers of marine mammals of a species or population stock, for periods of not more than one year, by United States citizens who engage in a specified activity (other than commercial fishing) within a specific geographic region if certain findings are made and notice of a 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), and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses. The authorization must set forth the permissible methods of taking, other means of effecting the least practicable adverse impact on the species or stock and its habitat, and requirements pertaining to the monitoring and reporting of such takings. 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."

Section 101(a)(5)(D) of the MMPA established an expedited process by which citizens of the United States can apply for an authorization to incidentally take small numbers of marine mammals by harassment. 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"].

Section 101(a)(5)(D) of the MMPA establishes a 45-day time limit for NMFS' review of an application followed by a 30-day public notice and comment period on any proposed authorization for the incidental harassment of small numbers of marine mammals. Not later than 45 days after the close of the public comment period, if the Secretary makes the findings set forth in section 101(a)(5)(D)(i) of the MMPA, the Secretary shall issue the authorization with appropriate conditions to meet the requirements of section 101(a)(5)(D)(ii) of the MMPA.

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.

1.3.4 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.

NMFS, Office of Protected Resources, Permits and Conservation Division has determined that issuance of an IHA for the taking of marine mammals incidental to the proposed survey will not have an adverse impact on EFH, because the federal action of issuing an ITA is limited to authorizing the incidental take of marine mammals, impacts to EFH should be evaluated in that context. Allowing the take of marine mammals through the issuance of an ITA is unlikely to affect the ability of the water column or substrate to provide necessary spawning, feeding, breeding, or growth to maturity functions for managed fish. Likewise, authorizing the take of marine mammals will probably not directly or indirectly reduce the quantity or quality of EFH by affecting the physical, biological or chemical parameters of EFH. Marine mammals have not been identified as a prey component of EFH for managed fish species, so authorizing the incidental take of marine mammals probably will not reduce the quantity and/or quality of EFH. Therefore, an EFH consultation is not required.

1.3.5 Coastal Zone Management Act

The federal Coastal Zone Management Act (CZMA) of 1972 authorizes states with approved Coastal Management Plans (CMPs) to review most federal activities and federally permitted activities within or affecting resources within the state's coastal zone to ensure that the activities will be conducted in a manner consistent with their approved CMP. The review authority is applicable to any exploration plan or development plan in any area that has been leased under the Outer Continental Shelf Lands Act (OCSLA) and that affects any land or water use or natural resources within the state's coastal zone. The Alaska Coastal Management Program (ACMP) implemented the CZMA and required Outer Continental Shelf (OCS) plans and projects in Alaska's coastal zone, including potential shorebases, to be reviewed for consistency with statewide standards.

On July 1, 2011, the Federally-approved ACMP 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 Description of the Specified Activity

ION's proposed activities consist of a geophysical in-ice (seismic reflection/refraction) survey and related vessel operations to be conducted primarily in the Alaskan Beaufort and Chukchi seas from October to December 2012. The primary survey area extends from the U.S.–Canadian border in the east to Point Barrow in the west. Two survey lines extend west of Point

Barrow into the northern Chukchi Sea and three short tie lines are proposed near the U.S.–Russian border (Figure 1-1). The bathymetry of the proposed survey area ranges from shallow (<20 m [66 ft]) to relatively deep (>3,500 m [11,483 ft]) water over the continental shelf, the continental slope, and the abyssal plain.

The survey would be conducted from the seismic vessel *Geo Arctic* escorted by the *Polar Prince*, a medium class (100A) icebreaker. The survey grid consists of ~7,175 km (4,458 mi) of transect line, not including transits when the airguns are not operating. There may be small amounts of additional seismic operations associated with airgun testing, start up, and repeat coverage of any areas where initial data quality is sub-standard. The seismic source towed by the *Geo Arctic* would be an airgun array consisting of 26 active Sercel G-gun airguns with a total volume of 4,450 in^3. A single hydrophone streamer 4.5–9 km (2.8 – 5.6 mi) in length, depending on ice conditions, would be towed by the *Geo Arctic* to record the returning seismic signals.

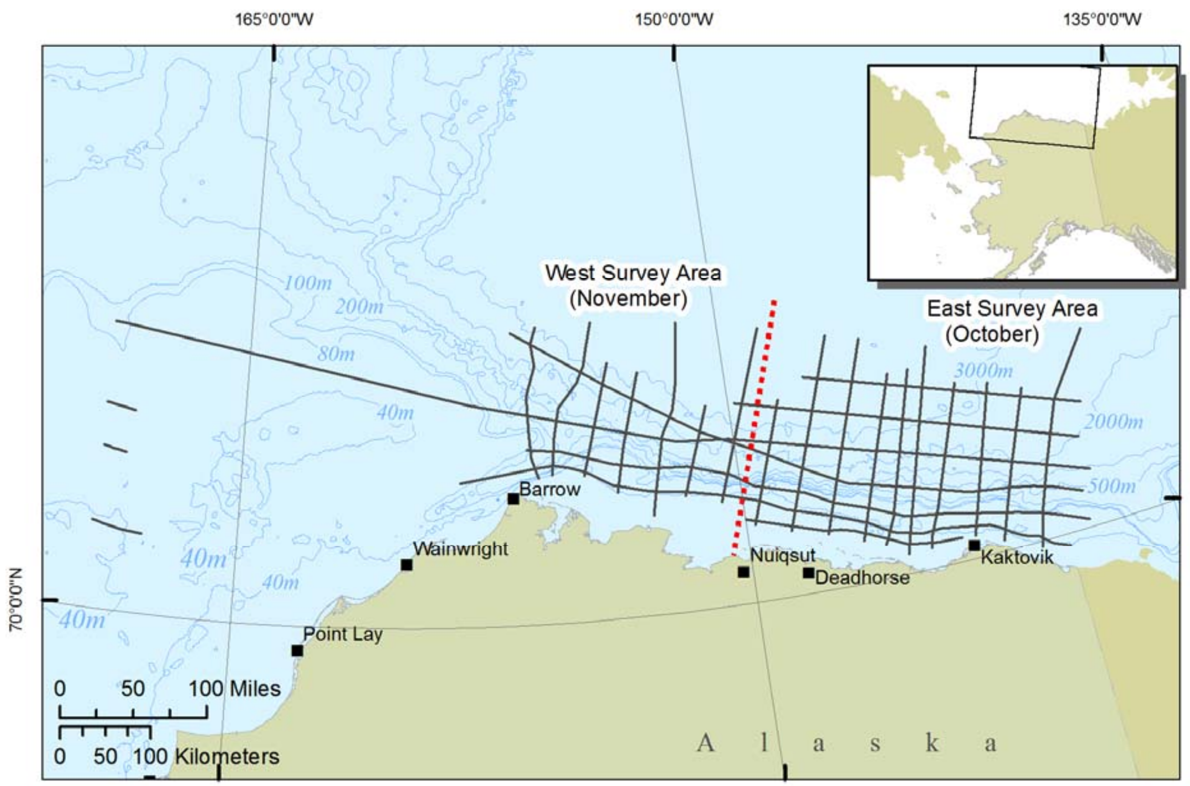

Figure 1-1. Proposed seismic survey lines for ION 2D seismic survey, Oct-Dec 2012. The red dashed line indicates the division between the "east survey area" and the "west survey area". (adapted from ION (2012a)).

The survey vessels would access the survey area from Canadian waters in late September to begin data collection on or after October 1, 2012. After completion of the survey, or when ice and weather conditions dictate, the vessels would exit to the south transiting through the Chukchi and Bering Seas. The *Polar Prince* may be used to perform an at-sea refueling (bunkering) operation to supply as much as 500 metric tons of Arctic diesel to the *Geo Arctic*. The *Polar Prince* would carry that fuel onboard at the start of the operation and it would be transferred to the *Geo Arctic* if/when necessary. Depending on its own fuel consumption, the *Polar Prince* may then transit to Tuktoyuktuk, Canada to take on additional fuel for itself. Once the *Polar Prince* returns to the *Geo Arctic* the survey would continue. The entire refueling operation would therefore involve one fuel transfer and potentially one transit to and from Tuktoyuktuk. The refueling operation would likely take place in late October, at which time vessels would likely be in the eastern or east-central Alaskan Beaufort Sea.

ION's geophysical survey has been designed and scheduled to minimize potential effects to marine mammals, bowhead whales in particular, and subsistence users. For mitigation and operational reasons the survey area has been bisected by a line that runs from 70.5° N, 150.5° W to 73° N, 148° W (Figure 1-1). Weather and ice permitting, ION plans to begin survey operations east of the line described above (eastern survey area) and in offshore waters (>1,000 m [3,281 ft]) where bowheads are expected to be least abundant in early October. This operational plan is based on the fact that only ~2% of bowhead whales observed by Bureau of Ocean Energy Management's (BOEM) aerial surveys from 1979–2007 occurred in areas of water depth >1,000 m (3,281 ft) (MMS 2010), and on average ~97% of bowheads have passed through the eastern U.S. Beaufort Sea by October 15 (Miller *et al.* 2002). The survey would then progress to shallower waters in the eastern survey area before moving to the western survey area in late October or early November 2012.

Ice conditions are expected to range from open water to 10/10 ice cover (100% ice coverage). However, the survey cannot take place in thick multi-year ice as both the icebreaker and seismic vessel must make continuous forward progress at 3 – 4 kts. In order for the survey to proceed, areas of high ice concentration can only consist of mostly newly forming juvenile first year ice or young first year ice less than 0.5 m (1.65 ft) thick. Sounds generated by the icebreaker and seismic vessel moving through these relatively light ice conditions are expected to be far below the high sound levels often attributed to icebreaking. These high sound levels (>200 dB re 1 µPa [rms]) have been recorded from icebreakers during backing and ramming operations in very heavy ice conditions and are created by cavitation of the propellers as the vessel is slowed by the ice or reverses direction (Erbe and Farmer 1998; Roth and Schmidt 2010).

Acoustic Sources

(1) Seismic Airgun Array

The seismic source used during the project would be an airgun array consisting of 28 Sercel G-gun airguns, of which 26 would be active and have a total discharge volume of 4,450 in^3. The 28 airguns would be distributed in two sub-arrays with 14 airguns per sub-array. Individual airgun sizes range from 70 to 380 in^3. Airguns would be operated at 2,000 psi. The seismic array and a single hydrophone streamer 4.5 – 9 km (2.8 – 5.6 mi) in length would be towed behind the *Geo Arctic*. Additional specifications of the airgun array are provided in Appendix B of ION's IHA application.

(2) Echo sounders

Both vessels would operate industry standard echo sounder/fathometer instruments for continuous measurements of water depth while underway. These instruments are used by all large vessels to provide routine water depth information to the vessel crew. Navigation echo sounders send a single, narrowly focused, high frequency acoustic signal directly downward to the sea floor. The sound energy reflected off the sea floor returns to the vessel where it is detected by the instrument and the depth is calculated and displayed to the user. Source levels of navigational echo sounders of this type are typically in the 180–200 dB re 1 μPa-m (Richardson *et al.* 1995a).

The *Geo Arctic* would use one navigational echo sounder during the project. The downward facing single-beam Simrad EA600 operates at frequencies ranging from 38 to 200 kHz with an output power of 100–2,000 Watts. Pulse durations are between 0.064 and 4.096 milliseconds and the pulse repetition frequency (PRF or ping rate) depends on the depth range. The highest PRF at shallow depths is about 40 pings per second. It can be used for water depths up to 4,000 m (13,123 ft) and provides up to 1 cm (0.4 in) resolution.

The *Polar Prince* would use one echo sounder, an ELAC LAZ-72. The LAZ-72 has an operating frequency of 30 kHz. The ping rate depends on the water depth and the fastest rate, which occurs in shallow depths, is about five pings per second.

Dates, Duration, and Region of Activity

The proposed geophysical survey would be conducted for ~76 days from approximately October 1 to December 15, 2012. Both the *Geo Arctic* and the *Polar Prince* would leave from Tuktoyaktuk, Canada, during late September and enter the Alaskan Beaufort Sea from Canadian waters. The survey area would be bounded approximately by 138º to 169º W longitude and 70º to 73º N latitude in water depths ranging from <20 to >3,500 m (66 – 11,483 ft) (see Figure 1 of ION's IHA application). For mitigation and operational reasons the survey area has been bisected by a line that runs from 70.5° N, 150.5° W to 73° N, 148° W. Weather and ice permitting, ION plans to begin survey operations east of the line (eastern survey area) in offshore waters (>1,000 m [3,281 ft]) where bowheads are expected to be least abundant in early October. The survey would then progress to shallower waters in the eastern survey area before moving to the west survey area in late October or early November. The vessels would depart the region to the south via the Chukchi and Bering Seas and arrive in Dutch Harbor in mid- to late December.

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 actions (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 and evaluated in detail the following two alternatives for the issuance of an IHA to ION to conduct its icebreaking seismic survey during the fall/winter 2012 season. In addition, NMFS considered two additional alternatives, but eliminated them from further consideration.

2.1 Alternative 1—No Action Alternative

Under the No Action Alternative, NMFS would not issue an IHA to ION for the harassment of marine mammals incidental to conducting an in-ice seismic survey in the Beaufort and Chukchi Seas during fall/winter 2012. The MMPA prohibits all takings of marine mammals unless authorized by a permit or exemption under the MMPA. The consequences of not authorizing incidental take are (1) the entity conducting the activity may be in violation of the MMPA if take occurs, (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 reduced. While NMFS does not authorize the icebreaking and geophysical activities itself (that authority falls to BOEM), NMFS does authorize the incidental harassment of marine mammals in connection with these activities and prescribes the methods of taking and other means of effecting the least practicable adverse impact on the species and stocks and their habitats. If an IHA is not issued, ION could decide either to cancel its icebreaking seismic survey program or to continue the activities described in Section 1.4 of this EA. If the latter decision is made, ION could independently implement (presently unidentified) mitigation measures; however, it would be proceeding without authorization from NMFS pursuant to the MMPA. If ION did not implement mitigation measures during icebreaking and survey activities, takes of marine mammals by harassment (and potentially by injury or mortality) could occur if the activities were conducted when marine mammals were present. Although the No Action Alternative would not meet the purpose and need to allow incidental takings of marine mammals under certain conditions, CEQ 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 an IHA with Required Mitigation, Monitoring, and Reporting Measures (Preferred Alternative)

Under this alternative, NMFS would issue an IHA under section 101(a)(5)(D) of the MMPA to ION, allowing the take by harassment of small numbers of marine mammal species incidental to conducting an in-ice 2D seismic survey activity in the Beaufort and Chukchi Seas during the 2012 fall/winter season. In order to reduce the incidental harassment of marine mammals to the lowest level practicable, ION would be required to implement the mitigation, monitoring, and reporting measures described in Chapters 5 and 6 of this 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 EA. Since the MMPA requires holders of IHAs to reduce impacts on marine mammals to the lowest level practicable, implementation of this alternative would meet NMFS' purpose and need as described in this EA.

2.3 Alternatives Considered but Eliminated from Further Consideration

Under one alternative, NMFS would require ION to employ a near real-time passive acoustic monitoring (PAM) and active acoustic monitoring (AAM) program, and also utilize unmanned aerial vehicles to conduct aerial monitoring. These measures would supplement those contained in Alternative 2 (Preferred Alternative). However, we determined these technologies should not be utilized in this particular instance because (1) the technologies are still being developed and thus, the efficacy of these measures for ION's survey would be questionable; and (2) the use of PAM, in particular, would require an additional icebreaker to serve as a PAM platform. After consulting with ION, we determined that a second icebreaker would not be practicable from an operational and economic perspective and could also result in additional environmental impacts such as additional noise being introduced into the water and disturbed habitat by additional icebreaking activities. Although NMFS has required the use of PAM in past IHAs (e.g., Houser *et al.* 2008; McPherson *et al.* 2012) and it has shown to be able to detect marine mammals beyond visual observation, as explained previously, we do not believe PAM is an appropriate mitigation tool for this project.

NMFS also considered an alternative that would allow for the issuance of an IHA with no mitigation or monitoring. However, the MMPA requires NMFS to prescribe, where applicable the means of effecting the least practicable impact on affected species or stocks and requirements pertaining to the monitoring of such taking by harassment. As we have already determined that measures exist to satisfy these elements of the MMPA, this alternative does not meet the purpose and need of our action and therefore, it has been eliminated from further consideration.

CHAPTER 3 AFFECTED ENVIRONMENT

This chapter describes the affected environment relative to physical, biological, and sociocultural resources found in the proposed 2012 proposed in-ice seismic survey project areas by ION. The Beaufort and Chukchi Seas environment is covered by the arctic ice pack seven to ten months each year, but supports 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 sociocultural settings of the Beaufort and Chukchi Seas communities are 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.

3.1 Physical Environment

3.1.1 Geology and Oceanography

The Beaufort and Chukchi Seas Proposed Action areas cover the relatively shallow, broad, continental shelf adjacent to the Arctic Ocean. A small portion in the north overlies the continental slope and abyssal plain. Water depths range from approximately 10 - 2,900 m (33 – 9,500 ft). Two shoals, the Hanna and Herald, are within the Chukchi Sea. These shoals rise above the surrounding seafloor to approximately 20 m (66 ft) below sea level. There are two major canyons—Herald Canyon and Barrow Canyon. The Barrow Sea Valley begins north of Wainwright and trends in a northeasterly direction parallel to the Alaskan coast. Herald Valley is to the north. Hope Valley, a broad depression, stretches from the Bering Strait to Herald Canyon. These topographic features exert a steering effect on the circulation patterns in this area. In contrast, the Beaufort shelf is a narrow shelf with no large topographic features. Water depths within the proposed seismic survey area in the Beaufort and Chukchi Seas range from less than 20 to over 3,500 m (66 – 11,483 ft).

The generalized circulation within the Beaufort and Chukchi Seas is influenced primarily by the Arctic circulation driven by large-scale atmospheric pressure fields. Cyclonic (counterclockwise) winds centered over the central Arctic Ocean predominate, alternating with anticyclonic (clockwise) winds for 5- to 7-year periods. In the Beaufort Sea, the large-scale, surface-water circulation is dominated by the Beaufort Gyre, which moves water to the west in a clockwise motion at a mean rate of about 5 - 10 cm/s (2.0 – 3.9 in). Below the surface waters, on the shelf edge, the Beaufort shelf-break jet moves to the east as a narrow current (Pickart 2004).

In the Chukchi Sea, three branches of North Pacific waters move across the shelf in a northward direction. This mean flow is primarily a product of the sea-level slope between the Pacific and the Arctic oceans. The first of these currents, the Alaska Coastal Current, flows northeastward along the Chukchi Sea coast of Alaska at approximately 4 cm/s (1.6 in/s) (Coachman 1993; Johnson 1989; Weingartner *et al.* 1998). The other waters moving north are the Bering Sea-shelf water and the Gulf of Anadyr water. These move into the Arctic Basin through Herald Valley and around Hanna Shoal.

The semidiurnal tidal range is only 6 - 10 cm (2.4 – 3.9 in) in the Beaufort Sea (Matthews 1980; Kowalik and Matthews 1982). Tidal currents generally are weak, about 4 cm/s (1.6

in/s) (Kowalik and Proshutinsky 1994). The level of the water changes constantly in response to the wind. Positive tidal surges occur with strong westerly winds, while negative surges occur with strong easterly winds. Tides are small in the Chukchi Sea, and the range generally is <30 cm (0.98 ft). Tidal currents are largest on the western side of the Chukchi and near Wrangel Island, ranging up to 5 cm/s (2.0 in/s) (Woodgate *et al.* 2005).

Waves in the Beaufort and Chukchi seas are controlled by wind and the amount of ice in the water, as ice dampens waves. With a solid ice cover, no waves are generated. Under heavy ice-cover conditions during the colder months, there is little wave development. When the ice thins out, particularly during late summer, the available open-water surface increases, and the waves grow in height. Typical wave heights are < 1.5 m (4.9 ft), with a wave period of approximately 6 s during summer and <2.5 m (8.2 ft) during fall. Expected maximum wave heights are 7 - 7.5 m (23.0 – 24.6 ft) in the Beaufort Sea and 8 - 9.5 m (26.3 – 31.2 ft) in the Chukchi Sea. A late summer storm in the Beaufort and Chukchi seas in September 2000 developed waves 6 - 7 m (19.7 – 23.0 ft) high at Point Barrow (Lynch *et al.* 2003).

Sea Ice

Sea ice is frozen water with the salt extruded out of the ice mass. The northern Alaskan coastal waters are covered by sea ice for three-quarters of the year, from approximately October until June. Sea ice has a large seasonal cycle, reaching a maximum extent in March and a minimum in September. The formation of sea ice has important influences on the transfer of energy and matter between the ocean and atmosphere. It insulates the ocean from the freezing air and the blowing wind.

There are three major forms of sea ice in the Arctic: landfast ice (which is attached to the shore, is relatively immobile, and extends to variable distances offshore); stamukhi ice (which is grounded, ridged sea ice); and pack ice (which includes first-year and multiyear ice and moves under the influence of winds and currents).

While there are wide-ranging spatial and temporal variations in arctic sea ice, the generalized annual patterns are as follows:

- September – Shore ice forms; the river deltas freeze; and frazil, brash, and greased ice form within bays and near the coast.

- Mid-October – Smooth, first-year ice forms within bays and near the coast. Thomas Napageak remarked: "…The critical months [for ice formation] are October, November, and December" (Napageak, as cited in Dames and Moore, 1996:7).

- November through May – Sea ice covers more than 97% of the areas. Spring leads form in the Chukchi Sea.

- Late May – Rivers flood over the nearshore sea ice.

- Early June – River floodwaters drain from the surface of the sea ice.

The southern Chukchi Sea is free of sea ice –one to two months longer each year than the northern Chukchi Sea. Warmer water flowing north through the Bering Strait, combined with strong sunlight returning earlier in the year at lower latitudes, melts or pushes the pack ice north starting as early as mid-June. The same effect keeps the surface ice free longer in the fall, typically until mid-November.

The extent of arctic sea ice (the area of ocean covered by ice), as observed mainly by satellite, has decreased at a rate of about 3% per decade since the 1970's (Parkinson *et al.* 1999; Johannessen *et al.* 1999). Within Canadian Arctic waters, a similar rate of decrease has been observed over the period 1969 - 2000. In recent years, satellite data have shown a further reduction in ice cover. In September 2002, sea ice in the Arctic reached a record minimum, 4% lower than any previous September since 1978 and 14% lower than the 1978 - 2000 mean (Serreze *et al.* 2003). Three years of low ice followed 2002. Taking these three years into account, the September ice-extent trend for 1979 - 2004 is declining by 7.7% per decade (Stroeve *et al.* 2005).

Changes in the landfast ice have been occurring. Events of shorefast ice breaking off have occurred near Barrow in January or February and even as late as March (George *et al.* 2003). These events also have increased in frequency.

3.1.2 Air Quality

The combination of limited industrial development and low population density results in good to excellent air quality throughout the Chukchi and Beaufort seas area. Only a few small, scattered emissions from widely scattered sources exist on the adjacent onshore areas. The only major local sources of industrial emissions are in the Prudhoe Bay/Kuparuk/Endicott oil-production complex. During the winter and spring, additional pollutants are transported by the wind to the Alaska Arctic Ocean from industrial sources in Europe and Asia (Rahn 1982). These pollutants cause a phenomenon known as arctic haze.

The U.S. Environmental Protection Agency (USEPA) defines Air Quality Control Regions (AQCR's) for all areas of the United States and classifies them based on six "criteria pollutants," and has established for each of them a maximum concentration above which adverse effects on human health may occur. These threshold concentrations are called National Ambient Air Quality Standards (NAAQS). When an area meets NAAQS, it is designated as an "attainment area." An area not meeting air quality standards for one of the criteria pollutants is designated as a "nonattainment area."

Areas are designated "unclassified" when insufficient information is available to classify areas as attainment or nonattainment. All areas in and around the Chukchi and Beaufort seas are classified as attainment areas.

The provisions of Alaska's Prevention of Significant Deterioration (PSD) program are applied to attainment areas and unclassified AQCR's with good air quality to limit their degradation from development activities. The areas are classified as PSD Class I, II, or III areas (in decreasing order of relative protection) based on land status/use and the associated protection afforded to the area. The region of Alaska adjacent to the Chukchi and Beaufort seas is a PSD Class II area. The nearest PSD Class I areas are the Bering Sea Wilderness Area within the St. Matthew Island group and the Denali National Park. There are no Class III areas in Alaska. States strive to allow industrial and commercial growth within PSD Class II areas without causing significant degradation of existing air quality or exceeding the NAAQS (MMS 2006).

3.1.3 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 ION's proposed seismic survey.

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 (National Research Council [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
- 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.* 1995a).

Typical background sound levels within the ocean are shown as a function of frequency (Figure 3-1; Wenz 1962). The sound levels are given in underwater dB frequency bands written as dB re 1 $\mu Pa^2/Hz$. Sea State or wind speed is the dominant factor in calculating ambient noise levels above 500 Hz.

3.1.3.1 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).

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 1983) 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.

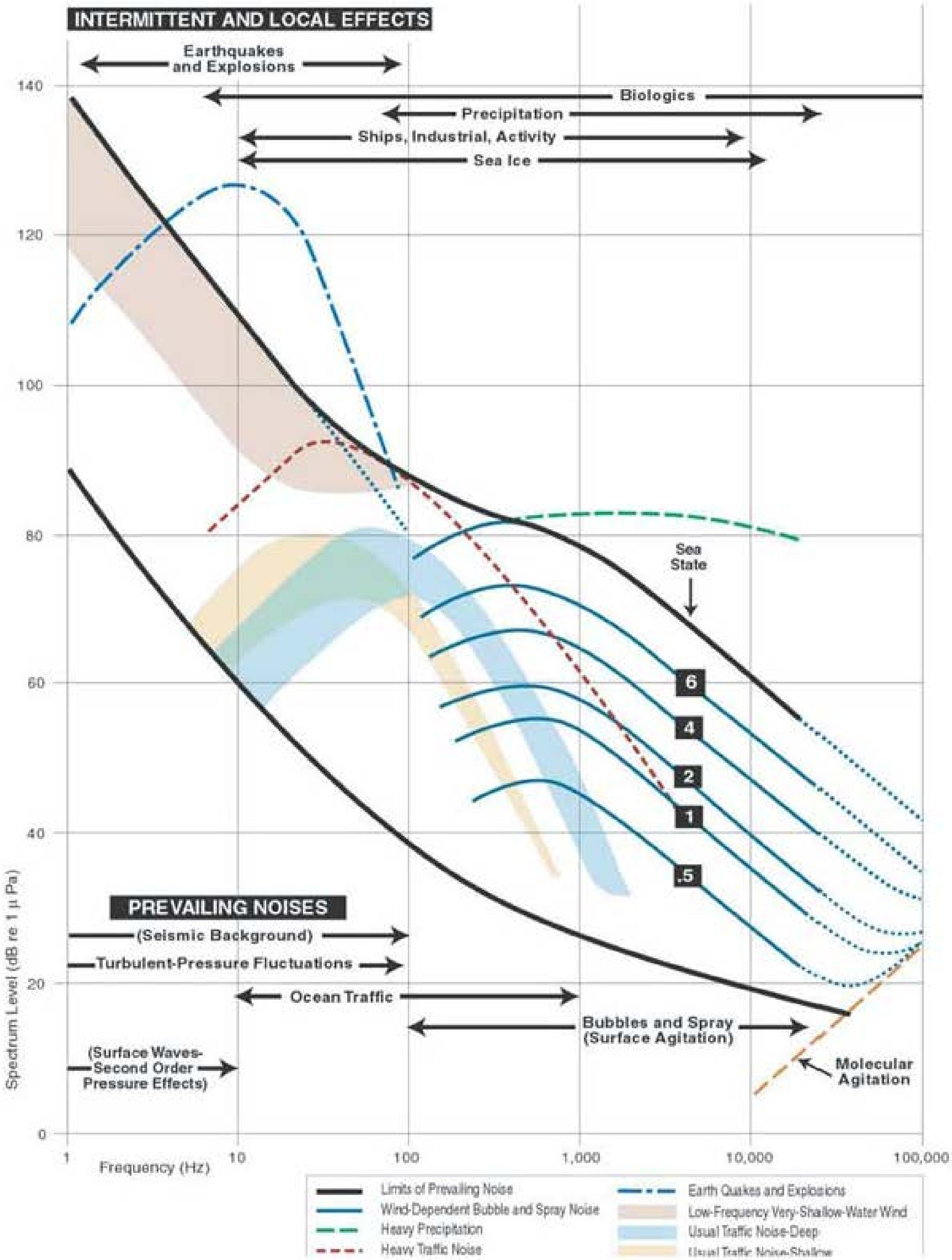

Figure 3-1. Background sound levels within the ocean (Source: Wenz (1962); adopted from the National Research Council (NRC; 2003a). Ocean Noise and Marine Mammals. National Academy Press. Washington DC).

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.

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.* 1995a). 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.* 1995a).

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).

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.* 1995a). 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.* (1995a) 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.

3.1.3.2 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 3-1 provides a comparison of manmade sound levels from various sources associated with the marine environment.

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, dominates 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 Chukchi Sea 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 drill ships. 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 transiting 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.

Table 3-1. A Comparison of Most Common Anthropogenic 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.* 1995a; [2] *Rober Lemeur*

Due to the short open water season, vessel transiting—particularly large vessel transiting—is minimal in arctic marine waters. Richardson *et al.* (1995a) 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.* 1995a).

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 10 km away from a receiver generally contribute only to background noise (Richardson *et al.* 1995a). In deep water, traffic noise up to 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.* 1995a). 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.* 1995a).

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 1987a; Richardson *et al.* 1995a). 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 5 km (3.1 mi) (Richardson *et al.* 1991). In some instances, icebreaking sounds are detectable from more than 50 km (31 mi) away. In general, spectra of icebreaker noise are wide and highly variable over time (Richardson *et al.* 1995a).

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.* 1995a). Much of the production noise from oil and gas operations on gravel islands is substantially attenuated within 4 km (2.5 mi) and often not detectable at 9.3 km (5.8 mi).

Recently Richardson and Williams (2004) summarized results from acoustic monitoring of the BP Exploration Alaska's (BPXA) 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 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 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 9.4 km when drilling was occurring and at 3 - 4 km (1.9 – 2.5 mi) when it was not. Irrespective of drilling, in-air background levels were reached at 5 - 10 km (3.1 – 6.2 mi) 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 30 km offshore. In

2002, sound levels were up to 128 dB re 1 μPa at 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 2 - 4 km from Northstar. Underwater sound levels from a hovercraft, which BPXA 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.* 1995a). Richardson *et al.* (1995a) reported that during unusually quiet periods, drilling noise from ice-bound islands would be audible at a range of about 10 km (6.2 mi), when the usual audible range would be ~2 km. Richardson *et al.* (1995a) also reported that broadband noise decayed to ambient levels within ~1.5 km, and low-frequency tones were measurable to ~9.5 km (~5.9 mi) under low ambient-noise conditions, but were essentially undetectable beyond ~1.5 km (~0.93 mi) with high ambient noise.

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 25 - 50 m (82 – 164 ft) deep, sound produced by airguns can be detected 50 - 75 km (31 – 46.6 mi) away, and these detection ranges can exceed 100 km (62 mi) in deeper water (Richardson *et al.* 1995a) and thousands of kilometres in the open ocean (Nieukirk *et al.* 2004). Typically, an airgun array is towed behind a vessel at 4 - 8 m (13.1 – 26.2 ft) 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 1 - 2 m (3.28 – 6.56 ft) of the airguns, as indicated in Table 3-1.

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 root-mean-square (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 (~3,200 m [~10,496 ft]) and shallow (~30 m [~98.4 ft]) 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 significant energy up to at least 500 - 1,000 Hz (Richardson *et al.* 1995a). 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.* (1995a) summarized that typical signals associated with vibroseis sound source used for on-ice seismic survey sweep from 10 - 70 Hz, but harmonics extend to about 1.5 kHz (Richardson *et al.* 1995a). 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.

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.

3.2 Biological Environment

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 communities in the Beaufort and Chukchi Seas in the proposed marine and seismic survey areas consist of benthic organisms, phytoplankton, zooplankton, and the epontic community. 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 Chukchi and Beaufort Seas 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 both 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.

3.2.1.1 Pelagic Community

Pelagic organisms are those that live in the water column, such as phytoplankton and zooplankton. Since plankton drift suspended in the water column, their movement is dependent upon ocean currents.

Phytoplankton are microscopic, unicellular algae. They are the source of primary production derived via photosynthesis in the Beaufort and Chukchi Seas. This primary production forms the base of the entire food chain in the Beaufort and Chukchi Seas. Areas with especially high primary productivity, such as coastal areas, support high zooplankton biomass. High primary productivity and zooplankton biomass produce excess material that falls to the seafloor, allowing for increased benthic productivity as well.

Primary productivity decreases north of the Bering Strait (MMS 1987). Light and nutrient availability are factors that affect primary productivity. Pelagic phytoplankton composition consists mostly of centric diatoms (Horner 1969). Zooplankton are major food sources for animals in the Beaufort and Chukchi Seas, including the bowhead whale. Species composition changes as one moves further offshore (Brodsky 1957).

3.2.1.2 Benthic Community

Benthic organisms are those that live on or in seafloor sediments. The benthic community within the marine and seismic survey areas in the Beaufort and Chukchi Seas can consist of macroscopic algae, benthic microalgae, and benthic invertebrates (MMS 1987). These organisms are important because they provide a crucial link between the primary producers and larger animals, facilitating the transfer of energy within the environment. The benthic community is the food source that supports key marine mammal species in the proposed marine and seismic survey areas, including the Pacific walrus and the gray whale.

Boulder kelp community is found in the Beaufort Sea, especially in the nearshore areas (MMS 2003). It is located behind the barrier islands of Stefansson Sound (MMS 2002). Kelp also grows sparsely in West Camden Bay (MMS 1998). Kelp beds are likely to occur elsewhere in the western Beaufort Sea but have not been systematically surveyed, and other kelp beds may be discovered as more areas are explored. Similar kelp communities in the Chukchi Sea are located close to shore.

The abundance of benthic organisms increases during the open water season. In the project areas, abundance and species diversity increase with water depth, because sediments in shallower waters are more prone to frequent ice gouging or complete covering by bottomfast ice. These areas covered by bottomfast ice in the winter are temporarily recolonized during the summer, ice-free months.

The northeastern Chukchi Sea supports a higher biomass of benthic organisms than do surrounding areas (Grebmeier and Dunton 2000). Areas such as this are probably more productive because the pelagic organisms cannot consume all of the phytoplankton. The excess primary production sinks to the seafloor and provides ample nutrition to support higher biodiversity and species abundance. The prevailing currents are generally not strong enough to remove nutrients before they are reused. Some benthic-feeding marine mammals, such as walruses and gray whales, take advantage of the abundant food resources and congregate in these highly productive areas. Harold and Hanna Shoals are two known highly productive areas in the Chukchi Sea rich with benthic animals.

3.2.1.3 Epontic Community

Epontic organisms are those that live on or are closely associated with the undersurface of sea ice. Included in this community are assemblages of plants, small invertebrates, and cryopelagic fish (MMS 1987). Algae that live on the underside of the sea ice or within the bottom three centimeters provide primary production for not only the epontic community, but the rest of the Beaufort and Chukchi Seas.

The ice algae species composition differs from the pelagic phytoplankton composition in the water column. Ice algae consist mostly of pennate diatoms such as Navicula marina, although approximately 200 diatom species have been identified in arctic sea ice (Alexander *et al.* 1974).

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). Ice algae productivity also increases significantly with the increase in light availability (Alexander *et al.* 1974). Years with thicker snow cover on the ice yield less productive populations of ice algae (Alexander *et al.* 1974). 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.

3.2.2 Fish, Fishery Resources, and Essential Fish Habitat

This section focuses on coastal and marine fish/fishery resources and habitats occurring in nearshore and offshore waters of the Beaufort and Chukchi Seas. The proposed marine and seismic survey activities would be conducted in federal waters offshore and, therefore, likely would not impact freshwater habitats. In addition, there are few commercial fisheries in the Alaskan Beaufort and Chukchi Seas and, therefore, there are few species covered by fishery management plans in these waters. Presently, the five species of Pacific salmon occurring in Alaska are the only managed species with essential fish habitat (EFH) designated in the Alaskan Beaufort and Chukchi Seas. Pacific salmon and their EFH are described later herein.

3.2.2.1 Fish Resources of Arctic Alaska and Their Ecology

Three LMEs encompass coastal and offshore waters of arctic Alaska. They are the Bering Sea, Chukchi Sea, and the Beaufort Sea. Each large marine ecosystem is characterized by distinct hydrographic regimes, submarine topographies, productivity, and trophically dependent populations, yet influences the others. The Chukchi Sea LME represents a transition zone between the fish assemblages of the Beaufort and Bering LMEs.

At least 98 fish species, representing 23 families, have been documented to occur in the Beaufort and Chukchi Seas (Mecklenburg *et al.* 2002). These families include: lampreys, sleeper sharks, dogfish sharks, herrings, smelts, whitefishes, trouts and salmons, lanternfishes, cods, sticklebacks, greenlings, sculpins, sailfin sculpins, fathead sculpins, poachers, lumpsuckers, snailfishes, eelpouts, pricklebacks, gunnels, wolffishes, sand lances, and righteye flounders. Lanternfishes have yet to be documented in the Alaskan portion of the Chukchi Sea. Dogfish sharks, sailfin sculpins, and gunnels have been documented in the Beaufort Sea, but not the Chukchi Sea. Forty-nine species are common to both large marine ecosystems. Additional species are likely to be found in Alaskan waters of either the Chukchi or Beaufort seas when coastal and offshore waters are more thoroughly surveyed. For example, the shulupaoluk (*Lycodes jugoricus*) was collected by N.J. Wilimovsky in the Chukchi Sea (Walters 1955); and McAllister (1962) collected two specimens in brackish waters of the Beaufort Sea at Herschel Island, Yukon Territory, Canada. Shulupaoluk is a name applied by Ungava Eskimos to an eelpout (McAllister 1962, citing Dunbar and Hildebrand 1952); to date, a shulupaoluk has yet to be documented as occurring in the Alaskan Beaufort Sea, although based on the noted collections, the species is likely to occur there.

Aquatic systems of the Arctic undergo extended seasonal periods of frigid and harsh environmental conditions; therefore, fish inhabiting such systems must be biologically and ecologically adapted to surviving such conditions so as to produce offspring that eventually do the same. Important environmental factors that arctic fishes must contend with include reduced light, seasonal darkness, prolonged low temperatures and ice cover, depauperate fauna and flora, and low seasonal productivity (see McAllister 1975 for a description of environmental factors relative to arctic fishes). During the 8- to 10-month winter period, freezing temperatures may reduce nearshore and freshwater fish habitat by more than 95% (Craig 1989). Furthermore, over wintering stream habitat may be reduced by as much as 97 - 98% by late winter (Craig 1989). 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, and most of a fish's yearly food supply must be acquired during the brief arctic summer (Craig 1989). There are fewer fish species inhabiting Arctic waters of Alaska as compared to those inhabiting warmer regions of the State. The Chukchi Sea is warmer, more productive, and also supports a more diverse fish fauna than occurs in the western Beaufort Sea (Craig 1984, citing Morris 1981; Craig and Skvorc 1982; Craig 1989). Also, most fish species inhabiting the frigid polar waters are thought to grow and mature more slowly relative to individuals or species inhabiting boreal, temperate, or tropical systems.

The Alaskan Arctic includes a variety of aquatic areas that may be exploited by fish. The Alaskan arctic coastline shapes the transitional and dynamic nearshore brackish ecotone (i.e., coastal waters) that results from the mixing of fluvial freshwaters from the Alaskan Arctic Coastal Plain with marine waters of the Beaufort and Chukchi Seas. Marine waters of the Beaufort and Chukchi Seas offer the greatest two- and three-dimensional area for arctic fishes to exploit; these include neritic waters and substrates (occurring landward of the continental shelf break, as delimited by the 200-m isobath) and oceanic waters and substrates (occurring seaward of the continental shelf break [>200-m isobath]).

The diverse fishes of the eastern Chukchi and western Beaufort seas use a range of waters and substrates for spawning, breeding, feeding, or growing to maturity. Biologists studying arctic fishes of Alaska have classified them into primary assemblages by occurrence in basic aquatic systems and by life-history strategies that allow the fishes 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 (Craig 1989 citing Stearns, 1976).

The primary assemblages of arctic fishes are:

- freshwater fishes that spend their entire life in freshwater systems (although some also might spend brief periods in nearshore brackish waters);

- marine fishes that spend their entire life in marine waters (some also spend brief periods in nearshore brackish waters along the coast); and

- diadromous and anadromous fishes 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 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 mi (20 km) from the Alaskan coastline (excluding barrier islands) is limited.

3.2.2.2 Pacific Salmon and Essential Fish Habitat

All five species of Pacific salmon occur in the Alaskan Beaufort and Chukchi seas (Craig and Halderson 1986; NMFS 2005); they are the pink (humpback), chum (dog), sockeye (red) salmon, chinook (king) salmon, and coho (silver) salmon. These five species of salmon are managed species for which EFH is described that includes areas in the Beaufort and Chukchi seas. Pacific salmon in the Alaskan Beaufort and Chukchi seas are considered "rare" species in terms of abundance and range.

Salmon numbers decrease north of the Bering Strait, and they are relatively rare in the Beaufort Sea (Craig and Halderson 1986). Spawning runs in arctic streams are minor compared to those of commercially important populations farther south (Craig and Halderson 1986). Rivers south of Point Hope support comparatively large runs of chum and pink salmon, and have historically been the northern distributional limits for chinook, coho, and sockeye salmon (Craig and Halderson 1986), although this appears to be changing. Craig and Halderson (1986) noted that only pink salmon and, to a lesser degree, chum salmon, occur with any regularity in arctic waters north of Point Hope and presumably maintain small populations in several of the northern drainages, with most occurring in streams west of Barrow.

EFH for each Pacific salmon species is described and mapped by NMFS (2005). The Alaska Department of Fish and Game maintains anadromous waters data in its Fish Distribution Database (http://www.sf.adfg.state.ak.us/sarr/FishDistrib/anadcat.cfm) and interactive mapping. More than 14,000 waterbodies containing anadromous salmonids identified in the State represent only part of the salmon EFH in Alaska, because many likely habitats have not been surveyed. 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 U.S. Exclusive Economic Zone (EEZ). This habitat includes waters of the continental shelf (to the 200-m [656-ft] 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 50 m (164 ft). Chinook and chum salmon use deeper layers, generally to about 300 m (984 ft), but on occasion to 500 m (1,640 ft). The marine EFH for Alaska salmon fisheries described above also is EFH for the Pacific coast salmon fishery for those salmon stocks of Pacific Northwest origin that migrate through Canadian waters into the Alaska EFH zone.

Because Pacific salmon appear to be expanding their range eastward and northward in the Canadian Beaufort Sea, it is reasonable to expect that Pacific salmon are expanding their distribution in the Chukchi Sea and that their populations may be increasing in both the northeastern Chukchi Sea and western Beaufort Sea.

3.2.2.3 Invertebrate Fishery Resources

The MSA defines "fish" to mean finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds. The term "fishery resource" means any fishery, any stock of fish, any species of fish, and any habitat of fish. In the western Beaufort and Chukchi Seas, squids and snow crabs are also important fishery resources.

Squid

Squid occur in the northeastern Chukchi and western Beaufort Seas; as squid on occasion (e.g., in 1998 and 2005) strand on the beach near Barrow (MMS 2006). In general, squid can be among the more dominant prey species for some marine fishes, seabirds, and marine mammals. No information was found as to the species inhabiting the areas; hence, we cannot describe their biology and ecology as relating to a baseline description.

Snow crab (*Chionoecetes opilo*) and Essential Fish Habitat

The snow crab is a circumpolar species for which there are substantial fisheries in the Atlantic and Pacific oceans (Paul *et al.* 1997). In the northwest Pacific Ocean, snow crabs occur in the northern Sea of Japan, the Bering and Chukchi seas from Wrangel Island to Point Barrow, and the Beaufort Sea at the mouth of the Mackenzie River (Paul *et al.* 1997, citing Slizkin 1989). In the northeastern Chukchi Sea, snow crabs are a dominant benthic species; however, because they have not been historically harvested their basic biology and ecology is poorly described.

Recent research by Dionne *et al.* (2003) determined the distribution pattern of juvenile snow crab in the northwestern Gulf of St. Lawrence, Canada. They found that juvenile snow crabs had a heterogeneous distribution among the temperature-depth strata and expressed specific habitat preferences, both ontogeny dependent. Temperature seemed to be more important than substratum for determining the spatial distribution of juvenile snow crabs. They also observed a shift in juvenile distribution towards shallower depths with increasing age, and suggested the ontogenic shift in juvenile distribution may reflect either high mortality in deep strata or migration to shallow waters. Such habitat shifts with ontogeny are common among mobile marine animals. They suggested that warmer surface temperatures could increase growth for older juvenile stages of snow crabs, as documented in other species of crabs.

Snow crabs feed on a wide assortment of marine life including worms, clams, mussels, snails, crabs, other crustaceans, and fish parts. They are fed on by demersal and pelagic fish, and humans. Migration patterns are not well understood. It is known that the sexes are separated during much of the year and move into the same areas during the reproductive season.

Paul *et al.* (1997) noted that little is known about the factors influencing the distribution and abundance of snow crabs, and that such factors must include larval recruitment dynamics, habitat requirements, thermal tolerance, water-depth preferences, predation, competition, and cannibalism, and that the relative importance of these factors is unknown. Theirs is the most recent study of snow crabs in the Chukchi Sea. Paul *et al.*

(1997) sampled 56 stations in the northeastern Chukchi Sea during1990 - 1991 and found snow crabs present at all stations, with the largest abundance and biomass tending to be in the southern part (south of 70° N. latitude to Point Hope) of their study area, but varying extensively between stations. Abundance and biomass estimates also varied considerably between trawls at most stations. Mature crabs of both sexes were collected in the Chukchi Sea during their study. Paul *et al.* (1997) found that Chukchi snow crab tended to be smaller than Bering Sea or North Atlantic individuals. They also found that fecundity estimates for Chukchi snow crab are similar to other estimates.

3.2.2.4 Commercial Fisheries

The North Pacific Fishery Management Council has published an Arctic Fishery Management Plan (FMP) that provides policy recommendations for potential commercial fisheries in the Chukchi Sea. The FMP requires that EFH species be identified prior to the opening of a commercial fishery, but a commercial fishery is not anticipated anytime soon (NPFMC 2009). Should a commercial fishery be opened, the fish species protected under EFH designation will likely include Arctic cod, saffron cod, and snow crab (NPFMC 2009).

3.2.3 Marine Birds

Although NMFS does not expect marine birds would be directly affected from the proposed action (issuing an IHA to ION for an in-ice seismic survey in the Beaufort and Chukchi Seas), they could be indirectly affected by the underlying activity. Therefore, as part of the environmental analysis, the baseline information on marine birds is provided here as part of the affected environment.

Two bird species of special concern may be encountered during transits off the coast of Alaska. Spectacled eiders (*Somateria fischeri*) travel west along the arctic coast after breeding across the Arctic Coastal Plain (ACP) of northern Alaska. Both marine and terrestrial (for males in particular) routes are used during migration (Troy 2003). Steller's eiders (*Polysticta stelleri*) also breed on the ACP and move to marine habitats after breeding (Fredrichson 2001), but occur in much lower densities than spectacled eiders and would be less likely to be encountered by transiting vessels in the southern Beaufort Sea. Spectacled and Steller's eiders were listed as threatened in the U.S. under the ESA in May 1993 and July 1997, respectively. The USFWS developed separate Recovery Plans for each species (USFWS 1996, 2002).

(1) Spectacled Eider

The spectacled eider is a medium-sized sea duck that breeds along coastal areas of western and northern Alaska and eastern Russia, and winters in the Bering Sea (Petersen *et al.* 2000). Three breeding populations have been described: one in the Yukon-Kuskokwim (Y-K) delta in western Alaska, a second on the North Slope of Alaska, and the third in northeastern Russia. Spectacled eider was listed as a threatened species because of declines in the breeding population in the Y-K delta (Stehn *et al.* 1993; Ely *et al.* 1994). The North Slope spectacled eider population seems to be stable, at least since the initiation of aerial surveys of the ACP since 1992 (Larned *et al.* 2009).

Spectacled eiders breed in low densities across the Alaskan Arctic Coastal Plain (ACP) east to about the Shaviovik River. Males leave the breeding grounds along the ACP around mid- to late June at the onset of incubation by female eiders. Males are followed by females whose nests fail, and finally by successful breeding females and young birds in August and September. Female spectacled eiders have been documented migrating west along the Alaska coast as far as 40 km offshore (TERA 1999). Large concentrations of spectacled eiders gather in Ledyard Bay in the eastern Chukchi Sea after the breeding season to feed and molt before moving to the Bering Sea wintering grounds. Ledyard Bay is located between Icy Cape and Cape Lisburne and was designated as the Ledyard Bay Critical Habitat Unit (LBCHU) by the USFWS in 2001.

The proposed 2012 geophysical activities will occur primarily in the Beaufort Sea beginning around October 1. Most spectacled eiders will have migrated from the Beaufort Sea by that time although small numbers of spectacled eiders could be encountered in nearshore locations of the proposed survey area. The *Geo Arctic* and *Polar Prince* could encounter spectacled eiders during the transit through the Chukchi Sea after completion of the survey activities, however most if not all spectacled eiders will have departed the Chukchi Sea by late October.

Activities associated with the proposed geophysical survey are not likely to affect spectacled eiders or other marine birds. The primary concern relates to the potential for bird collisions with vessels which could result in injury or mortality. Spectacled eiders and other marine birds can easily avoid oncoming vessels and in general there is little potential for impacts to marine birds to result from the proposed activities. Spectacled eiders are unlikely to occur in the proposed survey area during the survey period and impacts will likely be negligible.

(2) Steller's Eider

Most Steller's eiders breed across coastal eastern Siberia and a small number breed on the ACP of Alaska, most conspicuously near Barrow. A smaller population also breeds in western Russia and winters in northern Europe (Fredrichson 2001). Steller's eiders were formerly common breeders in the Y-K delta, but numbers there declined drastically and Steller's eider is now apparently rare as a breeding species on the Y-K delta (Kertell 1991; Flint and Herzog 1999). Steller's eider density on the ACP is low with the highest densities reported near Barrow. The largest population, located in eastern Russia, may number >128,000 birds (Hodges and Eldridge 2001).

Steller's eiders have been observed east of Barrow to the Prudhoe Bay area where they are considered rare (TERA 1997). Although Steller's eiders may breed in a relatively large area of the ACP as far east as the Prudhoe Bay area, densities are low. Steller's eiders apparently do not breed every year and breeding may be tied to the lemming cycle (Quakenbush *et al.* 2004).

After the breeding season Steller's eiders move to marine habitats and may use lagoon systems and coastal bays from Barrow to Cape Lisburne, the northeast Chukotka coast, and numerous locations in southwest Alaska (USFWS 2007). Few if any Steller's eiders would likely be encountered during proposed geophysical survey activities in the southern Beaufort or Chukchi seas or during transit through the Chukchi Sea after completion of the proposed survey.

(3) Other Seabirds, Shorebirds, and Waterfowl

In addition to the two eider species described above, a portion of the project area is within the range of a number of other seabird, shorebird, and waterfowl species. Most of these species would be found mainly within 30 km of shore. Summer bird densities in offshore marine waters of the Beaufort Sea are considered to be lower than in other marine areas adjacent to Alaska (U.S. Army Corps of Engineers 1999). There is a general absence of diving seabirds in the offshore waters of the southern Beaufort Sea, with the exception of small numbers of thick-billed murres (*Uria lomvia*), horned puffins (*Fratercula corniculata*), loons (*Gavia* spp.) and black guillemots (*Cepphus grylle*). A few species of surface-feeding birds also make use of offshore waters, including red and red-necked phalaropes (*Phalaropus fulicaria* and *P. lobatus*), pomarine, parasitic and long-tailed jaegers (*Stercorarius pomarinus*, *S. parasiticus*, and *S. longicaudus*), arctic tern (*Sterna paradisaea*), and glaucous gulls (*Larus hyperboreus*). Divoky (1979) reported a bird density during the open-water season in offshore waters deeper than 18 m (60 feet) of less than 10 birds/km^2.

Divoky (1983) conducted extensive boat-based surveys in the Beaufort Sea during early August through mid-September. The primary species observed during pelagic surveys were surface-feeding species including gulls, terns, phalaropes, and jaegers. Long-tailed ducks, loons, and migrant eiders as well as low densities of surface-feeding species were reported during nearshore surveys. Pelagic birds were feeding primarily on arctic cod while nearshore birds were feeding on epibenthic crustaceans and zooplankton.

Frame (1973) conducted seabird observations from an icebreaker in the Beaufort Sea during August 1969 and reported black-legged kittiwake (*Rissa tridactyla*) as the most abundant species, followed by Sabine's gull (*Xema sabini*). Pomarine and long-tailed jaegers were the other two most commonly observed species along with unidentified shorebirds.

Harwood *et al.* (2005) recorded the distribution of birds during oceanographic studies through the Canadian Basin, Beaufort Sea, and Chukchi Sea from August 16 through October 6, 2002. Sixteen bird species and a total of 1,213 individuals were recorded. The birds were found in greater density in areas where oceanographic features such as a shelf break, or an area of coastal upwelling, heightened productivity.

3.2.4 Marine Mammals

3.2.4.1 Threatened and Endangered Marine Mammals

Based on the best available information, there are two species of marine mammals that are listed as threatened or endangered under the ESA that can occur within or near ION's proposed in-ice seismic survey in the Beaufort and Chukchi Seas during the late fall/early winter season. The common and scientific names and the ESA status of these species are:

- Bowhead whale (*Balaena mysticetus*) Endangered
- Polar bear (*Ursus maritimus*) Threatened

Bowhead Whale

Distribution: The Western Arctic bowhead whales are distributed in seasonally ice-covered waters of the Arctic and near-Arctic, generally north of 60°N and south of 75°N in the western Arctic Basin (Braham 1984a, Moore and Reeves 1993). For management purposes, five stocks of bowhead whales have been recognized worldwide by the International Whaling Commission (IWC 1992, Rugh *et al.* 2003). Small stocks occur in the Sea of Okhotsk, and the offshore waters of Spitsbergen, comprised of only a few tens to a few hundreds of individuals (Shelden and Rugh 1995, Zeh *et al.* 1993). Until recently, available evidence indicated that only a few hundred bowheads were in the Hudson Bay and Davis Strait stocks, but it now appears these should be considered one instead of two stocks based on genetics (Postma *et al.* 2006), aerial surveys (Cosens *et al.* 2006), and tagging data (Dueck *et al.* 2006; Heide-Jørgensen *et al.* 2006), and the abundance may be over a thousand (Heide-Jørgensen *et al.* 2007). The only stock found within U. S. waters is the Western Arctic stock, also known as the Bering-Chukchi-Beaufort (BCB) stock (Rugh *et al.* 2003) or Bering Sea stock (Burns *et al.* 1993). Although Jorde *et al.* (2004) suggested there might be multiple stocks of bowhead whales in US waters, recent work (George *et al.* 2007; Taylor *et al.* 2007) concluded that data are most consistent with one bowhead stock that migrates around northern and western Alaska waters (IWC 2008).

The majority of the Western Arctic stock migrates annually from wintering areas (November to March) in the northern Bering Sea, through the Chukchi Sea in the spring (March through June), to the Beaufort Sea where they spend much of the summer (mid-May through September) before returning again to the Bering Sea in the fall (September through November) to overwinter (Braham *et al.* 1980, Moore and Reeves 1993). Figure 3-2 shows the general route followed by bowhead whales during their seasonal migrations through the Chukchi and Beaufort Seas. Most of the year, bowhead whales are closely associated with sea ice (Moore and Reeves 1993). The bowhead spring migration follows fractures in the sea ice around the coast of Alaska, generally in the shear zone between the shorefast ice and the mobile pack ice. During the summer, most of the population is in relatively ice-free waters in the southern Beaufort Sea, an area often exposed to industrial activity related to petroleum exploration and extraction (e.g., Richardson *et al.* 1987, Davies 1997). During the autumn migration, bowheads select shelf waters in all but “heavy ice” conditions, when they select slope habitat (Moore 2000). Sightings of bowhead whales do occur in the summer near Barrow (Moore 1992, Moore and DeMaster 2000) and are consistent with suggestions that certain areas near Barrow are important feeding grounds (Lowry *et al.* 2004). Some bowheads are found in the Chukchi and Bering Seas in summer, and these are thought to be a part of the expanding Western Arctic stock (Rugh *et al.* 2003).

Life History: Bowhead whales are large whales that use baleen to filter the water for food sources, primarily copepods and euphausiids (Lowry and Sheffield 1993). Energy requirements, especially for migration, are high. Thus, bowhead whales must find areas with above-average concentrations of zooplankton for feeding (Lowry and Sheffield 1993). Observations in the 1980s suggest that bowhead whales may feed opportunistically in the Chukchi Sea while they are migrating, but the feeding activity was not consistent (Ljungblad *et al.* 1988; Carroll *et al.* 1987).

Bowheads are long-lived, slow-growing, late-maturing, and they reproduce infrequently (Zeh *et al.* 1993; Koski *et al.* 1993). Females become sexually mature starting around age 15 (Koski *et al.* 1993). At sexual maturity, females are 12.5 – 14 m (41 – 46 ft). Males mature later, around 17 – 27 years (IWC 2004).

Bowhead whale mating may start as early as January or February, but mostly occurs during their spring migration (Nerini *et al.* 1984; Koski *et al.* 1993). Gestation lasts 13 – 14 months (Nerini *et al.* 1984). Calving starts in March and has been seen to occur until early August (Koski *et al.* 1993). A single calf is born every 3 – 4 years. Bowhead whales have no known predators besides subsistence users and occasionally orcas. They have been documented to live past 100 years of age (George *et al.* 2004).

Bowhead whale calls have been well described for the western Arctic population (Ljungblad *et al.* 1980; Ljungblad *et al.* 1982; Clark and Johnson 1984; Cummings and Holliday 1987). Three types of sounds summarized the acoustic repertoire of bowhead whales in the western Arctic: (1) percussive slaps, blows, gunshot, and crunch sounds; (2) simple frequency-modulated (FM) and complex amplitude-modulated (AM) calls given in no particular order, and (3) long patterned sequences of calls (often called “units” or “notes”), which are also classified as songs (Ljungblad *et al.* 1986; Würsig and Clark 1993; George *et al.* 2004; Stafford *et al.* 2007). Bowhead whales vocalize using low-frequency sounds. It is assumed that their hearing is most sensitive at the same frequencies that they use to vocalize. The frequency of their calls has been recorded as low as 35 Hz and as high as 5 kHz, although most calls range between 50 – 400 Hz (Würsig and Clark 1993).

Population and Abundance: All stocks of bowhead whales were severely depleted during intense commercial whaling prior to the 20th century, starting in the early 16th century near Labrador (Ross 1993) and spreading to the Bering Sea in the mid-19th century (Braham 1984a, Bockstoce and Burns 1993). Woody and Botkin (1993) summarized previous efforts to approximate how many bowheads there were prior to the onset of commercial whaling. They reported a minimum worldwide population estimate of 50,000, with 10,400 - 23,000 in the Western Arctic stock (dropping to less than 3,000 at the end of commercial whaling).

Since 1978, systematic counts of bowhead whales have been conducted from sites on sea ice north of Point Barrow during the whales’ spring migration (Krogman *et al.* 1989). These counts have been corrected for whales missed due to distance offshore (through acoustical methods, described in Clark *et al.* 1994), whales missed when no watch was in effect (through interpolations from sampled periods), and whales missed during a watch (estimated as a function of visibility, number of observers, and distance offshore; Zeh *et al.* 1993). A summary of the resulting abundance estimates is provided in Table 3-2. However, these estimates of abundance have not been corrected for a small portion of the population that may not migrate past Point Barrow during the period when counts are made. The most recent abundance estimate, based on surveys conducted in 2001, is 10,545 (CV = 0.128) (George *et al.* 2004).

Table 3-2. Summary of population abundance estimates for the western Arctic stock of bowhead whales. The historical estimates were made by back-projecting using a simple recruitment model. All other estimates were developed by corrected ice-based census counts. Historical estimates are from Woody and Botkin (1993); 1978-2001 estimates are from George *et al.* (2004) and Zeh and Punt (2004) (Adopted from Allen and Angliss 2010).

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

Bowhead whales were identified from aerial photographs taken in 1985 and 1986, and the results were used in a capture-recapture analysis. This approach provided estimates of 4,719 (95% CI: 2,382 - 9,343) to 7,022 (95% CI: 4,701 - 12,561), depending on the model used (daSilva *et al.* 2000). These population estimates and their associated error ranges are comparable to the estimates obtained from the combined ice-based visual and acoustic data for 1985 (5,762) and 1986 (8,917). Aerial photographs provided another sampling of the bowhead population in 2003 - 2004 (Koski *et al.* 2008). Capture-recapture results provided a preliminary estimate of 11,836 whales (95% CI: 6,795 to 20,618), an estimate which is consistent with trends in abundance estimates made from ice-based counts. The use of photo-identification to estimate bowhead whale population size provides a reasonable alternative to the traditional ice-based census and acoustic techniques.

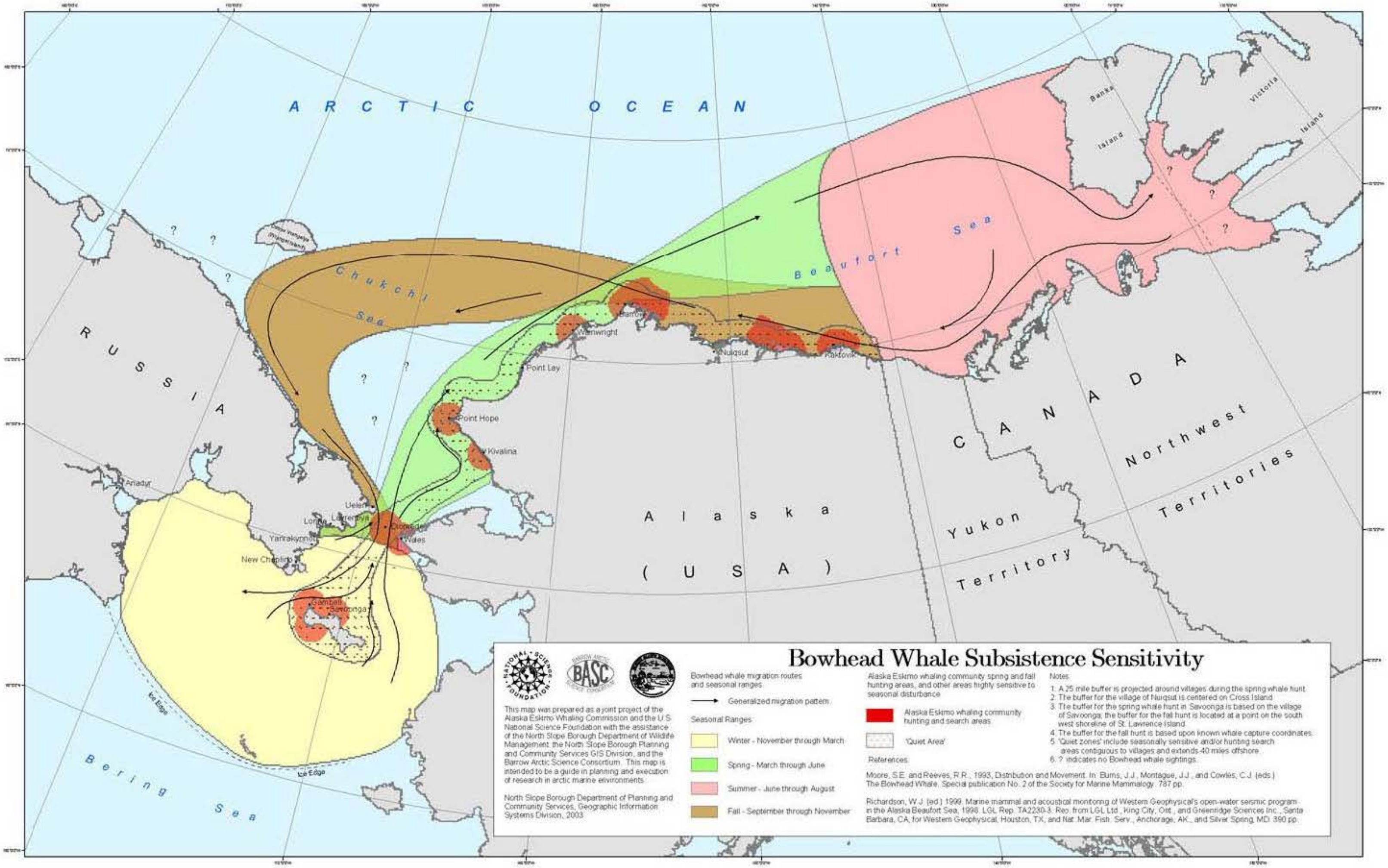

Figure 3-2. Bowhead whale migration routes and seasonal ranges in relation to subsistence activities (Adopted from the North Slope Borough Department of Planning and Community Services, Geographic Information Syustems Division).

Conservation Status: Bowhead whale is listed as "endangered" under the ESA and therefore also designated as "depleted" under the MMPA. NMFS intends to use recovery criteria developed for large whales in general (Angliss *et al.* 2002) and bowhead whales in particular (Shelden *et al.* 2001) in the next 5-year evaluation of stock status.

Polar Bear

Distribution and Habitat: Polar bears are the top predators of the Arctic marine ecosystem (Amstrup 2003) and are distributed throughout regions of arctic and subarctic waters where the sea is ice-covered for large portions of the year (Figure 3-3).

The size of a polar bear's home range is determined, in part, by the annual pattern of freezeup and breakup of sea ice and, therefore, by the distance a bear must travel to access prey (Durner *et al.* 2004). Polar bear life history is intimately linked to the sea ice environment, with sea ice providing the platform from which bears hunt, travel, mate, and sometimes den (Amstrup 2003).

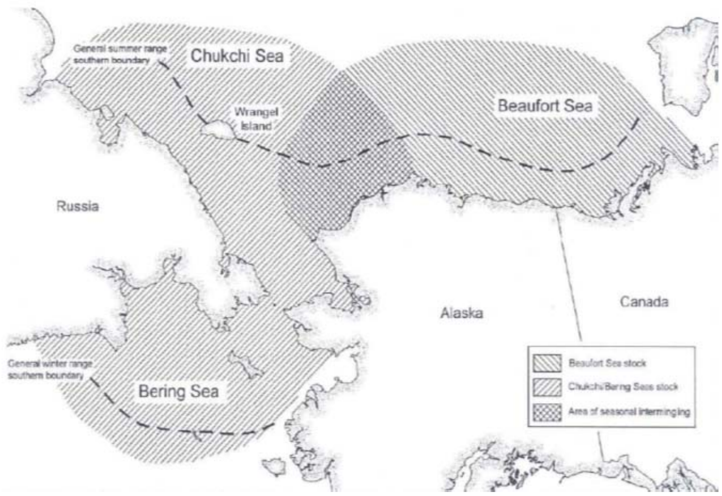

Figure 3-3. Range map of Beaufort Sea and Chukchi Sea polar bear stocks. (Adopted from USFWS (2009b)).

Seasonal movement patterns of polar bears illustrate their association with ice, as these movements appear correlated to the patterns of ice formation and ablation. Measured monthly movements of polar bear in the Beaufort Sea showed movements to the north from May – August. In October bears moved back to the south (Stirling and Derocher 1990, Amstrup *et al.* 2000), as October is usually the month of freezeup in the southern Beaufort Sea and ice becomes available over the shallow water near shore. Polar bears prefer shallow-water areas, perhaps reflecting similar preferences to their primary prey, ringed seals, as well as the higher productivity in these areas (Durner *et al.* 2004; MMS 2007a).

The distribution of seals and the habitat selection patterns by bears in the Beaufort Sea suggest that most polar bears do not feed extensively in the summer (Durner *et al.* 2004; MMS 2007a); in fact, 75% of bear locations in the summer occur on sea ice in waters greater than 350 m (1,148 ft) deep, which places them outside of prey concentrations and outside the proposed seismic survey area. Amstrup *et al.* (2000) showed that polar bears in the Beaufort Sea have their lowest level of movements in September, which correlates with the period when the sea ice has carried polar bears beyond the preferred habitat of seals (MMS 2007a).

The months showing the highest movement rate for polar bears and highest activity area in the Beaufort Sea were June – July and November – December (Gloerson *et al.* 1992).

The mean annual distance moved by six bears (followed by satellite telemetry) in the Chukchi Sea was 5,542 km (3,444 mi). To illustrate the potential mobility of polar bears in regions of continually changing ice patterns, the mean rate of northerly spring movement was approximately 14 km/day (9 mi/day) (Garner *et al.* 1990). The sea ice of the Chukchi and Beaufort Seas is dynamic and unpredictable, and the mobility of polar bears in these areas appears to be directly correlated to that variability (Garner *et al.* 1990; Gloerson *et al.* 1992). The coast, barrier islands, and shorefast ice edge provide a corridor for polar bears during the fall, winter, and spring months. Late winter and spring leads that form offshore from the Chukchi Sea coast also provide important feeding habitat for polar bears (MMS 2007a). These polynyas reach their maximum extent in June and may extend into the project area. By July, however, the polynyas no longer exist, and this area becomes relatively ice-free.

Recent research has indicated that the total sea ice extent has declined over the last few decades, in both nearshore areas and in the amount of multi-year ice in the polar basin (Parkinson and Cavalieri 2002). As a result of potential effects from predicted ice conditions, USFWS found the polar bear to be threatened.

Life History: Polar bears exist in relatively small populations and have low reproductive rates, requiring a high rate of survival to maintain population levels. The average reproductive interval for a polar bear is 3 – 4 years, and a female may produce 8 – 10 cubs in her lifetime, of which only 50 – 60% will survive to adulthood (Amstrup 2003).

In the northern Alaska coastal areas, pregnant females enter maternal dens by late November and emerge as late as early April. Maternal dens typically are located in snow drifts in coastal areas, stable parts of the offshore pack ice, or on landfast ice (Amstrup and Gardner 1994). Studies indicate that more bears are now denning nearshore rather than in far offshore regions (Fischback *et al.* 2007). The highest density of land dens in Alaska occur along the coastal barrier islands of the eastern Beaufort Sea and within the Arctic National Wildlife Refuge (USFWS 2009b). Insufficient data exist to accurately quantify polar bear denning locations along the Alaskan Chukchi Sea coast; however, dens in the area appear to be less concentrated than for other areas in the Arctic. The majority of denning of Chukchi Sea polar bears occurs on Wrangel Island, Herald Island, and other locations on the northern Chukotka coast of Russia (USFWS 2009b).

Polar bears derive essentially all their sustenance from marine mammal prey. The high fat intake from specializing on marine mammal prey allows polar bears to thrive in the harsh Arctic environment (Stirling and Derocher 1990, Amstrup 2003, USFWS 2009b). Over much of their range, polar bears are dependent on the ringed seal (*Phoca hispida*) (Smith 1980). Where common, bearded seals (*Erignathus barbatus*) can be a large part of polar bear diets and are probably the second most common prey item (Derocher *et al.* 2002). Walrus can be seasonally important in some parts of the polar bear‘s range (USFWS 2009b). Polar bears occasionally rely on belugas (*Delphinapterus leucas*), narwhals (*Monodon monoceros*), harbor seals (*P. vitulina*), and marine mammal carcasses along the shoreline (USFWS 2009b).

Population and Abundance: There are two polar bear stocks recognized in Alaska: the southern Beaufort Sea (SBS) stock and the Chukchi/Bering Seas (CBS) stock, though there is considerable overlap between the two in the western Beaufort/eastern Chukchi Seas (MMS 2007a). The ranges of these stocks are shown in Figure 3-5.

The SBS population ranges from the Baillie Islands, Canada, west to Point Hope, Alaska, and is subject to harvest from both countries. The CBS stock ranges from Point Barrow, Alaska, west to the Eastern Siberian Sea (MMS 2007a). The CBS population is widely distributed on the pack ice of the northern Bering, Chukchi, and eastern portions of the Eastern Siberian seas (Garner *et al.* 1990; Garner *et al.* 1994; USFWS 2009b).

The size of the SBS population was estimated at 1,800 animals in 1986 (USFWS 2009b). The population estimate of 1,526, which is based on data collected from 2001 – 2006 (Regehr *et al.* 2006), is considered the most current and valid U.S. population estimate (Allen and Angliss 2010). A reliable population estimate for the CBS stock currently does not exist (USFWS 2009b; Allen and Angliss 2010). Reliable estimates of population size based upon mark and recapture studies are not available for this region, and measuring the population size is a research challenge. The current Russian polar bear harvest is believed to exceed sustainable levels, as models run by the USFWS indicate that the average annual harvest of 180 bears could potentially reduce the population by 50% within 18 years (USFWS 2003). The International Union for Conservation of Nature (IUCN) Polar Bear Specialist Group (Aars *et al.* 2006) estimated this population to be approximately 2,000 animals, based on extrapolation of multiple years of denning data for Wrangel Island, assuming that 10% of the population dens annually as adult females (Aars *et al.* 2006). Due to the lack of information concerning the CBS population and due to the high levels of illegal harvest, the IUCN Species Survival Commission Polar Bear Specialist Group has designated it as “declining” (MMS 2007a; Aars *et al.* 2006; USFWS 2009b; Allen and Angliss 2010).

Conservation Status: Polar bears in the U.S. Arctic are currently listed as “threatened” under the ESA and therefore are classified as depleted under the MMPA. The conservation and management of polar bears are under the USFWS.

3.2.4.2 Non-ESA-Listed Marine Mammals

Marine mammal species that are not listed under the ESA that could occur in the proposed in-ice seismic survey area within the Beaufort and Chukchi Seas include four cetacean and five pinniped species. The common and scientific names of these species are:

- Gray whale (*Eschrichtius robustus*)
- Minke whale (*Balaenoptera acutorostrata*)
- Beluga whale (*Delphinapterus leucas*)
- Harbor porpoise (*Phocoena phocoena*)
- Ringed seal (*Phoca hispida*)
- Spotted seal (*P. largha*)

- Bearded seal (*Erignathus barbatus*)
- Ribbon seal (*Histriophoca fasciata*)
- Pacific walrus (*Odobenus rosmarus divergens*)

Gray Whale

Distribution: The eastern North Pacific or California gray whale population was once hunted to near extinction, but has since recovered significantly from commercial whaling. The eastern North Pacific gray whale stock (Rice and Wolman 1971) ranges from the Bering, Chukchi, and Beaufort Seas (in summer) to the Gulf of California (in winter) (Nelson *et al.* 1993). Gray whales have also been documented foraging in waters off Southeast Alaska, British Columbia, Washington, Oregon, and California (Rice and Wolman 1971; Berzin 1984; Darling 1984; Quan 2000; Calambokidis *et al.* 2002; Rice 1981). Most of the eastern north Pacific population makes a round-trip annual migration of more than 8,000 km (4,320 nm) from Alaska waters to Baja California in Mexico (Nelson *et al.* 1993). During most of this migration, they remain within sight of land (Nelson *et al.* 1993). From late May to early October, the majority of the population concentrates in the northern and western Bering Sea and the Chukchi Sea (Figure 3-4).

Figure 3-4. Approximate distribution of the Eastern North Pacific stock of gray whales (shaded area), including both summer and winter distributions. (Adopted from Allen and Angliss (2010)).

Gray whales are considered common summer residents in the nearshore waters of the eastern Chukchi Sea, and occasionally are seen east of Point Barrow in late spring and summer, as far east as Smith Bay (Green *et al.* 2007). On wintering grounds, mainly along the west coast of Baja California, gray whales utilize shallow, nearly land-locked lagoons and bays (Rice *et al.* 1981). From late February to June, the population migrates back to arctic and subarctic seas (Rice and Wolman 1971). During vessel-based and aerial surveys conducted in the Chukchi Sea, a total of 477 gray whales were observed by marine mammal observers (MMOs) between 2006 and 2008 (Statoil 2010).

Gray whales occur fairly often near Point Barrow, but historically only a small number of gray whales have been sighted in the Beaufort Sea east of Point Barrow. Hunters at Cross Island (near Prudhoe Bay) took a single gray whale in 1933 (Maher 1960). Only one gray whale was sighted in the central Alaskan Beaufort Sea during the extensive aerial survey programs funded by MMS and industry from 1979 – 1997. However, during September 1998, small numbers of gray whales were sighted on several occasions in the central Alaskan Beaufort (Miller *et al.* 1999). More recently, a single sighting of a gray whale was made on August 1, 2001, near the Northstar production island (Williams and Coltrane 2002). Several gray whale sightings were reported during both vessel-based and aerial surveys in the Beaufort Sea in 2006 and 2007 (Jankowski *et al.* 2008; Lyons *et al.* 2008) and during vessel-based surveys in 2008 (Savarese *et al.* 2009). Several single gray whales have been seen farther east in the Canadian Beaufort Sea (Statoil 2010, citing LGL Ltd. unpublished data), indicating that small numbers must travel through the Alaskan Beaufort during some summers. In recent years, ice conditions have become lighter near Barrow, and gray whales may have become more common there and perhaps in the Beaufort Sea. In the springs of 2003 and 2004, a few tens of gray whales were seen near Barrow by early to mid-June (Statoil 2010, citing LGL Ltd. unpublished data).

Gray whales routinely feed in the Chukchi Sea during the summer. Moore *et al.* (2000) reported that, during the summer, gray whales in the Chukchi Sea were clustered along the shore primarily between Cape Lisburne and Point Barrow and were associated with shallow, coastal shoal habitat. In autumn, gray whales were clustered near shore at Point Hope and between Icy Cape and Point Barrow, as well as in offshore waters northwest of Point Barrow at Hanna Shoal and southwest of Point Hope. Although they are most common in portions of the Chukchi Sea close to shore, gray whales may also occur in offshore areas of the Chukchi Sea, particularly over offshore shoals.

Life History: Gray whales are baleen whales that are mottled grey in color and have no dorsal fin. Their baleen is different from other baleen whales in that it is short, stiff, and light in color. They use this specialized baleen and their uniquely shaped mouths to suction sediments from the seafloor and filter out their prey (Frost 1994). During the summer in the Chukchi Sea, gray whales feed on benthic animals, mainly amphipods, on or near the ocean floor (Nelson *et al.* 1993). They can be identified easily from the air, because they leave behind large mud clouds while feeding on the seafloor. Hanna Shoal within the Chukchi Sea is a major feeding ground for gray whales (Nelson *et al.* 1993).

Gray whales concentrate in shallow lagoons to give birth. A single calf is born between December and February after a 13-month gestation period. Female gray whales are known for being protective of their young (Frost 1994).

Population and Abundance: Systematic counts of gray whales migrating south along the central California coast have been conducted by shore-based observers at Granite Canyon most years since 1967. The most recent abundance estimates are based on counts made during the 1997-98, 2000-01, and 2001-02 southbound migrations. Analyses of these data resulted in abundance estimates of 29,758 for 1997-98, 19,448 for 2000-01, and 18,178 for 2001-02 (Rugh *et al.* 2005).

Variations in estimates may be due in part to undocumented sampling variation or to differences in the proportion of the gray whale stock migrating as far as the central California coast each year (Hobbs and Rugh 1999). The decline in the 2000-01 and 2001-02 abundance estimates may be an indication that the abundance was responding to environmental limitations as the population approaches the carrying capacity of its environment (Allen and Angliss 2010). Low encounter rates in 2000-01 and 2001-02 may have been due to an unusually high number of whales that did not migrate as far south as Granite Canyon or the abundance may have actually declined following high mortality rates observed in 1999 and 2000 (Gulland *et al.* 2005). Visibly emaciated whales (LeBoeuf *et al.* 2000; Moore *et al.* 2001) suggest a decline in food resources, perhaps associated with unusually high sea temperatures in 1997 (Minobe 2002). Several factors since this mortality event suggest that the high mortality rate was a short-term, acute event and not a chronic situation or trend: 1) counts of stranded dead gray whales dropped to levels below those seen prior to this event, 2) in 2001 living whales no longer appeared to be emaciated, and 3) calf counts in 2001-02, a year after the event ended, were similar to averages for previous years (Rugh *et al.* 2005).

Conservation Status: In 1994, due to steady increases in population abundance, the eastern North Pacific stock of gray whales was removed from the List of Endangered and Threatened Wildlife, as it was no longer considered endangered or threatened under the ESA.

Minke Whale

Distribution: The Alaska stock of minke whales ranges from near the equator north to the Chukchi Sea (Figure 3-5) (Leatherwood *et al.* 1982). They have been seen penetrating ice in the Chukchi Sea during summer (Leatherwood *et al.* 1982). The minke whales seen in the Chukchi are thought to migrate south to California during the fall (Dorsey *et al.* 1990). Allen 2009 indicated that Minke whales are not considered abundant in any part of their range, but that some individuals venture north of the Bering Strait in summer. Reiser *et al.* (2009) reported eight and five Minke whale sightings in 2006 and 2007, respectively, during vessel-based surveys in the Chukchi Sea; and Haley *et al.* (2009, cited in Statoil 2010) reported 26 Minke whale sightings during similar vessel-based surveys in the Chukchi Sea in 2008.

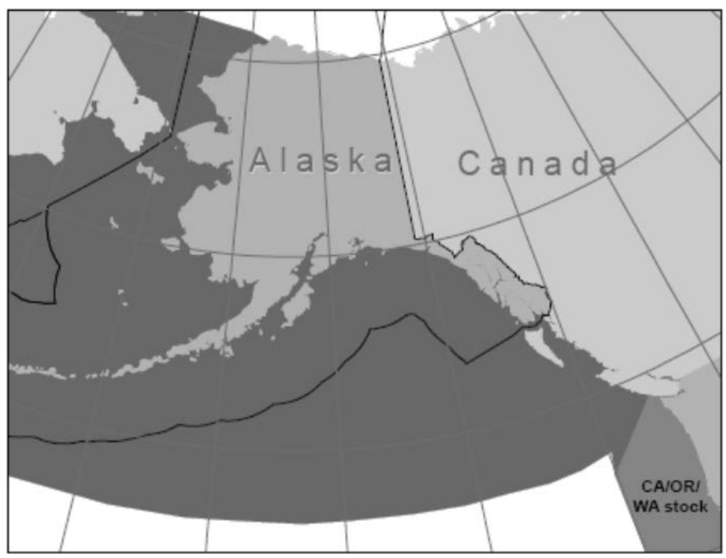

Figure 3-5. Approximate distribution of minke whales in the eastern North Pacific (shaded area). (Adopted from Allen and Angliss (2010)).

No minke whales were observed at the Burger Prospect in the Chukchi Sea during surveys in 1989 or 1990, and one whale was seen in the Popcorn prospect in 1990.

During vessel-based and aerial surveys conducted in the Chukchi Sea, a total of 16 minke whales were observed by MMOs between 2006 and 2008 (Statoil 2010).

Life History: Minke whales are the smallest of the baleen whales in North American waters. They are dark grey on top and light grey on their underside. They filter water using baleen to feed on plankton and small fish. Females are, on average, larger than males.

Sexual maturity is reached around age 6, and a single calf is born every 1 – 2 years after a gestation period of about 10 months. Calves nurse for about 6 months. Minke whales are thought to live to around age 50.

Population and Abundance: No estimates have been made for the number of minke whales in the entire North Pacific. However, some information is now available on the numbers of minke whales in the Bering Sea. A visual survey for cetaceans was conducted in the central-eastern Bering Sea in July - August 1999, and in the southeastern Bering Sea in 2000, in cooperation with research on commercial fisheries (Moore *et al.* 2000a; Moore *et al.* 2002). The survey included 1,761 km and 2,194 km of effort in 1999 and 2000, respectively. Results of the surveys in 1999 and 2000 provide provisional abundance estimates of 810 (CV = 0.36) and 1,003 (CV = 0.26) minke whales in the central-eastern and southeastern Bering Sea, respectively (Moore *et al.* 2002). These estimates are considered provisional because they have not been corrected for animals missed on the trackline, animals submerged when the ship passed, or responsive movement. These estimates cannot be used as an estimate of the entire Alaska stock of minke whales because only a portion of the stock's range was surveyed.

Conservation Status: Minke whales are not listed as "depleted" under the MMPA or listed as "threatened" or "endangered" under the ESA.

Beluga Whale

Distribution: Beluga whales are distributed throughout seasonally ice-covered arctic and subarctic waters of the Northern Hemisphere (Gurevich 1980), and are closely associated with open leads and polynyas in ice-covered regions (Hazard 1988). Depending on season and region, beluga whales may occur in both offshore and coastal waters, with concentrations in Cook Inlet, Bristol Bay, Norton Sound, Kasegaluk Lagoon, and the Mackenzie Delta (Hazard 1988). It is assumed that most beluga whales from these summering areas overwinter in the Bering Sea, excluding those found in the northern Gulf of Alaska (Shelden 1994). Seasonal distribution is affected by ice cover, tidal conditions, access to prey, temperature, and human interaction (Lowry 1985).

Within the U.S. waters, five stocks of beluga whales are recognized: 1) Cook Inlet, 2) Bristol Bay, 3) eastern Bering Sea, 4) eastern Chukchi Sea, and 5) Beaufort Sea (Figure 3-6). Two of these stocks that may be encountered during the proposed in-ice seismic survey in the Beaufort and Chukchi Seas are the Beaufort Sea stock and the eastern Chukchi stock (Allen and Angliss 2010).

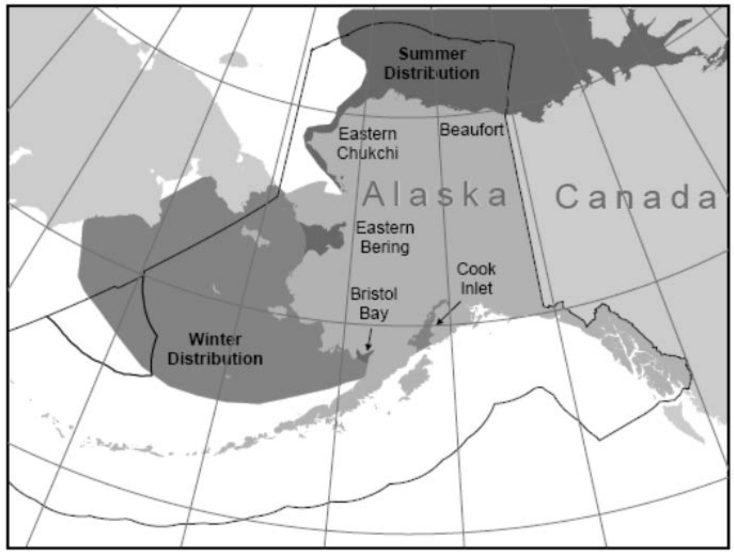

Figure 3-6. Approximate distribution of beluga whales in Alaska waters. The dark shading displays the summer distribution of the five stocks. Winter distributions are depicted with lighter shading. (Adopted from Allen and Angliss (2010)).

The general distribution pattern for beluga whales shows major seasonal changes. During the winter, they occur in offshore waters associated with pack ice. In the spring, they migrate to warmer coastal estuaries, bays, and rivers where they may molt (Finley 1982) and give birth to and care for their calves (Sergeant and Brodie 1969). Annual migrations may cover thousands of kilometers (Reeves 1990).

In the Bering-Chukchi-Beaufort Seas region, beluga whales migrate along open leads north from their wintering grounds in the Bering Sea during the spring (April – May) (Braham *et al.* 1984a) and return in the fall along the southern pack ice edge in their annual migration back to Bering Sea wintering areas in September (Richard *et al.* 1998). Migration generally occurs in deeper water along the ice front (Hazard 1988; Clarke *et al.* 1993; Miller *et al.* 1998). Much of the Chukchi Sea stock aggregates in Kasegaluk Lagoon from late June to mid-July, probably for breeding and molting (Suydam *et al.* 2005). During this time, the village of Point Lay conducts its subsistence hunt of the belugas.

Life History: Beluga whales are medium-sized, toothed cetaceans. At birth, they are dark grey but lighten in color as they age. By age 5 or 6 they are usually white. Beluga whales feed primarily on schooling fish. Female beluga whales reach sexual maturity by around age 5 and slightly later for males. Gestation lasts about 14.5 months before a single calf is born, usually tail first. Mating occurs during early spring, and calves are born between May and July. Calves are not weaned until after they reach about 3 years of age (Krasnova *et al.* 2005).

Population and Abundance: The sources of information to estimate abundance for belugas in the waters of northern Alaska and western Canada have included both opportunistic and systematic observations. Duval (1993) reported an estimate of 21,000 for the Beaufort Sea stock, similar to that reported by Seaman *et al.* (1985). The most recent aerial survey was conducted in July of 1992, and resulted in an estimate of 19,629 (CV = 0.229) beluga whales in the eastern Beaufort Sea (Harwood *et al.* 1996). To account for availability bias a correction factor (CF), which was not data-based, has been recommended for the Beaufort Sea beluga whale stock (Duval 1993), resulting in a population estimate of 39,258 (19,629 x 2) animals. A CV for the CF is not available.

The eastern Chukchi Sea stock of beluga whales were estimated at 1,200 by Frost *et al.* (1993), based on counts of animals from aerial surveys conducted during 1989-91. Survey effort was concentrated on the 170 km long Kasegaluk Lagoon, an area known to be regularly used by belugas during the open-water season. Other areas that belugas from this stock are known to frequent (e.g., Kotzebue Sound) were not surveyed. Therefore, the survey effort resulted in a minimum count. If this count is corrected, using radio telemetry data, for the proportion of animals that were diving and thus not visible at the surface (2.62, Frost and Lowry 1995), and for the proportion of newborns and yearlings not observed due to small size and dark coloration (1.18; Brodie 1971), the total corrected abundance estimate for the eastern Chukchi stock is 3,710 (1,200 x 2.62 x 1.18).

Conservation Status: Neither the Beaufort Sea stock nor the eastern Chukchi Sea stock of beluga whales are listed as “threatened” or “endangered” under the ESA, therefore, they are not considered “depleted” under the MMPA.

Harbor Porpoise

Distribution: In the eastern North Pacific Ocean, the harbor porpoise ranges from Point Barrow, along the Alaska coast, and down the west coast of North America to Point Conception, California (Gaskin 1984). The harbor porpoise primarily frequents coastal waters in the Gulf of Alaska and Southeast Alaska, they occur most frequently in waters less than 100 m in depth (Allen and Angliss 2010, citing Hobbs and Waite unpublished data). The average density of harbor porpoise in Alaska appears to be less than that reported off the west coast of the continental U.S., although areas of high densities do occur in Glacier Bay, Yakutat Bay, Copper River Delta, and Sitkalidak Strait (Dahlheim *et al.* 2000; Allen and Angliss 2010, citing Hobbs and Waite unpublished data).

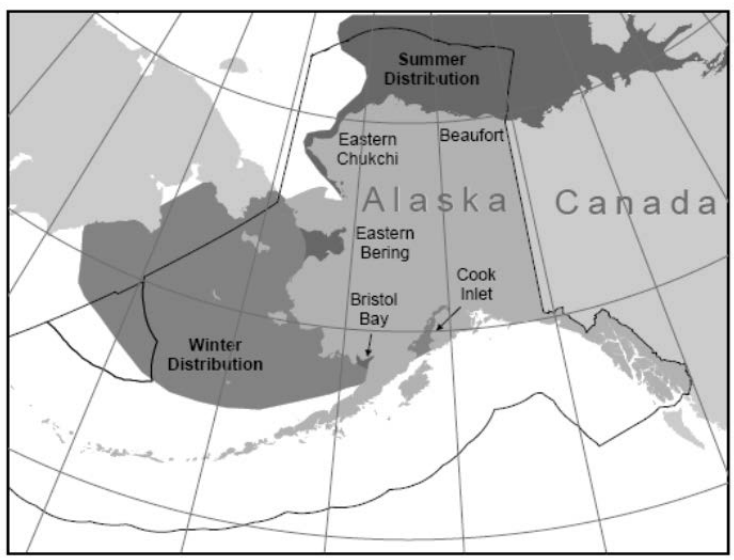

Figure 3-7. Approximate distribution of harbor porpoise in Alaska waters (shaded area). (Adopted from Allen and Angliss (2010)).

For management purposes, three separate harbor porpoise stocks in Alaska are recommended, recognizing that the boundaries were set arbitrarily (Allen and Angliss 2010): 1) the Southeast Alaska stock - occurring from the northern border of British Columbia to Cape Suckling, Alaska, 2) the Gulf of Alaska stock - occurring from Cape Suckling to Unimak Pass, and 3) the Bering Sea stock - occurring throughout the Aleutian Islands and all waters north of Unimak Pass (Figure 3-7). The harbor porpoise stock that could occur in the proposed in-ice seismic survey area is the Bering Sea stock.

Life History: Harbor porpoises are small, dark grey cetaceans, reaching approximately 1.9 m (6.2 ft). Females are slightly larger than the males. They can travel alone, in pairs, or in groups of up to ten individuals. Harbor porpoises feed mostly on fish. Sexual maturity is reached around 4 years. Gestation lasts about 11 months, and calves are usually born every 2 years. Calves are weaned around 8 months of age.

Population and Abundance: In June and July of 1999, an aerial survey covering the waters of Bristol Bay resulted in an observed abundance estimate for the Bering Sea harbor porpoise stock of 16,289 (CV = 0.132; Allen and Angliss 2010, citing Hobbs and Waite unpublished data). The observed abundance estimate includes a correction factor (1.337; CV = 0.062) for perception bias to correct for animals not counted because they were not observed. Laake *et al.* (1997) estimated the availability bias for aerial surveys of harbor porpoise in Puget Sound to be 2.96 (CV = 0.180); the use of this correction factor is preferred to other published correction factors (e.g., Barlow *et al.* 1988; Calambokidis *et al.* 1993b) because it is an empirical estimate of availability bias. The estimated corrected abundance estimate is 48,215 (16,289 x 2.96 = 48,215; CV = 0.223). The estimate for 1999 can be considered conservative, as the surveyed areas did not include known harbor porpoise range near either the Pribilof Islands or in the waters north of Cape Newenham (approximately 59^{o}N).

Conservation Status: Harbor porpoise are not listed as “depleted” under the MMPA or listed as “threatened” or “endangered” under the ESA. However, because the abundance estimates are 10 years old and information on incidental mortality in commercial fisheries is sparse, the Bering Sea stock of harbor porpoise is classified as a strategic stock (Allen and Angliss 2010).

Ringed Seal

Distribution: Ringed seals have a circumpolar distribution from approximately 35^{o}N to the North Pole, occurring in all seas of the Arctic Ocean (King 1983). In the North Pacific, they are found in the southern Bering Sea and range as far south as the Seas of Okhotsk and Japan. Throughout their range, ringed seals have an affinity for ice-covered waters and are well adapted to occupying seasonal and permanent ice. They tend to prefer large floes (i.e., > 48 m in diameter) and are often found in the interior ice pack where the sea ice coverage is greater than 90% (Simpkins *et al.* 2003). They remain in contact with ice most of the year and pup on the ice in late winter-early spring. Ringed seals are found throughout the Beaufort, Chukchi, and Bering Seas, as far south as Bristol Bay in years of extensive ice coverage (Figure 3-8). During late April through June, ringed seals are distributed throughout their range from the southern ice edge northward (Burns and Harbo 1972, Burns *et al.* 1981, Braham *et al.* 1984b). Preliminary results from recent surveys conducted in the Chukchi Sea in May-June 1999 and 2000 indicate that ringed seal density is higher in nearshore fast and pack ice, and lower in offshore pack ice (Bengtson *et al.* 2005). Results of surveys conducted by Frost and Lowry (1999) indicate that, in the Alaskan Beaufort Sea, the density of ringed seals in May-June is higher to the east than to the west of Flaxman Island. The overall winter distribution is probably similar, and it is believed there is a net movement of seals northward with the ice edge in late spring and summer (Burns 1970). Thus, ringed seals occupying the Bering and southern Chukchi Seas in winter apparently are migratory, but details of their movements are unknown.

Life History: Ringed seals are the smallest of the pinnipeds found in Alaska, rarely exceeding 1.5 m (5 ft) and 68 kg (150 lbs). They are grey in color, with black spots. In Alaska, ringed seals mostly eat Arctic cod, saffron cod, and crustaceans.

Figure 3-8. Approximate distribution of ringed seals (shaded area). The combined summer and winter distribution are depicted. (Adopted from Allen and Angliss (2010)).

Ringed seals overwinter on pack and shorefast ice (Bengston *et al.* 2005). They create breathing holes in the newly formed ice and maintain them throughout the year by scraping the sides using nails on their foreflippers (Smith and Hammill 1981). The seals excavate subnivean lairs above some of the holes to give birth and nurse their pups between March and April. Nursing lasts 4 – 6 weeks, during which time the pups stay in the lairs. The lairs protect the pups against hypothermia and predation by Arctic foxes and polar bears (Smith *et al.* 1991).

Population and Abundance: A reliable abundance estimate for the entire Alaska stock of ringed seals is currently not available. One partial estimate of ringed seal numbers was based on aerial surveys conducted in May-June 1985 - 1987 in the Chukchi and Beaufort Seas from southern Kotzebue Sound north and east to the U.S.-Canada border (Frost *et al.* 1988). Effort was directed towards shorefast ice within 20 nmi of shore, though some areas of adjacent pack ice were also surveyed. The estimate of the number of hauled out seals in 1987 was 44,360 ± 9,130 (95% CI). During May-June 1999 and 2000 surveys were flown along lines perpendicular to the eastern Chukchi Sea coast from Shishmaref to Barrow (Bengtson *et al.* 2005). Bengtson *et al.* (2005) indicate that the estimated abundance of ringed seals for the study area (corrected for seals not hauled out) in 1999 and 2000 was 252,488 and 208,857, respectively. Similar surveys were flown in 1996 - 1999 in the Alaska Beaufort Sea from Barrow to Kaktovik. Observed seal densities in that region ranged from 0.81 to 1.17/km^2 (Frost *et al.* 2002, 2004). Moulton *et al.* (2002) surveyed some of the same area in the central Beaufort Sea during 1997 - 1999, and reported lower seal densities than Frost *et al.* (2002). Frost *et al.* (2002) did not produce a population estimate from their 1990s Beaufort Sea surveys. However, the area they surveyed covered approximately 18,000 km^2 (Allen and Angliss 2010, citing L. Lowry, University of Alaska Fairbanks, pers. comm.), and the average seal density for all years and ice types was 0.98/km^2 (Frost *et al.* 2002), which indicates that there were approximately 18,000 seals hauled out in the surveyed portion of the Beaufort Sea. Combining this with the average abundance estimate of 230,673 from Bengtson *et al.* (2005) for the eastern Chukchi Sea results in a total of approximately 249,000 seals. This is a minimum population estimate because it does not include much of the geographic range of the stock and the estimate for the Alaska Beaufort Sea has not been corrected for the number of ringed seals not hauled out at the time of the surveys. Nonetheless, it provides an update to the estimate from 1987.

Conservation Status: Ringed seals are not listed as "depleted" under the MMPA or listed as "threatened" or "endangered" under the ESA. Due to a very low level of interactions between U.S. commercial fisheries and ringed seals, the Alaska stock of ringed seals is not considered a strategic stock.

In summer 2011, NMFS began receiving reports of an outbreak of skin lesions and sores among ringed seals and declared an unusual mortality event in December 2011. An investigative team was established, and testing has been underway. Testing has ruled out numerous bacteria and viruses known to affect marine mammals, including Phocine distemper, influenza, Leptospirosis, Calicivirus, orthopoxvirus, and poxvirus. Foreign animal diseases and some domestic animal diseases tested for and found negative include foot and mouth disease, VES, pan picornavirus, and Rickettsial agents. Recent, preliminary radiation testing results were announced which indicate radiation exposure is likely not a factor in the illness. Further quantitative radionuclide testing is occurring this spring. Results will be made publicly available as soon as the analyses are completed.

On May 28, 2008, NMFS received a petition from the Center for Biological Diversity (CBD) to list ringed seals under the ESA due to loss of sea ice habitat caused by climate change in the Arctic (CBD 2008a). NMFS published a *Federal Register* notice (73 FR 51615; September 4, 2008), indicating that there were sufficient data to warrant a review of the species. On December 10, 2010, NMFS proposed listing certain subspecies of the ringed seal as threatened (75 FR 77476).

Spotted Seal

Distribution: Spotted seals are distributed along the continental shelf of the Bering, Chukchi, and Beaufort seas, and the Okhotsk Sea south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977, Figure 3-9).

In the U.S. waters, they occur in the Bering, Chukchi, and Beaufort Seas. Satellite tagging studies showed that seals tagged in the northeastern Chukchi Sea moved south in October and passed through the Bering Strait in November. Seals overwintered in the Bering Sea along the ice edge and made east-west movements along the edge (Lowry *et al.* 1998). During spring they tend to prefer small floes (i.e., < 20 m in diameter), and inhabit mainly the southern margin of the ice, with movement to coastal habitats after the retreat of the sea ice (Fay 1974; Shaughnessy and Fay 1977; Lowry *et al.* 2000; Simpkins *et al.* 2003). In summer and fall, spotted seals use coastal haulouts regularly (Frost *et al.* 1993, Lowry *et al.* 1998), and may be found as far north as 69 – 72^{o}N in the Chukchi and Beaufort Seas (Porsild 1945; Shaughnessy and Fay 1977). To the south, along the west coast of Alaska, spotted seals are known to occur around the Pribilof Islands, Bristol Bay, and the eastern Aleutian Islands. Of eight known breeding areas, three occur in the Bering Sea, with the remaining five in the Okhotsk Sea and Sea of Japan. There is little morphological difference between seals from these areas.

Figure 3-9. Approximate distribution of spotted seals (shaded area). (Adopted from Allen and Angliss (2010)).

Life History: Spotted seals are intermediate in size (bigger than ringed seals, smaller than bearded seals) and light-colored, with dark spots covering their body. They typically weigh between 81 – 109 kg (180 – 240 lbs). Spotted seals feed mostly on schooling fish and crustaceans. Unlike ringed seals, spotted seals give birth on the ice surface and are considered annually monogamous. There are still uncertainties surrounding the breeding behavior of spotted seals, since most of it occurs underwater (Boveng 2009).

Spotted seals are closely related to and often mistaken for Pacific harbor seals (*Phoca vitulina richardsi*). The two species are often seen together and are partially sympatric, as their ranges overlap in the southern part of the Bering Sea (Quakenbush 1988). Yet, spotted seals breed earlier and are less social during the breeding season, and only spotted seals are strongly associated with pack ice (Shaughnessy and Fay 1977). These and other ecological, behavioral, genetic, and morphological differences support their recognition as two separate species (Quakenbush 1988).

Population and Abundance: A reliable estimate of spotted seal population abundance is currently not available (Rugh *et al.* 1995). However, early estimates of the world population were in the range of 335,000 - 450,000 animals (Burns 1973). The population of the Bering Sea, including Russian waters, was estimated to be 200,000 - 250,000 based on the distribution of family groups on ice during the mating season (Burns 1973). Fedoseev (1971) estimated 168,000 seals in the Okhotsk Sea. Aerial surveys were flown in 1992 and 1993 to examine the distribution and abundance of spotted seals in Alaska. In 1992, survey methods were tested and distributional studies were conducted over the Bering Sea pack ice in spring and along the western Alaska coast during summer (Rugh *et al.* 1993). In 1993, the survey effort concentrated on known haul out sites in summer (Rugh *et al.* 1994). The sum of maximum counts of hauled out animals were 4,145 and 2,951 in 1992 and 1993, respectively. Using mean counts from days with the highest estimates for all sites visited in either 1992 or 1993, there were 3,570 seals seen, of which 3,356 (CV = 0.06) were hauled out (Rugh *et al.* 1995).

Studies to determine a correction factor for the number of spotted seals at sea missed during surveys have been initiated, but only preliminary results are currently available. The Alaska Department of Fish and Game placed satellite transmitters on four spotted seals in Kasegaluk Lagoon and estimated the ratio of time hauled out versus time at sea. Preliminary results indicated that the proportion hauled out averaged about 6.8% (CV = 0.85) (Lowry *et al.* 1994). Using this correction factor with the maximum count of 4,145 from 1992 results in an estimate of 59,214.

Conservation Status: Spotted seals are not listed as “depleted” under the MMPA or listed as “threatened” or “endangered” under the ESA. Due to a minimal level of interactions between U.S. commercial fisheries and spotted seals, the Alaska stock of spotted seals is not considered a strategic stock.

On May 28, 2008, NMFS received a petition from CBD to list spotted seals under the ESA due to loss of sea ice habitat caused by climate change in the Arctic (CBD 2008a). NMFS published a *Federal Register* notice (73 FR 51615; September 4, 2008) indicating that there were sufficient data to warrant a review of the status of the species (Allen and Angliss 2010). After completing a status review, NMFS published a proposed rule on October 20, 2009, concluding the spotted seal exists as three distinct population segments (DPS) within the North Pacific Ocean. These are the southern, Okhotsk, and Bering DPSs. Based on consideration of the information presented in the status review and an analysis of the extinction risk probabilities for each of these DPSs, NMFS proposed listing the southern DPS as threatened (74 FR 53683).

Bearded Seal

Distribution: Bearded seals are circumpolar in their distribution, extending from the Arctic Ocean (85^{o}N) south to Hokkaido (45^{o}N) in the western Pacific. They generally inhabit areas of shallow water (less than 200 m) that are at least seasonally ice covered. During winter they are most common in broken pack ice (Burns 1967) and in some areas also inhabit shorefast ice (Smith and Hammill 1981). In Alaska waters, bearded seals are distributed over the continental shelf of the Bering, Chukchi, and Beaufort Seas (Ognev 1935; Johnson *et al.* 1966; Burns 1981, Figure 3-10). Bearded seals are evidently most concentrated from January to April over the northern part of the Bering Sea shelf (Burns 1981; Braham *et al.* 1984b). Spring surveys conducted in 1999 and 2000 along the

Alaskan coast indicate that bearded seals tend to prefer areas of between 70% and 90% sea ice coverage, and are typically more abundant 20-100 nmi from shore than within 20 nmi of shore, with the exception of high concentrations nearshore to the south of Kivalina (Bengtson *et al.* 2000; Bengtson *et al.* 2005; Simpkins *et al.* 2003). Many of the seals that winter in the Bering Sea move north through the Bering Strait from late April through June, and spend the summer along the ice edge in the Chukchi Sea (Burns 1967; Burns 1981). The overall summer distribution is quite broad, with seals rarely hauled out on land, and some seals may not follow the ice northward but remain in open-water areas of the Bering and Chukchi Seas (Burns 1981; Nelson 1981; Smith and Hammill 1981). An unknown proportion of the population moves southward from the Chukchi Sea in late fall and winter, and Burns (1967) noted a movement of bearded seals away from shore during that season as well.

Life History: Bearded seals are the largest of the northern seals, weighing up to 340 kg (750 lbs). Their color ranges from light brown to dark brown and sometimes silvery grey. They are easily distinguishable from other seals in the area because of their large size and their uniquely long whiskers.

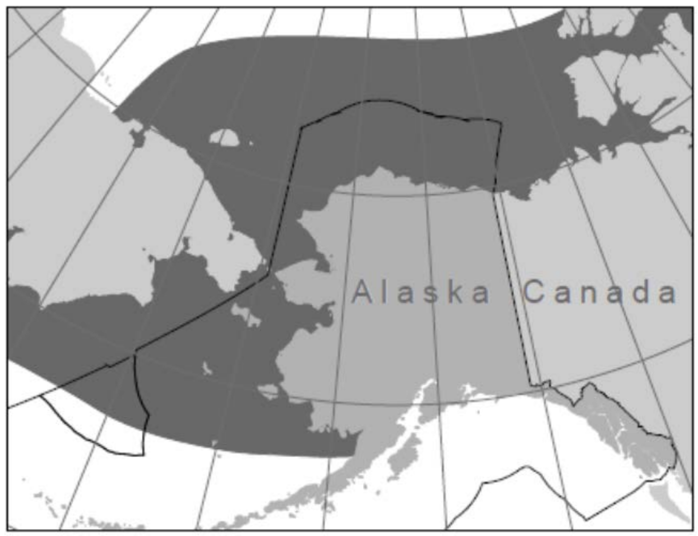

Figure 3-10. Approximate distribution of bearded seals (shaded area). The combined summer and winter distribution are depicted. (Adopted from Allen and Angliss (2010)).

The female gives birth to a single pup, weighing around 34 kg (75 lbs). Pupping occurs on drifting ice floes from late March through May (Kovacs *et al.* 1996). Pups are typically weaned when they are around 24 days old (Kovacs *et al.* 1996). Bearded seals are benthic feeders. They mainly feed on or in seafloor sediments including crabs, shrimp, and clams (Reeves *et al.* 1992).

Population and Abundance: Early estimates of the Bering-Chukchi Sea population range from 250,000 to 300,000 (Popov 1976; Burns 1981). Surveys flown from Shishmaref to Barrow during May-June 1999 and 2000 resulted in an average density of 0.07 seals/km^2 and 0.14 seals/km^2, respectively, with consistently high densities along the coast to the south of Kivalina (Bengtson *et al.* 2005). These densities cannot be used to develop an abundance estimate because no correction factor is available. There is no reliable population abundance estimate for the Alaska stock of bearded seals.

Conservation Status: Bearded seals are not listed as "depleted" under the MMPA or listed as "threatened" or "endangered" under the ESA. Due to a very low level of interactions between U.S. commercial fisheries and bearded seals, the Alaska stock of bearded seals is not considered a strategic stock.

On May 28, 2008, NMFS received a petition from CBD to list bearded seals under the ESA due to loss of sea ice habitat caused by climate change in the Arctic (CBD 2008a). NMFS published a *Federal Register* notice (73 FR 51615; September 4, 2008) indicating that there were sufficient data to warrant a status review of the species (Allen and Angliss 2010). On December 10, 2010, NMFS proposed listing a distinct population segment of the bearded seal as threatened (75 FR 77496).

Ribbon Seal

Distribution: Ribbon seals inhabit the North Pacific Ocean and adjacent parts of the Arctic Ocean. In Alaska waters, ribbon seals are found in the open sea, on the pack ice, and only rarely on shorefast ice (Kelly 1988). They range northward from Bristol Bay in the Bering Sea into the Chukchi and western Beaufort Seas (Figure 3-11). From late March to early May, ribbon seals inhabit the Bering Sea ice front (Burns 1970; Burns 1981; Braham *et al.* 1984b). They are most abundant in the northern part of the ice front in the central and western parts of the Bering Sea (Burns 1970; Burns *et al.* 1981). As the ice recedes in May to mid-July the seals move farther to the north in the Bering Sea, where they haul out on the receding ice edge and remnant ice (Burns 1970; Burns 1981; Burns *et al.* 1981). There is little known about the range of ribbon seals during the rest of the year. Recent sightings and a review of the literature suggest that many ribbon seals migrate into the Chukchi Sea for the summer (Kelly 1988). Satellite tag data from 2005 and 2007 suggest ribbon seals disperse widely. Ten seals tagged in 2005 near the eastern coast of Kamchatka spent the summer and fall throughout the Bering Sea and Aleutian Islands; eight of the 26 seals tagged in 2007 in the central Bering Sea moved to the Bering Strait, Chukchi Sea, or Arctic Basin as the seasonal ice retreated (Boveng *et al.* 2008).

Figure 3-11. Approximate distribution of ribbon seals (shaded area). The combined summer and winter distribution is depicted. (Adopted from Allen and Angliss (2010)).

Life History: Ribbon seals are intermediate in size, similar to spotted seals. Their appearance is unique as adults have light-colored ribbon shapes wrapped around their dark bodies.

Ribbon seals reach sexual maturity between the ages of 2 and 6. Pups are born on the ice surface between April and May. Ribbon seals nurse their pups for 3 – 4 weeks during the mating season.

Population and Abundance: A reliable abundance estimate for the Alaska stock of ribbon seals is currently not available. Burns (1981) estimated the worldwide population of ribbon seals at 240,000 in the mid-1970s, with an estimate for the Bering Sea at 90,000 - 100,000.

Aerial surveys were conducted in portions of the eastern Bering Sea in spring of 2003 (Simpkins *et al.* 2003), 2007 (Cameron and Boveng 2007, Moreland *et al.* 2008), and 2008 (Allen and Angliss 2010, citing Peter Boveng, NMML, unpubl. data). The data from these surveys are currently being analyzed to construct estimates of abundance for the eastern Bering Sea from frequencies of sightings, ice distribution, and the timings of seal haul-out behavior. In the interim, NMML researchers have developed a provisional estimate of 49,000 ribbon seals in the eastern and central Bering Sea during the surveys.

Conservation Status: Ribbon seals are not listed as "depleted" under the MMPA or listed as "threatened" or "endangered" under the ESA. Due to a very low level of interactions between U.S. commercial fisheries and ribbon seals, the Alaska stock of ribbon seals is not considered a strategic stock (Allen and Angliss 2010).

On 20 December 2007, NMFS received a petition from the CBD to list ribbon seals under the ESA due to loss of sea ice habitat caused by climate change in the Arctic (CBD 2007). NMFS published a *Federal Register* notice (73 FR 16617; March 28, 2008), indicating that there were sufficient data to warrant a review of the species. NMFS conducted a thorough review of the species and published a status review of the ribbon seal in December 2008 (Boveng *et al.* 2008). The findings of this review were reported in 73 FR 79822 (December 30, 2008), in which it was determined that listing of the ribbon seal is not warranted at this time. 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).

Pacific Walrus

Distribution: The Pacific walrus is the only walrus stock occurring in U.S. waters and considered in this account. Pacific walrus range throughout the continental shelf waters of the Bering and Chukchi seas, occasionally moving into the East Siberian Sea and the Beaufort Sea (Figure 3-12). During the summer months most of the population migrates into the Chukchi Sea; however, several thousand animals, primarily adult males, aggregate near coastal haulouts in the Gulf of Anadyr, Bering Strait region, and in Bristol Bay. During the late winter breeding season walrus are found in two major concentration areas of the Bering Sea where open leads, polynyas, or thin ice occur (Fay *et al.* 1984). While the specific location of these groups varies annually and seasonally depending upon the extent of the sea ice, generally one group ranges from the Gulf of Anadyr into a region southwest of St. Lawrence Island, and a second group is found in the southeastern Bering Sea from south of Nunivak Island into northwestern Bristol Bay.

Life History: Walruses are long-lived animals with low reproduction rates. Females reach sexual maturity at 4 – 9 years of age and give birth to one calf every 2 or more years. Males become fertile at 5 – 7 years of age and reach complete maturity at approximately age 15. Walruses can live up to the age of 40. Walruses inhabit pack ice of the Bering Sea in winter and breed between January and March, with implantation of the embryo delayed until June or July. Calving occurs on the sea ice in April–May, approximately 15 months after mating. Calves are weaned after 2 years or more after birth (Fay 1982).

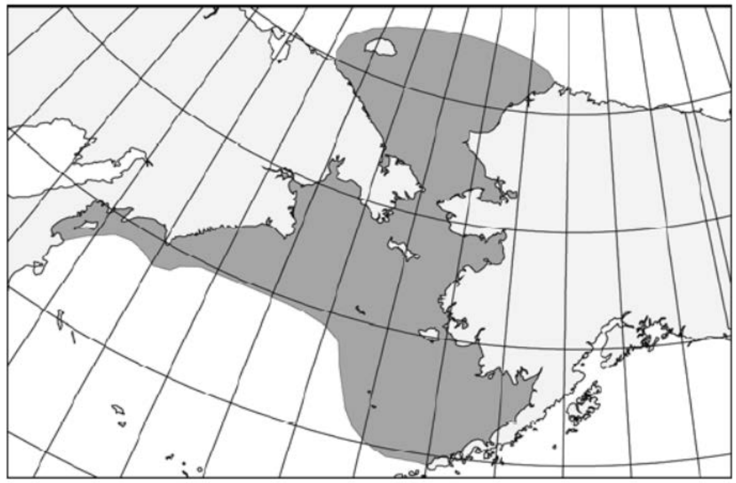

Figure 3-12. Approximate distribution of Pacific walrus in U.S. and Russia territory waters (shaded area). The combined summer and winter distributions are depicted. (Adopted from Allen and Angliss (2010)).

Walruses feed on benthic macroinvertebrates and prefer to forage in areas less than 80 m (262 ft) deep (Fay 1982). In Bristol Bay, 98 percent of satellite locations of tagged walruses were in water depths less than or equal to 60 m (197 ft) (Jay and Hills 2005). Walruses most commonly feed on bivalve mollusks (clams), but they also will feed on other benthic invertebrates (e.g., snails, shrimp, crabs, and worms). Some walruses have been reported to prey on marine birds and small seals (MMS 2007a).

Pacific walrus are currently managed as a single panmictic population; however, stock structure has not been thoroughly investigated. Scribner *et al.* (1997) found no difference in mitochondrial and nuclear DNA among walrus sampled shortly after the breeding season from four areas of the Bering Sea (Gulf of Anadyr, Koryak Coast, southeast Bering Sea, and St. Lawrence Island). More recently, Jay *et al.* (2008) found indications of stock structure based on differences in the ratio of trace elements in the teeth of walruses sampled in January and February from two breeding areas (southeast Bering Sea and St. Lawrence Island). Further research on stock structure of Pacific walruses is needed.

Population and Abundance: The size of the Pacific walrus population has never been known with certainty. Based on large sustained harvests in the 18th and 19th centuries, Fay (1982) speculated that the pre-exploitation population was represented by a minimum of 200,000 animals. Since that time, population size is believed to have fluctuated markedly in response to varying levels of human exploitation (Fay *et al.* 1989). Large-scale commercial harvests reduced the population to an estimated 50,000 - 100,000 animals in the mid-1950s (Fay *et al.* 1997). The population is believed to have increased rapidly in size during the 1960s and 1970s in response to reductions in hunting pressure (Fay *et al.* 1989).

Four years of field study by the USFWS and Russian partners led to the development of a survey method that uses thermal imaging systems to reliably detect walrus groups hauled out on sea ice (Burn *et al.* 2006, Udevitz *et al.* 2008). At the same time, the U.S. Geological Survey (USGS) developed satellite transmitters that record information on haul-out status of individual walrus, which can be used to estimate the proportion of the population in the water. This allows correction of an estimate of walrus numbers on ice to account for walrus in the water that cannot be detected in thermal imagery. These technological advances led to a joint U.S.-Russia survey in March and April of 2006, when the Pacific walrus population hauls out on sea ice habitats across the continental shelf of the Bering Sea.

The estimated area of available walrus sea ice habitat in 2006 averaged 668,000 km^2, and the area of surveyed blocks was 318,204 km^2. The number of Pacific walrus within the surveyed area was estimated at 129,000 with 95% confidence limits of 55,000 to 507,000 individuals. As this estimate does not account for areas that were not surveyed, some of which are known to have had walrus present, it is negatively biased to an unknown degree.

Conservation Status: Pacific walrus are not designated as “depleted” under the MMPA, and are not listed as “threatened” or “endangered” under the ESA. The conservation and management of Pacific walruses are under the USFWS.

In February 2008, the USFWS received a petition from CBD to list the Pacific walrus under the ESA (CBD 2008b). The 90-day finding on this petition was published in the *Federal Register* on September 10, 2009 (74 FR 46548), and found that there was substantial information in the petition to indicate that listing the Pacific walrus under the ESA may be warranted. USFWS published a *Federal Register* notice on February 10, 2011, indicating that listing the Pacific Walrus as endangered or threatened is warranted, but currently precluded by higher priority actions (76 FR 7634).

3.3 Socioecomic Environment

3.3.1 Traditional Knowledge

Traditional Knowledge, or TK, also known as indigenous knowledge and traditional ecological knowledge (TEK), is the collective knowledge possessed by a community and passed down from generation to generation for hundreds, if not thousands, of years. This knowledge is the product of the relationship a particular culture has with its environment, based on experience and adaptation over a long period of time. It can be ecological in nature, pertaining to the plants and animals within an ecosystem, and their respective relationships to each other and to the people who use them. It can also be environmental, such as information regarding snow, ice, and weather conditions (Hansen and VanFleet 2003; Miraglia 1998).

According to the Alaska Native Science Commission (ANSC), TK is more than a tool that people use to survive and thrive in their environment; it is a way of life (ANSC 2009). While rooted in the past, the term "traditional" is not meant to imply that the information is old, but rather based on tradition and "created in a manner that reflects the traditions of communities, therefore not relating to the nature of the knowledge itself, but to the way in which that knowledge is created, preserved, and disseminated" (Hansen and VanFleet 2003). TK is a living system that can be altered to reflect changing environmental conditions, cultural values, and spiritual or philosophical views, among other things. Contemporary TK incorporates non-traditional information, such as science, resulting in a modern, holistic way of existing with one's natural environment (ANSC 2009).

The need for and the process of transferring information about life—values, traditions, history, family, roles, technologies, lessons, etc.—from one generation to another is very important to the Iñupiat. Iñupiat TK is more than just the local knowledge of the North Slope and Northwest Arctic areas; it is also the act of transferring knowledge. According to Jana Harcharek, Iñupiaq educator and Coordinator of the NSB school district's bilingual and multicultural department, TK "endures through the continuing practice of customs associated with a subsistence lifestyle" (Harcharek 1995).

In northern Alaska, TK serves to inform hunters when particular animals should be hunted, as well as how to treat the spirits of those animals (Panikpak Edwardsen 1980). It is used as a way to teach children what their community expects of them. It is used to predict the weather, assess the safety of ice, and govern the use of resources (ANSC 2009; McNabb 1990). Iñupiaq knowledge is usually transmitted orally through songs, stories, and dance. It cannot be separated from the Iñupiat people who own it; it is their history, maintained in the present, advising their future.

Not only is it important that TK continue with the Iñupiaq communities, but Iñupiaq residents strive to have TK recognized and appreciated by those outside their culture. NSB mayor George Ahmaogak stressed the importance of applying Traditional Knowledge in industry and government activities (Ahmaogak 1995; NSB 2005). Additionally, residents have requested mandatory incorporation of TK in study, research, and monitoring plans (NSB 2005).

3.3.2 Community and Economy

Beaufort and Chukchi Seas communities that may be affected by the proposed in-ice seismic survey include Barrow, Kaktovik, Nuisqut, Wainwright, Point Lay, Point Hope, Kivalina, and Kotzebue. Barrow, Kaktovik, Nuisqut, Wainwright, Point Lay, and Point Hope are within the North Slope Borough (NSB, Figure 3-13); Kivalina and Kotzebue are in the Northwest Arctic Borough (NWAB, Figure 3-14). This section summarizes the NSB and NWAB and their economies.

3.3.2.1 North Slope Borough

In land mass, the NSB is the largest borough in the State of Alaska and encompasses 230,509 km^2 (89,000 mi^2). It extends across the top of Alaska from Point Hope on the Chukchi Sea to the Canadian border and from the Brooks Range to the Arctic Ocean

(NSB 2005). Fewer than 7,600 residents inhabit eight villages. The villages are Kaktovik, Nuiqsut, Anaktuvuk Pass, Atqasuk, Barrow, Wainwright, Point Lay, and Point Hope. Kaktovik is in the Alaska Wildlife Refuge, and Atqasuk is in the NPR-A.

The North Slope geographic area includes three regions with different climate, drainage, and geological characteristics: the Arctic Coastal Plain, the Brooks Range Foothills, and the northern portion of the Brooks Range. Arctic Slope Regional Corporation (ASRC), one of thirteen Alaska Native regional corporations, encompasses the North Slope and has substantial land and mineral rights.

The Iñupiat are the predominant inhabitants of eight villages in the region. Iñupiat have lived in the region for centuries and have actively traded with Canadian Natives (Alaska Department of Commerce, Community, and Economic Development [ADCCED] 2007). Vital to the Iñupiaq culture throughout the region are traditional whaling and other subsistence hunting, fishing, trapping, and gathering activities (NSB 2005).

The NSB government is funded by oil tax revenues; it provides public services to all of its communities and is the primary employer of local residents. North Slope oil field operations provide employment to over 5,000 non-residents, who rotate in and out of oil worksites from Anchorage, other areas of the state, and the lower 48 states. Census figures are not indicative of this transient worksite population (ADCCED 2007).

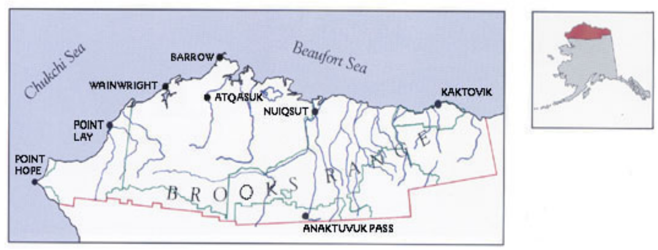

Figure 3-13. Map showing villages of North Slope Borough.

Air travel provides the only year-round access, while land transportation provides seasonal access. The Dalton Highway provides road access to Prudhoe Bay, although it is restricted during winter months. "Cat-trains" (a train of sleds, cabooses, etc., pulled by a Caterpillar™ tractor, used chiefly in the north during winter to transport freight) are sometimes used to transport freight overland from Barrow during the winter.

It is important to understand the economic drivers in the NSB and influence area of the Chukchi Sea Lease Sale 193. Future regional and local economic development depends on natural resource development. This very development has the potential to affect the environment and subsistence use areas. The resource development-based economy also provides jobs and opportunity. With the cash-based economy, residents are pulled from their subsistence economy, decreasing the Traditional Knowledge of subsistence reserves and habitat. The cumulative effects of the proposed Arctic Ocean oil and gas development must be counterbalanced by the indirect and direct economic benefits and community development that could also result.

ASRC and the village corporations exert considerable economic force in the region, providing employment in all sectors of the regional economy. Aside from the multinational resource development corporations, other major players in the North Slope economy are the federal government, State of Alaska, and local governments. The NSB is at the center of the region's economy, providing public services and facilities funded by oil and gas tax revenues. Revenues from oil and gas development provide most of the revenues to the NSB. These revenues are currently on the decline (Northern Economics, Inc. 2006).

Direct and indirect economic benefits of OCS oil and gas exploration and development have the potential for revenue sharing for the North Slope governments and village corporations. Workforce development and training programs are needed to increase local hiring in the villages and residents' employment participation within the resource development economy (Shepro *et al.* 2003).

High unemployment and underemployment remain characteristics of the North Slope, according to the North Slope Borough 2003 Economic Profile and Census Report. Most of the employment in the NSB is in the public sector: local, state, or federal government (Shepro *et al.* 2003).

3.3.2.2 Northwest Arctic Borough

The NWAB is the second-largest borough in Alaska, by size, encompassing approximately 101,010 km^2 (39,000 mi^2) along Kotzebue Sound and along the Wulik, Noatak, Kobuk, Selawik, Buckland, and Kugruk Rivers. It has a population of 7,407. The area has been occupied by Iñupiat for at least 10,000 years. Communities located within the Borough include Ambler, Buckland, Deering, Kiana, Kivalina, Kobuk, Kotzebue, Noorvik, Selawik, and Shungnak and the unincorporated community of Noatak (ADCCED 2009).

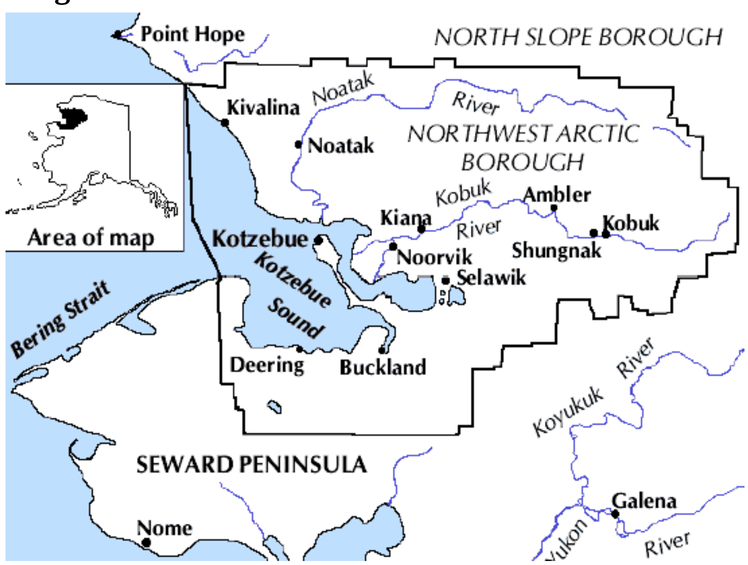

Figure 3-14. Map showing villages of Northwest Arctic Borough.

Activities related to government, mining, health care, transportation, services, and construction contribute to the NWAB economy. The Red Dog Mine, 145 km (90 mi) north of Kotzebue, is the world's largest zinc and lead mine and provides 370 direct year-round jobs and over a quarter of the Borough's wage and salary payroll. The ore is owned by NANA Regional Corporation and leased to Teck Alaska Incorporated (formerly Teck Cominco), which owns and operates the mine and shipping facilities.
Teck Alaska Incorporated, Maniilaq Association, the NWAB School District, Veco Construction (now owned by CH2M HILL), and Kikiktagruk Iñupiat Corporation are the

borough's largest employers. The smaller communities rely on subsistence food-gathering and Native craftmaking; 162 Borough residents hold commercial fishing permits (ADCCED 2009).

The economy of the NWAB is fueled by government jobs, in addition to opportunities provided by mining, health care, transportation and construction industries. Subsistence remains a significant economic factor in the NWAB, in the smaller communities in particular. As in the NSB, subsistence and wage-based employment exist as the primary interdependent aspects of the overall economy.

Kotzebue is the largest town in the NWAB and serves as the regional economic center, as well as transportation center. Transportation-related activities, resulting from the community's location at the confluence of several major river systems in conjunction with its marine docking facilities, contribute significantly to the local economy (NWAB 2009). Kotzebue maintains a higher rate of employment and mean income than smaller communities in the region. In 1991, nearly 75% of adults in the community reported holding some type of wage employment, though over half of those held seasonal jobs and only 45% were employed year-round. This is due in large part to the town's role as an economic center and the availability of seasonal jobs in the construction and fishing industries. Employment with federal, state, and local government provide the majority of resources for the community (MMS 1995). One hundred twelve residents have commercial fishing permits (NWAB 2009).

The economy in Kivalina is more heavily influenced by subsistence activities, which are supplemented and financed by wage-based employment (NWAB 2009). Government services in the administration, education, health, and social services sectors provide the primary employment opportunities in the community, and secondary economic contributions come from mining and retail trade. Kivalina has a relatively low level of employment, approximately 56% in 1991, and only 20% of available jobs provided year-round employment (MMS 1995). Art and jewelry produced from subsistence resources generate revenue for Kivalina residents. Local stores and airlines also provide jobs in the community, which has no restaurants or hotels. Two Kivalina residents have commercial fishing permits (NWAB 2009).

3.3.2.3 Economic Development

There are several prospects for future economic development in the NSB that have implications for societal and environmental baseline conditions and potential effects.

Oil and Gas Industry

Oil and gas development on the North Slope fuels the State of Alaska budget, NSB government, the industry, and employees working in the oil fields. Revenues derived from resource development on the North Slope have enabled the NSB to invest in modern infrastructure and facilities. While the NSB has supported onshore oil exploration and development, it has also required of the industry prevention measures to protect subsistence resources, wildlife, and the arctic environment. Given the vast reserves in the Arctic—not only oil and gas, but other natural resources—future economic development undoubtedly will be resource-based. There can be economies of scale in the development of infrastructure to support this development. The best available technology must be applied to the development challenges, utilizing the best available scientific studies balanced by Traditional Knowledge. Minimizing the environmental and societal effects of oil and gas exploration and development while providing business and job opportunities will go far in maintaining a high quality of life for residents.

Coal

Approximately one-third of the U.S. total coal resources are located in the western portion of the NSB (Glenn Gray and Associates 2005). This coal is high in British Thermal Unit value and low in sulfur. However, lack of surface transportation and other infrastructure is an obstacle to developing the coal resource.

Minerals

In the southwest area of the NSB, hard rock mineral deposits have been identified adjacent to the Red Dog zinc mine near Kotzebue in the northern portion of the NWAB. Should the transportation system that connects the Red Dog mine with the Chukchi Sea be extended, these minerals may be developed. As with potential development of coal, additional resource development affects the culture of the North Slope.

Sand and Gravel

Sand and gravel deposits located throughout the NSB and NWAB are a critical commodity for the villages in the region and the oil and gas industry. Locally available sand and gravel are valuable to the oil and gas industry for the construction and upkeep of roads and pads.

3.3.3 Subsistence

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 ling cod; 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).

3.3.3.1 Whales

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. Whaling is entwined with Iñupiaq culture, so much so that whaling is seen as an embodiment of Iñupiaq culture. Whaling has traditionally been a kinship-based activity; families are the foundation of whaling crews, and the distribution of meat and maktak is used to uphold ties between families and communities across Alaska. It also serves to connect the Iñupiat people with their community, their land and its resources, as well as their past.

Traditionally, as with all subsistence resources, all parts of the whale were harvested. Before these northern communities had access to modern building materials, whale bones were used in the construction of houses. Beluga oil could be used in the preparation of caribou hides and, although not as commonly done as with caribou or seals, the back of the beluga could be used for sinew, and beluga skin could be used for boot soles (Rachael Sakeagak and Irene Itta in Panikpak Edwardsen 1993). Whalebone was used for a multitude of items such as bowls, spoons, ladles, handles, and tools (Murdoch 1892). Baleen and bone are particularly popular in modern times for producing Native art.

Bowhead Whales: Of the three communities along the Beaufort Sea coast, Barrow is the only one that currently participates in a spring bowhead whale hunt. However, this hunt is not anticipated to be affected by ION's activities, as the spring hunt occurs in late April to early May, and ION's seismic survey will not begin until October.

All three communities participate in a fall bowhead hunt. In autumn, westward-migrating bowhead whales typically reach the Kaktovik and Cross Island (Nuiqsut hunters) areas by early September, at which point the hunts begin (Kaleak 1996; Long 1996; Galginaitis and Koski 2002; Galginaitis and Funk 2004, 2005; Koski *et al.* 2005). Around late August, the hunters from Nuiqsut establish camps on Cross Island from where they undertake the fall bowhead whale hunt. 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 (Shell 2010, citing 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 80 km (50 mi) offshore. Whaling crews use Kaktovik as their home base, leaving the village and returning on a daily basis. The core whaling area is within 19.3 km (12 mi) of the village with a periphery ranging about 13 km (8 mi) farther, if necessary. The extreme limits of the Kaktovik whaling hunt would be the middle of Camden Bay to the west. The timing of the Kaktovik bowhead whale hunt roughly parallels the Cross Island whale hunt (Shell 2010, citing Impact Assessment Inc 1990). In recent years, the hunts at Kaktovik and Cross Island have usually ended by mid- to late September.

Westbound bowheads typically reach the Barrow area in mid-September, and are in that area until late October (Brower 1996). However, over the years, local residents report having seen a small number of bowhead whales feeding off Barrow or in the pack ice off Barrow during the summer. Recently, autumn bowhead whaling near Barrow has normally begun in mid-September to early October, but in earlier years it began as early as August if whales were observed and ice conditions were favorable (USDOI/BLM 2005). The recent decision to delay harvesting whales until mid-to-late September has been made to prevent spoilage, which might occur if whales were harvested earlier in the season when the temperatures tend to be warmer. Whaling near Barrow can continue into October, depending on the quota and conditions.

Along the Chukchi Sea, the spring bowhead whale hunt for Wainwright occurs between April and June in leads offshore from the village. Whaling camps can be located up to 16 – 24 km (10 – 15 mi) from shore, depending on where the leads open up. Whalers prefer to be closer, however, and will sometimes go overland north of Wainwright to find closer leads. Residents of Point Lay have not hunted bowhead whales in the recent past, but were selected by the 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. In Point Hope, the bowhead whale hunt occurs between March and June, when the pack-ice lead is usually 10 – 11 km (6 – 7 mi) offshore. Camps are set up along the landfast ice edge to the south and southeast of the village. Point Hope whalers took between one and seven bowhead whales per year between 1978 and 2008, with the exception of 1980, 1989, 2002, and 2006, when no whales were taken (Statoil 2010, citing Suydam and George 2004; Suydam *et al.* 2005, 2006, 2007, 2008). There is no fall bowhead hunt in Point Hope, as the whales migrate back down on the west side of the Bering Strait, out of range of the Point Hope whalers (Fuller and George 1997).

Beluga Whales: Beluga whales are not a prevailing subsistence resource in the communities of Kaktovik and Nuiqsut. Kaktovik hunters may harvest one beluga whale in conjunction with the bowhead hunt; however, it appears that most households obtain beluga through exchanges with other communities. Although Nuiqsut hunters have not hunted belugas for many years while on Cross Island for the fall hunt, this does not mean that they may not return to this practice in the future. Data presented by Braund and Kruse (2009, in Statoil 2010) indicate that only one percent 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. ION will not be operating during the Kaktovik and Nuiqsut fall bowhead harvests.

In the Chukchi communities, the spring beluga hunt by Wainwright residents is concurrent with the bowhead hunt, but belugas are typically taken only during the spring hunt if bowheads are not present in the area. Belugas are also hunted later in the summer, between July and August, along the coastal lagoon systems. Belugas are usually taken less than 16 km (10 mi) from shore. Beluga whales are harvested in June and July by Point Lay residents. They are taken in the highest numbers in Naokak and Kukpowruk Passes south of Point Lay, but hunters will travel north to Utukok Pass and south to Cape Beaufort in search of belugas. The whales are usually herded by hunters with their boats into the shallow waters of Kasegaluk Lagoon (MMS 2007a). In Point Hope, belugas are also hunted in the spring, coincident with the spring bowhead hunt. A second hunt takes place later in the summer, in July and August, and can extend into September, depending on conditions and the IWC quota. The summer hunt is conducted in open water along the coastline on either side of Point Hope, as far north as Cape Dyer (MMS 2007a). Belugas are smaller than bowhead whales, but beluga whales often make up a significant portion of the total harvest for Point Hope (Fuller and George 1997; SRBA 1993). Ninety-eight belugas harvested in 1992 made up 40.3% of the total edible harvest for that year. Three bowhead whales represented 6.9% of the total edible harvest for the same year (Fuller and George 1997).

3.3.3.2 Walrus

Walrus are harvested for their meat, hides, and ivory tusks. Walrus hides are used for clothing, and ivory is used in the production of local art and crafts (AES 2009). As with seals, walrus intestines were used historically for window coverings or food containers (Hilda Webber in Panikpak Edwardsen 1993). Walrus have traditionally served as an important food source for dog teams but are predominantly used for human consumption today (SRBA 1993b).

3.3.3.3 Seals

Seals are harvested for their meat, oil, and hides (MMS 2007a). Seals harvested by Chukchi communities include ringed, spotted, and ribbon seals, all species of hair seals, and bearded seal, or ugruk in Iñupiaq. There is a preference for the meat of the bearded seals over that of ringed seals, which are the most common species of seal in the Chukchi (AES 2009; BLM 2003). While ringed seals are principally harvested for their meat, bearded seals are harvested for both their meat and blubber, which is rendered into oil (SRBA 1993a). Bearded seals are also prized for their hides, which are used for covering umiaqs, the traditional skin-covered boats used to hunt bowhead whales.

Traditionally, seal skins and intestines were used to make warm, waterproof clothing, bags, boots, and mittens, as well as a multitude of other items. Intestine bags were used as containers for seal oil, food, and water. They were carried on one's person, or sled bags were made specifically for use on dog sleds. Seals harvested at different times of the year were used for different things; fall seals, for example, were favored for boots because they did not have scratches on their skin. No part of the seal went to waste; laces were made from the seal skin, intestines were used for window coverings or rain gear, and when the skins were changed on the umiaqs, the old skin could be used for boot soles (Ida Numnik, Daisy Oomittuk, Bessie Ericklook, and Irene Itta in Panikpak Edwardsen 1993).

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 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 drains into Harrison Bay.

In the Chukchi Sea, seals are most often taken between May and September by Wainwright residents. Wainwright hunters will travel as far south as Kuchaurak Creek (south of Point Lay) and north to Peard Bay. Hunters typically stay within 72 km (45 mi) of the shore. Ringed and bearded seals are harvested all year by Point Lay hunters. Ringed seals are hunted 32 km (20 mi) north of Point Lay, as far as 40 km (25 mi) offshore. Hunters travel up to 48 m (30 mi) north of the community for bearded seals, which are concentrated in the Solivik Island area. Bearded seals are also taken south of the community in Kasegaluk Lagoon, and as far as 40 km (25 mi) from shore. 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).

Hunters tend to stay close to the shore but will travel up to 24 km (15 mi) offshore south of the point, weather dependent. Seals are hunted to the north of the community as well, but less often, as the ice is less stable and can be dangerous. Seals are taken between Akoviknak Lagoon to the south and Ayugatak Lagoon to the north (MMS 2007a).

3.3.3.4 Polar Bears

Polar bears are hunted for both their meat and pelts (AES 2009). At a conference in 1980, Iñupiaq elder Ida Numnik (Panikpak Edwardsen 1993) recalled using the sharpened forearm bones of polar bears for scraping hides; now metal scrapers can be purchased from the store. Hunters often took polar bear hides to sit on while sitting on the ice waiting for seals (Dinah Frankson in Panikpak Edwardsen 1993). Local harvest of polar bears has declined since 1972, when the State of Alaska 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).

3.3.3.5 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). Bird feathers were used in decoration for clothing, especially parkas (Statoil 2010, citing Martha Awalin, per. comm., January 22, 2009). Additionally, bird eggs are an important subsistence food source (BLM 2003).

3.3.3.6 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, some families would concentrate specifically on fishing, and other years they might not fish at all (SRBA 1993a). The subsistence trade network allows for this kind of resource procurement, and families can supplement their harvest with resources obtained from other families and communities. Marine, anadromous, and freshwater species are all harvested as subsistence species.

3.3.4 Coastal and Marine Use

3.3.4.1 Shipping and Boating

Other than vessels associated with the proposed in-ice marine seismic survey activities, vessel transit in the project area is expected to be limited during the fall-winter season. 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 12.5 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 United States Coast Guard (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 be in the proposed in-ice seismic survey area in 2012.

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 2008; 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 3-15 shows the activity of the USCG Cutter *Healy* (WAGB-20) during the period 2000 – 2009 (NSF 2009). Since 2002, *Healy* has supported scientific research in the arctic waters off Alaska's coast. As a Coast Guard cutter, 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.

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.

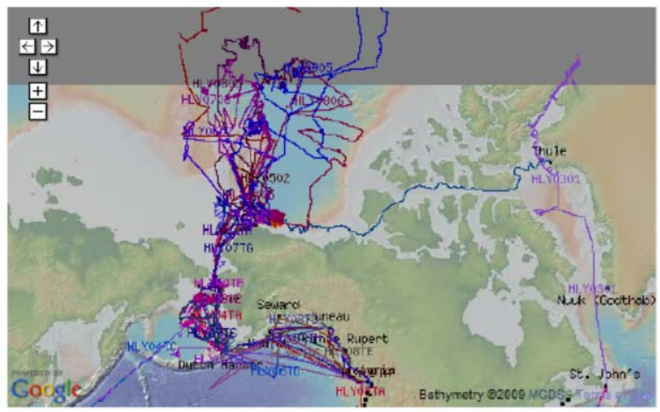

Figure 3-15. Cruise activity catalog of the USCG Cutter *Healy* (WAGB-20), 2000 - 2009. (Adopted from NSF (2009)).

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 in-ice seismic survey area. 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. No regulatory authority for commercial fishing exists in the NSB.

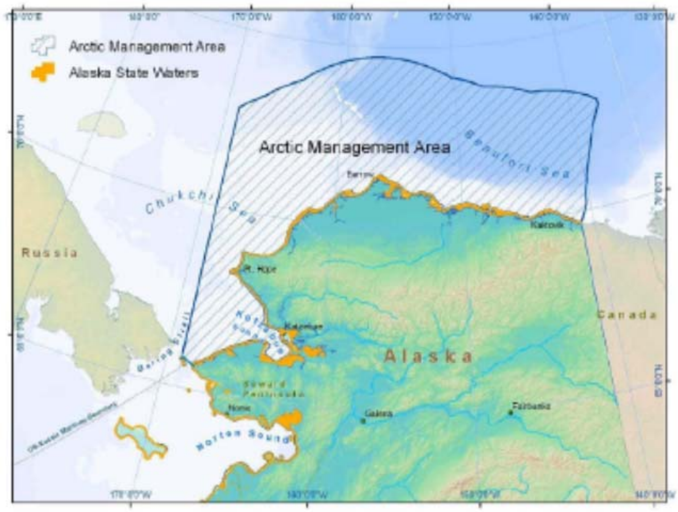

Figure 3-16. Map showing the Arctic Management Area. (Adopted from NPFMC (2009)).

The Arctic Fishery Management Plan has been implemented since December 3, 2009 (NOAA 2009). This plan closes the U.S. Arctic to commercial fishing within the EEZ or that area from 6 km (3 nm) offshore the coast of Alaska to 370 km (200 nm) seaward (see Figure 3-16, 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.

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 these 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).

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.

4.1 Effects of Alternative 1 – No Action Alternative

Under the No Action Alternative, NMFS would not issue the IHA to ION for the proposed icebreaking seismic survey in the Beaufort and Chukchi Seas. In this case, ION would decide whether or not they would want to continue with their marine and seismic survey activities. If ION chooses not to conduct the activities, then there would be no effects to marine mammals. Conducting the seismic and icebreaking activities without an MMPA authorization (i.e., an IHA) could result in a violation of Federal law. If ION decides to conduct some or all of the activities without implementing any mitigation measures, and if activities occur when marine mammals are present in the action areas, there is the potential for unauthorized harassment of marine mammals. The sounds produced by the icebreaker and airgun arrays are likely to cause behavioral harassment of marine mammals in the action areas, while some marine mammals may avoid the area of ensonification or with survey activities altogether. Additionally, masking of natural sounds may occur. Auditory impacts (i.e., temporary and permanent threshold shifts) could also occur if no mitigation or monitoring measures are implemented. As explained later in this document, monitoring of safety zones for the presence of marine mammals may allow for the implementation of mitigation measures, such as power-downs and shutdowns of the airguns when marine mammals occur within these zones. These measures are required to reduce the onset of shifts in hearing thresholds. However, if a marine mammal occurs within these high energy ensonified zones, it is possible that hearing impairments to marine mammals could occur. Additionally, although unlikely, based on its proximity to the airgun array, permanent threshold shift (PTS) could also occur, but this possibility is thought to be unlikely if the exposure is of a few pulses. If ION were to decide to implement mitigation measures similar to those described in Chapter 5 of this EA, then the impacts would most likely be similar to those described for Alternative 2 below.

4.2 Effects of Alternative 2 – Preferred Alternative

Under this alternative, NMFS would issue an IHA ION for its proposed in-ice marine seismic survey in the Beaufort and Chukchi Seas during late fall/early winter, 2012, with required mitigation, monitoring, and reporting requirements as discussed in Chapters 5 and 6 of this 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. Potentially affected marine mammal species under NMFS' jurisdiction would be: beluga whale; harbor porpoise; bowhead whale; gray whale; minke whale; bearded seal; spotted seal; ringed seal; and ribbon seal. One of these species, the bowhead whale, is listed as endangered under the ESA.

4.2.1 Effects on Physical Environment

Although NMFS does not expect the physical environment would be directly affected from the proposed action, it could be indirectly affected by the marine and seismic surveys. Therefore, as part of the environmental analysis, the effects on the physical environment are analyzed as part of the environment consequence analysis.

4.2.1.1 Effects on Geology and Oceanography

The in-ice marine seismic survey by ION in the Beaufort and Chukchi Seas would have no effects on the geology and geomorphology of the project area. The ION's proposed project is a marine seismic data survey, and the resultant activity would not affect the stratigraphy, seafloor sediments and geology, or sub-seafloor geology in any way. The proposed marine seismic survey would not affect the Arctic Ocean circulation patterns, topography, bathymetry, or incoming watermasses; atmospheric pressure systems; surface-water runoff; or density differences between watermasses.

The employment of an icebreaker during the survey could affect the structure and distribution of sea ice. However, although it is expected that ice conditions are expected to range from open water to 10/10 ice cover, the seismic survey can only proceed in areas of mostly newly forming juvenile first year ice or young first year ice less than 0.5 m (1.65 ft) thick. Therefore, any effects from icebreaking activities associated with the in-ice seismic survey are expected to have insignificant and localized alteration to the sea ice environment.

The narrow scope of the proposed ION in-ice marine seismic survey, the limited number of vessels, and limited duration of the survey activity will not have any effect on the climate and meteorology of the project area.

4.2.1.2 Effects on Air Quality

The proposed ION 2012 in-ice marine seismic survey in the Beaufort and Chukchi Seas would have a minimal, temporary, and localized effect on air quality in the project area and no measurable effect on air quality on the Alaska's Beaufort and Chukchi Seas. The short duration of the proposed seismic survey and significant distance to shore will ensure that the potential effects from the vessels' emissions will not represent any threat to the project area or the Alaska's Beaufort and Chukchi Seas coastline air quality.

4.2.1.3 Effects on Acoustic Environment

Potential effects on the marine acoustic environment within ION's 2012 in-ice seismic survey area in the Beaufort and Chukchi Seas mostly include sound generated by the seismic airguns and icebreaking activities, in addition to active acoustic sources for surveys and vessel transit. As described in Section 3.1.3.2, the most intense sources from the proposed in-ice seismic survey would be impulse sound generated by seismic airgun arrays. However, these effects are expected to be localized to the project areas and temporary, occurring only during seismic data acquisition.

Estimated Area Exposed to Airgun Sound Levels Higher Than 160 dB
ION's proposed in-ice seismic survey would tow an airgun array consisting of 28 Sercel G-gun airguns, of which 26 would be active and have a total discharge volume of 4,450 in^3. The 28 airguns would be distributed in two sub-arrays with 14 airguns per sub-array. Individual airgun sizes range from 70 to 380 in^3. Airguns would be operated at 2,000 psi.

Received sound levels were modeled for the full 26 airgun, 4,450 in^3 array in relation to distance and direction from the source (Zykov *et al.* 2010). Based on the model results, Table 4-1 shows the distances from the airguns where ION predicts that received sound levels will drop below 190, 180, and 160 dB re 1 μPa (rms).

Table 4-1. Distances where received levels expected to be ≥ 160 dB re 1 μPa based on water depth

Received Level (dB re 1 μPa)	Distance (m) from Source in Different Water Depth		
	less than 100 m	100 m–1,000 m	more than 1,000 m
190	600	180	180
180	2,850	660	580
160	27,800	42,200	31,600

The area of water potentially exposed to received levels of airgun sounds ≥160 dB rms was calculated by using a GIS to buffer the planned survey tracklines within each water depth category by the associated modeled ≥160 dB rms distances. The expected sound propagation from the airgun array was modeled by JASCO Applied Research (Zykov *et al.* 2010) and is expected to vary with water depth. Survey tracklines falling within the <100 m, 100–1,000 m, and >1,000 m water depth categories were buffered by distances of 27.8 km (17.3 mi), 42.2 km (26.2 mi), and 31.6 km (19.6 mi), respectively. The total area of water that would be exposed to sound ≥ 160 dB re 1 μPa (rms) on one or more occasions is estimated to be 209,752 km^2 (Figure 4-1).

Estimated Area Exposed to Icebreaking Sound Levels Higher Than 120 dB
Most of the sound generated by icebreaking is caused by cavitation of the propellers. Vibrations measured near the bow of the icebreaker *John A. MacDonald* during icebreaking were not correlated with received underwater sounds while vibrations measured at the stern, caused by propeller cavitation, clearly were (Thiele 1984; 1988). Propeller cavitation and resulting sounds tend to be greatest when a vessel is moving astern or when its forward progress has been stopped by heavy ice during ramming. Continuous forward progress through ice requires more power than when a vessel is traveling through open water. The greater the resistance, the greater the propeller cavitation and the greater the resulting sounds, although sound levels during forward progress are typically less strong than during backing and ramming in heavy ice.

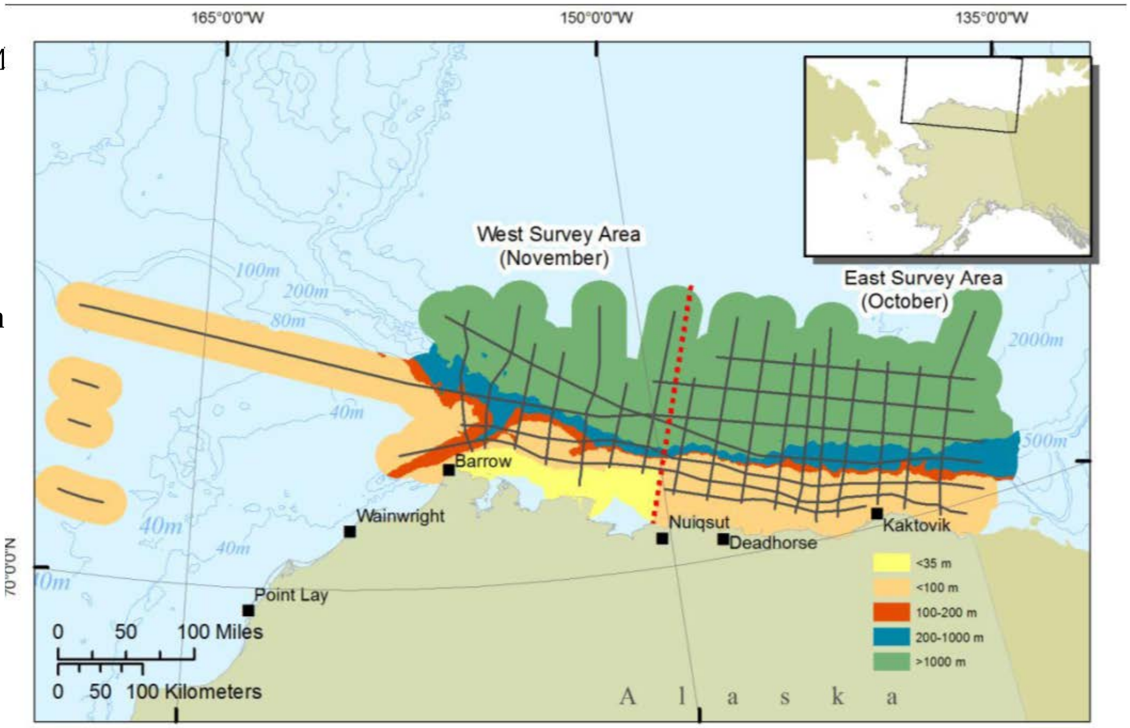

Figure 4-1. Areas estimated to be exposed to airgun sound at received levels ≥ 160 dB dB re 1 μPa (rms) by water depth category (Adopted ION (2012a)).

Measurements of the ic

Icebreaking supply ship *Robert Lemeur* pushing and breaking ice in the Beaufort Sea in 1986 resulted in an estimated broadband source level of 193 dB re 1 μPa-m (Richardson *et al.* 1995a). These measurements were made on September 2 (Greene 1987b). Ice conditions were not described in detail, but involved a band of drifting ice pans, presumably composed of second year ice or multi-year ice.

The broadband source levels of three different vessels pushing on or breaking ice during drilling activities in the U.S. Beaufort Sea in 1993 were estimated as 181–183, 184, and 174 dB re 1 μPa-m (Hall *et al.* 1994). Similar to the above, ice conditions in mid-August when these recordings were made were likely to have been thick first year (sea ice doesn't reach "second year" status until around September 1), second year, or multi-year ice.

The strongest sounds produced by an icebreaker backing and ramming an ice ridge were estimated at 203 dB re 1 μPa-m at the point when the propellers were still turning at full ahead but the vessel had come to a stop when it failed to break the ice ridge (Erbe and Farmer 1998). A similar maximum source level (200 dB re 1 μPa-m) was reported during backing and ramming activities by the USCGC *Healy* as measured by a sonobuoy deployed from that vessel in 2009 (Roth and Schmidt 2010).

Roth and Schmidt (2010) contains three very recent "case studies" of *Healy* breaking ice in the high Arctic. Ice type is not described, but given the date, location, and pictures provided, the ice is clearly not juvenile ice and instead likely second year or multi-year ice. The first case study provides an example of *Healy* traveling through 7–9/10ths ice (70 – 90% ice coverage) and then entering open-water. Average source levels in ice were estimated to be ~185 dB re 1 μPa-m while average source levels in open-water were estimated between 180 and 175 dB re 1 μPa-m. The second case study is an example of backing and ramming in 8/10ths ice (80% ice coverage). Maximum source level reached 191–195 dB re 1 μPa-m. The third case study is another example of backing and ramming, this time in 9/10ths ice (90% ice coverage) where maximum source levels reached 200 dB re 1 μPa-m.

None of these examples apply very well to the ice conditions likely to be encountered during the proposed October – December survey. The ice regimes expected to be encountered along the Alaskan Coast in the survey area during the survey period will vary considerably from predominantly or entirely open water in early October to predominantly new young and first year ice in November. The proposed seismic survey will take advantage of such variations to complete the more difficult survey lines when the ice conditions are favorable for that work.

The ION's proposed project would involve two ships working together when in or near sea ice. In this mode the icebreaker (*Polar Prince*) escorts the geophysical ship (*Geo Arctic*). As both ships must move continuously at near survey speed, it is essential that this work is carried out in ice conditions that do not require the icebreaker to undertake backing and ramming operations.

ION used the Arctic Ice Regime Shipping System (AIRSS) to aid their determination concerning suitable conditions for the survey. This system allows the Arctic Mariner/Ice Master to calculate the "toughness" of a particular ice regime. As a "rule of thumb" ice-seismic is normally considered achievable in ice where the calculation indicates navigation can safely be undertaken by the ice strengthened (Ice Class A1A, type A) geophysical ship, operating independently. Use of an escort icebreaker greatly augments this safety factor. This means the icebreaker is normally working very lightly but does have a large propulsive power capacity held in reserve in case small ridges or other such ice features are encountered. Thus the icebreaker is breaking ice at a fraction of its maximum or rated capacity.

Compared to the aggressive icebreaking involved in the examples above, the icebreaking for ice-seismic is of a much different and considerably lower order. In most ice regimes expected to be encountered during the survey the *Polar Prince* will have about 5,123 HP available for propulsion, which is far less than the power of the heavy icebreaker *Healy* reported in Roth and Schmidt (2010). There would still be a direct correlation between icebreaking effort and icebreaking noise, although there are also many other variables such as thermal gradient, stage of ice development, speed of impact, propulsion system characteristics, hull and bow form, etc., that may differentiate the sounds produced during the proposed survey. In the examples provided in Roth and Schmidt (2010), the *Healy* appears to be backing and ramming in heavy multi-year ice (based on interpretation of the pictures). Such conditions are beyond the allowable operational conditions of this project and if such conditions were encountered, the Type A geophysical ship could not follow such an ice-encumbered track of multi-year ice.

It should also be noted that the *Healy* was operating at maximum capacity during the measurements reported in Roth and Schmidt (2010), while during ice-seismic the escorting icebreaker rarely operates in excess of 50% capacity. Thus, accounting for the disparity in the horsepower ratings of the *Polar Prince* vs. the *Healy*, the *Polar Prince* will be rendering an output, in terms of horsepower expended, of <25% each of that of the Healy during the reported measurements.

Based on available information regarding sounds produced by icebreaking in various ice regimes and the expected ice conditions during the proposed survey, it is expected that vessel sounds generated during ice breaking are likely to have source levels between 175 and 185 dB re 1 μPa-m. As described above, it is assumed that seismic survey activity will occur along all of the planned tracklines shown in Figure 1-1. Therefore airgun array received levels ≥160 dB with radius of 26.7 – 42.2 km (16.6 – 26.2 mi) (depending on water depth, see Table 4-1) were applied to each side of all of the survey lines as shown in Figure 4-1. Assuming a source level of 185 dB re 1 μPa-m and $15 \log R$ for spreading loss, icebreaking sounds may be ≥ 120 dB re 1 μPa out to a maximum distance of ~21.6 km (~13.4 mi). Thus, all sounds produced by icebreaking are expected to diminish below 120 dB re 1 μPa within the zone where it is assumed mammals will be exposed to ≥160 dB re 1 μPa (rms) from seismic airgun sounds. Therefore, marine mammals exposed to 120 dB re 1 μPa (rms) non-pulse icebreaking noise would be contained within the 160 dB re 1 μPa isopleths.

If refueling of the *Geo Arctic* is required during the survey and then the *Polar Prince* transits to and from Canadian waters to acquire additional fuel for itself, an additional ~200 km (~124 mi) of transit may occur. Most of this transit would likely occur through ice in offshore waters >200 m (>656 ft) in depth. For estimation purposes it is assumed 25% of the transit would occur in 200 – 1,000 m (656 – 3,280 ft) of water and the remaining 75% would occur in >1,000 m (>3,280 ft) of water. This results in an estimated ~2,160 km^2 of water in areas 200 – 1,000 m (656 – 3,280 ft) deep and 6,487 km^2 in waters >1,000 m (>3,280 ft) deep being ensonified to ≥120 dB by icebreaking sounds.

If the *Polar Prince* cannot return to port via Canadian waters, then a transit of ~600 km (~373 mi) from east to west across the U.S. Beaufort would be necessary. Again, it is expected that most of this transit would likely occur in offshore waters >200 m (>656 ft) in depth. For estimation purposes we have assumed 25% of the transit will occur in 200 – 1,000 m (656 – 3,280 ft) of water and the remaining 75% will occur in >1,000 m of water. This results in an estimated ~3,240 km^2 of water in areas 200 – 1,000 m (656 – 3,280 ft) deep and 9,720 km^2 in waters >1,000 m deep being ensonified to ≥120 dB by icebreaking sounds within each half of the U.S. Beaufort Sea, for a total of 25,920 km^2 ensonified across the entire U.S. Beaufort Sea.

4.2.2 Effects on Biological Environment

4.2.2.1 Effects on Lower Trophical Organisms

Lower trophic-level organisms present in the prospect areas include phytoplankton, zooplankton, and benthic invertebrates. The types of lower trophic organisms found in the proposed in-ice seismic survey area in the Beaufort and Chukchi Seas are discussed in Section 3.2.1. The potential effect of sound from the seismic airguns and icebreaking activities on lower trophic-level organisms is discussed below.

Reactions of zooplankton to sound are, for the most part, not known. Their abilities to move significant distances are limited or nil, depending on the type of animal. Studies on euphausiids and copepods, which are some of the more abundant and biologically important groups of zooplankton in the Beaufort and Chukchi Seas, have documented the use of hearing receptors to maintain schooling structures (Wiese 1996) and detection of predators (Wong 1996); therefore, these organisms have some sensitivity to sound. However, the intensity of this type of seismic energy is much lower than the intensity of sound energy required to negatively affect zooplankton. Pressure changes of sufficient magnitude to cause that type of reaction would probably occur only near the airgun source, which is expected to be a very small area. Impacts on zooplankton behavior are predicted to be negligible.

The effect of seismic activities on snow crab is not expected to result in behavioral reactions or physiological stress that may negatively affect the Beaufort and Chukchi Seas snow crab population, or those species depending on crab for foraging opportunities (Christian *et al.* 2003, 2004). Crabs do not possess hearing capabilities, and only some crab species can detect sound waves. In a controlled experimental study, adult male snow crabs, female snow crabs carrying eggs, and fertilized snow crabs, were subject to a 200 in^3 airgun energy source fired directly 50 m above. This experiment did not result in any direct mortality. While the developmental rate for eggs of a single female snow crab was slower compared to unexposed fertilized eggs/embryos, embryos carried by female crabs were able to successfully hatch (Christian *et al.* 2004). Moreover, when caged snow crab were monitored with a video camera, they were found to remain within the 200-m (657-ft) radius of a hydrophone transmitting 221 dB of sound energy, and did not exhibit any notable startle responses during exposure to airguns (Christian *et al.* 2003).

The physiology of many marine invertebrates is such that they are the same density as the surrounding water; therefore, sudden changes in pressure, such as that caused by a sudden loud sound, is unlikely to cause physical damage. There have been some studies evaluating potential effects of sound energy from 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 1.0 m (3.3 ft) in water depths of 2.0 m (6.6 ft). 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. No appreciable, adverse effect on benthic populations would be expected, due in part to large reproductive capacities and naturally high levels of predation and mortality of these populations.

4.2.2.2 Effects on Fish

Fish can detect sounds via the saccule of the ear (one of the inner ear end organs) (Popper *et al.* 2003). Studies have demonstrated that many fish species produce and use sounds for a variety of behaviors, with some discriminating between different frequencies and intensities, and detect the presence of a sound within substantial background noise (Popper *et al.* 2003). Fish use sounds in behaviors including aggression, defense, territorial advertisement, courtship, and mating (Popper *et al.* 2003). Hearing in fish is not only for acoustic communication and detection of sound-emitting predators and prey but it also can play a major role in telling fish about the acoustic scene at distances well beyond the range of vision (Popper *et al.* 2003).

Impacts from Airgun Noise

Mortality and Physiological Damage: Seismic-survey acoustic-energy sources may damage or kill eggs, larvae, and fry of some fishes occurring in close proximity to an airgun, but the harm generally is limited to within 5 m (15 ft) from the airgun and greatest within 1 m (3 ft) of the airgun (e.g., Kostyuchenko 1973; Dalen and Knutsen 1987; Holliday *et al.* 1986; Turnpenny and Nedwell 1994). Airguns are unlikely to cause immediate deaths of adult and juvenile marine fishes. Sound sources that have resulted in documented physiological damage and mortality of adult, juvenile, and larval fish all have been at or above 180 dB re 1 μPa (Turnpenny and Nedwell 1994). The likelihood of physical damage is related to the characteristics of the sound wave, the species involved, lifestage, distance from the airgun array, configuration of array, and the environmental conditions.

The Canadian Department of Fisheries and Oceans (CDFO, 2004) reviewed scientific information on impacts of seismic sound on fish and concluded that exposure to seismic sound is considered unlikely to result in direct fish or invertebrate mortality. Damage to fish from seismic emissions may develop slowly after exposure (Hastings *et al.* 1996).

Overall, the available scientific and management literature suggests that mortality of juvenile and adult fish, the age-classes most relevant to future reproductive fitness and growth, likely would not result from seismic-survey activity. Fishes with impaired hearing may have reduced fitness, potentially making them vulnerable to predators, possibly unable to locate prey or mates, sense their acoustic environment or, in the case of vocal fishes, unable to communicate with other fishes. Given that this most likely would occur to fish within very close proximity to the sound source, any injury to adult and juvenile fish is expected to be limited to a small number of animals.

Impacts to Behavior: The most likely impacts to marine fish and invertebrates from seismic activity would be behavioral disruptions. Behavioral changes to marine fish and invertebrates from seismic-survey activity have been noted in several studies (e.g., Dalen and Knusten 1987; McCauley *et al.* 2000a, 2003; Pearson *et al.* 1992), including: balance problems (but recovery within minutes); disoriented swimming behavior; increased swimming speed; tightening schools; displacement; interruption of important biological behaviors (e.g., feeding, mating); shifts in the vertical distribution (either up or down); and occurrence of alarm and startle responses (generally around 180 dB re 1 μPa and above). Behavioral impacts are most likely to occur in the 160- to 200-dB range (Turnpenny and Nedwell 1994).

These responses are expected to be species specific. Displacement also may be relative to the biology and ecology of species involved. Available studies have indicated that these reactions are likely to be short-term in nature. Although repeated, short-term disturbances can result in long-term impacts, seismic activity associated with the proposed action would be limited to the October to December time period; therefore, the timeframe is limited in scope.

Fish distribution and feeding behavior can be affected by the sound emitted from airguns and airgun arrays (Turnpenny and Nedwell 1994). Pelagic fish-catch rates and local abundance were reduced within 33 km of the airgun array for at least five days after shooting (Engås *et al.* 1996). There is no conclusive evidence for long-term or permanent horizontal displacement, and vertical displacement may be the short-term behavioral response. Normal fish behavior likely returns when the airguns are turned off. The repopulation of the vacated area is reliant upon a diffusion-like process (Turnpenny and Nedwell, 1994).

Seismic surveys potentially may disrupt feeding activity and displace diadromous and marine fishes (i.e., capelin, cisco, and the whitefishes) from critical summer feeding areas along the coast. While we cannot say with certainty the impacts of seismic surveys on fish feeding behavior, there is no present evidence that the behavioral impact of seismic surveys has a major effect on fish feeding, except perhaps in the immediate vicinity of an active survey vessel.

Impacts to Migration, Spawning, and Hatchling Survival: Most important to this issue are behavioral reactions that could result in disruption of migratory pathways or diminishing the availability of fish resources for subsistence resources (e.g., through fish abandoning important fishing grounds). For coastwise migratory fish species, acoustic disturbance may displace and disrupt important migratory patterns, habitat use, and life-history behaviors. The populations of many species move from one habitat to another and back again repeatedly during their life (Begon *et al.* 1987). The time-scale involved may be hours, days, months, or years.

For wide-ranging, migratory fish species, disturbance and displacement may disrupt important migratory and life-history behaviors and patterns or habitat areas. Seismic surveys conducted in Federal waters close to State waters, where many fishes migrate through to spawning sites along the coast or in anadromous streams of the Arctic, may disrupt or impede their migrations as fishes attempt to avoid airgun emissions. In addition, conducting more than one seismic operation simultaneously may influence the distribution of some juvenile and adult fishes, inadvertently herding them away from suitable habitat areas (e.g., nurseries, foraging, mating, spawning, migratory corridors) and concentrating many fishes in areas of unsuitable use.

Migratory species at risk of brief spawning delays include Pacific herring, capelin, Pacific salmon (chiefly pinks and chums), cisco, broad whitefish, and Pacific sand lance. Pacific herring and arctic cod are hearing specialists and are most likely the most acoustically sensitive species occurring in the proposed in-ice seismic survey area in the Beaufort Sea. They are, therefore, the most likely to exhibit displacement and avoidance behaviors of the arctic fishes occurring in the proposed seismic survey area. Pacific salmon and the whitefish spawn in freshwater habitats of the Arctic coast. Pacific herring, capelin, and Pacific sand lance spawn on beaches or in nearshore waters. There is no known nursery or spawning area in the vicinity of the offshore in-ice marine seismic survey area proposed by ION.

Impacts from Icebreaking and Vessel Noise

Mitson and Knudsen (2003) examined the causes and effects of fisheries research-vessel noise on fish abundance estimation and noted that avoidance behavior by a herring school was shown due to a noisy vessel; by contrast, there is an example of no reaction of herring to a noise-reduced vessel. They note a study wherein the FRV *Johan Hjort* was using a propeller shaft speed of 125 revolutions per minute, giving a radiated noise level sufficient to cause fish avoidance behavior at 560 m distance when traveling at 9 knots, but it reduced to 355 m (1,164 ft) at 10 knots. They show that large changes in noise level occur for a small change in speed. Their data also suggest abnormal fish activity continues for some time as the vessel travels away from the recording buoy used in the study.

Vessel traffic associated with the seismic surveys, including the seismic-survey vessels and accompanying guard/chase boat or utility boat, are used chiefly during ice-free conditions. Vessel traffic may disturb some fish resources and their habitat during operations. Pacific salmon in the coastal and marine environment may be disturbed by vessel-traffic noise. However, vessel noise is expected to be chiefly transient; fishes in the immediate vicinity of such vessels are believed likely to avoid such noise perhaps by as much as several hundred meters. Vessel noise is likely to be of negligible impact to fish resources. There is no study on the effects of icebreaking noise on fish, nevertheless, it is expected that the effects on fish are similar to vessel noise exposure due to the similarity of acoustic characteristics between the two (non-impulse, broadband noise).

4.2.2.3 Effects on Marine Birds

Although NMFS does not expect marine birds would be directly affected from the proposed action (issuing an IHA to ION for an in-ice marine seismic survey in the Beaufort and Chukchi Seas), they could be indirectly affected by the proposed seismic survey. Therefore, as part of the environmental analysis, the effects on marine birds are analyzed as part of the environment consequence analysis.

Potential adverse effects of the proposed seismic survey on marine birds can be summarized in categories of:

- Disturbance from the presence and noise of seismic surveys; and
- Collision with vessels.

Disturbance from the Physical Presence of Vessels

How waterfowl and marine birds respond to disturbances can vary widely depending on the species, time of year, disturbance source, habituation, and other factors (Fox and Madsen 1997). It seems that in some species of waterfowl, the distance at which disturbances will be tolerated varies depending on flock size, because larger flocks react at greater distances than smaller flocks (Madsen 1985). There is an energetic cost to moving away from a disturbance as well as a cost in terms of lost foraging opportunities or displacement to an area of lower prey availability. Some sea-duck species (e.g., Steller's eider, long-tailed duck, and harlequin duck [*Histrionicus histrionicus*]) exhibit different responses to different size vessels near developed harbors on the Alaska Peninsula and eastern Aleutian Islands during the winter (U.S. Army Corps of Engineers 2000). These species appear to tolerate large, slow-moving commercial vessels passing through narrow channels but typically fly away when in visual distance of a fast-moving skiff. Skiffs running small outboard engines at high speed make a distinctive high-pitched sound, whereas large commercial vessels produce a lower rumble. As these sea ducks appear more tolerant of slow-moving skiffs, their reaction may be interpreted as incorporating aspects of vessel size, speed, and engine noise. It also could be that these species associate the small skiffs with hunters they encounter elsewhere in their range.

Very few studies have assessed the effects of seismic surveys on marine birds and waterfowl. Stemp (1985) observed responses of northern fulmars, black-legged kittiwakes, and thick-billed murres to seismic activities in Davis Strait offshore of Baffin Island. The first two years of the study involved the use of explosives (dynamite gel or slurry explosives) and, therefore, are not relevant as use of underwater explosives is not a method being considered for proposed marine and seismic surveys in the Beaufort and Chukchi seas. The final year of the study involved airguns, but the study locations were never in sight of colonies, feeding concentrations, or flightless murres. The results of this study did not indicate that seabirds were disturbed by seismic surveys using airguns. This conclusion was due in part to natural variation in abundance. Nevertheless, Stemp concluded that adverse effects from seismic surveys were not anticipated as long as activities were conducted away from colonies, feeding concentrations, and flightless murres.

In the Beaufort Sea, Lacroix *et al.* (2003) investigated the effects of seismic surveys on molting long-tailed ducks. These ducks molt in and near coastal lagoons on the North Slope, primarily during August, during which time they are flightless for 3 - 4 weeks. The molt is an energetically costly period. Long-tailed ducks are small sea ducks with higher metabolic rates and lower capacity to store energy than larger ducks (Goudie and Ankney 1986). Consequently, long-tailed ducks need to actively feed during the molt period because their energy reserves cannot sustain them during this period (Flint *et al.* 2003). Lacroix *et al.* (2003) stated there was no clear response by the ducks to seismic surveying, even when the seismic vessels were in visual range. However, there may be effects that were too subtle to be detected by this study. The presence of long-tailed ducks within several 2.5-km radii of the sound source was monitored, but it was not possible to determine short-distance movements in response to seismic activities. Diving behavior of long-tailed ducks also was monitored by radio-telemetry, because direct observations may have induced bias due to the presence of observers. Therefore, it is unclear whether changes in diving frequency were due to disturbance from seismic vessels or local abundance of prey items. For instance, ducks may dive more in response to disturbances from vessels or they may dive less to avoid underwater noises related to airguns. Further behavioral observations would be necessary to characterize the response of long-tailed ducks to seismic surveys, even though the Lacroix *et al.* (2003) study found no effect of seismic surveying activity on movements or diving behavior of long-tailed ducks.

Information collected by onboard observers during seismic surveys conducted in the Beaufort and Chukchi Seas indicated that at-sea densities of birds are low. Preliminary review of these survey data indicated that no bird species/groups occurred at a density greater than 1 bird/km^2. Murres, as a group, were found at the highest density, approximately 0.7 birds/km^2, followed by Larids (jaegers, gulls, and kittiwakes) at 0.5 birds/km^2. The only other birds noted were fulmars (n = 5) and one "unidentified small dark auklet" (MMS 2007a). Therefore, any disturbance to the coastal and marine birds in the proposed in-ice survey area is expected to be insignificant.

Seismic airguns have the potential to alter the availability of marine bird prey. Research indicates that there are few effects on invertebrates from noise produced by airguns, unless the invertebrate is within a few feet of the source (Brand and Wilson 1996; McCauley 1994). Consequently, noises from seismic airguns are not likely to decrease the availability of invertebrate crustaceans, bivalves, or mollusks.

It is possible that seismic surveys might affect fish and invertebrates in proximity to the airgun array (see discussion in Section 4.2.2.2). However, the effects of seismic surveys on marine fish that might change their availability to marine birds have not been documented under field operating conditions. If forage fishes are displaced by airgun noise, birds feeding on those resources might be temporarily displaced and stop feeding within a few kilometers of the survey activities.

It is possible, during the course of normal feeding or escape behavior that some birds could be near enough to an airgun to be injured by a pulse. The threshold for physiological damage, namely to the auditory system, for marine birds is unknown. Although NMFS has no information about the circumstances where this might occur, the reactions of birds to airgun noise suggest that a bird would have to be very close to the airgun to receive a pulse strong enough to cause injury, if that were possible at all. A mitigation measure to "ramp-up," which is a gradual increase in decibel level as the seismic activities begin, can allow diving birds to hear the start up of the seismic survey and help disperse them before harm occurs. During ongoing surveys, diving birds also are likely to hear the advance of the slow-moving survey vessel and associated airgun operations and move away. Mitigation measures to ramp up airguns for use and to document bird reactions to marine and seismic survey activities may help further evaluate the potential for marine birds to be harmed by airgun noises.

Collision with Vessels

Migrating birds colliding into manmade structures has been well documented in the literature. Weather conditions such as storms associated with rain, snow, icing, and fog or low clouds at the time of the occurrences often are attributed as causal factors (Weir 1976; Brown 1993). Lighting of structures, which can be intensified by fog or rain, also has been identified as a factor (Avery *et al.* 1980; Brown 1993; Jehl 1993). Birds are attracted to the lights, become disoriented, and may collide with the light support structure (e.g., pole, tower, or vessel).

Lights on fishing vessels at sea have been known to attract large numbers of seabirds during storms (Dick and Donaldson 1978). Black (2005) reported a collision of about 900 birds, mostly a variety of petrel species and Antarctic prion, with a 75-m fishing trawler near South Georgia. The collisions took place over a 6-hour period at night, when visibility was less than 1 nautical mile (nmi) due to fog and rain. Of the 900 birds on deck, 215 were dead. Most of the remaining birds were released alive after being allowed to dry off in boxes stored in a protected area on deck. Waterfowl and shorebirds also have been documented as colliding with lighted structures and boats at sea (Schorger 1952; *Day et al.* 2003).

Marine birds are at risk of collisions with seismic-survey vessels at night due to attraction and subsequent disorientation from high-intensity lights on ships. Sea ducks are vulnerable to collisions with seismic-survey vessels, primarily because they tend to fly low over the water. Johnson and Richardson (1982) documented that 88% of eiders migrating to molting areas along the Beaufort Sea coast flew below an estimated 10 m (32 ft) and more than 50% flew below 5 m (16 ft). Eiders (various species) leaving the North Slope travel day or night. Movement rates (birds/hour) did not differ between night and day, but movement rates and velocities were higher on nights with good visibility (Day *et al.* 2004).

Identification and avoidance of marine mammals is an important mitigation measure to prevent harmful impacts to marine mammals from seismic surveys. High-intensity lights are needed during the seismic surveys to help spot marine mammals during nighttime operations or when visibility is hampered by rain or fog. A mitigation measure to not use high-intensity lights when not needed can reduce the potential that marine birds would be attracted to and strike the seismic survey vessel (MMS 2006).

4.2.2.4 Effects on Marine Mammals

During in-ice seismic surveys, marine mammals potentially could be adversely affected by noise and disturbance both from the acoustic sources from seismic surveys, icebreaking activity, and vessels involved in the survey. Marine mammals conceivably could be struck by ships or boats during seismic surveys.

4.2.2.4a Effects of Airgun on Marine Mammals

The effects of sounds from airgun pulses might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and, at least in theory, temporary or permanent hearing impairment or non-auditory effects (Richardson *et al.* 1995a). As outlined in previous NMFS documents, the effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson *et al.* 1995a):

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. Numerous studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response (see review by Richardson *et al.* 1995a; Southall *et al.* 2007). That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times, mammals of all three types have shown no overt reactions. In general, pinnipeds and small odontocetes seem to be more tolerant of exposure to airgun pulses than baleen whales.

Behavioral Disturbance

The biological significance of many behavioral disturbances is difficult to predict, especially if the detected disturbances appear minor. While many behavioral responses would not be expected to likely affect the fitness of an individual, other more severe behavioral modifications, especially in certain circumstances, could potentially have adverse affects on growth, survival, and/or reproduction. Some more potentially significant behavioral modifications include: drastic change in diving/surfacing patterns (such as those thought to be potentially associate with beaked whale stranding due to exposure to military mid-frequency tactical sonar) or longer-term habitat abandonment

For example, at the Guerreo Negro Lagoon in Baja California, Mexico, which is one of the important breeding grounds for Pacific gray whales, shipping and dredging associated with a salt works may have induced gray whales to abandon the area through most of the 1960s (Bryant *et al*. 1984). After these activities stopped, the lagoon was reoccupied, first by single whales and later by cow-calf pairs.

The onset of behavioral disturbance from anthropogenic sound, which is difficult to predict, depends on both external factors (e.g., characteristics of sound sources and their paths) and the receiving animals (hearing, motivation, experience, demography) (Southall *et al*. 2007).

Currently NMFS uses 160 dB re 1 μPa (rms) received level for impulse noises (such as airgun pulses) as the threshold for the onset of Level B (behavioral) harassment.

In addition, behavioral disturbance is also expressed as the change in vocal activities of animals. For example, there is one recent summary report indicating that calling fin whales distributed in one part of the North Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that preliminary paper whether the whales ceased calling because of masking, or whether this was a behavioral response not directly involving masking (i.e., important biological signals for marine mammals being “masked” by anthropogenic sound; see below). Also, 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; 2009b). Some of the changes in marine mammal vocal communication are thought to be used to compensate for acoustic masking resulting from increased anthropogenic noise (see below). For example, blue whales are found to increase call rates when exposed to seismic survey noise in the St. Lawrence Estuary (Di Iorio and Clark 2009). Researchers have noted North Atlantic right whales (*Eubalaena glacialis*) exposed to high shipping noise increase call frequency (Parks *et al*. 2007) and intensity (Parks *et al.* 2010), while some humpback whales respond to low-frequency active sonar playbacks by increasing song length (Miller *el al.* 2000). These behavioral responses could also have adverse effects on marine mammals.

Mysticete: Baleen whales generally tend to avoid operating airguns, but avoidance distances are quite variable among species, locations, whale activities, oceanographic conditions affecting sound propagation, etc. (reviewed in Richardson *et al.* 1995a; Gordon *et al.* 2004). Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong sound pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. Some of the major studies and reviews on this topic are Malme *et al.* (1984, 1985, 1988); Richardson *et al.* (1986, 1995a, 1999); Ljungblad *et al.* (1988); Richardson and Malme (1993); McCauley *et al.* (1998, 2000a, 2000b); Miller *et al.* (1999, 2005); Gordon *et al.* (2004); Moulton and Miller (2005); Stone and Tasker (2006); Johnson *et al.* (2007); Nowacek *et al.* (2007) and Weir (2008). Although baleen whales often show only slight overt responses to operating airgun arrays (Stone and Tasker 2006; Weir 2008), strong avoidance reactions by several species of mysticetes have been observed at ranges up to 6 – 8 km and occasionally as far as 20 – 30 km from the source vessel when large arrays of airguns were used. Experiments with a single airgun showed that bowhead, humpback and gray whales all showed localized avoidance to a single airgun of 20 – 100 in^3 (Malme *et al.* 1984, 1985, 1986, 1988; Richardson *et al.* 1986; McCauley *et al.* 1998, 2000a, 2000b).

Studies of gray, bowhead, and humpback whales have shown that seismic pulses with received levels of 160 – 170 dB re 1 μPa (rms) seem to cause obvious avoidance behavior in a substantial portion of the animals exposed (Richardson *et al.* 1995a). In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4 – 15 km (2.5 – 9.3 mi) from the source. More recent studies have shown that some species of baleen whales (bowheads and humpbacks in particular) at times show strong avoidance at received levels lower than 160 – 170 dB re 1 μPa (rms). The largest avoidance radii involved migrating bowhead whales, which avoided an operating seismic vessel by 20 – 30 km (12.4 – 18.6 mi) (Miller *et al.* 1999; Richardson *et al.* 1999). In the cases of migrating bowhead (and gray) whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme *et al.* 1984; Malme and Miles 1985; Richardson *et al.* 1995a). Feeding bowhead whales, in contrast to migrating whales, show much smaller avoidance distances (Miller *et al.* 2005; Harris *et al.* 2007), presumably because moving away from a food concentration has greater cost to the whales than does a course deviation during migration.

Baleen whales generally tend to avoid operating airguns, but avoidance distances are variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, studies of migrating humpback and migrating bowhead whales done since the late 1990s show reactions, including avoidance, that sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel can be biased. Observations over broader areas may be needed to determine the range of potential effects of some large-source seismic surveys where effects on cetaceans may extend to considerable distances (Richardson *et al.* 1999; Moore and Angliss 2006). Longer-range observations, when required, can sometimes be obtained via systematic aerial surveys or aircraft-based observations of behavior (e.g., Richardson *et al.* 1986, 1999; Miller et al. 1999, 2005; Yazvenko et al. 2007a, 2007b) or by use of observers on one or more support vessels operating in coordination with the seismic vessel (e.g., Smultea *et al.* 2004; Johnson *et al.* 2007). However, the presence of other vessels near the source vessel can, at least at times, reduce sightability of cetaceans from the source vessel (Beland *et al.* 2009), thus complicating interpretation of sighting data.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioral changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

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 diminish to these levels at distances ranging from 4 - 15 km (2.5 – 9.3 mi) from the source. A substantial proportion of the baleen whales within such distances may show avoidance or other strong disturbance reactions to the operating airgun array. However, in other situations, various mysticetes tolerate exposure to full-scale airgun arrays operating at even closer distances, with only localized avoidance and minor changes in activities. At the other extreme, in migrating bowhead whales, avoidance often extends to considerably larger distances (20 – 30 km [12.4 – 18.6 mi]) and lower received sound levels (120–130 dB re 1 μPa (rms)). Also, even in cases where there is no conspicuous avoidance or change in activity upon exposure to sound pulses from distant seismic operations, there are sometimes subtle changes in behavior (e.g., surfacing–respiration–dive cycles) that are only evident through detailed statistical analysis (e.g., Richardson *et al.* 1986; Gailey *et al.* 2007).

Mitigation measures for seismic surveys, especially nighttime seismic surveys, typically assume that many marine mammals (at least baleen whales) tend to avoid approaching airguns, or the seismic vessel itself, before being exposed to levels high enough for there to be any possibility of injury. This assumes that the ramp-up (soft-start) procedure is used when commencing airgun operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As noted above, single-airgun experiments with three species of baleen whales show that those species typically do tend to move away when a single airgun starts firing nearby, which simulates the onset of a ramp up. The three species that showed avoidance when exposed to the onset of pulses from a single airgun were gray whales (Malme *et al.* 1984, 1986, 1988); bowhead whales (Richardson *et al.* 1986; Ljungblad *et al.* 1988); and humpback whales (Malme *et al.* 1985; McCauley *et al.* 1998, 2000a, 2000b). Since startup of a single airgun is equivalent to the start of a ramp-up (i.e., soft start), this strongly suggests that many baleen whales will begin to move away during the initial stages of a ramp-up and thereby reduce the potential for adverse physical impacts.

Data on short-term reactions by cetaceans to impulsive noises do not necessarily indicate there are associated long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme *et al.* 1984; Richardson *et al.* 1995a), and there has been a substantial increase in the population over recent decades (Allen and Angliss 2010). The western Pacific gray whale population did not seem adversely affected by a seismic survey in its feeding ground during a prior year (Johnson *et al.* 2007). Similarly, bowhead whales have 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), and their numbers have increased notably during that same time period (Allen and Angliss 2010). Bowheads also have been observed over periods of days or weeks in areas ensonified repeatedly by seismic pulses (Richardson *et al.* 1987; Harris *et al.* 2007). However, it is generally not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. In any event, in the absence of some unusual circumstances, the history of coexistence between seismic surveys and baleen whales suggests that brief exposures to sound pulses from any single seismic survey are unlikely to result in prolonged effects.

Odontocete: Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales. However, there are recent systematic data on sperm whales (e.g., Gordon *et al.* 2006; Madsen *et al.* 2006; Winsor and Mate 2006; Jochens *et al.* 2008; Miller *et al.* 2009). There is also an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea *et al.* 2004; Moulton and Miller 2005; Bain and Williams 2006; Holst *et al.* 2006; Stone and Tasker 2006; Potter *et al.* 2007; Hauser *et al.* 2008; Holst and Smultea 2008; Weir 2008; Barkaszi *et al.* 2009; Richardson *et al.* 2009).

Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies near the U.K., Newfoundland and Angola, in the Gulf of Mexico, and off Central America have shown localized avoidance. Also, belugas summering in the Canadian Beaufort Sea showed larger-scale avoidance, tending to avoid waters out to 10 – 20 km (6.2 – 12.4 mi) from operating seismic vessels. In contrast, recent studies show little evidence of conspicuous reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are few specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from tactical military mid-frequency sonars. However, there are no beaked whales present in the proposed action area.

Overall, odontocete reactions to large arrays of airguns are variable and, at least for delphinids and some porpoises, seem to be confined to a smaller distance than has been observed for some mysticetes. However, other data suggest that some odontocete species, including belugas and harbor porpoises, may be more responsive than might be expected given their poor low-frequency hearing. Reactions at longer distances may be particularly likely when sound propagation conditions are conducive to transmission of the higher-frequency components of airgun sound to the animals' location (DeRuiter *et al.* 2006; Goold and Coates 2006; Tyack *et al.* 2006; Potter *et al.* 2007).

For delphinids, and possibly the Dall's porpoise, the available data suggest that individuals may not react until sounds are ≥170 dB re 1 μPa (rms). With a medium-to-large airgun array, received levels typically diminish to 170 dB within 1 – 4 km (0.62 – 2.5 mi), whereas levels typically remain above 160 dB out to 4 – 15 km (2.5 –

9.3 mi) (e.g., Tolstoy *et al.* 2009). Reaction distances for delphinids are more consistent at the typical 170 dB re 1 µPa (rms) distances. Stone (2003) and Stone and Tasker (2006) reported that all small odontocetes (including killer whales) observed during seismic surveys in UK waters remained significantly further from the source during periods of shooting on surveys with large volume airgun arrays than during periods without airgun shooting.

Due to their relatively higher frequency hearing ranges when compared to mysticetes, odontocetes may have stronger responses to mid- and high-frequency sources such as sub-bottom profilers, side scan sonar, and echo sounders than mysticetes (Richardson *et al.* 1995a; Southall *et al.* 2007). Although the mid- and high-frequency active acoustic sources with operating frequency between 2 and 50 kHz that are proposed to be used by Ion have much lower power outputs (167 – 200 dB re 1 µPa-m at source level) than those from the airguns, they could cause mild behavioral reactions to odontocete whales because their operating frequencies fall within the sensitive hearing range of these animals. However, scientific information is lacking regarding behavioral responses by odontocetes to mid- and high-frequency sources. Nevertheless, based on our current knowledge on mysticete reaction towards low-frequency airgun pulses, we could induce that more or less similar reactions could be exhibited by odontocete whales towards mid- and high-frequency sources.

Pinnipeds: Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review of the early literature, see Richardson *et al.* 1995a). However, pinnipeds have been observed during a number of seismic monitoring studies. Monitoring in the Beaufort Sea during 1996 – 2002 provided a substantial amount of information on avoidance responses (or lack thereof) and associated behavior. Additional monitoring of that type has been done in the Beaufort and Chukchi Seas in 2006 – 2009. Pinnipeds exposed to seismic surveys have also been observed during seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of pinnipeds exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, gray seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons in Greene *et al.* 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear. Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves *et al.* 1996). Thus, pinnipeds are expected to be rather tolerant of, or to habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. These studies show that many pinnipeds do not avoid the area within a few hundred meters of an operating airgun array. However, based on the studies with large sample size, or observations from a separate monitoring vessel, or radio telemetry, it is apparent that some phocid seals do show localized avoidance of operating airguns. The limited nature of this tendency for avoidance is a concern. It suggests that pinnipeds may not move away, or move very far away, before received levels of sound from an approaching seismic survey vessel approach those that may cause hearing impairment.

Polar Bear: Airgun effects on polar bears have not been studied, but would likely be minimal. When swimming, polar bears normally keep their heads above or at the water's surface, where underwater noise is weak or undetectable (Richardson *et al.* 1995a). Direct impacts potentially causing TTS from the seismic surveys are possible if animals entered the 190-dB zone immediately surrounding the sound source, just like pinnipeds discussed above.

For most of the year, polar bears are not very sensitive to noise or other human disturbances (Amstrup 1993). However, pregnant females and those with newborn cubs in maternity dens are sensitive to noise and vehicular traffic (Amstrup and Garner 1994). Vessel traffic associated with seismic-survey activity is not expected to cause impacts to polar bears, because they show little reaction to vessels and generally do not linger in open water. Brueggeman *et al.* (1991) observed polar bears in the Chukchi Sea during oil and gas activities and recorded their response to an icebreaker. While bears did respond (walking toward, stopping and watching, walking/swimming away) to the vessel, their responses were brief. Seismic surveys have the potential to disturb polar bears that are swimming between ice floes or between the pack ice and shore. Swimming can be energetically expensive for polar bears, particularly for bears that engage in long-distance travel between the leading ice edge and land. Bears that encounter seismic operations may be temporarily deflected from their chosen path, and some may choose to return to where they came from. However, bears swimming to shore are most likely heading for reliable food sources (i.e., Native-harvested marine mammal carcasses on shore), for which they have a strong incentive to continue their chosen course. Therefore, although some bears may be temporarily deflected and or inhibited from continuing toward land due to seismic operations, this interruption likely would be brief in duration.

Masking

Masking is the obscuring of sounds of interest by other sounds, often at similar frequencies. Chronic exposure to excessive, though not high-intensity, noise could cause masking at particular frequencies for marine mammals that utilize sound for vital biological functions. Masking can interfere with detection of acoustic signals such as communication calls, echolocation sounds, and environmental sounds important to marine mammals. Since marine mammals depend on acoustic cues for vital biological functions, such as orientation, communication, finding prey, and avoiding predators, marine mammals that experience severe acoustic masking could have reduced fitness in survival and reproduction (Clark *et al.* 2009a).

Masking occurs when noise and signals (that animal utilizes) overlap at both spectral and temporal scales. For the airgun noise generated from the proposed in-ice marine seismic survey, these are low frequency (under 1 kHz) pulses with extremely short durations (in the scale of milliseconds). Lower frequency man-made noises are more likely to affect detection of communication calls and other potentially important natural sounds such as surf and prey noise. There is little concern regarding masking 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 (e.g., bowhead and gray whales) when they occur near the noise band and thus reduce the communication space of animals (e.g., Clark *et al.* 2009a, 2009b) and cause increased stress levels (e.g., Foote *et al.* 2004; Holt *et al.* 2009). However, in areas of shallow water, multipath propagation of airgun pulses could be more profound, thus affect communication signals from marine mammals even at close distances. Nevertheless, the intensity of the noise is also greatly reduced at such long distances.

Although masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, there are few specific studies on this. Some whales continue calling in the presence of seismic pulses and whale calls often can be heard between the seismic pulses (e.g., Richardson *et al.* 1986; McDonald *et al.* 1995; Greene *et al.* 1999a, 1999b; Nieukirk *et al.* 2004; Smultea *et al.* 2004; Holst *et al.* 2005a, 2005b, 2006; Dunn and Hernandez 2009). However, there is one recent summary report indicating that calling fin whales distributed in one part of the North Atlantic went silent for an extended period starting soon after the onset of a seismic survey in the area (Clark and Gagnon 2006). It is not clear from that preliminary paper whether the whales ceased calling because of masking, or whether this was a behavioral response not directly involving masking. Also, 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; 2009b).

Among the odontocetes, there has been one report that sperm whales ceased calling when exposed to pulses from a very distant seismic ship (Bowles *et al.* 1994). However, more recent studies of sperm whales found that they continued calling in the presence of seismic pulses (Madsen *et al.* 2002; Tyack *et al.* 2003; Smultea *et al.* 2004; Holst *et al.* 2006; Jochens *et al.* 2008). Madsen *et al.* (2006) noted that airgun sounds would not be expected to mask sperm whale calls given the intermittent nature of airgun pulses. Dolphins and porpoises are also commonly heard calling while airguns are operating (Gordon *et al.* 2004; Smultea *et al.* 2004; Holst *et al.* 2005a, 2005b; Potter *et al.* 2007). Masking effects of seismic pulses are expected to be inconsequential in the case of the smaller odontocetes, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are the dominant components of airgun sounds.

Pinnipeds have best hearing sensitivity and/or produce most of their sounds at frequencies higher than the dominant components of airgun sound, but there is some overlap in the frequencies of the airgun pulses and the calls. However, the intermittent nature of airgun pulses presumably reduces the potential for masking.

Marine mammals are thought to be able to compensate for masking by adjusting their acoustic behavior such as shifting call frequencies, increasing call volume and vocalization rates. For example, blue whales are found to increase call rates when exposed to seismic survey noise in the St. Lawrence Estuary (Di Iorio and Clark 2009). The North Atlantic right whales (*Eubalaena glacialis*) exposed to high shipping noise increase call frequency (Parks *et al.* 2007), while some humpback whales respond to low-frequency active sonar playbacks by increasing song length (Miller *el al.* 2000).

Hearing Impairment

Marine mammals exposed to high intensity sound repeatedly or for prolonged periods can experience hearing threshold shift (TS), which is the loss of hearing sensitivity at certain frequency ranges (Kastak *et al.* 1999; Schlundt *et al.* 2000; Finneran *et al.* 2002; 2005). TS can be permanent (PTS), in which case the loss of hearing sensitivity is unrecoverable, or temporary (TTS), in which case the animal's hearing threshold will recover over time (Southall *et al.* 2007). Just like masking, marine mammals that suffer from PTS or TTS may have reduced fitness in survival and reproduction, either permanently or temporarily. Repeated sound exposure that leads to TTS could cause PTS. For transient sounds, the sound level necessary to cause TTS is inversely related to the duration of the sound.

TTS: 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. It is a temporary phenomenon, and (especially when mild) is not considered to represent physical damage or "injury" (Southall *et al.* 2007). Rather, the onset of TTS is an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility.

The magnitude of TTS depends on the level and duration of noise exposure, and to some degree on frequency, among other considerations (Kryter 1985; Richardson *et al.* 1995a; Southall et al. 2007). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. In terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. Only a few data have been obtained on sound levels and durations necessary to elicit mild TTS in marine mammals (none in mysticetes), and none of the published data concern TTS elicited by exposure to multiple pulses of sound during operational seismic surveys (Southall *et al.* 2007).

For toothed whales, experiments on a bottlenose dolphin (*Tursiops truncates*) and beluga whale showed that exposure to a single watergun impulse at a received level of 207 kPa (or 30 psi) peak-to-peak (p-p), which is equivalent to 228 dB re 1 μPa (p-p), resulted in a 7 and 6 dB TTS in the beluga whale at 0.4 and 30 kHz, respectively. Thresholds returned to within 2 dB of the pre-exposure level within 4 minutes of the exposure (Finneran *et al.* 2002).

Finneran *et al.* (2005) further examined the effects of tone duration on TTS in bottlenose dolphins. Bottlenose dolphins were exposed to 3 kHz tones (non-impulsive) for periods of 1, 2, 4 or 8 seconds (s), with hearing tested at 4.5 kHz. For 1-s exposures, TTS occurred with sound exposure levels (SELs) of 197 dB, and for exposures >1 s, SEL >195 dB resulted in TTS (SEL is equivalent to energy flux, in dB re 1 μPa^2-s). At an SEL of 195 dB, the mean TTS (4 min after exposure) was 2.8 dB. Finneran *et al.* (2005) suggested that an SEL of 195 dB is the likely threshold for the onset of TTS in dolphins and belugas exposed to tones of durations 1 – 8 s (i.e., TTS onset occurs at a near-constant SEL, independent of exposure duration). That implies that, at least for non-impulsive tones, a doubling of exposure time results in a 3 dB lower TTS threshold.

However, the assumption that, in marine mammals, the occurrence and magnitude of TTS is a function of cumulative acoustic energy (SEL) is probably an oversimplification. Kastak *et al.* (2005) reported preliminary evidence from pinnipeds that, for prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer, i.e., the results were not fully consistent with an equal-energy model to predict TTS onset. Mooney *et al.* (2009a) showed this in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130 to 178 dB re 1 μPa for periods of 1.88 to 30 minutes (min). Higher SELs were required to induce a given TTS if exposure duration was short than if it was longer. Exposure of the aforementioned bottlenose dolphin to a sequence of brief sonar signals showed that, with those brief (but non-impulse) sounds, the received energy (SEL) necessary to elicit TTS was higher than was the case with exposure to the more prolonged octave-band noise (Mooney *et al.* 2009b). Those authors concluded that, when using (non-impulse) acoustic signals of duration ~0.5 s, SEL must be at least 210 – 214 dB re 1 μPa^2-s to induce TTS in the bottlenose dolphin. Most recent studies conducted by Finneran *et al.* (2010a, 2010b) also support the notion that exposure duration has a more significant influence compared to sound pressure level (SPL) as the duration increases, and that TTS growth data are better represented as functions of SPL and duration rather than SEL alone (Finneran *et al.* 2010a, 2010b). In addition, Finneran et al. (2010b) conclude that when animals are exposed to intermittent noises, there is recovery of hearing during the quiet intervals between exposures through the accumulation of TTS across multiple exposures. Such findings suggest that when exposed to multiple seismic pulses, partial hearing recovery also occurs during the seismic pulse intervals.

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 lower than those to which odontocetes are most sensitive, and natural ambient noise levels at those low frequencies tend to be higher (Urick 1983). 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). From this, it is suspected that received levels causing TTS onset may also be higher in baleen whales. However, no cases of TTS are expected to result from the proposed action given the small size of the airguns proposed to be used and the strong likelihood that baleen whales (especially migrating bowheads) would avoid the approaching airguns (or vessel) before being exposed to levels high enough for there to be any possibility of TTS.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from prolonged exposures suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak *et al.* 1999, 2005). However, more recent indications are that TTS onset in the most sensitive pinniped species studied (harbor seal, which is closely related to the ringed seal) may occur at a similar SEL as in odontocetes (Kastak *et al.* 2004).

There are no available data on TTS in polar bears. However, TTS is unlikely to occur in polar bears if they are on the water surface, given the pressure release and Lloyd's mirror effects at the water's surface.

Most cetaceans show some degree of avoidance of seismic vessels operating an airgun array (see above). It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high enough level for a sufficiently long enough period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. TTS would be more likely in any odontocetes that bow- or wake-ride or otherwise linger near the airguns. However, while bow- or wake-riding, odontocetes would be at the surface and thus not exposed to strong sound pulses given the pressure release and Lloyd Mirror effects at the surface. But if bow- or wake-riding animals were to dive intermittently near airguns, they could be exposed to strong sound pulses, possibly repeatedly.

If some cetaceans did incur mild or moderate TTS (a Level B harassment) through exposure to airgun sounds in this manner, this would very likely be a temporary and reversible phenomenon. However, even a temporary reduction in hearing sensitivity could be deleterious in the event that, during that period of reduced sensitivity, a marine mammal needed its full hearing sensitivity to detect approaching predators.

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are generally not as strong or consistent as those of cetaceans. Pinnipeds occasionally seem to be attracted to operating seismic vessels. There are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses.

However, given the indirect indications of a lower TTS threshold for the harbor seal than for odontocetes exposed to impulse sound (see above), it is possible that some pinnipeds within the 190-dB isopleths for a prolonged time of a large airgun array could incur TTS.

Current NMFS' noise exposure standards require that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 μPa (rms). These criteria were taken from recommendations by an expert panel of the High Energy Seismic Survey (HESS) Team that did assessment on noise impacts by seismic airguns to marine mammals in 1997, although the HESS Team recommended a 180-dB limit for pinnipeds in California (HESS 1999). The 180 and 190 dB re 1 μPa (rms) levels have not been considered to be the levels above which TTS might occur. Rather, they were the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above, data that are now available imply that TTS is unlikely to occur in various odontocetes (and probably mysticetes as well) unless they are exposed to a sequence of several airgun pulses stronger than 180 dB re 1 μPa (rms). On the other hand, for the harbor seal, harbor porpoise, and perhaps some other species, TTS may occur upon exposure to one or more airgun pulses whose received level equals the NMFS "do not exceed" value of 180 dB re 1 μPa (rms). That criterion corresponds to a single-pulse SEL of 175–180 dB re 1 μPa^2-s in typical conditions, whereas TTS is suspected to be possible in harbor seals and harbor porpoises with a cumulative SEL of ~171 and ~164 dB re 1 μPa^2-s, respectively.

It has been shown that most marine mammals show at least localized avoidance of ships and/or seismic operations. Even when avoidance is limited to the area within a few hundred meters of an airgun array, that should usually be sufficient to avoid TTS based on what is currently known about thresholds for TTS onset in cetaceans. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans near the airguns at the time of startup (if the sounds are aversive) to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. Thus, most baleen whales likely will not be exposed to high levels of airgun sounds provided the ramp-up procedure is applied. Likewise, many odontocetes close to the trackline are likely to move away before the sounds from an approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment.

PTS: When PTS occurs, there is physical damage to 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). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times. (Rise time is the interval required for sound pressure to increase from the baseline pressure to peak pressure.)

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the potential that some marine mammals may remain within the 180 or 190 dB isopleths from an airgun array for a prolonged time and might incur at least mild TTS (see above), there has been further speculation about the possibility that some individuals occurring within these safety zones that experienced repeated TTS might also incur PTS (e.g., Richardson *et al.* 1995a; Gedamke *et al.* 2008). Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated exposures to levels that may cause PTS, or (in some cases) single exposures to a level well above that causing TTS onset, might elicit PTS.

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). 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 >6 dB higher (Southall *et al.* 2007). The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak *et al.* 1999; Schlundt *et al.* 2000; Finneran *et al.* 2002, 2005; Nachtigall *et al.* 2003, 2004). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson *et al.* 1995a; Southall *et al.* 2007). However, there is special concern about strong sounds whose pulses have very rapid rise times. In terrestrial mammals, there are situations when pulses with rapid rise times (e.g., from explosions) can result in PTS even though their peak levels are only a few dB higher than the level causing slight TTS. The rise time of airgun pulses is fast, but not as fast as that of an explosion.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- exposure to single very intense sound,
- fast rise time from baseline to peak pressure,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

More recently, Southall *et al.* (2007) estimated that received levels would need to exceed the TTS threshold by at least 15 dB, on an SEL basis, for there to be risk of PTS. Thus, for cetaceans exposed to a sequence of sound pulses, they estimate that the PTS threshold might be an M-weighted SEL (for the sequence of received pulses) of ~198 dB re 1 μPa^2-s. Additional assumptions had to be made to derive a corresponding estimate for pinnipeds, as the only available data on TTS-thresholds in pinnipeds pertained to nonimpulse sound (see above). Southall *et al.* (2007) estimated that the PTS threshold could be a cumulative SEL of ~186 dB re 1 μPa^2-s in the case of a harbor seal exposed to impulse sound. The PTS threshold for the California sea lion and northern elephant seal would probably be higher given the higher TTS thresholds in those species. Southall *et al.* (2007) also note that, regardless of the SEL, there is concern about the possibility of PTS if a cetacean or pinniped received one or more pulses with peak pressure exceeding 230 or 218 dB re 1 μPa, respectively. Thus, PTS might be expected upon exposure of cetaceans to either SEL ≥198 dB re 1 μPa^2-s or peak pressure ≥230 dB re 1 μPa. Corresponding proposed dual criteria for pinnipeds (at least harbor seals) are ≥186 dB SEL and ≥ 218 dB peak pressure (Southall *et al.* 2007). These estimates are all first approximations, given the limited underlying data, assumptions, species differences, and evidence that the "equal energy" model may not be entirely correct.

Sound impulse duration, peak amplitude, rise time, number of pulses, and inter-pulse interval are the main factors thought to determine the onset and extent of PTS. Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

As described above for TTS, in estimating the amount of sound energy required to elicit the onset of TTS (and PTS), it is assumed that the auditory effect of a given cumulative SEL from a series of pulses is the same as if that amount of sound energy were received as a single strong sound. There are no data from marine mammals concerning the occurrence or magnitude of a potential partial recovery effect between pulses. In deriving the estimates of PTS (and TTS) thresholds quoted here, Southall *et al.* (2007) made the precautionary assumption that no recovery would occur between pulses.

There is some concern about bowriding odontocetes, but for animals at or near the surface, auditory effects are reduced by Lloyd's mirror and surface release effects. The presence of the vessel between the airgun array and bow-riding odontocetes could also, in some but probably not all cases, reduce the levels received by bow-riding animals (e.g., Gabriele and Kipple 2009). The TTS (and thus PTS) thresholds of baleen whales are unknown but, as an interim measure, assumed to be no lower than those of odontocetes. Also, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. The TTS (and thus PTS) thresholds of some pinnipeds (e.g., harbor seal) as well as the harbor porpoise may be lower (Kastak *et al.* 2005; Southall *et al.* 2007; Lucke *et al.* 2009). If so, TTS and potentially PTS may extend to a somewhat greater distance for those animals. Again, Lloyd's mirror and surface release effects will ameliorate the effects for animals at or near the surface. NMFS considers PTS to be a Level A harassment.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in many marine mammals, caution is warranted given:

- the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales, and pinnipeds;

- the seemingly greater susceptibility of certain species (e.g., harbor porpoise and harbor seal) to TTS and presumably also PTS; and

- the lack of knowledge about TTS and PTS thresholds in many species, including various species closely related to the harbor porpoise and harbor seal.

The avoidance reactions of many marine mammals, along with commonly-applied monitoring and mitigation measures (visual and passive acoustic monitoring, ramp ups, and power downs or shut downs when mammals are detected within or approaching the "safety radii" – see Chapter 5), would further reduce the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

Non-auditory Physical Effects

Based on evidence from terrestrial mammals and humans, sound is a potential source of stress (Wright *et al.* 2007a, 2007b). However, almost no information is available on sound-induced stress in marine mammals, or on its potential (alone or in combination with other stressors) to affect the long-term well-being or reproductive success of marine mammals (Fair and Becker 2000; Hildebrand 2005; Wright *et al.* 2007a, 2007b). Such long-term effects, if they occur, would be mainly associated with chronic noise exposure, which is characteristic of some seismic surveys and exposure situations (McCauley *et al.* 2000b; Nieukirk *et al.* 2009) but not of some others.

Available data on potential stress-related impacts of anthropogenic noise on marine mammals are extremely limited, and additional research on this topic is needed. NMFS is aware of only three specific studies of noise-induced stress in marine mammals. (1) Romano *et al.* (2004) examined the effects of single underwater impulse sounds from a seismic water gun (source level up to 228 dB re 1 μPa (p–p)) and single short-duration pure tones (sound pressure level up to 201 dB re 1 μPa) on the nervous and immune systems of a beluga and a bottlenose dolphin. They found that neural-immune changes to noise exposure were minimal. Although levels of some stress-released substances (e.g., catecholamines) changed significantly with exposure to sound, levels returned to baseline after 24 hr. (2) During playbacks of recorded drilling noise to four captive beluga whales, Thomas *et al.* (1990) found no changes in blood levels of stress-related hormones. Long-term effects were not measured, and no short-term effects were detected. (3) Rolland *et al.* (2012) showed that reduced ship traffic in the Bay of Fundy, Canada, following the events of 11 September 2001 was associated with decreased baseline levels of stress-related faecal hormone metabolites (glucocorticoids) in the North Atlantic right whale (*Eubalaena glacialis*). The reduction of the noise level was measured to be 6 dB, with a significant reduction below 150 Hz. This is the first evidence that exposure to low-frequency ship noise may be associated with chronic stress in whales, and has implications for all baleen whales in heavy ship traffic areas. For all these three studies, caution is necessary when extrapolating these results to other species and to real-world situations given the small sample sizes.

Aside from stress, other types of physiological effects that might, in theory, be involved in beaked whale strandings upon exposure to naval sonar (Cox *et al.* 2006), such as resonance and gas bubble formation, have not been demonstrated and are not expected upon exposure to airgun pulses. If seismic surveys disrupt diving patterns of deep-diving species, this might perhaps result in bubble formation and a form of “the bends”, as speculated to occur in beaked whales exposed to sonar. However, there is no specific evidence that exposure to airgun pulses has this effect.

In summary, very little is known about the potential for seismic survey sounds (or other types of strong underwater sounds) to cause non-auditory physiological effects in marine mammals. Such effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. The available data do not allow identification of a specific exposure level above which non-auditory effects can be expected (Southall *et al.* 2007), or any meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways.

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 in marine waters for commercial seismic surveys or (with rare exceptions) for seismic research; they have been replaced by airguns and other non-explosive sources. Airgun pulses are less energetic and have slower rise times, and there is no specific evidence 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 and, in one case, a 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). Hildebrand (2005) reviewed the association of cetacean strandings with high-intensity sound events and found that deep-diving odontocetes, primarily beaked whales, were by far the predominant (95%) cetaceans associated with these events, with 2% mysticete whales (minke). However, as summarized below, there is no definitive evidence that airguns can lead to injury, strandings, or mortality even for marine mammals in close proximity to large airgun arrays.

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 increasing 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. The evidence for this remains circumstantial and associated with exposure to naval mid-frequency sonar, not seismic surveys (Cox *et al.* 2006; Southall *et al.* 2007).

Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz. Typical military mid-frequency sonar emit non-impulse sounds at frequencies of 2 – 10 kHz, generally with a relatively narrow bandwidth at any one time (though the frequency may change over time). Thus, it is not appropriate to assume that the effects of seismic surveys on beaked whales or other species would be the same as the apparent effects of military sonar. For example, resonance effects (Gentry 2002) and acoustically-mediated bubble-growth (Crum *et al.* 2005) are implausible in the case of exposure to broadband airgun pulses. Nonetheless, 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. One of the hypothesized mechanisms by which naval sonar lead to strandings might, in theory, also apply to seismic surveys: If the strong sounds sometimes cause deep-diving species to alter their surfacing–dive cycles in a way that causes bubble formation in tissue, that hypothesized mechanism might apply to seismic surveys as well as mid-frequency naval sonar. However, there is no specific scientific evidence of this effect as a result of exposure to airgun pulses.

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 seismic vessel R/V *Maurice Ewing* was operating a 20-airgun, 8,490-in^3 airgun array in the general area. The evidence linking the stranding to the seismic survey was inconclusive and not based on any physical evidence (Yoder 2002 in LGL 2008). The ship was also operating its multibeam echosounder at the same time, but this had much less potential than the aforementioned naval sonar to affect beaked whales, given its downward-directed beams, much shorter pulse durations, and lower duty cycle. Nonetheless, the Gulf of California incident associated with the L-DEO survey plus the beaked whale stranding events that have been documented near certain naval exercises involving use of mid-frequency military tactical 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). However, beaked whales do not inhabit the area where the proposed action would occur so they are not a concern in this case.

4.2.2.4b Effects of Icebreaking Activity on Marine Mammals

Limited information is available about the effects of icebreaking ships on most species of marine mammals. Early concerns arose due to proposals (which were never realized) to conduct shipping of oil and gas in the Arctic via large icebreakers (Peterson 1981). Smaller icebreaking ships have been used by the oil and gas industry in the Beaufort and Chukchi seas to extend the offshore drilling period in support of offshore drilling, and several icebreakers or strengthened cargo ships have been used in the Russian northern sea route as well as elsewhere in the Arctic and Antarctic (Armstrong 1984; Barr and Wilson 1985; Brigham 1985).

The primary concern regarding icebreaking activities involves the production of underwater sound (Richardson *et al.* 1995a). Vessel sounds from the ice-breaking cargo vessel MV Arctic were estimated to be detectable by seals under fast ice at distances up to 20-35 km (Davis and Malme 1997). However, icebreaking activities may also have non-acoustic effects such as the potential for causing injury, ice entrapment of animals that follow the ship, and disruption of ice habitat (reviewed in Richardson *et al.* 1989:315). The species of marine mammals that may be present and the nature of icebreaker activities are strongly influenced by ice type. Some species are more common in loose ice near the margins of heavy pack ice while others appear to prefer heavy pack ice. Propeller cavitation noise created by icebreaking ships travelling through loose or thin ice is likely similar to that in open water. In contrast, icebreaker noise is expected to be much greater in areas of heavier pack ice or thick landfast ice where ship speed would be reduced, power levels would be higher, and there would be greater propeller cavitation (Richardson *et al.* 1995a).

Erbe and Farmer (1998) measured masked hearing thresholds of a captive beluga whale. They reported that the recorded noise of a Canadian Coast Guard ship, *Henry Larsen*, ramming ice in the Beaufort Sea, masked recordings of beluga vocalizations at a noise-to-signal pressure ratio of 18 dB. In linear units, the ramming noise was 8 times as strong as the call (Erbe and Farmer 1998). A similar study using a software model to estimate the zones of impact around icebreakers affecting beluga whales in the Beaufort Sea predicted that masking of beluga communication signals by ramming noise from an icebreaker could occur within 40–71 km, depending on the location. However, Arctic beluga whales have shown avoidance of icebreakers when first detected (Erbe and Farmer 2000; see below), so individuals are unlikely to get close enough for potentially harmful effects such as masking to occur. In addition, vocal behavior of beluga whales in the St, Lawrence in the presence of a ferry and a small motorboat have shown that belugas can change the types of calls they use, as well as shift the mean call frequency upward during noise exposure (Lesage *et al.* 1999). Furthermore, few belugas are expected to remain within the survey area during the October–December period. Therefore, masking effects of icebreaking activities on beluga whales are expected to be negligible for the proposed survey.

In 1991 and 1994 in the Alaskan Beaufort Sea, Richardson *et al.* (1995b) recorded reactions of beluga and bowhead whales to playbacks of underwater propeller cavitation noise from the icebreaking supply ship *Robert Lemeur* operating in heavy ice. Migrating belugas were observed close to the playback projectors on three dates, but interpretable data were only collected on 17 groups for two of these occasions. A minimum of six groups apparently altered their path in response to the playback, but whales approached within a few hundred (and occasionally tens of) meters before exhibiting a response. Icebreaker sound levels were estimated at 78–84 dB re 1µPa in the 1/3-octave band centered at 5,000 Hz, or 8–14 dB above ambient sound levels in that band, for the six groups that reacted. The authors estimated that reactions at this level would be estimated to occur at distances of ~10 km (6.2 mi) from an operating icebreaker.

Beluga whales are expected to avoid icebreaking vessels at distances of ~10 km (6.2 mi). The impacts of icebreaking associated with the seismic program on the behavior of belugas are expected to be temporary, lasting only as long as the activity is on-going in the vicinity, and would not have any effect on the beluga population. Also, as noted above, belugas are expected to be scarce within the operating area during October–December, so any disturbance effects are expected to be infrequent.

In 1991 and 1994 in the Alaskan Beaufort Sea, Richardson *et al.* (1995b) recorded reactions of beluga and bowhead whales to playbacks of underwater propeller cavitation noise from the icebreaking supply ship *Robert Lemeur* operating in heavy ice. Bowhead whales migrating in the nearshore zone appeared to tolerate exposure to projected icebreaker sounds at received levels up to 20 dB or more above ambient noise levels. However, some bowheads appeared to divert their paths to remain further away from the projected sounds, particularly when exposed to levels >20 dB above ambient. Turning frequency, surface duration, number of blows per surfacing, and two multivariate indices of behavior were significantly correlated with the signal-to-noise ratio >20 dB (and as low as 10 dB for turning frequency). The authors suggested that bowheads may commonly react to icebreakers at distances up to 10–50 km (6.2 – 31 mi), but note that reactions were very dependent on several variables not controlled in the study.

There are few other studies on the reactions of baleen whales to icebreaking activities. During fall 1992, migrating bowhead whales apparently avoided (by at least 25 km [15.5 mi]) a drillsite that was supported near-daily by intensive icebreaking activity in the Alaskan Beaufort Sea (Brewer *et al*. 1993). However, bowheads also avoided a nearby drillsite in the fall of another year that had little icebreaking support (LGL and Greeneridge 1987). Thus, it is difficult or impossible to distinguish the effects of icebreaking, ice concentration, and drilling noise.

Bowhead whales are expected to avoid vessels that are underway, especially icebreakers that are breaking ice and producing additional sound during that activity. However, during the planned project, icebreaking would affect the behavior of bowheads only if bowheads are still in the study area during the early part of the seismic project and if there is much ice cover at that time. Most bowheads will likely have passed through the survey area prior to the start of survey activities. The effects of icebreaking activities on bowhead whales are expected to be minor and short-term.

Reactions of walruses to icebreakers are probably described more thoroughly than are reactions by other pinnipeds. When comparing the reaction distances of walruses to icebreaking ships vs. other ships traveling in open water, Fay *et al.* (1984) found that walruses reacted at longer distances to icebreakers. They were aware of the icebreaker when it was >2 km away, and females with pups entered the water and swam away when the ship was ~1 km away while adult males did so at distances of 0.1 to 0.3 km (0.06 – 0.18 mi). However, it was also noted that some walruses, ringed seals, and bearded seals also climbed onto ice when an icebreaker was oriented toward them.

Ringed and bearded seals on pack ice approached by an icebreaker typically dove into the water within 0.93 km (0.58) of the vessel, but tended to be less responsive when the same ship was underway in open water (Brueggeman *et al.* 1992). In another study, ringed and harp seals remained on the ice when an icebreaker was 1–2 km away, but seals often dove into the water when closer to the icebreaker (Kanik *et al.* 1980 in Richardson *et al.* 1995a). Ringed seals have also been seen feeding among overturned ice floes in the wake of icebreakers (Brewer *et al.* 1993).

Although documentation on effects of other marine mammals to icebreakers is limited due to their low occurrence, it is nevertheless reasonable to assume that other marine mammals will have similar responses to icebreakers and be affected in similar ways.

Ringed seals and any bearded seals encountered in October–December during the planned project would not include any newborn pups. At that time of year, there would be no concern about crushing of ringed seal pups in lairs, or about seal pups being forced into the water at an early age.

Seals swimming are likely to avoid approaching vessels by a few meters to a few tens of meters, while some "curious" seals are likely to swim toward vessels. Seals hauled out on ice also show mixed reaction to approaching vessels/icebreakers. Seals are likely to dive into the water if the icebreaker comes within 1 km. The potential impact of vessel traffic on seals is expected to be negligible due to the very limited number of vessels (2) and the slow speed of the vessels used during the proposed survey.

Little information is available on the reactions of polar bears to icebreaking activities. Polar bears apparently show little reaction to shipping, with some bears briefly walking, running, or swimming away in a localized area (Fay *et al.* 1984) or others showing no reaction (Brueggeman *et al.* 1991). It is likely that the ION icebreaker will encounter polar bears; however, the impact of vessel traffic on polar bears is expected to be negligible due to the very limited number of vessels (2) used during the proposed survey.

4.2.2.4c Effects of Vessel Presence and Noise on Marine Mammals

In addition to the noise generated from seismic airguns and active sonar systems, various types of vessels will be used in the operations, including source vessels and support vessels. Sounds from boats and vessels and their potential impacts to the overall marine environment are discussed in Section 4.2.1.3.

Whales have been shown to alter their behavior around various vessels, including whale-watching and fishing boats (Williams *et al.* 2002). For example, in the presence of whale-watching and fishing boats in Johnstone Strait, British Columbia, killer whales increased their travel budgets by 12.5% and reduced the time they spent feeding. These lost feeding opportunities could have resulted in a substantial estimated decrease in energy intake. These observations suggest that, in order to lessen the potential impacts of human activities, avoiding impacts to important feeding areas would provide considerable benefits to cetaceans and other marine mammals that are sensitive to human disturbance.

Marine mammals may temporarily move away from areas of heavy vessel activity but re-inhabit the same area when traffic is reduced (Allen and Read 2000; Lusseau 2004), or they may abandon a once-preferred region for as long as disturbance persists (Gerrodette and Gilmartin 1990). For example, evidence exists indicating killer whales evade potentially harmful noise on annual and regional spatial scales (Morton and Symonds 2002). When animals switch from short-term evasive tactics to long-term site avoidance in response to increasing disturbance, the costs of tolerance have likely exceeded the benefits of remaining in previously preferred habitat. For example, in a long-term study in Shark Bay Western Australia, cumulative vessel activity related to ecotourism (i.e., whale watching vessels) was shown to result in a decline in abundance of bottlenose dolphins over a relatively short time (Bejder *et al.* 2006). The authors attributed this to the long-term displacement of dolphins away from the area of disturbance. For animals such as cetaceans that exhibit enduring, individually specific social relationships, disruption of social bonds through displacement of sensitive individuals may have far-reaching repercussions (Bejder *et al.* 2006). Given the scarcity of long-term studies to fully evaluate the potential impacts of human activities, a cumulative impact, like those detected in Shark Bay and Johnstone Strait, could go unnoticed for decades. Thus, management measures must consider information from well-documented study sites, where long-term information can be taken into account (Bejder *et al.* 2006).

Noise, rather than the simple presence of vessels, seems the likeliest mechanism for vessels to alter whale behavior. It is perhaps unsurprising that cetaceans have been shown to shorten their feeding bouts and initiate fewer of them in the presence of ships and boats. For marine mammals, it is reasonable to assume that larger and noisier vessels, such as seismic and ice-breaking ships, would have greater and more dramatic impacts upon behavior than would smaller vessels.

Nevertheless, the proposed in-ice seismic survey by ION would only involve two vessels during a limited period. Both seismic vessel and icebreaker, which would be moving at speeds of 3 – 5 kt, would not be expected to cause "takes" of marine mammals if not for their intense active sources. All vessels involved in the proposed seismic surveys are small in tonnage compared to large container ships, therefore, their source levels, if not engaged in icebreaking activities, are expected to be much lower than vessels used in commercial shipping.

In addition to acting as a source of noise and disturbance, vessels used in the proposed in-ice seismic survey could potentially strike marine mammals, causing injury or death. However, due to the extremely low marine mammal density and slow speed of operating vessels during the proposed surveys, vessel strike incidents are very unlikely.

4.2.2.4d Effects of the Proposed Activity on Marine Mammal Habitat

The proposed airgun operations would not result in any permanent impact on habitats used by marine mammals, or to their food sources. The main impact issue associated with the proposed activities will be temporarily elevated noise levels and their associated direct effects on marine mammals, as discussed above, as well as the potential effects of icebreaking. The potential effects of icebreaking include locally altered ice conditions and the potential for the destruction of ringed seal lairs or polar bear dens. However, these animals are not expected to enter these structures until later in the season. Ice conditions at this time of year are typically quite variable with new leads opening and pressure ridges forming as wind and waves move the newly forming ice. This dynamic environment may be responsible for the mean date of permanent den entry on sea ice in the Beaufort Sea being later than on land (Amstrup and Gardner 1994). The icebreaker and seismic vessel transit is not expected to significantly alter the formation of sea ice during this period.

Icebreaking will open leads in the sea ice along the vessel tracklines and could potentially destroy ringed seal lairs or polar bear dens. However, ringed seals will not need lairs for pupping until March or April (Hammill 2009), so the impacts are not expected to impact pup survival. Ringed seals excavate lairs in snow that accumulates on sea ice near their breathing holes, and an individual seal maintains several breathing holes (Smith and Stirling 1975). Ringed seal lairs are found in snow depths of 20 – 150 cm (Smith and Stirling 1975), and seals are not expected to enter lairs before the survey takes place. Damage to lairs caused by survey activities is not expected to exceed that which occurs naturally, and lair destruction in the early winter would likely not impact ringed seal survival. Lanugal pups born in the spring can become hypothermic if wetted, but by early winter they are robust to submersion having spent the entire summer at sea (Smith *et al.* 1991). The highest density of ringed seals reported from aerial surveys conducted during spring when seals were emerging from lairs was in areas with water depth ranging from 5 – 35 m (Frost *et al.* 2004). A relatively small proportion (5%; 364 km) of the proposed survey trackline is planned in that area.

Refueling at sea has the potential to impact the marine environment if a spill were to occur. However, there are multiple procedures and safeguards in place to avoid such an accident. Prior to conducting a fuel transfer the area around the vessels would be checked for the presence of marine mammals and operations delayed until the area was clear. A leak during refueling would be detected and the system shut down within a maximum of 30 seconds. The diesel oil transfer pump is rated at 50 IGPM @ 60 ft pressure head. Therefore, the maximum amount of oil that could be spilled during a transfer is 25 imperial gallons. This risk is reduced further with the standard use of 'dry-break' fittings for fuel transfers.

4.2.3 Effects on Socioecomic Environment

4.2.3.1 Effects on Community and Economy

The proposed in-ice seismic survey activities in the Beaufort and Chukchi Seas would have no more than minimal, if any, effects on the human population, infrastructure, and government organization of the communities closest to the project areas. The Beaufort and Chukchi Seas communities in the vicinity of the proposed in-ice seismic survey activities include Kaktovik, Nuiqsut, and Barrow.

Very few economic effects are anticipated for the affected communities as a result of the proposed ION in-ice seismic survey. The seismic source vessel and icebreaker will be self-contained. Subsistence is a large component of both the NSB and NWAB economies and is essential to the way of life in the Beaufort and Chukchi villages. Because of the timing of the proposed in-ice marine seismic survey activity, NMFS expects that there would be no unmitigable effects on subsistence activities.

Nevertheless, ION's seismic survey project will potentially have a positive effect on employment for residents of the NSB and NWAB. Employment opportunities would include temporary positions for Protected Species Observers (PSOs) on the vessels. Iñupiat PSOs will be hired to work on the vessels for the duration of the projects.

Increased NSB and NWAB employment and personal income could be generated if exploration, development, and production activities occurred in the future. Generally, employment and associated personal income expectations related to oil and gas activities are low during the limited seasons of exploration, peak during development, and drop to a plateau during production.

Aside from PSO jobs, NMFS expects no immediate economic development directly resulting from the ION's seismic survey. If the project leads to future exploration, development and production, there may be an opportunity for economic development in both the NSB and the NWAB. These potential, indirect effects are beyond the scope of this document, and evaluation of these will be required at a later date if exploration occurs.

4.2.3.2 Effects on Subsistence

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.

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives; species hunted include bowhead and beluga whales; ringed, spotted, and bearded seals; walruses, and polar bears. The importance of each of the various species varies among the communities based largely on availability. Bowhead whales are the marine mammal species primarily harvested during the time of the proposed seismic survey. Subsistence remains the basis for Alaska Native culture and community, and subsistence activities are often central to many aspects of human existence, including patterns of family life, artistic expression, and community religious and celebratory activities.

Noise and icebreaking activity during ION's proposed in-ice marine seismic surveys 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. Additionally, vessel presence in the vicinity of traditional hunting areas could negatively impact a hunt.

Bowhead Whales: Bowhead whale hunting is the key activity in the subsistence economies of Barrow and two smaller communities along the Beaufort Sea and Chukchi coast. Whale harvests have a great influence on social relations by strengthening the sense of Inupiat culture and heritage in addition to reinforcing family and community ties.

An overall quota system for the hunting of bowhead whales was established by the International Whaling Commission in 1977. The quota is now regulated through an agreement between NMFS and the Alaska Eskimo Whaling Commission (AEWC). The AEWC allots the number of bowhead whales that each whaling community may harvest annually during five-year periods (USDOI/BLM 2005).

The community of Barrow hunts bowhead whales in both the spring and fall during the whales' seasonal migrations along the coast. Often, the bulk of the Barrow bowhead harvest is taken during the spring hunt. However, with larger quotas in recent years, it is common for a substantial fraction of the annual Barrow quota to remain available for the fall hunt. The communities of Nuiqsut and Kaktovik participate only in the fall bowhead harvest. The fall migration of bowhead whales that summer in the eastern Beaufort Sea typically begins in late August or September. Fall migration into Alaskan waters is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene *et al.* 1999a; Blackwell *et al.* 2004b).

The spring hunts at Wainwright and Barrow occurs after leads open due to the deterioration of pack ice; the spring hunt typically occurs from early April until the first week of June. The location of the fall subsistence hunt depends on ice conditions and (in some years) industrial activities that influence the bowheads movements as they move west (Brower 1996). The fall migration of bowhead whales that summer in the eastern Beaufort Sea typically begins in late August or September. Fall migration through Alaskan waters is primarily during September and October. In the fall, subsistence hunters use aluminum or fiberglass boats with outboards. Hunters prefer to take bowheads close to shore to avoid a long tow during which the meat can spoil, but Braund and Moorehead (1995) report that crews may (rarely) pursue whales as far as 80 km. The autumn hunt at Barrow usually begins in mid-September, and mainly occurs in the waters east and northeast of Point Barrow. The whales have usually left the Beaufort Sea by late October (Treacy 2002a; b).

The scheduling of ION's proposed in-ice seismic survey was introduced to representatives of those concerned with the subsistence bowhead hunt including the AEWC and the North Slope Borough (NSB) Department of Wildlife Management during a meeting in Barrow on December 15, 2009. Additional meetings are being planned in order to share information regarding the survey with other members of the subsistence hunting community. The timing of the proposed geophysical survey in October–December would not affect the spring bowhead hunt. The fall bowhead hunt may be occurring near Barrow during October, and operations would be coordinated with the AEWC.

Beluga Whales: Beluga whales are available to subsistence hunters at Barrow in the spring when pack-ice conditions deteriorate and leads open up. Belugas may remain in the area through June and sometimes into July and August in ice-free waters. Hunters usually wait until after the spring bowhead whale hunt is finished before turning their attention to hunting belugas. The average annual harvest of beluga whales taken by Barrow for 1962–1982 was five (MMS 1996). The Alaska Beluga Whale Committee recorded that 23 beluga whales had been harvested by Barrow hunters from 1987 to 2002, ranging from 0 in 1987, 1988 and 1995 to the high of 8 in 1997 (Fuller and George 1999, Alaska Beluga Whale Committee 2002 in USDOI/BLM 2005). During 2003-2005, the average annual beluga whale harvest for Barrow was 3 (Appendix C in MMS 2007a). The timing of ION's proposed in-ice seismic survey will not overlap with the beluga harvest.

Ringed Seals: Ringed seals are hunted mainly from October through June. Hunting for these smaller mammals is concentrated during winter because bowhead whales, bearded seals and caribou are available through other seasons. In winter, leads and cracks in the ice off points of land and along the barrier islands are used for hunting ringed seals. The proposed in-ice seismic survey would be largely in offshore waters where the activities will not influence ringed seals in the nearshore areas where they are hunted.

Spotted Seals: The spotted seal subsistence hunt peaks in July and August, at least in 1987 to 1990, but involves few animals. Spotted seals typically migrate south by October to overwinter in the Bering Sea, and therefore the proposed October–December survey will not affect hunting of this species. Admiralty Bay, <60 km to the east of Barrow, is a location where spotted seals are harvested. Spotted seals are also occasionally hunted in the area off Point Barrow and along the barrier islands of Elson Lagoon to the east (USDOI/BLM 2005). The average annual spotted seal harvest by the community of Barrow from 1987–1990 was one (Braund *et al.* 1993).

Bearded Seals: Bearded seals, although not favored for their meat, are important to subsistence activities in Barrow because of their skins. Six to nine bearded seal hides are used by whalers to cover each of the skin-covered boats traditionally used for spring whaling. Because of their valuable hides and large size, beard-ed seals are specifically sought. Bearded seals are harvested during the summer months in the Beaufort Sea (USDOI/BLM 2005). The animals inhabit the environment around the ice floes in the drifting ice pack, so hunting usually occurs from boats in the drift ice. Braund *et al.* (1993) mapped the majority of bearded seal harvest sites from 1987 to 1990 as being within ~24 km (~15 mi) of Point Barrow. The average annual take of bearded seals by the Barrow community from 1987 to 1990 was 174. Because bearded seal hunting typically occurs during the summer months, the proposed October–December survey is not expected to affect bearded seal harvests.

In the event that both marine mammals and hunters were near the *Geo Arctic* when it is conducting operations near Barrow, the proposed project potentially could impact the availability of marine mammals for the harvest in a very small area immediately around the *Geo Arctic*.

ION's proposed in-ice seismic survey would not occur during the primary period when marine mammals are typically harvested. Also, the seismic survey would be largely in offshore waters where the activities will not influence marine mammals in the nearshore and coastal areas where they are hunted. Therefore, the proposed in-ice marine seismic surveys in the Beaufort and Chukchi Seas are not expected to have any significant adverse effects to the whale and seal subsistence harvest.

4.2.4 Effects on Coastal and Marine Use

ION's proposed in-ice seismic survey activity in the Beaufort and Chukchi Seas is not anticipated to have any effect on the coastal and marine uses or the recreational and visual resources in the project areas. The proposed project is expected to be conducted in areas and time 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 seismic acquisition project. The presence of a seismic survey vessel and an icebreaker in the proposed survey area during fall/winter months will have no effect on current levels of cruise or recreational vessels over the span of the in-ice marine seismic survey. The planned in-ice marine seismic survey will have no effect on commercial fishing, recreational fishing, or mariculture, as none of these is known to exist in the Beaufort and Chukchi Sea.

It is anticipated that the proposed marine and seismic activities will not have effects on coastal and marine uses.

4.3 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 the proposed actions. The methods to estimate take by harassment and present estimates of the numbers of marine mammals that might be affected during ION's proposed in-ice marine seismic survey is described in detail in ION's IHA application and the proposed IHA, which was published in the *Federal Register* on August 17, 2012 (77 FR 49922). Specifically, the average estimate of "take" for each species was calculated by multiplying the expected average species densities by the area of ensonification for the 160 dB re 1 μPa (rms) for seismic airgun exposures in the survey region, in addition to the area of ensonification for the 120 dB re 1 μPa (rms) for icebreaking activities when seismic airgun is not operating, and habitat zone to which that density applies.

4.3.1 Potential Number of Level B Takes

The marine mammal species NMFS believes likely to be taken by Level B harassment incidental to ION's proposed in-ice 2D marine seismic survey in the Beaufort and Chukchi

Seas during the fall/winter 2012 are: beluga whale, harbor porpoise, bowhead whale, gray whale, minke whale, bearded seal, ribbon seal, ringed seal, and spotted seal. Takes are most likely to result from noise propagation during the use of airguns. Most anticipated takes would be by Level B harassment, involving temporary changes in behavior. The required mitigation and monitoring measures are described in Chapters 5 and 6 of this EA.

It is estimated that up to 5,232 beluga whales, 23 harbor porpoise, 284 bowhead whales, 23 gray whales, 23 minke whales, 60,574 ringed seals, 95 bearded seals, 23 spotted seals, and 23 ribbon seals would be taken by Level B harassment incidental to the proposed in-ice seismic survey program that would be conducted by ION. These take numbers represent up to 13.33% of the Eastern Chukchi Sea stock of beluga whales, 0.05% of the Bering Sea stock of harbor porpoise, 3.4% of the Bering-Chukchi-Beaufort stock of bowhead whales, 0.12% of the Eastern North Pacific stock of gray whales, 1.87% of the Alaska stock of minke whales, and 24.33%, 0.04%, 0.04%, and 0.05% of the Alaska stocks of ringed, bearded, spotted, and ribbon seals, respectively (Tables 4-2 through 4-4).

4.3.2 Potential Number of Level A Takes

Due to the limited effectiveness of monitoring and mitigation measures for animals under ice cover and during long lowlight hours, NMFS is proposing to authorize takes of marine mammals by TTS (Level B harassment) and PTS (Level A harassment or injury) when exposed to received noise levels above 180 and 190 dB re 1 μPa (rms) for prolonged periods, although this is unlikely to occur. Therefore, the result of the analysis is conservative in which animals are estimated to be affected by receiving TTS or even PTS.

Table 4-2. Estimates of the possible numbers of marine mammals exposed to ≥160 dB re 1 μPa (rms) during ION's proposed seismic program in the Beaufort and Chukchi Seas, October – December 2012.

Cetaceans	Water Depth			Total
	<200 m	200-1,000 m	>1,000 m	
Beluga whale	43	1,195	3,077	4,215
Harbor porpoise	9	2	10	21
Bowhead whale	269	3	10	282
Gray whale	9	2	10	21
Minke whale	9	2	10	21
Pinnipeds (Beaufort East)	Water Depth			Total
	<35 m	35-200 m	>200 m	
Ringed seal	1,794	805	25	2,624
Bearded seal	9	4	25	38
Spotted seal	2	1	6	9
Ribbon seal	2	1	6	9
Pinnipeds (Beaufort West & Chukchi Sea)	<35 m	35-200 m	>200 m	Total
Ringed seal	16,969	40,682	18	57,669
Bearded seal	4	25	18	47
Spotted seal	1	6	5	12
Ribbon seal	1	6	5	12

Table 4-3. Estimates of the possible numbers of marine mammals exposed to ≥120 dB re 1 μPa (rms) during icebreaking activities associated with the preferred alternative for refueling during ION's proposed seismic program in the Beaufort Sea, October – December 2012.

Species	Water Depth		Total
	200-1,000 m	>1,000 m	
Beluga whale	253	320	573
Harbor porpoise	0	1	1
Bowhead whale	1	1	2
Gray whale	0	1	1
Minke whale	0	1	1
Ringed seal	181	3	184
Bearded seal	1	3	4
Spotted seal	0	1	1
Ribbon seal	0	1	1

Although all marine mammal species identified above could be exposed to icebreaking activities, the species most likely to be present in the Alaskan Beaufort Sea late in the survey period are the beluga and bowhead whales, and the ringed seal. Although in most circumstances marine mammals would avoid areas where intense noise could cause injury, including PTS, there is still some slight chance that animals may choose to stay for some reason. A modeled calculation shows that approximate 23 beluga whales, 8 bowhead whales, and 38 seals (presumably all ringed seals) would be exposed to received levels above 180 dB re 1 μPa (for whales) and 190 dB re 1 μPa (for seals), respectively. Assuming that 10% of the individuals that are initially exposed to received levels above 180 dB re 1 μPa (for beluga and bowhead whales) and 190 dB re 1 μPa (for ringed seals) do not vacate the area, and subsequent exposure leads to some degree of PTS, then approximately 3 beluga whales, 1 bowhead whale, and 4 ringed seals could be taken by Level A harassment. However, NMFS considers this estimate to be very conservative.

Table 4-4. Estimates of the possible numbers of marine mammals exposed to ≥120 dB re 1 μPa (rms) during icebreaking activities associated with the secondary alternative for refueling during ION's proposed seismic program in the Beaufort and Chukchi Seas, October – December 2012.

Species	Water Depth		Total
	200-1,000 m	>1,000 m	
Beluga whale	417	500	917
Harbor porpoise	0	2	2
Bowhead whale	1	2	3
Gray whale	0	2	2
Minke whale	0	2	2
Ringed seal	273	8	281
Bearded seal	2	8	10
Spotted seal	0	2	2
Ribbon seal	0	2	2

4.4 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. 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 affected nine marine mammal species and their habitats.

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 action area are discussed in the following subsections.

4.4.1 Past Commercial Whaling

Commercial hunting between 1848 and 1915 caused severe depletion of the bowhead population(s) that inhabits the Bering, Chukchi, and Beaufort 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-1800's (Schmitt *et al.* 1980; Reeves and Barto, 1985). In the 1900's, 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.

4.4.2 Subsistence Hunting

4.4.2.1 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 Alaska Eskimo Whaling Commission (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, Alaskan Native hunters from 10 villages 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 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.

4.4.2.2 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 to 2006 (Allen and Angliss 2010). 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 2010).

4.4.2.3 Ice Seals

The Division of Subsistence, Alaska Department of Fish and Game (ADFG) maintains a database that provides additional information on the subsistence harvest of ice seals in different regions of Alaska (ADFG 2000a; 2000b). 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.

At this time, there are no efforts to quantify the current level of harvest of bearded seals by all Alaska communities. However, the U.S. Fish and Wildlife Service collects information on the level of ice seal harvest in five villages during their Walrus Harvest Monitoring Program. Results from this program indicated 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).

4.4.3 Climate Change

Global and regional climates have changed throughout the Earth's history, but warming during the past several decades on the North Slope and vicinity has been unusually rapid (NRC 2003b). Changes associated with arctic warming complicate and confound the assessment and isolation of the effects of oil and gas activities on the North Slope and the Beaufort and Chukchi seas. If recent warming trends continue, their effects could accumulate to alter the extent and timing of sea ice; affect the composition, distribution, and abundance of marine and terrestrial plants and animals; affect permafrost; affect existing oil-field infrastructure; and affect coastal Alaskan Native subsistence cultures (NRC 2003b).

The scientific evidence indicates that average air, land, and sea temperatures are increasing at an accelerating rate. Although climate changes have been documented over large areas of the world, the changes are not uniform and affect different areas in different ways and intensities. Arctic regions have experienced some of the largest changes, with major implications for the marine environment as well as for coastal communities. Recent assessments of climate change, conducted by international teams of scientists (Gitay *et al.* 2002; ACIA 2004; IPCC 2007), have reached several conclusions of consequence for this SEA:

- Average Arctic temperatures increased at almost twice the global average rate in the past 100 years.

- Satellite data since 1978 show that perennial arctic sea ice extent has shrunk by 2.7% per decade, with larger decreases in sea ice extent in summer of 7.4% per decade.

- Ice cover in the Arctic Ocean has been shrinking by about 3% per decade over the past 20 years (Johannessen *et al.* 1999), and that the Arctic may be reverting in some ways to initial conditions not seen since the 1970s (NOAA 2006).

- Arctic sea ice thickness has declined by about 40% during the late summer and early autumn in the last three decades of the twentieth century.

- The ice pack is retreating from the land sooner in the spring and reforming later in the fall. This affects the timing of phytoplankton blooms and zooplankton concentrations.

- The ice pack is retreating further seaward than in the past, which creates larger areas of open water near coastal areas and leads to larger waves, higher storm surges, and accelerated rates of coastal erosion. This dynamic is exacerbated by rising sea levels due to thermal expansion of seawater and other sources.

- The arctic tundra is warming rapidly, causing permafrost to thaw deeper in the summer and over much larger areas than previously observed, accompanied by substantial changes in vegetation and hydrology.

- The melting ice pack, melting glaciers, and increased precipitation are adding large amounts of freshwater to the sea, causing decreases in salinity that may combine with longer ice-free seasons to affect the timing and intensity of phytoplankton blooms.

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 led to the disappearance of the Thule culture (McGhee 1984; Tynan and DeMaster 1997, citing Aagaard and Carmack 1994). 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 SOI deep seismic surveys (Funk *et al.* 2008) 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 most recent analysis of climate change (IPCC 2007) concluded that there is very strong evidence for global warming and associated weather changes and that humans have "very likely" contributed to the problems through burning fossil fuels and adding other "greenhouse gasses" to the atmosphere. This study involved numerous models to predict changes in temperature, sea level, ice pack dynamics, and other parameters under a variety of future conditions, including different scenarios for how human populations respond to the implications of the study. It is not clear how governments and individuals will respond or how much these future efforts will reduce greenhouse gas emissions. Although the intensity of climate changes will depend on how quickly and deeply humanity responds, the models predict that the climate changes observed in the past 30 years will continue at the same or increasing rates for at least 20 years.

The implications of these trends 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 and polar bears. 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 proposed oil and gas activities that may take marine mammals would likely need to undergo separate reviews and analyses as part of the MMPA and NEPA processes.

4.4.4 Geophysical Survey and Oil and Gas Development

4.4.4.1 Marine and Seismic Surveys

BOEM-permitted seismic surveys have been conducted in the Federal waters of the Beaufort Sea since the late 1960's/early 1970's (MMS 2007a). For activities since July 2010, NMFS issued an IHA to Shell to take 8 species of marine mammals by Level B behavioral harassment incidental to conducting site clearance and shallow hazards surveys in the Beaufort Sea on August 6, 2010 (75 FR 49710; August 13, 2010). No seismic surveys were conducted in the Beaufort Sea in 2011.

Besides the proposed in-ice seismic surveys being analyzed here in this EA, BP Exploration (Alaska), Inc. (BPXA) is currently conducting an open-water ocean-bottom-cable seismic survey in the Simpson Lagoon area of the Beaufort Sea between July and October 2012. BP's open-water seismic survey uses a total of three seismic source vessels (two main source vessels and one mini source vessel). The sources are arrays of sleeve airguns. Each main source vessel would carry an array that consists of two sub-arrays. Each sub-array contains eight 40 in^3 airguns, totaling 16 guns per main source vessel with a total discharge volume of 2×320 in^3, or 640 in^3. NMFS issued an IHA to BPXA to take small numbers of marine mammals by Level B harassment incidental to this seismic survey on June 29, 2012.

Given the growing interest of oil and gas companies to explore and develop oil and gas resources on the Arctic Ocean OCS, seismic surveys will continue in the Beaufort Sea into the near future and be dependent on: (1) the amount of data that is collected in 2012; and (2) what the data indicate about the subsurface geology. NMFS anticipates that future marine and seismic surveys will continue as the demands on oil and gas are expected to grow worldwide.

Available information, however, indicates that marine and seismic surveys for oil and gas exploration activities have had no detectable long-term adverse population-level effects on the overall health, current status, or recovery of marine mammal species and populations in the Arctic region. For example, data indicate that the BCB bowhead whale population has continued to increase over the timeframe that oil and gas activities have occurred. There is no evidence of long-term displacement from habitat (although studies have not specifically focused on addressing this issue). Past behavioral (primarily, but not exclusively, avoidance) effects on bowhead whales from oil and gas activity have been documented in many studies. Inupiat whalers have stated that noise from seismic surveys and some other activities at least temporarily displaces whales farther offshore, especially if the operations are conducted in the main migration corridor. Monitoring studies indicate that most fall migrating whales avoid an area with a radius about 20 - 30 km around a seismic vessel operating in nearshore waters (Miller *et al.* 2002). NMFS is not aware of data, however, that indicate that such avoidance is long-lasting after cessation of the activity.

An assessment of the cumulative impacts of seismic surveys must consider the decibel levels used, location, duration, and frequency of operations from the surveys as well as other reasonably foreseeable seismic-survey activity. In general, the high-resolution, site clearance and shallow hazards surveys are of lesser concern regarding impacts to cetaceans than the deep 2D/3D surveys. High-resolution and 2D/3D seismic surveys usually do not occur in proximity to each other, as they would interfere with each others' information collection methods. This operational requirement indirectly minimizes the potential for adverse effects on marine mammals that could otherwise be exposed to areas with overlapping intense noise originating from multiple sources.

In addition, the potential for significant cumulative impacts to marine mammals from all current and proposed seismic surveys would be limited through a series of mitigation and monitoring measures (see Chapter 5).

Finally, most marine and seismic surveys are limited in space and usually occur during the open water season to avoid data acquiring systems being damaged by floating ice. Therefore, the cumulative effects of the proposed seismic survey in the Beaufort Sea are not likely to appreciably impact the existing marine environment.

4.4.4.2 Oil and Gas Development and Production

Oil and gas exploration and production activities have occurred on the North Slope since the early 1900's, and production has occurred for more than 50 years. Since the discovery and development of the Prudhoe Bay and Kuparuk oil field, more recent fields generally have been developed not in the nearshore environment, but on land in areas adjacent to existing producing areas. Pioneer Natural Resources Co. is developing its North Slope Oooguruk field, which is in the shallow waters of the Beaufort Sea approximately 8 mi northwest of the Kuparuk River unit.

BPXA is currently producing oil from an offshore development in the Northstar Unit, which is located between 3.2 and 12.9 km (2 and 8 mi) offshore from Point Storkersen in the Beaufort Sea. This development is the first in the Beaufort Sea that makes use of a subsea pipeline to transport oil to shore and then into the Trans-Alaska Pipeline System. The Northstar facility was built in State of Alaska waters on the remnants of Seal Island ~9.5 km (6 mi) offshore from Point Storkersen, northwest of the Prudhoe Bay industrial complex, and 5 km (3 mi) seaward of the closest barrier island. The unit is adjacent to Prudhoe Bay, and is approximately 87 km (54 mi) northeast of Nuiqsut, an Inupiat community. To date, it is the only offshore oil production facility north of the barrier islands in the Beaufort Sea.

On November 6, 2009, BP submitted an application requesting NMFS issue regulations and subsequent LOAs governing the taking of marine mammals, by both Level B harassment and serious injury and mortality, incidental to operation of the Northstar development in the Beaufort Sea, Alaska. Construction of Northstar was completed in 2001. The proposed activities for 2012-2017 include a continuation of drilling, production, and emergency training operations but no construction or activities of similar intensity to those conducted between 1999 and 2001. NMFS published a notice of proposed rulemaking in the Federal Register on July 6, 2011, requesting comments and information from the public (76 FR 39706). NMFS is currently working on the final rulemaking governing BP's marine mammal take authorizations for operating its Northstar facility.

In addition, Shell Offshore Inc. (Shell) plans to drill two exploration wells at two drill sites in Camden Bay, Beaufort Sea, Alaska, during the 2012 Arctic open water season (July through October). On May 2, 2012, NMFS issued an IHA to Shell Offshore Inc. (Shell) to take 8 species of marine mammals, by harassment, incidental to offshore exploration drilling on Outer Continental Shelf (OCS) leases in the Beaufort Sea, Alaska, from July 1, 2012, through October 31, 2012.

Existing onshore and offshore oil and gas development and production facilities and their associated pipelines have the potential to release industrial chemicals or spill oil. Oil spills from offshore production activities are of concern because as additional offshore oil exploration and production occurs at such projects as the Liberty, Oooguruk, and Nikaitchuq, occurs, the potential for large spills in the marine environment increases. In addition to potential oil spills from industry infrastructure, the potential also exists for oil/fuel spills to occur from associated support vessels, fuel barges, and even aircraft. However, this risk is considered slight in ice-free waters, and any spills which result from the proposed action would most likely be of small volume, and are not considered a serious threat to marine mammals in the action area. Even if a small oil/fuel spill were to occur, it would be easily avoidable by marine mammals. Any impacts to them most likely would include temporary displacement until cleanup activities are completed and short-term effects on health from the ingestion of contaminated prey (MMS 2007). However, a large scale oil spill in the Arctic could be devastating to the region's marine ecosystem.

Drilling for oil and gas in the Arctic generally occurs from natural and artificial islands, caissons, bottom-founded platforms, and ships and submersibles. With varying degrees, these operations produce low-frequency sounds with strong tonal components. Drilling occurs once a lease has been obtained for oil and gas development and production and may continue through the life of the lease.

Underwater sound from vessels operating near the Northstar facility in the Beaufort Sea often were detectable as far as 30 km offshore, while sounds from construction, drilling, and production reached background (i.e., ambient) values at a distance of 2 - 4 km. BPXA began to use hovercraft in 2003 to access Northstar, which have proven to generate considerably less underwater noise than similar-sized conventional vessels and, therefore, may be an attractive alternative when there is concern over underwater noise (Richardson and Williams 2004). Richardson and Williams (2004) concluded that there was little effect from the low-to-moderate level, low-frequency industrial sounds emanating from the Northstar facility on ringed seals during the open-water period, and that the overall effects of the construction and operation of the facility were minor, short term, and localized, with no consequences to the seal populations as a whole.

Drilling activities are expected to occur in the near future on Beaufort leases and the Northstar facility and within the Hammerhead leases and shoreline within the Point Thomson unit. Drilling in State waters is also expected to occur. Other active drilling will take place on land at sites away from coastlines.

Given this information, the duration and frequency of drilling within marine mammal habitat is anticipated to be relatively minimal and impacts are not expected to be significant.

4.4.5 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 seismic surveys are not expected to contribute substantially to these risks, as seismic exploration will occur in ice-free seas and because most marine mammals are likely to actively avoid areas in close proximity to seismic operations.

Vessel traffic in the Alaskan Arctic generally occurs within 20 km of 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 Sea 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., reach background noise levels within a 10 km distance away from vessel) and greater in deeper waters (traffic noise up to 4,000 km away may contribute to background noise levels) (Richardson *et al.* 1995a). Aside from seismic-survey vessels, 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. 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.* 1995a).

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 use leads and polynas to avoid icebreaking and to reduce transit time. Leads and polynas are critical habitat for polar bears and belugas, especially during winter and spring, and increased shipping traffic could disturb polar bears and belugas during these critical times.

4.4.6 Conclusion

Based on the analyses provided in this section, NMFS believes that the proposed ION in-ice seismic survey in the Beaufort and Chukchi Seas during the fall/winter 2012 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 and the short duration of the proposed project. In addition, mitigation and monitoring measures described in Chapter 5 are expected to further reduce any potential adverse effects.

Chapter 5 Mitigation Measures

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 (Chapter 6), that would be required under the IHA issued for the proposed in-ice marine seismic survey described earlier in this EA. Mitigation measures have been proposed by ION for its 2012 in-ice seismic survey. Additional measures have also been considered by NMFS pursuant to its authority under the MMPA to ensure that the proposed activity 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 IHA will help to ensure that takings are of small numbers, potential 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 IHA, especially those related to avoiding impacts to subsistence hunting, must be followed.

5.1 Proposed Mitigation Measures for Marine Mammals

In order to issue an incidental take authorization (ITA) under Section 101(a)(5)(D) of the MMPA, NMFS must set forth the permissible methods of taking pursuant to such activity, and other means of effecting the least practicable impact on such species or stock and its habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance, and on the availability of such species or stock for taking for certain subsistence uses.

For ION's proposed in-ice marine seismic survey in the Beaufort and Chukchi Sea, ION worked with NMFS and proposed the following mitigation measures to minimize the potential impacts to marine mammals in the project vicinity as a result of the in-ice seismic survey activities.

The proposed mitigation measures are divided into the following major groups: (1) Exclusion zones, (2) Speed or course alternation, (3) Ramp ups, (4) Power down procedures, and (5) Shutdown procedures. The primary purpose of these mitigation measures is to detect marine mammals within, or about to enter designated exclusion zones and to initiate immediate shutdown or power down of the airgun(s).

The following discussion provides details of the mitigation measures associated with the Preferred Alternative:

5.1.1 Sound Source Measurements

Under current NMFS guidelines, "safety radii" or "exclusion zones" for marine mammals around industrial sound sources are customarily defined as the distances within which received sound levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. These safety criteria are based on an assumption that sound energy at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels might have some such effects. Disturbance or behavioral effects to marine mammals from underwater sound may occur after exposure to sound at distances greater than the exclusion zone (Richardson *et al.* 1995; see above).

As discussed in Chapter 4, received sound levels were modeled for the full 28 airgun, 4,450 in^3 array in relation to distance and direction from the source (Zykov *et al.* 2010). Based on the model results, as shown in Table 4-1, the distances from the airguns where ION predicts that received sound levels will drop below 190 and 180 dB re 1 μPa (rms) exclusion zones vary depending on water depth. A single 70 in^3 airgun would be used during turns or if a power down of the full array is necessary due to the presence of a marine mammal within or about to enter the applicable exclusion zone of the full airgun array. Underwater sound propagation of a 30-in^3 airgun was measured in <100 m of water near Harrison Bay in 2007 and results were reported in Funk *et al.* (2008). The constant term of the resulting equation was increased by 2.45 dB based on the difference between the volume of the two airguns $2.45 = 20\log\left(\frac{70}{30}\right)^{1/3}$. The 190 and 180 dB (rms) distances from the adjusted equation, 19 m and 86 m respectively, would be used as the exclusion zones around the single 70 in^3 airgun in all water depths until results from field measurements are available.

An acoustics contractor would perform the direct measurements of the received levels of underwater sound versus distance and direction from the energy source arrays using calibrated hydrophones (see below "Sound Source Verification" in the "Proposed Monitoring" section). The acoustic data would be analyzed as quickly as reasonably practicable in the field and used to verify (and if necessary adjust) the size of the exclusion zones. The field report will be made available to NMFS and the Protected Species Observers (PSOs) within 120 hrs of completing the measurements. The mitigation measures to be implemented at the 190 and 180 dB (rms) sound levels would include power downs and shut downs as described below.

5.1.2 Speed or Course Alteration

If a marine mammal (in water) is detected outside the exclusion zone and, based on its position and the relative motion, is likely to enter the exclusion zone, the vessel's speed and/or direct course shall be changed in a manner that also minimizes the effect on the planned objectives when such a maneuver is safe.

Another measure proposed is to avoid concentrations or groups of whales by all vessels in transit under the direction of ION. Operators of vessels should, at all times, conduct their activities at the maximum distance possible from such concentrations of whales.

All vessels during transit shall be operated at speeds necessary to ensure no physical contact with whales occurs. If any barge or transit vessel approaches within 1.6 km (1 mi) of observed bowhead whales, the vessel operator shall take reasonable precautions to avoid potential interaction with the bowhead whales by taking one or more of the following actions, as appropriate:

(A) Reducing vessel speed to less than 5 knots within 300 yards (900 feet or 274 m) of the whale(s);

(B) Steering around the whale(s) if possible;

(C) Operating the vessel(s) in such a way as to avoid separating members of a group of whales from other members of the group;

(D) Operating the vessel(s) to avoid causing a whale to make multiple changes in direction; and

(E) Checking the waters immediately adjacent to the vessel(s) to ensure that no whales will be injured when the propellers are engaged.

When weather conditions require, such as when visibility drops, adjust vessel speed accordingly to avoid the likelihood of injury to whales.

In the event that any aircraft (such as helicopters) are used to support the planned survey, the proposed mitigation measures below would apply:

(A) Under no circumstances, other than an emergency, shall aircraft be operated at an altitude lower than 1,000 feet above sea level (ASL) when within 0.3 mile (0.5 km) of groups of whales.

(B) Helicopters shall not hover or circle above or within 0.3 mile (0.5 km) of groups of whales.

5.1.3 Ramp Ups

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 is to "warn" marine mammals 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 seismic survey program, the seismic operator will ramp up the airgun arrays slowly. Full ramp ups (i.e., from a cold start after a shut down or when no airguns have been firing) will begin by firing a single airgun in the array. In addition, a full ramp up, following a cold start, can be applied if the exclusion zone has been free of marine mammals for a consecutive 30-minute period. The entire exclusion zone must have been visible during these 30 minutes. If the entire exclusion zone is not visible, then ramp up from a cold start cannot begin.

Ramp up procedures from a cold start shall be delayed if a marine mammal is sighted within the exclusion zone during the 30-minute period prior to the ramp up. The delay shall last until the marine mammal(s) has been observed to leave the exclusion zone or until the animal(s) is not sighted for at least 15 or 30 minutes. The 15 minutes applies to small odontocetes and pinnipeds, while a 30 minute observation period applies to baleen whales and large toothed whales.

If, for any reason, electrical power to the airgun array has been discontinued for a period of 10 minutes or more, ramp-up procedures shall be implemented. Only if the PSO watch has been suspended, a 30-minute clearance of the exclusion zone is required prior to commencing ramp-up. Discontinuation of airgun activity for less than 10 minutes does not require a ramp-up.

The seismic operator and PSOs shall maintain records of the times when ramp-ups start and when the airgun arrays reach full power.

During turns and transit between seismic transects, the 70 in^3 single airgun will remain operational. The ramp up procedure will still be followed when increasing the source levels from one airgun to the full array. PSOs will be on duty whenever the airguns are firing during daylight and during the 30 minute periods prior to full ramp ups. Daylight will occur for ~11 hours/day at the start of the survey in early October diminishing to ~3 hours/day in mid-November.

5.1.4 Power Down Procedures

A power down involves decreasing the number of airguns in use such that the radii of the 190 and 180 dB re 1 μPa (rms) zones are decreased to the extent that observed marine mammals are not in the applicable exclusion zone. A power down may also occur when the vessel is moving from one seismic line to another. During a power down, only one airgun is operated. The continued operation of one airgun is intended to (a) alert marine mammals to the presence of the seismic vessel in the area, and (b) retain the option of initiating a ramp up to full array under poor visibility conditions. In contrast, a shut down is when all airgun activity is suspended (see next section).

If a marine mammal is detected outside the exclusion zone but is likely to enter the exclusion zone, and if the vessel's speed and/or course cannot be changed to avoid having the mammal enter the exclusion zone, the airguns may (as an alternative to a complete shut down) be powered down before the mammal is within the exclusion zone. Likewise, if a mammal is already within the exclusion zone when first detected, the airguns will be powered down immediately if this is a reasonable alternative to a complete shut down. During a power down of the array, the number of guns operating will be reduced to a single 70 in^3 airgun. The pre-season estimates of the 190 dB re 1 μPa (rms) and 180 dB re 1 μPa (rms) exclusion zones from the 70 in^3 airgun around the power down source are 19 m (62 ft) and 86 m (282 ft), respectively. The 70 in^3 airgun power down source will be measured during acoustic sound source measurements conducted at the start of seismic operations. If a marine mammal is detected within or near the applicable exclusion zone around the single 70 in^3 airgun, it too will be deactivated resulting in a complete shut down (see next subsection).

Marine mammals hauled out on ice may enter the water when approached closely by a vessel. If a marine mammal on ice is detected by PSOs within the exclusion zones it will be watched carefully in case it enters the water. In the event the animal does enter the water and is within an applicable exclusion zone of the airguns during seismic operations, a power down or other necessary mitigation measures will immediately be implemented. If the animal does not enter the water, it will not be exposed to sounds at received levels for which mitigation is required, therefore no mitigation measures will be taken.

Following a power down, operation of the full airgun array will not resume until the marine mammal has cleared the exclusion zone. The animal will be considered to have cleared the exclusion zone if it

- is visually observed to have left the exclusion zone, or
- has not been seen within the zone for 15 min in the case of pinnipeds (excluding walruses) or small odontocetes, or
- has not been seen within the zone for 30 min in the case of mysticetes or large odontocetes.

5.1.5 Shut-down Procedures

The operating airgun(s) will be shut down completely if a marine mammal approaches or enters the then-applicable exclusion zone and a power down is not practical or adequate to reduce exposure to less than 190 or 180 dB re 1 μPa (rms). The operating airgun(s) will also be shut down completely if a marine mammal approaches or enters the estimated exclusion zone around the reduced source (one 70 in^3 airgun) that will be used during a power down. Airgun activity will not resume until the marine mammal has cleared the exclusion zone. The animal will be considered to have cleared the exclusion zone if it is visually observed to have left the exclusion zone, or if it has not been seen within the zone for 15 min (pinnipeds and small odontocetes) or 30 min (mysticetes and large odontocetes). Ramp up procedures will be followed during resumption of full seismic operations after a shut down of the airgun array.

5.1.6 Additional Mitigation Measures Proposed by NMFS

In addition to ION's proposed mitigation measures discussed above, NMFS proposes the following additional measures during the long periods of darkness when the seismic survey is proposed. Specifically in this case, with the exception of turns when starting a new trackline, or short transits or maintenance with a duration of less than one hour, NMFS does not recommend keeping one airgun (also referred to as the "mitigation gun" in past IHAs) firing for long periods of time during darkness or other periods of poor visibility, as it would only introduce more noise into the water with no potential near-term avoidance benefits for marine mammals.

Furthermore, NMFS proposes that the airgun array be shut down if a pinniped is sighted hauled out on ice within the underwater exclusion zone (received level 190 dB re 1 μPa (rms)). Even though the pinniped may not be exposed to in-air noise levels that could be considered a take, the presence of the seismic vessel could prompt the animal to slip into the water, and thus be exposed to a high intensity sound field as a result.

5.2 Proposed Mitigation Measures for Subsistence Activities

5.2.1 Subsistence Mitigation Measures

Since ION's proposed October- December in-ice seismic survey in the Beaufort and Chukchi Seas is not expected to affect subsistence use of marine mammals by Alaskan Natives due to its proposed time and location, no specific mitigation measures are proposed other than those general mitigation measures discussed above.

5.2.2 Plan of Cooperation (POC) and Conflict Avoidance Agreement (CAA)

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.

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.

ION has signed a Conflict Avoidance Agreement (CAA) with the Alaska Eskimo Whaling Commission (AEWC) and communities' Whaling Captains' Association for the proposed 2012 in-ice seismic survey. The main purpose of the CAA is to provide (1) equipment and procedures for communications between subsistence participants and industry participants; (2) avoidance guidelines and other mitigation measures to be followed by the industry participants working in or transiting the vicinity of active subsistence hunters, in areas where subsistence hunters anticipate hunting, or in areas that are in sufficient proximity to areas expected to be used for subsistence hunting that the planned activities could potentially adversely affect the subsistence bowhead whale hunt through effects on bowhead whales; and (3) measures to be taken in the event of an emergency occurring during the term of the CAA.

The CAA states that all vessels (operated by ION) shall report to the appropriate Communication Center (Com-Center) at least once every six hours commencing with a call at approximately 06:00 hours. The appropriate Com-Center shall be notified if there is any significant change in plans, such as an unannounced start-up of operations or significant deviations from announced course, and such Com-Center shall notify all whalers of such changes.

The CAA further states that each Com-Center shall have an Inupiat operator ("Com-Center operator") on duty 24 hours per day during the 2012 subsistence bowhead whale hunt.

In addition, ION has developed a "Plan of Cooperation" (POC) for the proposed 2012 seismic survey in the Beaufort and Chukchi Seas in consultation with representatives of Barrow, Nuiqsut, Kaktovik, and Wainwright and subsistence users within these communities. NMFS received the final POC on May 22, 2012, and final POC on August 10, 2012. A record of all consultation with subsistence users was included in the 2012 Final POC document. The signed CAA and final POC are posted on NMFS website at http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications.

5.3 Mitigation Conclusions

NMFS has carefully evaluated the applicant's proposed mitigation measures and considered a range of other measures in the context of MMPA requirements and the NEPA requirement to discuss means to mitigate adverse environmental impacts. Our evaluation of potential measures included consideration of the following factors in relation to one another:

- the manner in which, and the degree to which, the successful implementation of the measure is expected to minimize adverse impacts to marine mammals;
- the proven or likely efficacy of the specific measure to minimize adverse impacts as planned; and
- the practicability of the measure for applicant implementation.

Based on our evaluation of the applicants' proposed measures, as well as other measures considered by NMFS, NMFS has determined that the proposed mitigation measures under Alternative 2 (Preferred Alternative) are sufficient to minimize any potential adverse impacts to the human environment, particularly marine mammal species or stocks and their habitat.

CHAPTER 6 MONITORING AND REPORTING REQUIREMENTS

Under both the Preferred Alternative (Alternative 2) and Alternative 3, NMFS would require ION to undertake the monitoring activities described in Section 6.1. The monitoring and reporting measures described in that section are standard measures that have been required of IHA holders in Arctic waters in recent years. Section 6.2 describes "emerging" monitoring technologies that would be required for ION if Alternative 3 were the selected alternative. However, as will be described in further detail below, many of these monitoring technologies are infeasible at this time.

6.1 Proposed Monitoring Measures

In order to issue an ITA for an activity, Section 101(a)(5)(D) of the MMPA states that NMFS must set forth "requirements pertaining to the monitoring and reporting of such taking". The MMPA implementing regulations at 50 CFR 216.104(a)(13) indicate that requests for ITAs 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.

6.1.1 Monitoring Measures Proposed for 2012 IHA

The monitoring plan proposed by ION can be found in ION's Marine Mammal Monitoring and Mitigation Plan (4MP) (ION 2012b). The plan may be modified or supplemented based on comments or new information received from the public during the public comment period. A summary of the primary components of the plan follows.

6.1.1.1 Protected Species Observers (PSOs)

Vessel-based monitoring for marine mammals will be performed by trained PSOs throughout the period of survey activities, supplemented by the officers on duty, to comply with expected provisions in the IHA (if issued). The observers will monitor the occurrence and behavior of marine mammals near the survey vessels during all daylight periods. PSO duties will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the survey operations; and documenting "take by harassment" as defined by NMFS.

6.1.1.1a Number of Observers

A sufficient number of PSOs will be required onboard the survey vessel to meet the following criteria:

- 100% monitoring coverage during all periods of survey operations in daylight;
- maximum of 4 consecutive hours on watch per PSO; and
- maximum of ~12 hours of watch time per day per PSO.

An experienced field crew leader will supervise the PSO team onboard the survey vessels. ION's proposed survey will occur in October–December when the number of hours of daylight is significantly reduced, and thus will require fewer PSOs to be aboard the survey vessel than required for surveys conducted during the open water season with nearly 24 hrs of daylight. PSOs aboard the icebreaker operating 0.5–1 km (0.31 – 0.61 mi) ahead of the survey vessel will provide early detection of marine mammals along the survey track. Three PSOs will be stationed aboard the icebreaker Polar Prince to take advantage of this forward operating platform and provide advance notice of marine mammals to the PSO on the survey vessel. Three PSOs will be stationed aboard the survey vessel Geo Arctic to monitor the exclusion zones centered on the airguns and to request mitigation actions when necessary.

6.1.1.1b Observer Qualifications and Training

Crew leaders and most other biologists serving as observers will be individuals with recent experience as observers during one or more seismic monitoring projects in Alaska, the Canadian Beaufort Sea, or other offshore areas.

Biologist-observers will have previous marine mammal observation experience, and field crew leaders will be highly experienced with previous vessel-based marine mammal monitoring and mitigation projects. Résumés for all individuals will be provided to NMFS for review and acceptance of their qualifications. Inupiat observers will be experienced in the region, familiar with the marine mammals of the area, and complete an approved observer training course designed to familiarize individuals with monitoring and data collection procedures. A PSO handbook, adapted for the specifics of the planned survey program, will be prepared and distributed beforehand to all PSOs (see summary below).

Biologist-observers and Inupiat observers will also complete a two or three-day training and refresher session together on marine mammal monitoring, to be conducted shortly before the anticipated start of the seismic survey. When possible, experienced observers will be paired with inexperienced observers. The training session(s) will be conducted by qualified marine mammalogists with extensive crew-leader experience during previous vessel-based seismic monitoring programs.

Primary objectives of the training include:

- review of the marine mammal monitoring plan for this project, including any amendments specified by NMFS in the IHA (if issued);

- review of marine mammal sighting, identification, and distance estimation methods using visual aids;

- review of operation of specialized equipment (reticle binoculars, night vision devices (NVDs), and GPS system);

- review of, and classroom practice with, data recording and data entry systems, including procedures for recording data on marine mammal sightings, monitoring operations, environmental conditions, and entry error control. These procedures will be implemented through use of a customized computer database and laptop computers;

- review of the specific tasks of the Inupiat Communicator; and

- exam to ensure all observers can correctly identify marine mammals and record sightings.

6.1.1.1c PSO Handbook

A PSOs' Handbook will be prepared for IONs' monitoring program. Handbooks contain maps, illustrations, and photographs, as well as text, and are intended to provide guidance and reference information to trained individuals who will participate as PSOs. The following topics will be covered in the PSO Handbook for the ION project:

- summary overview descriptions of the project, marine mammals and underwater noise, the marine mammal monitoring program (vessel-based, aerial, acoustic measurements), the NMFS' IHA (if issued) and other regulations/permits/agencies, the Marine Mammal Protection Act;

- monitoring and mitigation objectives and procedures, initial exclusion zones;

- responsibilities of staff and crew regarding the marine mammal monitoring plan;

- instructions for ship crew regarding the marine mammal monitoring plan;

- data recording procedures: codes and coding instructions, common coding mistakes, electronic database; navigational, marine physical, field data sheet;

- list of species that might be encountered: identification cues, natural history information;

- use of specialized field equipment (reticle binoculars, NVDs, forward-looking infrared (FLIR) system);

- reticle binocular distance scale;

- table of wind speed, Beaufort wind force, and sea state codes;

- data storage and backup procedures;

- safety precautions while onboard;

- crew and/or personnel discord; conflict resolution among PSOs and crew;

- drug and alcohol policy and testing;

- scheduling of cruises and watches;
- communication availability and procedures;
- list of field gear that will be provided;
- suggested list of personal items to pack;
- suggested literature, or literature cited; and
- copies of the NMFS IHA and USFWS LOA when available.

6.1.1.2 Monitoring Methodology

6.1.1.2a General Monitoring Methodology

The observer(s) will watch for marine mammals from the best available vantage point on the survey vessels, typically the bridge. The observer(s) will scan systematically with the unaided eye and 7×50 reticle binoculars, supplemented during good visibility conditions with 20×60 image-stabilized Zeiss Binoculars or Fujinon 25×150 “Big-eye” binoculars, a thermal imaging (FLIR) camera, and night-vision equipment when needed (see below). Personnel on the bridge will assist the marine mammal observer(s) in watching for marine mammals.

Information to be recorded by observers 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). When a mammal sighting is made, the following information about the sighting will be recorded:

- species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if determinable), bearing and distance from observer, apparent reaction to activities (e.g., none, avoidance, approach, etc.), closest point of approach, and pace;
- additional details for any unidentified marine mammal or unknown observed;
- time, location, speed, and activity of the vessel, sea state, ice cover, visibility, and sun glare; and
- the positions of other vessel(s) in the vicinity of the observer location.

The ship’s position, speed of the vessel, water depth, sea state, ice cover, visibility, airgun status (ramp up, mitigation gun, or full array), 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 containing a reticle to measure the vertical angle of the line of sight to the animal relative to the horizon. Observers may use a laser rangefinder to test and improve their abilities for visually estimating distances to objects in the water. However, previous experience has shown that a Class 1 eye-safe device was not able to measure distances to seals more than about 70 m (230 ft) away. The device was very useful in improving the distance estimation abilities of the observers at distances up to about 600 m (1,968 ft), 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.

When a marine mammal is seen within the exclusion zone applicable to that species, the geophysical crew will be notified immediately so that mitigation measures required by the IHA (if issued) can be implemented. It is expected that the airgun array will be shut down within several seconds, often before the next shot would be fired, and almost always before more than one additional shot is fired. The protected species observer will then maintain a watch to determine when the mammal(s) appear to be outside the exclusion zone such that airgun operations can resume.

ION will provide or arrange for the following specialized field equipment for use by the onboard PSOs: 7×50 reticle binoculars, Big-eye binoculars or high power image-stabilized binoculars, GPS unit, laptop computers, night vision binoculars, digital still and possibly digital video cameras in addition to the above mentioned FLIR camera system (see below).

6.1.1.2b Monitoring at Night and in Poor Visibility

Night-vision equipment (Generation 3 binocular image intensifiers, or equivalent units) will be available for use when/if needed. Past experience with NVDs in the Beaufort Sea and elsewhere has indicated that NVDs are not nearly as effective as visual observation during daylight hours (e.g., Harris *et al.* 1997, 1998; Moulton and Lawson 2002). A FLIR camera system mounted on a high point near the bow of the icebreaker will also be available to assist with detecting the presence of seals and polar bears on ice and, perhaps also in the water, ahead of the airgun array. The FLIR system detects thermal contrasts and its ability to sense these differences is not dependent on daylight.

Additional details regarding the monitoring protocol during NVD and FLIR system use has been developed in order to collect data in a standardized manner such that the effectiveness of the two devices can be analyzed and compared.

(1) FLIR and NVD Monitoring

The infrared system is able to detect differences in the surface temperature of objects making it potentially useful during both daylight and darkness periods. NVDs, or light intensifiers, amplify low levels of ambient light from moonlight or sky glow light in order to provide an image to the user. Both technologies have the potential to improve monitoring and mitigation efforts in darkness. However, they remain relatively unproven in regards to their effectiveness under the conditions and it the manner of use planned for this survey. The protocols for FLIR and NVD use and data collection described below are intended to collect the necessary data in order to evaluate the ability of these technologies to aid in the detection of marine mammals from a vessel.

- All PSOs will monitor for marine mammals according to the procedures outlined in the PSO handbook.

- One PSO will be responsible for monitoring the FLIR system (IR-PSO) during most darkness and twilight periods. The on-duty IR-PSO will monitor the IR display and alternate between the two search methods described below. If a second PSO is on watch, they will scan the same area as the FLIR using the NVDs for comparison. The two PSOs will coordinate what area is currently being scanned.

- The IR-PSO should rotate between the search methods (see below) every 30 minutes in the suggested routine (see below):
    - 00:00-00:30: Method I
    - 00:30-01:00: Method II, Port side
    - 01:00-01:30: Method I
    - 01:30-02:00: Method II, Starboard side

(2) FLIR Search Methods

The FLIR system consists of a camera that will be mounted on high point in front of the vessel. The camera is connected to a joystick control unit (JCU) and a display monitor that will be located on the bridge of the vessel. The IR-PSO will manually control the view that is displayed by adjusting the pan (360° continuous pan) and tilt (+/-90° tilt) settings using the JCU. The FLIR manufacturer has indicated that they have tested the FLIR unit (model M626L) to -25 C (-13 F), but expect that it will operate at colder temperatures. During the time of the proposed seismic survey, the average minimum temperatures at Prudhoe Bay in October and November are +10 F and -10 F, respectively. Colder temperatures are certainly likely at times, but overall the temperatures should generally be within the operational range of the equipment.

As noted above, two different search methods will be implemented for FLIR monitoring and results from the two will be compared. The first method involves a back-and-forth panning motion and the second utilizes the FLIR unit focused on a fixed swath ahead and to one side of the vessel track:

<u>Method I:</u> Set the horizontal tilt of the camera to an angle that provides an adequate view out in front of the vessel and also provides good resolution to potential targets (this will likely mean that the lower portion of the view displayed on the monitor is of an area relatively close to the vessel (<100 m [<328 ft]) while the middle and upper portions of the view are at greater distances (500 – 2,000 m [1,640 – 6,562 ft])). Pan back and forth across the forward 180° of the vessels heading at a slow-scanning rate of approximately 1-2°/sec, as one would with binoculars. This method is intended to replicate the type of

observations conducted using binoculars and cover a relatively wider swatch compared to Method II. It should produce sightings data that can be analyzed using line-transect methodologies to estimate marine mammal densities in the survey area.

Method II: Set the horizontal tilt of the camera to an angle that provides an adequate view out in front of the vessel (similar or identical to the above), and then set the camera at a fixed position that creates a swath of view off the bow and to one side of the vessel (see Figure 1 of ION's monitoring plan). This method essentially establishes a fixed-strip width that is intended to produce sightings data that can be analyzed using strip-transect methodologies to estimate marine mammal densities.

(3) NVD Methods

The NVDs are goggles worn by the observer and are to be used in a similar fashion as binoculars. When observing in conjunction with the FLIR system, the objective will be to replicate the monitoring methodology being employed by the FLIR system. Method I requires a full 180° scan (or as large of a range as possible from the observer's location) with the NVDs, and Method II requires a focused scan of the ~60° swath being monitored by the FLIR system.

6.1.1.2c Field Data-Recording, Verification, Handling, and Security

The observers will record their observations onto datasheets or directly into handheld computers. During periods between watches and periods when operations are suspended, those data will be entered into a laptop computer running a custom computer database. The accuracy of the data entry will be verified in the field by computerized validity checks as the data are entered, and by subsequent manual checking of the database printouts. These procedures will allow initial summaries of data to be prepared during and shortly after the field season, and will facilitate transfer of the data to statistical, graphical or other programs for further processing. Quality control of the data will be facilitated by (1) the start-of-season training session, (2) subsequent supervision by the onboard field crew leader, and (3) ongoing data checks during the field season.

The data will be backed up regularly onto CDs and/or USB disks, and stored at separate locations on the vessel. If possible, data sheets will be photocopied daily during the field season. Data will be secured further by having data sheets and backup data CDs carried back to the Anchorage office during crew rotations.

In addition to routine PSO duties, observers will use Traditional Knowledge and Natural History datasheets to record observations that are not captured by the sighting or effort data. Copies of these records will be available to observers for reference if they wish to prepare a statement about their observations. If prepared, this statement would be included in the 90-day and final reports documenting the monitoring work.

6.1.1.2d Effort and Sightings Data Collection Methods

Observation effort data will be designed to capture the amount of PSO effort itself, environmental conditions that impact an observer's ability to detect marine mammals, and the equipment and method of monitoring being employed. These data will be collected every 30 minutes or when an effort variable changes (e.g., change in the equipment or method being used to monitor, on/off-signing PSO, etc.), and will be linked to sightings data. Effort and sightings data forms are the same forms used during other marine mammal monitoring in the open water season, but additional fields have been included to capture information specific to monitoring in darkness and to more accurately describe the observation conditions. The additional fields include the following.

- Observation Method: FLIR, NVD, spotlight, eye (naked eye or regular binoculars), or multiple methods. This data is collected every 30 minutes with the Observer Effort form and with every sighting.

- Cloud Cover: Percentage. This can impact lighting conditions and reflectivity.

- Precipitation Type: Fog, rain, snow, or none.

- Precipitation Reduced Visibility: Confirms whether or not visibility is reduced due to precipitation. This will be compared to the visibility distance (# km) to determine when visibility is reduced due to lighting conditions versus precipitation.

- Daylight Amount: Daylight, twilight, dark. The addition of the twilight field has been included to record observation periods where the sun has set and observation distances may be reduced due to lack of light.

- Light Intensity: Recorded in footcandles (fc) using an incident light meter. This procedure was added to quantify the available light during twilight and darkness periods and may allow for light-intensity bins to be used during analysis.

Analysis of the sightings data will include comparisons of nighttime (FLIR and NVD) sighting rates to daylight sighting rates. FLIR and NVD analysis will be independent of each other and according to method (I or II) used. Comparison of NVD and FLIR sighting rates will allow for a comparison of marine mammal detection ability of the two methods. However, results and analyses could be limited if relatively few sightings are recorded during the survey.

6.1.1.3 Acoustic Monitoring Plan

6.1.1.3a Sound Source Measurements

As described above, received sound levels were modeled for the full 26 airgun, 4,450 in^3 array in relation to distance and direction from the source (Zykov *et al.* 2010). These modeled distances will be used as temporary exclusion zones until measurements of the airgun sound source are conducted. The measurements will be made at the beginning of the field season and the measured radii will be used for the remainder of the survey period. An acoustics contractor with experience in the Arctic conducting similar measurements in recent years will use their equipment to record and analyze the underwater sounds and write the summary reports as described below.

The objectives of the sound source measurements planned for 2012 in the Beaufort Sea will be (1) to measure the distances in potentially ice covered waters in the broadside and endfire directions at which broadband received levels reach 190, 180, 170, 160, and 120 dB re 1 μPa (rms) for the energy source array combinations that may be used during the survey activities, and (2) measure the sounds produced by the icebreaker and seismic vessel as they travel through sea ice. Conducting the sound source and vessel measurements in ice-covered waters using bottom founded recorders creates a risk of not being able to retrieve the recorders and analyze the data until the following year. If the acoustic recorders are not deployed or are unable to be recovered because of too much sea ice, ION will use measurements of the same airgun source taken in the Canadian Beaufort Sea in 2010, along with sound velocity measurements taken in the Alaskan Beaufort Sea at the start of the 2012 survey to update the propagation model and estimate new exclusion zones. These modeled results will then be used for mitigation purposes during the remainder of the survey.

The airgun configurations measured will include at least the full 26 airgun array and the single 70 in^3 mitigation airgun that will be used during power downs. The measurements of airgun array sounds will be made by an acoustics contractor at the beginning of the survey and the distances to the various radii will be reported as soon as possible after recovery of the equipment. The primary area of concern will be the 190 and 180 dB re 1 μPa (rms) exclusion zones for pinnipeds and cetaceans, respectively, and the 160 dB re 1 μPa Level B harassment (for impulsive sources) radii. In addition to reporting the radii of specific regulatory concern, nominal distances to other sound isopleths down to 120 dB re 1 μPa (rms) will be reported in increments of 10 dB.

Data will be previewed in the field immediately after download from the hydrophone instruments. An initial sound source analysis will be supplied to NMFS and the airgun operators within 120 hours of completion of the measurements. The report will indicate the distances to sound levels based on fits of empirical transmission loss formulae to data in the endfire and broadside directions. A more detailed report will be issued to NMFS as part of the 90-day report following completion of the acoustic program.

6.1.1.3b Seismic Hydrophone Streamer Recordings of Vessel Sounds

Although some measurements of icebreaking sounds have previously been reported, acoustic data on vessels traveling through relatively light ice conditions, as will be the case during the proposed survey, are not available. In order to gather additional information on the sounds produced by this type of icebreaking, ION proposes to use the hydrophones in the seismic streamer on a routine basis throughout the survey. Once every hour the airguns would not be fired at 2 consecutive intervals (one seismic pulse interval is typically ~18 seconds, so there will be ~54 seconds between seismic pulses at this time) and instead a period of background sounds would be recorded, including the sounds generated by the vessels. Over the course of the survey this should generate as many as 750 records of vessel sounds traveling through various ice conditions (from open water to 100% cover juvenile first year ice or lighter multi-year ice). The acoustic data during each sampling period from each hydrophone along the 9 km (5.6 mi) streamer would be analyzed and used to estimate the propagation loss of the vessel sounds. The acoustic data received from the hydrophone streamer would be recorded at an effective bandwidth of 0–400 Hz. In order to estimate sound energy over a larger range of frequencies (broadband), results from previous measurements of icebreakers could be generalized and added to the data collected during this project.

6.1.1.3c Over-winter Acoustic Recorders

In order to collect additional data on the propagation of sounds produced by icebreaking and seismic airguns in ice-covered waters, as well as on vocalizing marine mammals, ION intends to collaborate with other Industry operators to deploy acoustics recorders in the Alaskan Beaufort Sea in fall of 2012, to be retrieved during the 2013 open-water season.

During winter 2011–2012 AURAL acoustic recorders were deployed at or near each of the 5 acoustic array sites established by Shell for monitoring the fall bowhead whale migration through the Beaufort Sea, as well as one site near the shelf break in the central Alaskan Beaufort Sea. These recorders were retrieved in July 2012 when Shell deployed Directional Autonomous Seafloor Acoustic Recorders (DASARs) at 5 array locations. When the DASAR arrays are retrieved in early October ION intends to coordinate with Shell to re-deploy the 6 AURAL recorders to the same locations used during the 2011–2012 winter. Redeploying the recorders in the same locations will provide comparable data from a year with little to no offshore industrial activity (2011) to a year with more offshore industrial activity (2012). Acoustic data from the over-winter recorders will be analyzed to address the following objectives:

- Characterize the sounds and propagation distances produced by ION’s source vessel, icebreaker, and airguns on and to the edge of the U.S. Beaufort Sea shelf,

- Characterize ambient sounds and marine mammal calls during October and November to assess the relative effect of ION’s seismic survey on the background conditions, and to characterize marine mammal calling behavior, and

- Characterize ambient sound and enumerate marine mammal calls through acoustic sampling of the environment form December 2012 through July 2013, when little or no anthropogenic sounds are expected.

6.1.2 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 convened independent peer review panels to review ION’s mitigation and monitoring plan in its IHA applications submitted in 2010 and 2011 for taking marine mammals incidental to the proposed seismic survey in the Beaufort and Chukchi Seas, during 2010 and 2011. The panel met on March 25 and 26, 2010, and on March 9, 2011, and provided their final report to NMFS on April 22, 2010 and on April 27, 2011, respectively. The full panel report can be viewed at: http://www.nmfs.noaa.gov/pr/permits/incidental.htm#applications.

ION's proposed 2012 action is essentially the same as described in its 2010 and 2011 IHA applications. NMFS worked with ION in 2010 and 2011 to address the peer review panels' recommendations on its 2010 and 2011 4MPs. Since ION's 2012 4MP addressed all issues raised during the 2010 and 2011 peer reviews and incorporated all of NMFS' requested changes, no peer-review of ION's 2012 4MP was conducted.

In 2010, NMFS provided the panel with ION's 4MP and asked the panel to address the following questions and issues for ION's plan:

(1) The monitoring program should document the effects (including acoustic) on marine mammals and document or estimate the actual level of take as a result of the activity. Does the monitoring plan meet this goal?

(2) Ensure that the monitoring activities and methods described in the plan will enable the applicant to meet the requirements listed in (1) above;

(3) Are the applicant's objectives achievable based on the methods described in the plan?

(4) Are the applicant's objectives the most useful for understanding impacts on marine mammals?

(5) Should the applicant consider additional monitoring methods or modifications of proposed monitoring methods for the proposed activity? And

(6) What is the best way for an applicant to report their data and results to NMFS?

In 2011, NMFS revised its guidance to the peer review panel and asked the panel to focus on more specific questions:

(1) Are the applicant's stated objectives the most useful for understanding impacts on marine mammals and otherwise accomplishing the goals stated in the paragraph above?

(2) Are the applicant's stated objectives able to be achieved based on the methods described in the plan?

(3) Are there techniques not proposed by the applicant, or modifications to the techniques proposed by the applicant, that should be considered for inclusion in the applicant's monitoring program to better accomplish the goals stated above?

(4) What is the best way for an applicant to present their data and results (formatting, metrics, graphics, etc.) in the required reports that are to be submitted to NMFS?

In 2010, the panel members provided general recommendations that were applicable to all monitoring plans from all seismic activities during that year in section 3 of the report, and recommendations that were specific to ION's in-ice seismic survey 4MP in section 4.1.

In 2011, the panel members provided general recommendations that were applicable to all monitoring plans from all seismic activities during that year in section 4 of the report, and recommendations that were specific to ION's in-ice seismic survey 4MP in section 5.2.

NMFS reviewed the report and evaluated all recommendations made by the panel. NMFS determined that there were several measures that ION could incorporate into its 2012 in-ice seismic survey monitoring plan. Additionally, there were other recommendations that NMFS has determined would also result in better data collection, and could potentially be implemented by oil and gas industry applicants, but which likely could not be implemented for the 2012 in-ice season due to technical issues (see below). While it may not be possible to implement those changes this year, NMFS believes that they are worthwhile and appropriate suggestions that may require additional technology advancement for them to be implemented, and ION should consider incorporating them into future monitoring plans should ION decide to apply for IHAs in the future.

The following subsections lay out measures from the panel reports that NMFS recommended for implementation as part of the 2012 in-ice seismic survey by ION and those that are recommended for future programs.

6.1.2.1 Recommendations for Inclusion in the 2012 4MP and IHA

Section 3.3 of the 2010 panel report contains several recommendations regarding PSOs, which NMFS agreed that ION should incorporate:

- Observers should be trained using visual aids (e.g., videos, photos), to help them identify the species that they are likely to encounter in the conditions under which the animals will likely be seen.

- Observers should understand the importance of classifying marine mammals as "unknown" or "unidentified" if they cannot identify the animals to species with confidence. In those cases, they should note any information that might aid in the identification of the marine mammal sighted. For example, for an unidentified mysticete whale, the observers should record whether the animal had a dorsal fin.

- Observers should attempt to maximize the time spent looking at the water and guarding the exclusion zones. They should avoid the tendency to spend too much time evaluating animal behavior or entering data on forms, both of which detract from their primary purpose of monitoring the exclusion zone.

- “Big eye” binoculars (e.g., 25 x 150 power) should be used from high perches on large, stable platforms. They are most useful for monitoring impact zones that extend beyond the effective line of sight. With two or three observers on watch, the use of big eyes should be paired with searching by naked eye, the latter allowing visual coverage of nearby areas to detect marine mammals. When a single observer is on duty, the observer should follow a regular schedule of shifting between searching by naked-eye, low-power binoculars, and big-eye binoculars based on the activity, the environmental conditions, and the marine mammals of concern.

- Observers should use the best possible positions for observing (e.g., outside and as high on the vessel as possible), taking into account weather and other working conditions.

- Whenever possible, new observers should be paired with experienced observers to avoid situations where lack of experience impairs the quality of observations. If there are Alaska Native MMOs, the MMO training that is conducted prior to the start of the survey activities should be conducted with both Alaska Native MMOs and biologist MMOs being trained at the same time in the same room. There should not be separate training courses for the different MMOs.

In Section 3.4 of the 2010 panel report, panelists recommend collecting some additional data to help verify the utility of the “ramp-up” requirement commonly contained in IHAs. To help evaluate the utility of ramp-up procedures, NMFS recommends that observers be required to record, analyze, and report their observations during any ramp-up period. NMFS also supports the inclusion of specific studies using multiple types of monitoring (visual, acoustic, tagging) to evaluate how marine mammals respond to increasing received sound levels. Such information should provide useful evidence as to whether ramp-up procedures are an effective form of mitigation.

In the same section of the 2010 report, panelists recommend collecting data to evaluate the efficacy of using FLIR vs. night-vision binoculars. The panelists note that while both of these devices may increase detection capabilities by PSOs of marine mammals, the reliability of these technologies should be tested under appropriate conditions and their efficacy evaluated. NMFS recommends that ION design a study using both FLIR and night-vision binoculars and collect data on levels of detection of marine mammals using each type of device.

Among other things, Section 3.5 of the 2010 panel report recommends recording visibility data because of the concern that the line-of-sight distance for observing marine mammals is reduced under certain conditions. PSOs should “carefully document visibility during observation periods so that total estimates of take can be corrected accordingly”.

Section 4.1 of the 2010 panel report contained recommendations specific to ION’s 2010 2D marine seismic survey monitoring plan, which were also relevant to ION’s 2012 4MP. NMFS worked with ION and decided that some of the measures presented in this section of the report, such as supporting overwintering buoy studies and coordinating in conducting tagging studies using satellite linked telemetry, were not ready for ION's to implement for its 2010 season operations, but are feasible for its 2012 season as ION has worked to make the necessary preparation over the past two years. In addition, the following recommendations will also be implemented for the 2012 season:

- Conduct sound source verification measurements to verify calculated exclusion zones to account for possible sound channels in deeper water.

- Summarize observation effort and conditions, the number of animals seen by species, the location and time of each sighting, position relative to the survey vessel, the company's activity at the time, each animal's response, and any adjustments made to operating procedures. Provide all spatial data on charts (always including vessel location).

- Make all data available in the report or (preferably) electronically for integration with data from other companies.

- Accommodate specific requests for raw data, including tracks of all vessels and aircraft associated with the operation and activity logs documenting when and what types of sounds are introduced into the environment by the operation.

NMFS spoke with ION about the inclusion of these recommendations into the 2012 4MP and IHA. ION indicated to NMFS that they will incorporate these recommendations into the 4MP, and NMFS will make several of these recommendations requirements in any issued IHA.

Section 4.3 of the 2011 report contains several recommendations regarding PSOs. NMFS agreed that the following measures should be incorporated into the 2012 4MP.

- PSOs record additional details about unidentified marine mammal sightings, such as "blow only", mysticete with (or without) a dorsal fin, "seal splash", etc. That information should also be included in 90-day and final reports.

In Section 4.7 of the 2011 panel report, panelists included a section regarding the need for a more robust and comprehensive means of assessing the collective or cumulative impact of many of the varied human activities that contribute noise into the Arctic environment. Specifically, for data analysis and integration, the panelists recommended, and NMFS agrees, that the following recommendations be incorporated into the 2012 program:

- To better assess impacts to marine mammals, data analysis should be separated into periods when a seismic airgun array (or a single mitigation airgun) is operating and when it is not. Final and comprehensive reports to NMFS should summarize and plot:
    - Data for periods when a seismic array is active and when it is not; and

    - The respective predicted received sound conditions over fairly large areas (tens of km) around operations.

- To help evaluate the effectiveness of PSOs and more effectively estimate take, reports should include sightability curves (detection functions) for distance-based analyses.

- To better understand the potential effects of oil and gas activities on marine mammals and to facilitate integration among companies and other researchers, the following data should be obtained and provided electronically in the final and comprehensive reports:
    - the location and time of each aerial or vessel-based sighting or acoustic detection;
    - position of the sighting or acoustic detection relative to ongoing operations (i.e., distance from sightings to seismic operation, drilling ship, support ship, etc.), if known;
    - the nature of activities at the time (e.g., seismic on/off);
    - any identifiable marine mammal behavioral response (sighting data should be collected in a manner that will not detract from the PSO's ability to detect marine mammals); and
    - any adjustments made to operating procedures..

In Section 4.9 of the 2011 panel report, the panelists discussed improving take estimates and statistical inference into effects of the activities. NMFS agreed that the following measures should be incorporated into the 2012 4MP:

- Reported results from all hypothesis tests should include estimates of the associated statistical power.

- Estimate and report uncertainty in all take estimates. Uncertainty could be expressed by the presentation of confidence limits, a minimum-maximum, posterior probability distribution, etc.; the exact approach would be selected based on the sampling method and data available.

Section 5.2 of the 2011 report contained recommendations specific to ION's 2011 2D seismic survey monitoring plan. Of the recommendations presented in this section, NMFS determined that the following should be implemented for the 2012 season:

- ION should test thermal imaging technologies during the proposed activities.

- Airguns should be turned off for two shots (i.e., 60 seconds) to provide sufficient time to record the background noise associated with the vessels.

- ION should deploy overwintering acoustic recorders within their survey area during their eastward transit across the Alaskan Beaufort to the Canadian Beaufort Sea early in the summer. The recorders would monitor sounds during the summer, the seismic shoot, and over the winter. ION should contract someone to return in 2012 (2013 in the case that the seismic survey is delayed to 2012) to retrieve the instruments and analyze the data. These acoustic data would provide some true baseline information to compare the occurrence, distribution, and behavior of marine mammals at times when ION's activities are occurring and when they are absent. To accomplish this, ION should present a plan for an acoustic monitoring program to a NMFS-approved expert for review. The plan should consider the best placement of the instruments relative to ION's proposed activities, the expected distribution and gradients in marine mammal distribution, and other existing overwintering recorders. There are relatively few data on the distribution and relative abundance of marine mammals in the Beaufort Sea during ION's planned seismic survey.

- The report should clearly compare authorized takes to the level of actual estimated takes.

- Sightability curves (detection functions) for PSOs should be provided.

In addition, the panelists included a list of general recommendations from the 2010 Peer-review Panel Report to be implemented by operators in their 2011 open-water season activities. NMFS agreed that the following recommendations should be implemented in ION's 2012 monitoring plan:

- Sightings should be entered and archived in a way that enables immediate geospatial depiction to facilitate operational awareness and analysis of risks to marine mammals. Real-time monitoring is especially important in areas of seasonal migration or influx of marine mammals. Various software packages for real-time data entry, mapping, and analysis are available for this purpose.

- Whenever possible, new observers should be paired with experienced observers to avoid situations where lack of experience impairs the quality of observations.

6.1.2.2 Recommendations for Inclusion in Future Monitoring Plans

Section 3.5 of the 2010 report recommends methods for conducting comprehensive monitoring of a large-scale seismic operation. One method for conducting this monitoring recommended by panel members is the use of passive acoustic devices. Additionally, Section 3.2 of the 2010 report encourages the use of such systems if aerial surveys will not be used for real-time mitigation monitoring. NMFS acknowledges that there are challenges involved in using this technology in conjunction with seismic airguns in this environment, especially in real time. However, NMFS recommends that ION work to help develop and improve this type of technology for use in the Arctic (and use it once it is available and effective), as it could be valuable both for real-time mitigation implementation, as well as for archival data collection.

The panelists also recommend adding a tagging component to monitoring plans. "Tagging of animals expected to be in the area where the survey is planned also may provide valuable information on the location of potentially affected animals and their behavioral responses to industrial activities. Although the panel recognized that such comprehensive monitoring might be difficult and expensive, such an effort (or set of efforts) reflects the complex nature of the challenge of conducting reliable, comprehensive monitoring for seismic or other relatively-intense industrial operations that ensonify large areas of ocean." While this particular recommendation is not feasible for implementation in 2012, NMFS recommends that ION consider adding a tagging component to future seismic survey monitoring plans should ION decide to conduct such activities in future years.

To the extent possible, NMFS recommends implementing the recommendation contained in Section 4.1.6 of the 2010 report: "Integrate all observer data with information from tagging and acoustic studies to provide a more comprehensive description of the acoustic environment during its survey." However, NMFS recognizes that this integration process may take time to implement. Therefore, ION should begin considering methods for the integration of the observer data now if ION intends to apply for IHAs in the future.

In Section 4.7 of the 2011 report, the panelists stated that advances in integrating data from multiple platforms through the use of standardized data formats are needed to increase the statistical power to assess potential effects. Therefore, the panelists recommended that industry examine this issue and jointly propose one or several data integration methods to NMFS at the Open Water Meeting in 2012 (in this case, at the Open Water Meeting in 2013, since ION cancelled its proposed 2011 operation). NMFS concurs with the recommendation and encourages ION to collaborate with other companies to discuss data integration methods to achieve these efforts and to present the results of those discussions at the 2013 Open Water Meeting.

6.1.2.3 Other Recommendations in the Report

The panel also made several recommendations in 2010, which were not discussed in the two preceding subsections. NMFS determined that many of the recommendations were made beyond the bounds of what the panel members were tasked to do. For example, the panel recommended that NMFS begin a transition away from using a single metric of acoustic exposure to estimate the potential effects of anthropogenic sound on marine living resources. This is not a recommendation about monitoring but rather addresses a NMFS policy issue. NMFS is currently in the process of revising its acoustic guidelines on a national scale. Section 3.7 of the 2010 report contains several recommendations regarding comprehensive ecosystem assessments and cumulative impacts. These are good, broad recommendations, however, the implementation of these recommendations would not be the responsibility solely of oil and gas industry applicants. The recommendations require the cooperation and input of several groups, including Federal, state, and local government agencies, members of other industries, and members of the scientific research community. NMFS will encourage the industry and others to build the relationships and infrastructure necessary to pursue these goals, and incorporate these recommendations into future MMPA authorizations, as appropriate. Section 3.8 of the 2010 report makes a recommendation regarding data sharing and reducing the duplication of seismic survey effort. While this is a valid recommendation, it does not relate to monitoring or address any of the six questions which the panel members were tasked to answer.

For some of the recommendations, NMFS determined that additional clarification was required by the panel members before NMFS could determine whether or not applicants should incorporate them into the monitoring plans. NMFS asked for additional clarification on some of the recommendations regarding data collection and take estimate calculations. In addition, NMFS asked the panel members for clarification on the recommendation contained in Section 3.6 of the 2010 report regarding baseline studies.

6.2 Proposed Reporting Measures

6.2.1 SSV Report

A report on the preliminary results of the acoustic verification measurements, including as a minimum the measured 190-, 180-, 160-, and 120-dB re 1 μPa (rms) radii of the airgun arrays will be submitted within 120 hr after collection and analysis of those measurements at the start of the field season. This report will specify the distances of the exclusion zones that were adopted for the marine survey activities.

6.2.2 Field Reports

Throughout the survey program, the observers will prepare a report each day or at such other intervals as the IHA may specify (if issued), or ION may require summarizing the recent results of the monitoring program. The field reports will summarize the species and numbers of marine mammals sighted. These reports will be provided to NMFS and to the survey operators.

6.2.3 Technical Reports

The Results of the vessel-based monitoring, including estimates of "take by harassment", will be presented in the 90-day and final technical reports. Reporting will address the requirements established by NMFS in the IHA (if issued). The technical report will include:

(A) summaries of monitoring effort: total hours, total distances, and distribution of marine mammals through the study period accounting for sea state and other factors affecting visibility and detectability of marine mammals;

(B) methods, results, and interpretation pertaining to all acoustic characterization work and vessel-based monitoring;

(C) analyses of the effects of various factors influencing detectability of marine mammals including sea state, number of observers, and fog/glare;

(D) species composition, occurrence, and distribution of marine mammal sightings including date, water depth, numbers, age/size/gender categories, group sizes, and ice cover; and

(E) analyses of the effects of survey operations:

- sighting rates of marine mammals during periods with and without airgun activities (and other variables that could affect detectability);
- initial sighting distances versus airgun activity state;
- closest point of approach versus airgun activity state;
- observed behaviors and types of movements versus airgun activity state;
- numbers of sightings/individuals seen versus airgun activity state;
- distribution around the survey vessel versus airgun activity state; and
- estimates of "take by harassment".

6.2.4 Notification of Injured or Dead Marine Mammals

In addition to the reporting measures proposed by ION, NMFS will require that ION notify NMFS' Office of Protected Resources and NMFS' Stranding Network of sighting an injured or dead marine mammal in the vicinity of marine survey operations. Depending on the circumstance of the incident, ION shall take one of the following reporting protocols when an injured or dead marine mammal is discovered in the vicinity of the action area.

(A) In the unanticipated event that survey operations clearly cause the take of a marine mammal in a manner prohibited by this Authorization, such as an injury, serious injury or mortality (e.g., ship-strike, gear interaction, and/or entanglement), ION shall immediately cease survey operations and immediately report the incident to the Supervisor of Incidental Take Program, Permits and Conservation Division, Office of Protected Resources, NMFS, and the Alaska Regional Stranding Coordinators. The report must include the following information:

(i) time, date, and location (latitude/longitude) of the incident;

(ii) the name and type of vessel involved;

(iii) the vessel's speed during and leading up to the incident;

(iv) description of the incident;

(v) status of all sound source use in the 24 hours preceding the incident;

(vi) water depth;

(vii) environmental conditions (e.g., wind speed and direction, Beaufort sea state, cloud cover, and visibility);

(viii) description of marine mammal observations in the 24 hours preceding the incident;

(ix) species identification or description of the animal(s) involved;

(x) the fate of the animal(s); and

(xi) 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 ION to determine what is necessary to minimize the likelihood of further prohibited take and ensure MMPA compliance. ION may not resume their activities until notified by NMFS via letter, email, or telephone.

(B) In the event that ION 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), ION will immediately report the incident to the Supervisor of the Incidental Take Program, Permits and Conservation Division, Office of Protected Resources, NMFS, and the Alaska Regional Stranding Coordinators. The report must include the same information identified above. Activities may continue while NMFS reviews the circumstances of the incident. NMFS will work with ION to determine whether modifications in the activities are appropriate.

(C) In the event that ION 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 activities authorized in the IHA (if issued) (e.g., previously wounded animal, carcass with moderate to advanced decomposition, or scavenger damage), ION shall report the incident to the Supervisor of the Incidental Take Program, Permits and Conservation Division, Office of Protected Resources, NMFS, and the Alaska Regional Stranding Coordinators, within 24 hours of the discovery. ION shall provide photographs or video footage (if available) or other documentation of the stranded animal sighting to NMFS and the Marine Mammal Stranding Network. ION can continue its operations under such a case.

6.3 "Emerging" Monitoring Technologies

Section 2.3 discusses additional monitoring measures that may be required by NMFS in the future, including use of PAM and AAM to detect the presence of marine mammals. However, at this time, the existing technology for PAM has not yet been proven effective for monitoring or mitigation as would be required under an IHA, while AAM would require additional anthropogenic noise to be introduced into the water column in addition to that from the seismic airguns and icebreaker.

Regarding the use of AAM and PAM for near real-time monitoring and the use of unmanned aerial vehicles for aerial monitoring, at this time, these technologies are still being developed or refined. NMFS does not believe that at the current stage, requiring PAM (either towed or stationary) for real-time acoustic monitoring or deploying unmanned aircraft for aerial monitoring would yield reliable data. As far as AAM is concerned, many technical issues (such as detection range and resolution) and unknowns (such as target strength of marine mammal species in the Arctic) remain to be resolved before it can be made a reliable monitoring tool. Environmental consequences concerning additional sound being introduced into the water column from an active sonar source would also need to be addressed. Therefore, NMFS does not believe it is beneficial to adopt these "emerging" monitoring technologies at this time.

6.4 Conclusion

The inclusion of the mitigation and monitoring requirements in the IHA, as described in the Preferred Alternative, will ensure that ION's activity and the proposed mitigation measures under Alternative 2 (Preferred Alternative) 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 1.4 of this EA) by ION, and NMFS' proposed issuance of an IHA to ION, will result at worst in a temporary modification of behavior (Level B harassment) of some individuals of 9 species of marine mammals, and minor levels of PTS of 1 bowhead whale, 3 beluga whales, and 4 ringed seals in the Beaufort and Chukchi Seas. In addition, no take by death and/or serious injury is anticipated.

LIST OF PREPARERS AND AGENCIES AND PERSONS CONSULTED

List of Preparer:

Shane Guan
Fishery Biologist
Office of Protected Resources
NOAA/National Marine Fisheries Service
Silver Spring, MD

List of Agencies and Persons Consulted

Bureau of Ocean Energy Management, Regulation and Enforcement, Alaska Region

LITERATURE CITED

Aars, J., N.J. Lunn and A.E. Derocher 2006. Status of the polar bear. Proceedings of the 14th Working Meeting of the IUCN/SSC Polar Bear Specialist Group. Seattle, United States; Gland, Switzerland; Cambridge, UK.

ACIA (Arctic Climate Impact Assessment). 2004. Impacts of a warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, Cambridge, UK.

ADCCED. 2007. Community Information Summaries. ADCCED (Alaska Department of Commerce Community & Economic Development). http://www.dced.state.ak.us/dca/commdb/CF_COMDB.htm.

ADCCED. 2009. Community Database Online. ADCCED (Alaska Department of Commerce, Community and Economic Development). http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.cfm.

ADFG. 2000a. Community Profile Database 3.04 for Access 97. Division of Subsistence, Anchorage.

ADFG. 2000b. Seals+ Database for Access 97. Division of Subsistence, Anchorage.

AES. 2009. Subsistence Advisor Program Summary North Slope, Alaska. Prepared for Shell Exploration and Production Company. *In:* Exploration Plan 2010 Exploration Drilling Program, Posey Blocks 6713, 6714, 6763, 6764, and 6912, Karo Blocks 6864 and 7007, Burger, Crack. Submitted to MMS, Anchorage, AK: ASRC Energy Services.

Ahmaogak, Sr., G.N. 1995. Concerns of Eskimo People Regarding Oil and Gas Exploration and Development in the United States Arctic. unpublished. Workshop on Technologies and Experience of Arctic Oil and Gas Operations. April 10-12, 1995. Girdwood, AK.

Alexander, V., R. Horner and R.C. Clasby. 1974. Metabolism of Arctic Sea Ice Organisms. College: University of Alaska Fairbanks, Institute of Marine Science.

Allen, B.M., and R.P. Angliss. 2010. Alaska Marine Mammal Stock Assessments, 2009. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. NMFS-AFSC-206. No. 3.

Allen, M.C., and A.J. Read. 2000. Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. Marine Mammals Science 16:815-824.

Amstrup, S.C. 2003. Polar Bear. *In:* B.C. Thompson, J.A. Chapman, and G.A. Feldhamer (*eds.*). Wild Mammals of North America: Biology, Management, and Conservation. Johns Hopkins University Press, Baltimore, MD.

Amstrup, S.C., and C. Gardner. 1994. Polar bear maternity denning in the Beaufort Sea. Journal of Wildlife Management 58(1):1-10.

Amstrup, S.C., G.M. Durner and T.L. McDonald. 2000. Estimating Potential Effects of Hypothetical Oil Spills from the Liberty Oil Production Island on Polar Bears. Anchorage, AK: USGS, Biological Resource Division, 42 pp.Bailey, A.M. 1948. Birds of Arctic Alaska. Popular Series No. 8. Denver CO: Colorado Museum of Natural History.

Angliss, R.P., G.K. Silber and R. Merrick. 2002. Report of a workshop on developing recovery criteria for large whale species. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-OPR-21. 32 pp.

ANSC. 2009. What is Traditional Knowledge. Alaska Native Science Commission. http://www.nativescience.org/html/traditional_knowledge.html.

Arctic Council. 2009. Arctic Marine Shipping Assessment 2009 Report. Arctic Council.

Armstrong, T. 1984. The Northern Sea Route, 1983. Polar Record. 22(137): 173-182.

Arrigo, K.R., and G.L. van Dijken. 2004. Annual cycles of sea ice and phytoplankton in Cape Bathurst polynya, southeastern Beaufort Sea, Canadian Arctic. Geophysical Research Letters 31, L08304, doi: 10.1029/2003GL018978.

Avery, M.L., P.F. Springer and N.S. Dailey. 1980. Avian Mortality at Man-Made Structures: An Annotated Bibliography (Revised). FWS/OBS-80/54. Washington, DC: USDOI, FWS, Office of Biological Services, National Power Plant Team, 152 pp.

Balcomb, K.C., III, and D.E. Claridge. 2001. A mass stranding of cetaceans caused by naval sonar in the Bahamas. Bahamas Journal of Science 8(2):2-12.

Barger, J.E., and W.R. Hamblen. 1980. The Airgun Impulsive Underwater Transducer. Journal of the Acoustical Society of America 684:1038-1045.

Barkaszi, M.J., D.M. Epperson and B. Bennett. 2009. Six-year compilation of cetacean sighting data collected during commercial seismic survey mitigation observations throughout the Gulf of Mexico, USA. p. 24-25 *In:* Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Canada, Oct. 2009. 306 p.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part 1: Ship surveys in summer and fall of 1991. Fishery Bulletin 93:1-14.

Barlow, J., C.W. Oliver, T.D. Jackson and B.L. Taylor. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: II. Aerial surveys. Fishery Bulletin 86:433-444.

Barr, W., and E.A. Wilson. 1985 The shipping crisis in the Soviet Eastern Arctic and the close of the 1983 navigation season. Arctic, 38(1): 1-17.

Begon, M., J.L. Harper and C.R. Townsend. 1986. Ecology: Individuals, Populations, and Communities, 2nd ed. Boston, MA: Blackwell Scientific Publications, 945 pp.

Bejder, L., A. Samuels, H. Whitehead, N. Gales, J. Mann, R. Connor, M. Heithaus, J. Watson-Capps, C. Flaherty and M. Krutzen. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Conservation Biology, 20(6):1791-1798.

Beland, J.A., B. Haley, C.M. Reiser, D.M. Savarese, D.S. Ireland and D.W. Funk. 2009. Effects of the presence of other vessels on marine mammal sightings during multi-vessel operations in the Alaskan Chukchi Sea. Pp. 29, *In:* Abstracts for the 18th Biennial Conference for the Biology of Marine Mammals, Québec, Octario. 2009:29. 306 p.

Bengtson, J.L., P.L. Boveng, L.M. Hiruki-Raring, K.L. Laidre, C. Pungowiyi and M.A. Simpkins. 2000. Abundance and distribution of ringed seals (*Phoca hispida*) in the coastal Chukchi Sea. Pp. 149-160, *In:* A.L. Lopez and D.P. DeMaster (*eds.*). Marine Mammal Protection Act and Endangered Species Act Implementation Program 1999. AFSC Processed Rep. 2000-11, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115.

Bengtson, J.L., L.M. Hiruki-Raring, M.A. Simpkins and P.L. Boveng. 2005. Ringed and bearded seal densities in the eastern Chukchi Sea, 1999-2000. Polar Biol. 28: 833-845.

Berzin, A.A. 1984. Soviet Studies on the Distribution and Numbers of the Gray Whale in the Bering and Chukchi Seas from 1968 to 1982. *In:* S.L. Swartz, S. Leatherwood and M.L. Jones (*eds.*). The Gray Whale, *Eschristius robustus*. pp. 409-419. Orlando: Academic Press.

Black, A. 2005. Light induced seabird mortality on vessels operating in the Southern Ocean: incidents and mitigation measures. Antarctic Science 171:67-68.

Blackwell, S.B., and C.R. Greene, Jr. 2002. Acoustic Measurements in Cook Inlet, Alaska during August 2001. Greenridge Report 271-1. Anchorage, AK: USDOC, NMFS, Protected Resources Division.

Blackwell, S.B., and C.R. Greene, Jr. 2004. Sounds from Northstar in the Open-Water Season: Characteristics and Contribution of Vessels. In: Monitoring of Industrial Sounds, Seals, and Bowhead Whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 1999-2003., W.J. Richardson and M.T. Williams, eds. LGL Report TA4002-4. Anchorage, AK: BPXA, Dept. of Health, Safety, and Environment.

Blackwell, S.B., and C.R. Greene, Jr. 2005. Underwater and in–air sounds from a small hovercraft. Journal of the Acoustical Society of America 118(6):3646–3652.

Blackwell, S.B., and C.R. Greene, Jr. 2006. Sounds from an oil production island in the Beaufort Sea in summer: characteristics and contribution of vessels. Journal of the Acoustical Society of America 119(1):182–196.

Blackwell, S.B., J.W. Lawson and M.T. Williams. 2004a. Tolerance by ringed seals (*Phoca hispida*) to impact pipe-driving and construction sounds at an oil production island. Journal of the Acoustical Society of America, 115(5):2346-2357.

Blackwell, S.B., R.G. Norman, C.R. Greene Jr., M.W. McLennan, T.L. McDonald and W.J. Richardson. 2004b. Acoustic monitoring of bowhead whale migration, autumn 2003. p. 71 to 744 *In:* Richardson, W.J. and M.T. Williams (*eds.*) 2004. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea, 1999-2003. [Dec. 2004 ed.] LGL Rep. TA4002. Rep. from LGL Ltd. (King City, Ont.), Greeneridge Sciences Inc. (Santa Barbara, CA) and WEST Inc. (Cheyenne, WY) for BP Explor. (Alaska) Inc., Anchorage, AK. 297 p. + Appendices A - N on CD-ROM.

Blackwell, S.B., W.C. Burgess, R.G. Norman, C.R. Greene, Jr., M.W. McLennan and W.J. Richardson. 2008. Acoustic monitoring of bowhead whale migration, autumn 2007. p. 2-1 to 2-36 *In:* L.A.M. Aerts and W.J. Richardson (*eds.*). Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2007: Annual Summary Report. LGL Rep. P1005b. Rep. from LGL Alaska Research Associates (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA), and Applied Sociocultural Research (Anchorage, AK) for BP Exploration (Alaska) Inc., Anchorage, AK.

Blackwell, S.B., C.R. Greene, T.L. McDonald, C.S. Nations, R.G. Norman and A. Thode. 2009a. Beaufort Sea bowhead whale migration route study. Chapter 8 *In:* D.S. Ireland, D.W. Funk, R. Rodrigues and W.R. Koski (*eds.*). 2009. Joint Monitoring Program in the Chukchi and Beaufort seas, open water seasons, 2006-2007. LGL Alaska Rep. P971-2. Rep. from LGL Alaska Res. Assoc. Inc. (Anchorage, AK) et al. for Shell Offshore Inc. (Anchorage, AK) et al. 485 p. plus appendices.

Blackwell, S.B., C.S. Nations, T.L. McDonald, A.M. Thode, K.H. Kim, C.R. Greene and M.A. Macrander. 2009b. Effects of seismic exploration activities on the calling behavior of bowhead whales in the Alaskan Beaufort Sea. p. 35 *In:* Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Canada, 12-16 Oct. 2009. 306 p.

BLM. 2003. Northwest National Petroleum Reserve – Alaska Final Integrated Activity Plan/Environmental Impact Statement. Vol. 1. U.S. Department of the Interior, Bureau of Land Management, in cooperation with the U.S. Department of the Interior Minerals Management Service. BLM/AK/PL-04/002+3130+930.

Bockstoce, J.J., and J.J. Burns. 1993. Commercial whaling in the North Pacific sector. Pp. 563-577 *In:* J.J. Burns, J.J Montague and C.J. Cowles (*eds.*). The Bowhead Whale. Society for Marine Mammalogy, Special Publication No. 2.

Bonk, V. 2009. The Edge of the World. Coast Guard Magazine. U.S. Coast Guard. Issue 4.

Boveng, P.L., J.L. Bengtson, T.W. Buckley, M.F. Cameron, S.P. Dahle, B.A. Megrey, J.E. Overland and N.J. Williamson. 2008. Status review of the ribbon seal (*Histriophoca fasciata*). U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-191, 115 p.

Boveng, P.L., J.L. Bengtson, T.W. Buckley, M.F. Cameron, S.P. Dahle, B.P. Kelly, B.A. Megrey, J.E. Overland and N.J. Williamson. 2009. Status review of the spotted seal (*Phoca largha*). U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-200, 153 p.

Braham, H.W. 1984. The bowhead whale, Balaena mysticetus. Marine Fisheries Review 46(4):45-53.

Braham, H.W., M.A. Fraker and B.D. Krogman. 1980. Spring migration of the western Arctic population of bowhead whales. Marine Fisheries Review 42(9-10):36-46.

Braham, H.W., B.D. Krogman and G.M. Caroll. 1984a. Bowhead and White Whale Migration, Distribution, and Abundance in the Bering, Chukchi, and Beaufort Seas, 1975-78. Technical Report, NOAA.

Braham, H.W., J.J. Burns, G.A. Fedoseev and B.D. Krogman. 1984b. Habitat partitioning by ice-associated pinnipeds: distribution and density of seals and walruses in the Bering Sea, April 1976. Pp. 25-47, *In:* F.H. Fay and G.A. Fedoseev (*eds.*), Soviet-American cooperative research on marine mammals. vol. 1. Pinnipeds. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 12.

Brand, A.R., and U.A.W. Wilson. 1996. Seismic Surveys and Scallop Fisheries: A Report on the impact of a Seismic Survey on the 1994 Isle of Man Queen Scallop Fishery. Port Erin, Isle of Man, British Commonwealth: Port Erin Marine Laboratory.

Braund, S.R., and E.L. Moorehead. 1995. Contemporary Alaska Eskimo bowhead whaling villages. Pp.253-279, *In:* A.P. McCartney (*ed.*), Hunting the Largest Animals/Native Whaling in the Western Arctic and Subarctic. Studies in Whaling 3. Can. Circumpolar Inst., Univ. Alberta, Edmonton, Alb. 345 p.

Braund, S.R., K. Brewster, L. Moorehead, T. Holmes and J. Kruse. 1993. North Slope subsistence study/Barrow 1987, 1988, 1989. OCS Study MMS 91-0086. Rep. from Stephen R. Braund & Assoc. and Inst. Social & Econ. Res., Univ. Alaska Anchorage. 466 p.

Brewer, K, M. Gallagher, P.Regos, P.Insert, and J. Hall. 1993. Kuvlum #1 Exploration Prospect: Site Specific Monitoring Program. Final Report. Prepared by Coastal and Offshore Pacific Corporation, Walnut Creek, CA, for ARCO Alaska Inc., Anchorage, AK. 80 p.

Brigham, L.W. 1985. New developments in Soviet nuclear Arctic ships. U.S. Naval Institute Proceedings, 111(12): 131-133.

Brodie, P.F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale with reference to the Cumberland Sound, Baffin Island, population. Journal of Fisheries Research Board of Canada 28:1309-1318.

Brodsky, W.A. 1957. The Copepod (Calanoida) Fauna and Zoogeographic Division into Districts in the Northern Part of the Pacific Ocean and of the Adjacent Waters. Moscow: Zoological Institute, Academy of Sciences of the U.S.S.R.

Brower, H., Jr. 1996. Observations on locations at which bowhead whales have been taken during the fall subsistence hunt (1988 through 1995) by Eskimo hunters based in Barrow, Alaska. North Slope Borough Department of Wildlife Management, Barrow, AK. 8 p. Revised 19 Nov. 1996.

Brower, H. 2004. The Whales, They Give Themselves. Conversations with Harry Brower, Sr. [ed.] Karen Brewster. University of Alaska Press, 2004. Vol. 4, Oral Biography Series. Series Editor: William Schneider. Fairbanks, AK.

Brower, W.A., Jr., R.G. Baldwin, Jr. C.N. Williams, J.L. Wise and L.D. Leslie. 1988. Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Vol. I, Gulf of Alaska. Vol. I, Gulf of Alaska. Document ID: NAVAIR 50-1C-551; MMS 87-0011. Asheville, NC and Anchorage, AK: USDOD, NOCD; USDOI, MMS, Alaska OCS Region; and USDOC, NOAA, NOS, 530 pp.

Brown, W. 1993. Avian Collisions with Utility Structures, Biological Perspectives. *In:* EPRI, Proceedings: Avian Interactions with Utility Structures, International Workshop, pp. 12-13.

Brueggeman, J. 2009a. Marine Mammal Surveys at the Klondike and Burger Survey Areas in the Chukchi Sea During the 2008 Open Water Season.

Brueggeman, J. 2009b. 90-Day Report of the Marine Mammal Monitoring Program for the ConocoPhillips Alaska Shallow Hazards Survey Operations during the 2008 Open Water Season in the Chukchi Sea. Prepared for ConocoPhillips Alaska, Inc. Canyon Creek Consulting LLC, Seattle, WA.

Brueggeman, J., C. Malme, R. Grotefendt, D. Volsen, J. Burns, D. Chapman, D. Ljungblad and G. Green. 1990. 1989 Walrus Monitoring Program, Klondike, Burger, and Popcorn Prospects in the Chukchi Sea. Shell Western E&P.

Brueggeman, J.J., D.P. Volsen, R.A. Grotefendt, G.A. Green, J.J. Burns, and D.K. Ljungblad. 1991. 1990 Walrus Monitoring Program/The Popcorn, Burger and Crackerjack Prospects in the Chukchi Sea. Houston, TX: Shell Western E&P, Inc.

Brueggeman, J.J., R.A. Grotefendt, M.A. Smultea, G.A. Green, R.A. Rowlett, C.C. Swanson, D.P. Volsen, C.E. Bowlby, C.I. Malme, R. Mlawski and J.J. Burns. 1992. Final Report, Chukchi Sea 1991, Marine Mammal Monitoring Program (Walrus and Polar Bear) Crackerjack and Diamond Prospects. Anchorage, AK: Shell Western E&P Inc. and Chevron U.S.A., Inc.

Brueggeman, J., D. Volsen, R. Grotefendt, G. Green, J. Burns and D. Ljungblad. 1991. Walrus Monitoring Program, the Popcorn, Burger, and Crackerjack Prospects in the Chukchi Sea. Bellevue: EBASCO.

Burek, K.A., F.M.D. Gulland and T.M. O'Hara. 2008. Effects of climate change on Arctic marine mammal health. Ecological Applications 18(2):S126-S134.

Burgess, W.C., and C.R. Greene, Jr. 1999. Physical Acoustic Measurements. *In:* Marine Mammal and Acoustical Monitoring of Western Geophysical's Open-Water Seismic Program in the Alaskan Beaufort Sea, 1998, W.J. Richardson, ed. LGL Report TA2230-3. Houston, TX; Anchorage, AK; and Silver Spring, MD: Western Geophysical and USDOC, NMFS, 390 pp.

Burn, D.M., M.A. Webber and M.S. Udevitz. 2006. Application of airborne thermal imagery to surveys of Pacific walrus. Wildlife Society Bulletin 34(1):51-58.

Burns, J.J. 1967. The Pacific bearded seal. Alaska Department of Fish and Game, Pittman-Robertson Project Report W-6-R and W-14-R. 66 pp.

Burns, J.J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi Seas. Journal of Mammalogy 51:445-454.

Burns, J.J. 1973. Marine mammal report. Alaska Department of Fish and Game, Pittman-Robertson Project Report W-17-3, W-17-4, and W-17-5.

Burns, J.J. 1981. Bearded seal - *Erignathus barbatus* Erxleben, 1777. Pp. 145-170, *In:* S.H. Ridgway and R.J. Harrison (*eds.*), Handbook of Marine Mammals. vol. 2. Seals. Academic Press, New York.

Burns, J.J., and S.J. Harbo. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25:279-290.

Burns, J.J., L.H. Shapiro and F.H. Fay. 1981. Ice as marine mammal habitat in the Bering Sea. Pp. 781-797, *In:* D.W. Hood and J.A. Calder (*eds.*), The eastern Bering Sea shelf: oceanography and resources. vol. 2. U.S. Department of Commerce, NOAA, Off. Mar. Pollut. Assess., Juneau, Alaska.

Burns, J.J., J.J Montague and C.J. Cowles (*eds.*). 1993. The Bowhead Whale. Society for Marine Mammalogy, Special Publication No. 2. 787 pp.

Calambokidis, J., G.H. Steiger, J.C. Cubbage, K.C. Balcomb III and P. Bloedel. 1989. Biology of humpback whales in the Gulf of the Farallones. Report to Gulf of the Farallones National Marine Sanctuary, San Francisco, CA by Cascadia Research Collective, 218½ West Fourth Avenue, Olympia, WA. 93 pp.

Calambokidis, J., G.H. Steiger and J. R. Evenson. 1993a. Photographic identification and abundance estimates of humpback and blue whales off California in 1991-92. Final Contract Report 50ABNF100137 to Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. 67 pp.

Calambokidis, J., J.R. Evenson, J.C. Cubbage, S.D. Osmek, D. Rugh and J.L. Laake. 1993b. Calibration of sighting rates of harbor porpoise from aerial surveys. Final report to the National Marine Mammal Laboratory, AFSC, NMFS, NOAA, 7600 Sand Point Way, NE, Seattle, WA 98115. 55 pp.

Calambokidis, J., G.H. Steiger, J.M. Straley, T. Quinn, L.M. Herman, S. Cerchio, D.R. Salden, M. Yamaguchi, F. Sato, J.R. Urban, J. Jacobson, O. Von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, N. Higashi, S. Uchida, J.K.B. Ford, Y. Miyamura, P. Ladrón de Guevara, S.A. Mizroch, L. Schlender and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final Contract Report 50ABNF500113 to Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. 72 pp.

Calambokidis, J., G.H. Steiger, J.M. Straley, L.M. Herman, S. Cerchio, D.R. Salden, J. Urban R., J.K. Jacobsen, O. von Ziegesar, K.C. Balcomb, C.M. Gabriele, M.E. Dahlheim, S. Uchida, G. Ellis, Y. Miyamura, P. Ladrón de Guevara P., M. Yamaguchi, F. Sato, S.A. Mizroch, L. Schlender, K. Rasmussen, J. Barlow and T.J. Quinn, II. 2001. Movements and population structure of humpback whales in the North Pacific. Marine Mammal Science 17(4):769-794.

Calambokidis, J., J.D. Darling, V. Deeke, P. Gearin, M. Gosho, W. Megill, C.M. Tombach, D. Goley, C. Toropova and B. Gisbourne. 2002. Abundance, range, and movements of a feeding aggregation of gray whales (*Eschrichtius robustus*) from California and southeastern Alaska in 1998. Journal of Cetacean Research Management 4(3): 267-276.

Calambokidis, J., E.A. Falcone, T.J. Quinn, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán R., D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins and N. Maloney. 2008. SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific. Final report for Contract AB133F-03-RP-00078 U.S. Dept of Commerce Western Administrative Center, Seattle, Washington. (available at http://www.cascadiaresearch.org/SPLASH/SPLASH-contract-Report-May08.pdf)

Cameron, M.F., and P.L. Boveng. 2007. Abundance and distribution surveys for ice seals aboard USCG Healy and the Oscar Dyson. Alaska Fisheries Science Center Quarterly Report, April – May – June 2007:12 – 14.

Carroll, G.M., J.C. George, L.F. Lowry and K.O. Coyle. 1987. Bowhead Whale (*Balaena mysticetus*) Feeding near Point Barrow, Alaska During the 1985 Spring Migration. Arctic 40:105-110.

Cavanagh, R.C. 2000. Criteria and thresholds for adverse effects of underwater noise on marine animals. AFRLHE-WP-TR-2000-0092. Report from Science Applications International Corp., McLean, VA, for Air Force Res. Lab., Wright-Patterson AFB, OH.

CBD. 2007. Petition to list the ribbon seal (*Histriophoca fasciata*) as a threatened or endangered species under the Endangered Species Act. Center for Biological Diversity, San Francisco, CA.

CBD. 2008a. Petition to list three seal species under the Endangered Species Act: ringed seal (*Pusa hispica*), bearded seal (*Erignatha barbatus*), and spotted seal (*Phoca largha*). Center for Biological Diversity, San Francisco, CA.

CBD. 2008b. Petition to list the Pacific walrus (*Odobenus rosmaurs divergens*) as a threatened or endangered species under the Endangered Species Act. Center for Biological Diversity, San Francisco, CA.

CDFO. 2004. Review of Scientific Information on Impacts of Seismic Sound on Fish, Invertebrates, Marine Turtles and Marine Mammals. Habitat Status Report 2004/002. Ottawa, Ont., Canada: CDFO, Canadian Science Advisory Section.

Christian, J.R., A. Mathien, D.H. Thomson, D. White and R.A. Buchaman. 2003. Effect of seismic energy on snow crab (*Chionoecetes opilio*). Rep. by LGL Ltd., St. John's, Nfld., for Environmental Studies Research Fund (ESRF), Calgary, Alta, 56 p.

Christian, J.R., A. Mathien and R.A. Buchaman. 2004. Chronic effects of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report No. 158, March 2004. Calgary, Alta. 45p.

Clark, C.W., and G.C. Gagnon. 2006. Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. International Whaling Commission Working Paper. SC/58/E9. 9 p.

Clark, C.W., and J.H. Johnson. 1984. The sounds of the bowhead whales, *Balaena mysticetus*, during the spring migrations of 1979 and 1980. Canadian Journal of Zoology 62:1436–1441.

Clark, C.W., and W.T. Ellison. 2004. Potential use of low-frequency sounds by baleen whales for probing the environment: Evidence from models and empirical measurements. Pp. 564-589, *In:* J.A. Thomas, C.F. Moss and M. Vater (*eds.*), Echolocation in Bats and Dolphins. University of Chicago Press, Chicago, IL. 604 p.

Clark, C.W., S. Mitchell and R. Charif. 1994. Distribution and behavior of the bowhead whale, *Balaena mysticetus,* based on preliminary analysis of acoustic data collected during the 1993 spring migration off Point Barrow, Alaska. Unpublished report submitted to International Whaling Commission. (SC/46/AS19). 24 pp.

Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel and D. Ponirakis. 2009a. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Marine Ecology Progress Series 395:201-222.

Clark, C.W., W.T. Ellison, B.L. Southall, L. Hatch, S. Van Parijs, A. Frankel and D. Ponirakis. 2009b. Acoustic masking in marine ecosystems as a function of anthropogenic sound sources. Report to the International Whaling Commission. SC-61 E10. 19 pp.

Clarke, J.T., S.E. Moore and M.M. Johnson. 1993. Observations on Beluga Fall Migration in the Alaskan Beaufort Sea, 1982-87, and Northeastern Chukchi Sea, 1982-91. International Whaling Commission.

Coachman, L.K. 1993. On the Flow Field in the Chirikov Basin. Continental Shelf Research 135(6):481-508.

Coffing, M., C. Scott and C.J. Utermohle. 1998. The subsistence harvest of seals and sea lions by Alaska Natives in three communities of the Yukon-Kuskokwim Delta, Alaska, 1997-1998. Technical Paper No. 255, Alaska Dep. Fish and Game, Division of Subsistence, Juneau.

Cosens, S.E., H. Cleator and P. Richard. 2006. Numbers of bowhead whales (*Balaena mysticetus*) in the Eastern Canadian Arctic, based on aerial surveys in August 2002, 2003 and 2004. Unpublished paper submitted to the Scientific Committee of the International Whaling Commission. June 2006 (SC/58/BRG7). 19 pp.

Cox, T.M., T.J. Ragen, A.J. Read, E. Vos, R.W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houserp, R. Hullar, P.D. Jepson, D. Ketten, C.D. Macleod, P. Miller, S. Moore, D.C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Meads and L. Benner. 2006. Understanding the impacts of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7(3):177-187.

Craig, P.C. 1984. Fish Use of Coastal Waters of the Alaskan Beaufort Sea: A Review. Transactions of the American Fisheries Society 113:265-282.

Craig, P.C. 1989. An Introduction to Anadromous Fishes in the Alaskan Arctic. In: Research Advances on Anadromous Fish in Arctic Alaska and Canada, nine papers contributing to an ecological synthesis, D.W. Norton, ed. Biological Papers of the University of Alaska No. 24. Fairbanks, AK: Institute of Arctic Biology, pp. 27-54.

Craig, P.C., and L. Halderson. 1986. Pacific Salmon in the North American Arctic. Arctic 391:2-7.

Craig, P.C., and P. Skvorc. 1982. Fish Resources of the Chukchi Sea, Status of Existing Information and Field Program Design. OCS Study, MMS-89-0071. Anchorage, AK: USDOI, MMS, pp. 1-63.

Crum, L.A., M.R. Bailey, J. Guan, P.R. Hilmo, S.G. Kargl and T.J. Matula. 2005. Monitoring bubble growth in supersaturated blood and tissue ex vivo and the relevance to marine mammal bioeffects. Acoustic Research Letters Online 6(3):214-220.

Cummings, W.C., and D.V. Holliday. 1987. Sounds and source levels from bowhead whales off Pt. Barrow, Alaska. Journal of the Acoustical Society of America 82:814–821.

Cummings, W.C., D.V. Holliday, W.T. Ellison and B.J. Graham. 1983. Technical Feasibility of Passive Acoustic Location of Bowhead Whales in Population Studies off Point Barrow, Alaska. T-83-06-002. Barrow, AK: NSB.

Dahlheim, M., A. York, R. Towell, J. Waite and J. Breiwick. 2000. Harbor porpoise (*Phocoena phocoena*) abundance in Alaska: Bristol Bay to Southeast Alaska, 1991-1993. Marine Mammal Science 16:28-45.

Dalen, J., and G.M. Knutsen. 1987. Scaring effects in fish and harmful effects on eggs, larvae and fry by offshore seismic explorations. Progress in Underwater Acoustics:93-102.

Dames and Moore. 1996. Northstar Project Whalers' Meeting., Nuiqsut, Ak. Anchorage, AK: Dames and Moore.

Darling, J.D. 1984. Gray Whales off Vancouver Island, British Columbia. *In:* S.L. Swartz, S. Leatherwood and M.L. Jones (*eds.*). The Gray Whale, *Eschrichtius robustus*. pp. 267-287. Orlando: Academic Press.

daSilva, C.Q., J. Zeh, D. Madigan, J. Laake, D. Rugh, L. Baraff, W. Koski and G. Miller. 2000. Capture-recapture estimation of bowhead whale population size using photo-identification data. Journal of Cetacean Research and Management 2(1):45-61.

Davies, J.R. 1997. The impact of an offshore drilling platform on the fall migration path of bowhead whales: a GIS-based assessment. Unpubl. MS Thesis, Western Washington University, Bellingham, WA. 51 pp.

Davis, R.A., and C.I. Malme. 1997. Potential effects on ringed seals of ice-breaking ore carriers associated with the Voisey's Bay Nickel Project. LGL Rep. TA2147-1. Report by LGL Limited, King City, ON, for Voisey's Bay Nickel Company Limited, St. John's, NL. 34 p.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans and W.G. Alliston. 1982. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales (*Balaena mysticetus*) in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. SC/34/PS20. International Whaling Commission, Cambridge, UK. 13 p.

Davis, R.A., C.R. Greene and P.L. McLaren. 1985. Studies of the potential for drilling activities on Seal Island to influence fall migration of bowhead whales through Alaskan nearshore waters. Rep. from LGL Ltd., King City, Ont., for Shell Western E & P Inc., Anchorage, AK. 70 p.

Day, R.H., J.R. Rose, A.K. Prichard, R.J. Blaha and B.A. Cooper. 2004. Environmental effects on the fall migration of eiders at Barrow, Alaska. Marine Ornithology 32:13-24.

Derocher, A.E., O. Wiig and M. Anderson. 2002. Diet composition of polar bears in Svalbard and the western Barents Sea. Polar Biology 25:448-452.

DeRuiter, S.L., P.L. Tyack, Y.-T. Lin, A.E. Newhall, J.F. Lynch and P.J.O. Miller. 2006. Modeling acoustic propagation of airgun array pulses recorded on tagged sperm whales (*Physeter macrocephalus*). Journal of the Acoustical Society of Amerca 120(6):4100-4114.

Di Iorio, L., and C.W. Clark. 2009. Exposure to seismic survey alters blue whale acoustic communication. Biology Letters doi: 10.1098/rsbl.2009.0651.

Diachok, O.I., and R.S. Winokur. 1974. Spatial variability of underwater ambient noise at the Arctic icewater boundary. Journal Acoustic Society America 55(4): 750-753.

Dick, M.H., and W. Donaldson. 1978. Fishing vessel endangered by crested auklet landings. Condor 80:235-236.

Dionne, M., B. Sainte-Marie, E. Bourget and D. Gilbert. 2003. Distribution and Habitat Selection of Early Benthic Stages of Snow Crab *Chionoecetes opilio*. Marine Ecology Progress Series 259:117-128.

Divoky, G.J. 1979. Sea ice as a factor in seabird distribution and ecology in the Beaufort, Chukchi and Bering Seas. Pp. 9-18 in Conservation of marine birds of northern North America (J.C. Bartonek and D.N. Nettleship, eds.). U.S. Fish Wildl. Res. Rept. No. 11.

Divoky, G.J. 1983. The pelagic and nearshore birds of the Alaskan Beaufort Sea. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 23(1984):397-513. NTIS PB85-212595.

Dorsey, E.M., S.J. Stern, A.R. Hoelzel and J. Jacobsen. 1990. Minke whale (*Balaenoptera acutorostrata*) from the west coast of North America: individual recognition and small scale site fidelity. Reports of the International Whaling Commission (Special Issue 12):357-368.

Dueck, L.P., M.P. Hiede-Jorgensen, M.V. Jensen and L.D. Postma. 2006. Update on investigations of bowhead whale (*Balaena mysticetus*) movements in the eastern Arctic, 2003-2005, based on satellite-linked telemetry. Unpublished paper submitted to the Scientific Committee of the International Whaling Commission. June 2006 (SC/58/BRG5). 17 pp.

Dunn, R.A., and O. Hernandez. 2009. Tracking blue whales in the eastern tropical Pacific with an ocean-bottom seismometer and hydrophone array. Journal of the Acoustical Society of America 126(3):1084-1094.

Durner, G.M., S.C. Amstrup, R. Nielson and T. McDonald. 2004. Using discrete choice modeling to generate resource selection functions for female polar bears in the Beaufort Sea. *In:* S. Huzurbazar (*ed.*). Resource Selection Methods and Applications: Proceedings of the 1st International Conference on Resource Selection. pp. 107-120. Laramie, WY.

Duval, W.S. 1993. Proceedings of a workshop on Beaufort Sea beluga: February 3-6, 1992. Vancouver, B.C. Env. Studies Res. Found. Rep. No 123. Calgary. 33 pp. + appendices.

Ely, C.R., C.P. Dau and C.A. Babcock. 1994. Decline in a population of spectacled eiders nesting on the Yukon-Kuskokwim delta, Alaska. Northw. Natural. 75:81-87.

Engås, A., S. Løkkeborg, E. Ona and A.V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhu*a) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fish and Aquatic Science 53:2238-2249.

Engel, M.H., M.C.C. Marcondes, C.C.A. Martins, F.O. Luna, R.P. Lima and A. Campos. 2004. Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult humpback whales in Abrolhos Bank, northeastern coast of Brazil. Paper SC/56/E28 presented to the IWC Scientific Committee, IWC Annu. Meet., 19-22 July, Sorrento, Italy.

Erbe, C., and D.M. Farmer. 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. Deep-Sea Research II. 45:1373-1388.

Erbe, C., and D.M. Farmer. 2000. Zones of impact around icebreakers affecting beluga whales in the Beaufort Sea. Journal of the Acoustical Society of America. 108 (3): 1332-1340.

Evans, C.R., S.R. Johnson and W.R. Koski. 1987. Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea, autumn 1986: Aerial surveys of whale distribution. Report by LGL Ltd., King City, Ontario, for Shell Western E& P Inc., Anchorage. 69 p.

Fair, P.A., and P.R. Becker. 2000. Review of stress in marine mammals. Journal of Aquatic Ecosystem Stress Recovery 7:335-354.

Fay, F.H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. Pp. 383-389, *In:* D.W. Hood and E.J. Kelley (*eds.*), Oceanography of the Bering Sea. Univ. Alaska, Fairbanks, Inst. Mar. Sci. Occas. Publ. 2.

Fay, F.H. 1982. Ecology and Biology of the Pacific Walrus (*Odobenus rosmarus divergens*). North American Fauna 74. U.S. Fish and Wildlife Service, Washington, DC., 279 pp.

Fay, F.H., B.P. Kelly, P.H. Gehnrich, J.L. Sease and A.A. Hoover. 1984. Modern populations, migrations, demography, trophics, and historical status of the Pacific walrus. Final Report R.U. #611. NOAA Outer Continental Shelf Environmental Assessment Program, Anchorage AK., 142 pp.

Fay, F.H., B.P. Kelly and J.L. Sease. 1989. Managing the exploitation of Pacific walruses: a tragedy of delayed response and poor communication. Marine Mammal Science 5:1-16.

Fay, F.H., L.L. Eberhardt, B.P. Kelly, J.J. Burns and L.T. Quakenbush. 1997. Status of the Pacific walrus Population, 1950-1989. Marine Mammal Science 13(4):537-565.

Fedoseev, G. A. 1971. The distribution and numbers of seals on whelping and moulting patches in the Sea of Okhotsk. Pp. 135-158 In K. K. Chapskii and E. S. Mil'chenko (*eds.*), Research on marine mammals. Nauchno-issled. Inst. Rybn. Khoz. Okeanogr. 39:1-344 (Translated from Russian by Can. Fish. Mar. Serv., 1974, Transl. Ser. 3185).

Ferguson, S.H., I. Stirling and P. McLoughlin. 2005. Climate change and ringed seal (*Phoca hispida*) recruitment in western Hudson Bay. Marine Mammal Science 21(1):121–135

Fernández, A., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, E. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham and P.D. Jepson. 2004. Pathology: whales, sonar and decompression sickness (reply). Nature 428(6984, 15 Apr.). doi: 10.1038/nature02528a.

Fernández, A., J.F. Edwards, F. Rodriquez, A.E. de los Monteros, P. Herráez, P. Castro, J.R. Jaber, V. Martin and M. Arbelo. 2005. "Gas and fat embolic syndrome" involving a mass stranding of beaked whales (Family Ziphiidae) exposed to anthropogenic sonar signals. Veterin. Pathol. 42(4):446-457.

Finley, K.J. 1982. The estuarine habitat of the beluga or white whale, *Delphinapterus leucas*. Cetus 4:4-5.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S. H. Ridgway. 2002. Temporary shift in masked hearing thresholds (MTTS) in odontocetes after exposure to single underwater impulses from a seismic watergun. Journal of the Acoustical Society of America 111:2929-2940.

Finneran, J.J., D.A. Carder, C.E. Schlundt and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. Journal of the Acoustical Society of America 118:2696-2705.

Finneran, J.J., D.A. Carder, C.E. Schlundt and R.L. Dear. 2010a. Growth and recovery of temporary threshold shift at 3 kHz in bottlenose dolphins: Experimental data and mathematical models. Journal of the Acoustical Society of America 127(5):3256-3266.

Finneran, J.J., D.A. Carder, C.E. Schlundt and R.L. Dear. 2010b. Temporary threshold shift in a bottlenose dolphin (*Tursiops truncatus*) exposed to intermittent tones. Journal of the Acoustical Society of America 127(5):3267-3272.

Fischback, A.S., S.C. Amstrup and D.C. Douglas. 2007. Landward and eastward shift of Alaskan polar bear denning associated with recent sea ice changes. Polar Biology 30:1395-1405.

Flint, P.L. and M.P. Herzog. 1999. Breeding of Steller's eiders, *Polysticta stelleri*, on the Yukon-Kuskokwim delta, Alaska. Canadian Field-Naturalist. 113(2):306-308.

Foote, A.D., R.W. Osborne and A.R. Hoelzel. 2004. Whale-call response to masking boat noise. Nature 428:910.

Forney, K.A., and R.L. Brownell. 1996. Preliminary report of the 1994 Aleutian Island marine mammal survey. Unpublished report submitted to International Whaling Commission. (SC/48/O 11). 15 pp.

Forney, K.A., J. Barlow and J.V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. Fishery Bulletin 93:15-26.

Fox, A., and J. Madsen. 1997. Behavioural and distributional effects of hunting disturbance on waterbirds in Europe: implications of refuge design. Journal of Applied Ecology 34:1-13.

Frame, G.W. 1973. Occurrence of birds in the Beaufort Sea, summer 1969. Auk 90(3):552-563.

Fredrichson, L.H. 2001. Steller's Eider (*Polysticta stelleri*). *In*: A. Poole and F. Gill (*eds.*), The Birds of North America, No. 571. The Birds of North America, Inc., Philadelphia, PA.

Frost, K. 1994. ADF&G Wildlife Notebook Series- Gray Whale. http://www.adfg.state.ak.us/pubs/notebook/marine/gray.php.

Frost, K.J., and L.F. Lowry. 1983. Demersal Fishes and Invertebrates Trawled in the Northeastern Chukchi and Western Beaufort Seas, 1976-1977. NOAA Technical Report NMFS SSRF- 764. Seattle, WA: USDOC, NOAA, NMFS, 22 pp.

Frost, K.J., and L.F. Lowry. 1995. Radio tag based correction factors for use in beluga whale population estimates. Working paper for Alaska Beluga Whale Committee Scientific Workshop, Anchorage, AK, 5-7 April 1995. 12 pp. (available upon request- Alaska Dep. Fish and Game, 1300 College Rd., Fairbanks, AK 99701).

Frost, K.J., and L.F. Lowry. 1999. Monitoring distribution and abundance of ringed seals in northern Alaska. Interim Rep. Cooperative Agreement Number 14-35-0001-30810 submitted to the U.S. Deppartment of the Interior, Minerals Management Service, Anchorage, AK. 37p + appendix

Frost, K.J., L.F. Lowry, J.R. Gilbert and J.J. Burns. 1988. Ringed seal monitoring: relationships of distribution and abundance to habitat attributes and industrial activities. Final Rep. contract no. 84-ABC-00210 submitted to U.S. Department of the Interior, Minerals Management Service, Anchorage, AK. 101 pp.

Frost, K.J., L.F. Lowry and G. Carroll. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic 46:8-16.

Frost, K.J., L.F. Lowry, G. Pendleton and H.R. Nute. 2002. Monitoring distribution and abundance of ringed seals in northern Alaska. OCS Study MMS 2002-04. Final report from the Alaska Dep. Fish and Game, Juneau, AK, for U.S. Minerals Management Service, Anchorage, AK. 66 pp. + Appendices.

Frost, K.J., L.F. Lowry, G. Pendleton and H.R. Nute. 2004. Factors affecting the observed densities of ringed seals, *Phoca hispida*, in the Alaskan Beaufort Sea, 1996-99. Arctic 57:115-128.

Fujino, K. 1960. Monogenetic and marking approaches to identifying sub-populations of the North Pacific whales. Scientific Reports of Whales Research Institute, Tokyo 15:84-142.

Fugro (Fugro-McClelland Marine Geosciences, Inc.). 1989. Summary Report, High-Resolution Geophysical Survey and Assessment of Potential Shallow Drilling Hazards, Burger Prospect, Chukchi Sea, Alaska. Report to Shell Western E&P, Inc., Houston, Texas.

Fuller, A., and J. George. 1997. Evaluation of Subsistence Harvest Data from the North Slope Borough 1993 Census for Eight North Slope Villages: For the Calendar Year 1992. Second Edition. Department of Wildlife Management, North Slope Borough, Barrow, Alaska.

Funk, D., D. Hannay, D. Ireland, R. Rodrigues and W. Koski. (*eds.*). 2008. Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–November 2007: 90-day report. LGL Report P969-1. Report from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for Shell Offshore Inc, National Marine Fisheries Service and U.S. Fish and Wildlife Service. 218 pp plus appendices.

Funk, D.W., D.S. Ireland, R. Rodrigues and W.R. 2009. Koski. Joint Monitoring Program in the Chukchi and Beaufort Seas, Open Water Seasons, 2006-2008. Anchorage: LGL Alaska.

Gabriele, C.M., and B. Kipple. 2009. Measurements of near-surface, near-bow underwater sound from cruise ships. Pp. 86, *In:* Abstract of the 18th Biennial Conference for the Biology of Marine Mammals, Québec, Oct. 2009. 306 p.

Gailey, G., B. Würsig and T.L. McDonald. 2007. Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, northeast Sakhalin Island, Russia. Environmental Monitoring and Assessment 134(1-3):75-91.

Galginaitis, M.S., and W.R. Koski. 2002. Kaktovikmiut whaling: historical harvest and local knowledge of whale feeding behavior. Pp. 2-1 to 2-30 (Chap. 2), *In:* W.J. Richardson and D.H. Thomson (*eds.*). Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, vol. 1. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Management Service, Anchorage, AK, and Herndon, VA. 420 p.

Galginaitis, M., and D.W. Funk. 2004. Annual assessment of subsistence bowhead whaling near Cross Island, 2001 and 2002: ANIMIDA Task 4 final report. OCS Study MMS 2004-030. Report from Applied Sociocultural Res. and LGL Alaska Res. Assoc. Inc., Anchorage, AK, for U.S. Minerals Management Service, Anchorage, AK. 55 p. + CD-ROM.

Galginaitis, M., and D.W. Funk. 2005. Annual assessment of subsistence bowhead whaling near Cross Island, 2003: ANIMIDA Task 4 annual report. OCS Study MMS 2005-025. Report from Applied Sociocultural Research and LGL Alaska Res. Assoc. Inc., Anchorage, AK, for U.S. Minerals Management Service, Anchorage, AK. 36 p. + Appendices.

Gallaway, B.J., and R.G. Fechhelm., 2000. Anadromous and Amphidromous Fishes. *In:* The Natural History of an Arctic Oil Field: Development and the Biota, J.C. Truett and S.R. Johnson, eds. San Francisco, CA: Academic Press, pp. 349-369.

Garner, W., and D. Hannay. 2009. Sound measurements of Pioneer vessels. Chapter 2, *In:* M.R. Link and R. Rodrigues (*eds.*). Monitoring of in-water sounds and bowhead whales near the Oooguruk and Spy Island drillsites in eastern Harrison Bay, Alaskan Beaufort Sea, 2008. Report from LGL Alaska Research Associates, Inc., Anchorage, AK, Greeneridge Sciences, Inc., Santa Barbara, CA, and JASCO Applied Sciences, Victoria, BC, for Pioneer Natural Resources, Inc, Anchorage, AK, and Eni US Operating Co. Inc., Anchorage, AK.

Garner, G.W., S.T. Knick and D.C. Douglas. 1990. Seasonal movements of adult female polar bears in the Bering and Chukchi Seas. International Conference on Bear Research and Management.

Garner, G.W., S.C. Amstrup, I. Stirling and S. E. Belikov. 1994. Habitat considerations for polar bears in the North Pacific Rim. Transactions of the North American Wildlife and Natural Resource Conference. 1994. 111-120.

Gaskin, D.E. 1984. The harbor porpoise *Phocoena phocoena* (L.): Regional populations, status, and information on direct and indirect catches. Report of the International Whaling Commission 34:569-586.

Gedamke, J., S. Frydman and N. Gales. 2008. Risk of baleen whale hearing loss from seismic surveys: preliminary results from simulations accounting for uncertainty and individual variation. International Whaling Commission. Working Pap. SC/60/E9. 10 p.

Gentry, R. (*ed.*). 2002. Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans. 24-25 April, Natitional Marine Fisheries Service, Silver Spring, MD. 19 p. Available at http://www.nmfs.noaa.gov/pr/acoustics/reports.htm

George, J.C., L.M. Philo, K. Hazard, D. Withrow, G.M. Carroll and R.S. Suydam. 1994. Frequency of Killer whale (*Orcinus orca*) attacks and ship collisions based on scarring on bowhead whales (*Balaena mysticetus*) of the Bering-Chukchi-Beaufort Seas Stock. Arctic 473:247-255.

George, J.C., H. Hunington, K. Brewster, H. Eicken, D.W. Norton and R. Glenn. 2003. Observations on Shorefast Ice Dynamics in Arctic Alaska and the Responses of the Inupiat Hunting Community. Arctic 574:363-374.

George, J.C., J. Zeh, R. Suydam and C. Clark. 2004. Abundance and Population Trend (1978-2001) of Western Arctic Bowhead Whales Surveyed Near Barrow, Alaska. Marine Mammal Science 20:755-773.

George, J.C., S.E. Moore and R. Suydam. 2007. Summary of stock structure research on the Bering-Chukchi-Beaufort Seas stock of bowhead whales 2003-2007. Unpublished report submitted to International Whaling Commission. (SC/59/BRG3). 15 pp.

Gerrodette, T., and W.G. Gilmartin. 1990. Demographic consequences of changed pupping and hauling sites of the Hawaiian monk seal. Conservation Biology 4:423-430.

Georgette, S., M. Coffing, C. Scott and C. Utermohle. 1998. The subsistence harvest of seals and sea lions by Alaska Natives in the Norton Sound-Bering Strait Region, Alaska, 1996-97. Technical Paper No. 242, Alaska Dep. Fish and Game, Division of Subsistence, Juneau.

Gitay, H., A. Suarez, R.T. Watson and D.J. Dokken (eds.). 2002. IPCC Technical Paper V. Climate Change and Biodiversity. IPCC, Geneva.

Glenn Gray and Associates. 2005. North Slope Borough Coastal Management Plan Public Review Draft. Prepared for the Alaska Coastal Management Program, Department of Natural Resources, Anchorage. April 20, 2005.

Gloerson, P., W.J. Campbell, D.J. Cavalieri, J.C. Comiso, C.L. Parkinson and H.J. Zwally. 1992. Arctic and Antarctic sea ice, 1978-1987: satellite passive-microwave observations and analysis. Special Publication SP-511, National Aeronautics and Space Administration.

Goold, J.C., and P.J. Fish. 1998. Broadband spectra of seismic survey airgun emissions, with reference to dolphin auditory thresholds. Journal of the Acoustical Society of America 103:2177-2184.

Goold, J.C., and R.F.W. Coates. 2006. Near source, high frequency air-gun signatures. Paper SC/58/E30 presented to the IWC Scientific Committee, IWC Annu. Meeting, 1-13 June, St. Kitts.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. Marine Technology Society Journal 37(4):16-34.

Gordon, J., R. Antunes, N. Jaquet and B. Würsig. 2006. An investigation of sperm whale headings and surface behaviour before, during and after seismic line changes in the Gulf of Mexico. International Whaling Commission Working Paper SC/58/E45. 10 p.

Goudie, R., and C. Ankney. 1986. Body size, activity budgets, and diets of sea ducks wintering in Newfoundland. Ecology 67:1475-1482.

Grebmeier, J., and K. Dunton. 2000. Benthic Processes in the Northern Bering/Chukchi Seas: Status and Global Change. *In:* Impacts of Change in Sea Ice and Other Environmental Parameters in the Arctic. Marine Mammal Workshop, Girdwood, Ak., Feb. 15-17, 2000. Bethesda, MD: Marine Mammal Commission, pp. 61-71.

Grebmeier, J M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin and S.L. McNutt. 2006. A Major Ecosystem Shift in the Northern Bering Sea. Science 311:1461-1464.

Greene, C.R. 1981. Underwater acoustic transmission loss and ambient noise in arctic regions.

Greene, C.R. 1987a. Response of Bowhead Whales to an Offshore Drilling Operation in the Alaska Beaufort Sea, Autumn 1986: Acoustic Studies of Underwater Noise and Localization of Whale Calls. Greeneridge Science Inc. Santa Barbara, CA.

Greene, C.R. 1987b. Acoustic studies of underwater noise and localization of whale calls. (Chap. 2, 128 p.) *In:* LGL and Greeneridge (1987), Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea, autumn 1986. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Shell Western E & P Inc., Anchorage, AK. 371 p.

Greene, C.R., Jr. 1997. Physical acoustics measurements. (Chap. 3, 63 p.) *In:* W.J. Richardson (*ed.*), 1997. Northstar Marine Mammal Marine Monitoring Program, 1996. Marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. Rep. TA2121-2. Report from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Exploration (Alaska) Inc., Anchorage, AK, and U.S. Nation Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD. 245 p.

Greene, C.R., Jr., and S.E. Moore. 1995. Man made noise, Chapter 6, *In:* W.J. Richardson, C.R. Greene, Jr., C.I. Malme and D.H. Thomson (*eds.*). Marine Mammals and Noise. Academic Press, San Diego, CA.

Greene, C.R Jr., and W.J. Richardson, 1988. Characteristics of Marine Seismic Survey Sounds in the Beaufort Sea. Journal of the Acoustical Society of America. 83(6):2246–2254.

Greene, G.D., F.R. Engelhardt and R.J. Paterson (*eds.*). 1985. Proceedings of the Workshop on Effects of Explosives Use in the Marine Environment, Jan. 1985, Halifax, NS. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Branch, Ottawa, Ont.

Greene, C.R., Jr., N.S. Altman and W.J. Richardson. 1999a. Bowhead whale calls. p. 6-1 to 6-23 *In:* W.J. Richardson (*ed.*), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Report TA2230-3. Report from LGL Ltd., King City, Ontario, and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and National Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD. 390 p.

Greene, C.R., Jr., N.S. Altman and W.J. Richardson. 1999b. The influence of seismic survey sounds on bowhead whale calling rates. Journal of the Acoustical Society of America 106(4, Pt. 2):2280 (Abstract).

Gulland, F.M.D., H. Pérez-Cortés M., J. Urgán R., L. Rojas-Bracho, G. Ylitalo, J. Weir, S.A. Norman, M.M. Muto, D.J. Rugh, C. Kreuder and T. Rowles. 2005. Eastern North Pacific gray whale (*Eschrichtius robustus*) unusual mortality event, 1999-2000. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-AFSC-150, 33 pp.

Gurevich, V.S. 1980. Worldwide distribution and migration patterns of the white whale (beluga), Delphinapterus leucas. Reports of the International Whaling Commission 30:465-480.

Hall, J.D., M.L. Gallagher, K.D. Brewer, P.R. Regos and P.E. Isert. 1994. ARCO Alaska, Inc. 1993 Kuvlum Exploration Area Site Specific Monitoring Program. Final Report. Anchorage, AK: ARCO Alaska, Inc.

Hammill, M.O., C. Lydersen, M. Ryg and T.G. Smith. 1991. Lactation in the ringed seal (*Phoca hispida*). Canadian Journal of Fisheries and Aquatic Science. 48(12):2471-2476.

Hansen, S.A., and J.W. VanFleet. 2003. Traditional Knowledge and Intellectual Property: A Handbook on Issues and Options for Traditional Knowledge Holders in Protecting their Intellectual Property and Maintaining Biological Diversity. American Association for the Advancement of Science, Washington, DC.

Harcharek, J. 1995. Inupiaq Arctic Coast. Edited by Smithsonian Institution. Smithsonian Institution. http://alaska.si.edu/culture_inupiaq.asp?subculture=Arctic%20Coast&continue=1.

Harris, R.E., G.W. Miller, R.E. Elliott and W.J. Richardson. 1997. Seals [1996]. p. 4-1 to 4-42 In: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Harris, R.E., A.N. Balla-Holden, S.A. MacLean and W.J. Richardson. 1998. Seals [1997]. p. 4-1 to 4-54 In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska's) open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.Harris, R.E., T. Elliott and R.A. Davis. 2007. Results of mitigation and monitoring program, Beaufort Span 2-D marine seismic program, open-water season 2006. LGL Rep. TA4319-1. Rep. from LGL Ltd., King City, Ont., for GX Technol. Corp., Houston, TX. 48 p.

Harwood, L.A., S. Innes, P. Norton and M. C. S. Kingsley. 1996. Distribution and abundance of beluga whales in the Mackenzie Estuary, southeast Beaufort Sea and west Amundsen Gulf during late July 1992. Canadian Journal of Fish and Aquatic Science 53:2262-2273.

Harwood, L.A., F. McLaughlin, R.M. Allen, J. Illasiak Jr. and J. Alikamik. 2005. First-ever marine mammal and bird observations in the deep Canada Basin and Beaufort/Chukchi seas: expeditions during 2002. Polar Biol. 28(3):250-253.

Hastings, M.C., A.N. Popper, J.J. Finneran and P.J. Lanford. 1996. Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatus*. Journal of the Acoustical Society of America 993:1759-1766.

Hauser, D.D.W., V.D. Moulton, K. Christie, C. Lyons, G. Warner, C. O'Neill, D. Hannay, and S. Inglis. 2008. Marine mammal and acoustical monitoring of the Eni/PGS open-water seismic program near Thetis, Spy, and Leavitt islands, Alaskan Beaufort Sea, 2008: 90-day report. Prepared by LGL Alaska Research Associates, Inc., Anchorage, AK, LGL Limited, environmental research associates, King City, Ontario, and JASCO Research Ltd., Victoria, BC, for Eni US Operating Co. Inc., Anchorage, AK, PGS Onshore, Inc., Anchorage, AK, the National Marine Fisheries Service, Silver Springs, MD, and the U.S. Fish and Wildlife Service, Anchorage, AK.

Hazard, K. 1988. Beluga whale, *Delphinapterus leucas*. Pp. 195-235, *In:* J. W. Lentfer (*ed.*), Selected marine mammals of Alaska. Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Heide-Jørgensen, M.P., K.L. Laidre, M.V. Jensen, L. Dueck and L.D. Postma. 2006. Dissolving stock discreteness with satellite tracking: bowhead whales in Baffin Bay. Marine Mammal Science 22:34-45.

Heide-Jørgensen, M.P., K. Laidre, D. Borchers, F. Samarra and H. Stern. 2007. Increasing abundance of bowhead whales in West Greenland. Biology Letters 3:577-580.

HESS. 1999. High Energy Seismic Survey review process and interim operational guidelines for marine surveys offshore Southern California. Report from High Energy Seismic Survey Team for Calif. State Lands Commission and Minerals Management Service, Camarillo, CA. 39 p. + Appendices.

Hildebrand, J.A. 2005. Impacts of anthropogenic sound. Pp. 101-124, *In:* J.E. Reynolds, W.F. Perrin, R.R. Reeves, S. Montgomery and T. Ragen (*eds.*), Marine Mammal Research: Conservation Beyond Crisis. Johns Hopkins Univ. Press, Baltimore, MD. 223 p.

Hildebrand, J.A. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series. 395:5-20.

Hobbs, R.C., and D.J. Rugh. 1999. The abundance of gray whales in the 1997/98 southbound migration in the eastern North Pacific. Unpublished report submitted to International Whaling Commission (SC/51/AS10). 18 pp.

Hodges, J.I., and W.D. Eldridge. 2001. Aerial surveys of eiders and other waterbirds on the eastern Arctic coast of Russia. Wildfowl 52:127-142.

Holliday, D.V., R.E. Pieper, M.E. Clarke and C.F. Greenlaw. 1986. The Effects of Airgun Energy Releases on the Eggs, Larvae, and Adults of the Northern Anchovy (*Engraulis mordax*). Tracor Document No. T-86-06-7001-U. Washington, DC: American Petroleum Institute, 98 pp.

Holst, M., and M.A. Smultea. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off Central America, February – April 2008. LGL Rep. TA4342-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nationla Marine Fisheries Service, Silver Spring, MD. 133 p.

Holst, M., M.A. Smultea, W.R. Koski and B. Haley. 2005a. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Southern Gulf of Mexico, January–February 2005. LGL Rep. TA2822-31. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and National Marine Fisheries Service, Silver Spring, MD.

Holst, M., M.A. Smultea, W.R. Koski and B. Haley. 2005b. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November–December 2004. LGL Rep. TA2822-30. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and National Marine Fisheries Service, Silver Spring, MD.

Holst, M., W.J. Richardson, W.R. Koski, M.A. Smultea, B. Haley, M.W. Fitzgerald and M. Rawson. 2006. Effects of large- and small-source seismic surveys on marine mammals and sea turtles. Eos, Trans. Am. Geophys. Union 87(36), Joint Assembly Suppl., Abstract OS42A-01. 23-26 May, Baltimore, MD.

Holt, M.M., D.P. Noren, V. Veirs, C.K. Emmons and S. Veirs. 2009. Speaking up: Killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. Journal of the Acoustical Society of America 125:27–32.

Horner, R A. 1969. Phytoplankton Studies in the Coastal Waters Near Barrow, Alaska. Ph.D. Thesis. University of Washington, Seattle, WA.

Hauser, D.D.W., M. Holst, and V.D. Moulton. 2008. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific, April–August 2008. LGL Rep. TA4656/7-1. Rep. from LGL Ltd., King City, Ont. and St. John's, Nfld, for Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, and National Marine Fisheries Service, Silver Spring, MD. 98 p.

IAGC. 2004. Further analysis of 2002 Abrolhos Bank, Brazil humpback whale strandings coincident with seismic surveys. Internnational Association of Geophysical Contractors, Houston, TX. 12 p.

IMO. 2010. International Maritime Organization (IMO). www.imo.org/Conventions/mainframe.asp.

ION. 2012a. Request by ION Geophysical for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals during a Marine Seismic Survey in the Arctic Ocean, October–December 2012. ION Geophysical, Houston, TX, and LGL Alaska Research Associates, Inc., Anchorage AK. LGL Document P1236-1, February 2012, Revised June 2012. 158 p.

ION. 2012b. Marine Mammal Monitoring and Mitigation Plan for Marine Seismic Surveys of the Alaska Beaufort Sea, 2010. ION Geographical. August 2010. 12 p.

IPCC (Intergovernmental Panel on Climate Change). 2007. The physical science basis summary for policymakers. Fourth Assessment Report of the IPCC. United Nations, Geneva, Switzerland.

IWC. 1992. Chairman's Report of the forty-third annual meeting. Report of the International Whaling Commission 42:11-50.

IWC. 2003. Annex F. Report of the Sub-Committee on Bowhead, Right and Gray Whales. Cambridge, UK: International Whaling Commission.

IWC. 2004. Report of the Sub-Committee on Bowhead, Right, and Gray Whales. Cambridge: International Whaling Commission.

IWC. 2007. Report of the standing working group on environmental concerns. Annex K to Report of the Scientific Committee. Journal of Cetacean Research and Management 9(Suppl.):227-260.

IWC. 2008. Report of the scientific Committee. Eastern Canada-West Greenland bowhead whales. Journal of Cetacean Research and Management. (Supplemental Issue) 10:27-28.

Jarvela, L.E., and L.K. Thorsteinson. 1999. The Epipelagic Fish Community of Beaufort Sea Coastal Waters, Alaska. Arctic 52:80-94.

Jay, C.V., and S. Hills. 2005. Movements of Walruses Radiotagged in Bristol Bay, Alaska. Arctic 58:192-202.

Jay, C.V., P.M. Outridge and J.L. Garlich-Miller. 2008. Indication of two Pacific walrus stocks from whole tooth elemental analysis. Polar Biology 31:933–943.

Jehl, J.R., Jr. 1993. Observations on the fall migration of eared grebes, based on evidence from a mass drowning in Utah. Condor 95:470-473.

Jepson, P.D., M. Arbelo, R. Deaville, I.A.P. Patterson, P. Castro, J.R. Baker, E. Degollada, H.M. Ross, P. Herráez, A.M. Pocknell, F. Rodríguez, F.E. Howie, A. Espinosa, R.J. Reid, J.R. Jaber, V. Martin, A.A. Cunningham and A. Fernández. 2003. Gas-bubble lesions in stranded cetaceans. Nature 425(6958):575-576.

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack and B. Würsig. 2008. Sperm whale seismic study in the Gulf of Mexico/Synthesis report. OCS Study MMS 2008-006. Rep. from Dep. Oceanogr., Texas A & M University, College Station, TX, for U.S. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. 323 p.

Johannessen, O.M., E.V. Shalina and M.W. Miles. 1999. Satellite Evidence for an Arctic Sea Ice Cover in Transformation. Science 2865446:312-314.

Johannessen, O.M., L. Bengtsson, M.W. Miles, S.I. Kuzmina, V.A. Semenov, G.V. Alexseev, A.P. Nagurnyi, V.F. Zakharov, L.P. Bobylev, L.H. Pettersson, K. Hasselmann and H.P. Cattle. 2004. Arctic climate change: observed and modeled temperature and sea-ice variability. Tellus 56A:328-341.

Johnson, M.L., C.H. Fiscus, B.T. Stenson and M.L. Barbour. 1966. Marine mammals. Pp. 877-924, *In:* N.J. Wilimovsky and J.N. Wolfe (*eds.*), Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Comm., Oak Ridge, TN.

Johnston, R.C., and B. Cain. 1981. Marine Seismic Energy Sources: Acoustic Performance Comparison. Manuscript presented at the 102nd Meeting of the Acoustical Society of America, Dec. 1981, Miami, Fla., 35 pp.

Johnson, S.R., and W.J. Richardson. 1982. Waterbird migration near the Yukon and Alaskan coast of the Beaufort Sea: II. Moult migration of seaducks in summer. Arctic 352:291-301.

Johnson, S.R., C.R. Greene, R.A. Davis and W.J. Richardson. 1986. Bowhead whales and underwater noise near the Sandpiper Island drillsite, Alaskan Beaufort Sea, autumn 1985. Report from LGL Ltd., King City, Ont., for Shell Western E & P Inc., Anchorage, AK. 130 p.

Johnson, S., K. Frost and L. Lowry. 1992. Use of Kasegaluk Lagoon, Chukchi Sea, Alaska, by Marine Birds and Mammals, I: An Overview. Unpublished report. Herndon, VA: USDOI, MMS, pp. 4-56.

Johnson, S.R., W.J. Richardson, S.B. Yazvenko, S.A. Blokhin, G. Gailey, M.R. Jenkerson, S.K. Meier, H.R. Melton, M.W. Newcomer, A.S. Perlov, S.A. Rutenko, B. Würsig, C.R. Martin and D.E. Egging. 2007. A western gray whale mitigation and monitoring program for a 3-D seismic survey, Sakhalin Island, Russia. Environmental Monitoring and Assessment 134(1-3):1-19.

Johnson, W.R. 1989. Current Response to Wind in the Chukchi Sea: A Regional Coastal Upwelling Event. Journal of Geophysical Research 94:2057-2064.

Jones, A. 2006. Iaqluich Nigiñaqtuat, Fish That We Eat. U.S. Fish and Wildlife Service, Office of Subsistence Management, Fisheries Resource Monitoring Program. Final Report No. FIS02-023.

Jorde, P.E., T. Schweder and N.C. Stenseth. 2004. The Bering-Chukchi-Beaufort stock of bowhead whales: one homogeneous population? Unpublished report submitted to International Whaling Commission. (SC/56/BRG36) 21 pp.

Kaleak, J. 1996. History of whaling by Kaktovik village. Pp. 69-71, *In:* Proc. 1995 Arctic Synthesis Meeting, Anchorage, AK, Oct. 1995. OCS Study MMS 95-0065. U.S. Minerals Management Service, Anchorage, AK. 206 p. + Appendices.

Kastak, D., R.J. Schusterman, B.L. Southall and C.J. Reichmuth. 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. Journal of the Acoustical Society of America 106:1142-1148.

Kastak, D., B.L. Southall, M. Holt, C.R. Kastak and R.J. Schusterman. 2004. Noise-induced temporary threshold shifts in pinnipeds: Effects of noise energy. Journal of the Acoustical Society of America 116(4): 2531-2532.

Kastak, D., B.L. Southall, R.J. Schusterman and C. Reichmuth Kastak. 2005. Underwater temporary threshold shift in pinnipeds: effects of noise level and duration. Journal of the Acoustical Society of America 118(5):3154-3163.

Kelly, B.P. 1988. Ribbon seal, *Phoca fasciata*. Pp. 96-106, *In:* J.W. Lentfer (*ed.*), Selected marine mammals of Alaska. Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Kertell, K. 1991. Disappearance of the Steller's eider from the Yukon-Kuskokwim delta, Alaska. Arctic 44(3):177-187.

Ketten, D.R. 1994. Functional analysis of whale ears: adaptations for underwater hearing. IEEE Proceedings of Underwater Acoustics 1:264-270.

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. Pp. 391-407, *In:* R.A. Kastelein, J.A. Thomas and P.E. Nachtigall (*eds.*), Sensory Systems of Aquatic Mammals. De Spil Publishers, Woerden, Netherlands. 588 p.

Ketten, D.R., J. Lien and S. Todd. 1993. Blast injury in humpback whale ears: evidence and implications. Journal of the Acoustical Society of America 94(3, Pt. 2):1849-1850 (Abstract).

King, J.E. 1983. Seals of the world. 2nd ed. British Museum (Natural Hitstory), London. 240 pp.

Koski, W.R., R.A., Davis, G.W. Miller and D.E. Withrow. 1993. Reproduction. *In:* The Bowhead Whale. J.J. Montague, C.J. Cowles and J.J. Burns (*eds.*). 239-274. Society for Marine Mammalogy.

Koski, W.R., J.C. George, G. Sheffield and M.S. Galginaitis. 2005. Subsistence harvests of bowhead whales (*Balaena mysticetus*) at Kaktovik, Alaska (1973-2000). Journal of Cetacean Research and Management 7(1):33-37.

Koski, W., J. Mocklin, A. Davis, J. Zeh, D. Rugh, J.C. George and R. Suydam. 2008. Preliminary estimates of 2003-2004 Bering-Chukchi-Beaufort bowhead whale (*Balaena mysticetus*) abundance from photoidentification data. Unpublished report submitted to International Whaling Commission. (SC/60/BRG18). 7pp.

Kostyuchenko, L.P. 1973. Effect of elastic waves generated in marine seismic prospecting on fish eggs in the Black Sea. Hydrobiological Journal 9:45-48.

Kovacs, K.M., C. Lydersen and I. Gjertz. 1996. Birth-site characteristics and prenatal molting in bearded seals (*Erignathus barbatus*). Journal of Mammalogy 774:1085-1091.

Kowalik, Z., and J.B. Matthews. 1982. The M2 Tide in the Beaufort and Chukchi Seas. Journal of Physical Oceanography 127:743-746.

Kowalik, Z., and A.Y. Proshutinsky. 1994. Diurnal Tides in the Arctic Ocean. *In:* The Polar Oceans and Their Role in Shaping the Global Environment, O.M. Johannessen, R.D. Muench and J.E. Overland (*eds.*). Washington, DC: American Geophysical Union, pp. 137-159.

Krasnova, V.V., V.M. Bel'kovich and A.D. Chernetsky. 2005. Mother-infant spatial relationships in wild beluga (*Delphinapterus leucas*) during postnatal development under natural conditions. Biology Bulletin 33, no. 1 (2005): 53-58.

Krogman, B., D. Rugh, R. Sonntag, J. Zeh and D. Ko. 1989. Ice-based census of bowhead whales migrating past Point Barrow, Alaska, 1978-1983. Marine Mammal Science 5:116-138.

Kryter, K.D. 1985. The Effects of Noise on Man. 2nd ed. Academic Press, Orlando, FL. 688 p.

Kryter, K.D. 1994. The Handbook of Hearing and the Effects of Noise. Academic Press, Orlando, FL. 673 p.

Laake, J.L., J. Calambokidis, S.D. Osmek and D.J. Rugh. 1997. Probability of detecting harbor porpoise from aerial surveys: Estimating g(0). Journal of Wildlife Management 61(1):63-75.

Lacroix, D.I., R.B. Lanctot, J.A. Reed and T.L. McDonald. 2003. Effect of underwater seismic surveys on molting male long-tailed ducks in the Beaufort Sea, Alaska. Canadian Journal of Zoology 81:1862-1875.

Lage, J. 2009. Hydrographic Needs in a Changing Arctic Environment: An Alaskan Perspective. US Hydro 2009. Norfolk, VA.

Larned, W., R. Stehn and R. Platte. 2009. Eider breeding population survey, Arctic Coastal Plain, Alaska 2008. USFWS, Migratory Bird Management, Waterfowl Management, Soldatna and Anchorage, AK.

Leatherwood, S., R.R. Reeves, W.F. Perrin and W. E. Evans. 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters: a guide to their identification. U.S. Department of Commerce, NOAA Technical Report. NMFS Circular 444, 245 pp.

LeBoeuf, B.J., M.H. Perez Cortes, R.J. Urban, B.R. Mate and U. F. Ollervides. 2000. High gray whale mortality and low recruitment in 1999: Potential causes and implications. Journal of Cetacean Research and Management 2(2):85-99.

Lesage, V., C. Barrette, M.C.S. Kingsley and B. Sjare. 1999. The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River Estuary, Canada. Marine Mammal Science. 15: 65-84.

Lewis, J.K., and W.W. Denner. 1987. Arctic ambient noise in the Beaufort Sea: Seasonal space and time scales. Journal of the Acoustical Society of America 82(3):988-997.

Lewis, J.K, and W.W. Denner. 1988. Arctic ambient noise in the Beaufort Sea: Seasonal relationships to sea ice kinematics. Journal of the Acoustical Society of America 83(2):549-565.

LGL. 2005. Environmental Assessment of a Marine Geophysical Survey by the Coast Guard Cutter Healy across the Atlantic Ocean. LGL Report 4122-1. King City, Ont., Canada: LGL Ltd.

LGL. 2008. Environmental Assessment of a Marine Geophysical Survey by the R/V Marcus G. Langseth in Southeast Asia, March–July 2009. Prepared for Lamont-Doherty Earth Observatory, Palisades, NY and National Science Foundation Division of Ocean Sciences, Arlington, VA.

LGL and Greeneridge. 1987. Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea, autumn 1986. Rep. from LGL Ltd., King City, Ont., and Greenridge Sciences Inc., Santa Barbara, CA, for Shell Western E&P Inc., Anchorage, AK. 371 p.

LGL and Greeneridge. 1996. Northstar Marine Mammal Monitoring Program, 1995: Baseline surveys and retro-spective analyses of marine mammal and ambient noise data from the Central Alaskan Beaufort Sea. Report from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK. 104 p.

Littlejohn, L. 2009. Shrinking Sea Ice Framing solutions for potential marine incidents using an integrated risk/scenario-based approach. U.S. Coast Guard Exercise Coordination and Support Division. http://www.uscg.mil/proceedings/articles/100_Littlejohn_Shrinking%20Sea%20Ice.pdf.

Ljungblad, D.K., S. Leatherwood and M.E. Dahlheim. 1980. Sounds recorded in the presence of an adult and calf bowhead whales. Marine Fisheries Review. 42:86–87.

Ljungblad, D.K., P.O. Thompson and S.E. Moore. 1982. Underwater sounds recorded from migrating bowhead whales, Balaena mysticetus, in 1979. Journal of the Acoustical Society of America 71:477–482.

Ljungblad, D.K., S.E. Moore and D.R. VanSchoik. 1986. Seasonal patterns of distribution, abundance, migration and behavior of the western Arctic stock of bowhead whales, Balaena mysticetus, in Alaskan Seas. Reports of the International Whaling Commission. 8:177–205.

Ljungblad, D.K., S.E. Moore, J.T. Clarke and J.C. Bennett. 1988a. Distribution, Abundance, Behavior, and Bioacoustics of Endangered Whales in the Western Beaufort and Northeastern Chukchi Seas, 1979-87. Anchorage: Minerals Management Service.

Ljungblad, D.K., B. Würsig, S.L. Swartz, and J.M. Keene. 1988b. Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41(3):183-194.

Long, F., Jr. 1996. History of subsistence whaling by Nuiqsut. Pp.73-76, *In:* Proc. 1995 Arctic Synthesis Meeting, Anchorage, AK, Oct. 1995. OCS Study MMS 95-0065. U.S. Minerals Management Service, Anchorage, AK. 206 p. + Appendices.

Lowry, L. F. 1985. The belukha whale (*Delphinapterus leucas*). Pp. 3-13, *In:* J. J. Burns, K. J. Frost and L. F. Lowry (*eds.*), Marine mammal species accounts. Alaska Department of Fish and Game, Game Tech. Bull. 7.

Lowry, L.F., and G. Sheffield. 1993. Foods and Feeding Ecology. *In:* The Bowhead Whale. J.J. Montague, C.J. Cowles J.J. Burns (*eds*). 201-238. Society for Marine Mammalogy.

Lowry, L.F., G. Sheffield and J.C. George. 2004. Bowhead Whale Feeding in the Alaskan Beaufort Sea, Based on Stomach Contents Analyses. Journal of Cetacean Research and Management 63:223.

Lowry, L.F., K.J. Frost, R.Davis, R.S. Suydam and D.P. DeMaster. 1994. Movements and behavior of satellitetagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-38. 71 pp.

Lowry, L.F., K.J. Frost, R. Davis, D.P. DeMaster and R. S. Suydam. 1998. Movements and behavior of satellitetagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. Polar Biology 19:221-230.

Lowry, L.F., V.N. Burkanov, K.J. Frost, M.A. Simpkins, A. Springer, D.P. DeMaster and R. Suydam. 2000. Habitat use and habitat selection by spotted seals (Phoca largha) in the Bering Sea. Canadian Journal of Zoology 78:1959-1971.

Lowry, L.F., G. Sheffield and J.C. George. 2004. Bowhead whale feeding in the Alaskan Beaufort Sea, based on stomach contents analyses. Journal of Cetacean Research and Management 6(3):215-223.

Lucke, K., U. Siebert, P.A. Lepper and M.-A. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. Journal of the Acoustical Society of America 125(6):4060-4070.

Lusseau, D. 2004. The hidden cost of tourism: Detecting long-term effects of tourism using behavioral information. Ecology and Society: http://www.ecologyandsociety.org/vol9/iss1/art2.

Lynch, A.H., E.N. Cassano, J.J. Cassano and L.R. Lestak. 2003. Case Studies of High Wind Events in Barrow, Alaska: Climatological Context and Development Processes. Monthly Weather Review 1314:719–732.

Madsen, J. 1985. Impact of disturbance on field utilization of pink-footed geese in west Jutland, Denmark. Biological Conservation 33:53-63.

Madsen, P.T., B. Møhl, B.K. Nielsen and M. Wahlberg. 2002. Male sperm whale behavior during exposures to distant seismic survey pulses. Aquatic Mammals 28(3):231-240.

Madsen, P.T., M. Johnson, P.J.O. Miller, N. Aguilar de Soto, J. Lynch and P.L. Tyack. 2006. Quantitative measures of air gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. Journal of the Acoustical Society of America 120(4):2366–2379.

Maher, W.J. 1960. Recent records of the California gray whale (*Eschrichtius glaucus*) along the north coast of Alaska. Arctic 13(4):257-265.

Malakoff, D. 2002. Suit ties whale deaths to research cruise. Science 298(5594):722-723.

Malme, C.I., and P.R. Miles. 1985. Behavioral responses of marine mammals (gray whales) to seismic discharges. Pp. 253-280, *In:* G.D. Greene, F.R. Engelhard and R.J. Paterson (*eds.*), Proc. Workshop on Effects of Explosives Use in the Marine Environment, Jan. 1985, Halifax, NS. Tech. Rep. 5. Can. Oil & Gas Lands Admin., Environ. Prot. Br., Ottawa, Ont. 398 p.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II: January 1984 migration. BBN Report No. 5586. Report from Bolt Beranek & Newman Inc., Cambridge, MA, for Minerals Management Service, Alaska OCS Region, Anchorage, AK. NTIS PB86-218377.

Malme, C.I., P.R. Miles, P. Tyack, C.W. Clark and J.E. Bird. 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Report No. 5851; OCS Study MMS 85-0019. Report from BBN Labs Inc., Cambridge, MA, for Minerals Management Service, Anchorage, AK. NTIS PB86-218385.

Malme, C.I., B. Würsig, J.E. Bird and P. Tyack. 1986. Behavioral responses of gray whales to industrial noise: feeding observations and predictive modeling. BBN Report No. 6265. OCS Study MMS 88-0048. Outer Continental Shelf Environmental Assessment Progress, Final Report. Princ. Invest., NOAA, Anchorage 56(1988): 393-600. NTIS PB88-249008.

Malme, C.I., B. Würsig, B., J.E. Bird and P. Tyack. 1988. Observations of feeding gray whale responses to controlled industrial noise exposure. Pp. 55-73, *In:* W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (*eds.*), Port and Ocean Engineering Under Arctic Conditions. Vol. II. Symposium on Noise and Marine Mammals. University of Alaska Fairbanks, Fairbanks, AK. 111 p.

Martin, B., D. Hannay, C. Whitt, X. Mouy and R. Bohan. 2009. Chukchi Sea acoustic monitoring program. Chapter 5 *In*: Funk, D.W., D.S. Ireland, R. Rodrigues, and W.R. Koski (*eds.*). Joint monitoring program in the Chukchi and Beaufort seas, July–November 2006-2008. LGL Alaska Report P1050-1. Report from LGL Alaska Research Associates, Inc., Anchorage, AK, LGL Ltd., environmental research associates, King City, Ont., Greeneridge Sciences, Inc., Goleta, CA, and JASCO Research, Victoria, B.C., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 488 p. plus appendices.

Mate, B.R., and J.T. Harvey. 1987. Acoustical deterrents in marine mammal conflicts with fisheries. ORESU-W-86-001. Oregon State Univ., Sea Grant Coll. Prog., Corvallis, OR. 116 p.

Matthews, J.B. 1980. Characterization of the Nearshore Hydrodynamics of an Arctic Barrier Island-Lagoon System. Environmental Assessment of the Alaskan Continental Shelf Annual Reports of Principal Investigators for the Year Ending March 1980 Vol. VI Transport. Boulder, CO and Anchorage, AK: USDOC, NOAA and USDOI, BLM, pp. 577-601.

McAllister, D.E. 1962. Fishes of the 1960 Salvelinus Program from Western Arctic Canada. National Museum of Canada Bulletin 158:17-39.

McAllister, D.E. 1975. Ecology of the Marine Fishes of Arctic Canada. *In:* Proceedings of the Circumpolar Conference on Northern Ecology, Ottawa. Ottawa, Ont., Canada: National Research Council of Canada.

McCauley, R.D. 1994. Seismic Surveys. *In:* Environmental Implications of Offshore Oil and Gas Development in Australia – The Finding of an Independent Review, J.M. Swan, I.M. Neff, and P.C. Young, eds. Sydney, AU: Australian Petroleum Exploration Assoc.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe and J. Murdoch. 1998. The response of humpback whales (*Megaptera novaeangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. APPEA Journal 38:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.N. Jenner, J. Penruse, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000a. Marine Seismic Surveys - A Study of Environmental Implications. APPEA Journal 40:692-708.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch and K. McCabe. 2000b. Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Report from Centre for Marine Science and Technology, Curtin University, Perth, Western Australia, for Australian Petroleum Productopm and Exploration Association, Sydney, NSW. 188 p.

McCauley, R.D., J. Fewtrell and A.N. Popper. 2003. High intensity anthropogenic sound damages fish ears. Journal of the Acoustical Society of America 113:638-642.

McDonald, M.A., and C. G. Fox. 1999. Passive acoustic methods applied to fin whale population density estimation. Journal of the Acoustical Society of America 105(5):2643-2651.

McDonald, M.A., J.A. Hildebrand and S.C. Webb. 1995. Blue and fin whales observed on a seafloor array in the Northeast Pacific. Journal of the Acoustical Society of America 98(2, Pt. 1):712-721.

McPherson, C., B. Martin and D. Hannay. 2012. Passive Acoustic Monitoring during Statoil's 2010 Chukchi Sea Seismic Survey, Analysis Report. JASCO Document 00357. Technical report by JASCO Applied Sciences for Statoil USA E&P.

McGhee, R. 1984. Thule prehistory of Canada. Pp.369-376. *In:* D. Damas (*ed.*) Handbook of North American Indians. Vol. 5, Arctic. Smithsonian Institution, Washington, D.C.

McNabb, S.L. 1990. The uses of "inaccurate" data: a methodological critique and applications of Alaska native data. American Anthropologist 92(1):116-129.

Mecklenburg, C.W., T.A. Mecklenburg and L.K. Thorsteinson. 2002. Fishes of Alaska. Bethesda, MD: American Fisheries Society.

Miller, G.W., R.E. Elliott, W.R. Koski and W.J. Richardson. 1997. Whales. Pp.5-1 to 5-115, *In:* W.J. Richardson (*ed.*), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Report from LGL Ltd., King City, ON and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc. and National Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD. 245 p.

Miller, G.W., R.E. Elliott and W.J. Richardson. 1998. Whales. Pp.5-1 to 5-123, *In:* W.J. Richardson (*ed.*), Northstar marine mammal monitoring program, 1997: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Report 2150-3. Report from LGL Ltd., King City, ON and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc. and National Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD. 318 p.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton and W.J. Richardson. 1999. Whales. Pp. 5-1 to 5-109, *In:* W.J. Richardson (*ed.*), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Report TA2230-3. Report from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. National Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD. 390 p.

Miller, G.W., R.E. Elliott, T.A. Thomas, V.D. Moulton and W.R. Koski. 2002. Distribution and numbers of bowhead whales in the eastern Alaskan Beaufort Sea during late summer and autumn, 1979-2000. Pp.9-1 to 9-39 (Chap. 9), *In:* W.J. Richardson and D.H. Thomson (*eds.*), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, vol. 1. OCS Study

MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Management Service, Anchorage, AK, and Herndon, VA. 420 p. NTIS PB2006-100382.

Miller, G.W., R.E. Elliot, T.A. Thomas, V.D. Moulton and W.R. Koski. 2002. Distribution and numbers of bowhead whales in the eastern Alaskan Beaufort Sea during late summer and autumn, 1979-2000. Chapter 9. *In:* Richardson, W.J., and D.H. Thomson (*eds*). 2002. Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. xliv + 697 p. 2 vol. NTIS PB2004-101568. Available from www.mms.gov/alaska/ref/AKPUBS.HTM#2002.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray and D. Hannay. 2005. Monitoring seismic effects on marine mammals—southeastern Beaufort Sea, 2001-2002. Pp. 511-542, *In:* S.L. Armsworthy, P.J. Cranford and K. Lee (*eds.*), Offshore Oil and Gas Environmental Effects Monitoring/Approaches and Technologies. Battelle Press, Columbus, OH.

Miller, P.J.O., M.P. Johnson, P.T. Madsen, N. Biassoni, M. Quero and P.L. Tyack. 2009. Using at-sea experiments to study the effects of airguns on the foraging behavior of sperm whales in the Gulf of Mexico. Deep-Sea Research I 56(7):1168-1181.

Miller, P.J.O., N. Biassoni, A. Samuels and P.L. Tyack. 2000. Whale songs lengthen in response to sonar. Nature 405:903.

Milne, A.R., and Ganton, J.H. 1964. Ambient noise under Arctic sea ice. Journal of the Acoustical Society of America. 36(5): 855-863.

Minobe, S. 2002. Interannual to interdecadal changes in the Bering Sea and concurrent 1998/99 changes over the North Pacific. Progress in Oceanography. 55(1-2):45-64.

Miraglia, R. 1998. Traditional Ecological Knowledge Handbook: A training manual and reference guide for designing, conducting, and participating in research projects using traditional ecological knowledge. Alaska Department of Fish and Game, Subsistence Division, Anchorage, Alaska.

Mitson, R.B., and H.P. Knudsen. 2003. Causes and effects of underwater noise on fish abundance estimation. Aquatic Living Resources 16:255-263

MMS. 1987. Alaska Outer Continental Shelf Chukchi Sea Oil & Gas Lease Sale 109 - Final Environmental Impact Statement. Anchorage: U.S. Department of the Interior, Minerals Management Service, Alaska OCS Region, 1987. Environmental Impact Statement. OCS EIS/EA MMS 87-0110.

MMS. 1995. An Investigation of the Sociocultural Consequences of Outer Continental Shelf Development in Alaska: Alaska Peninsula and Arctic. *In:* J.A. Fall and C.J. Utermohle, (*eds.*). Alaska Department of Fish and Game, Division of Subsistence Technical Report no. 160; MMS 95-014. Cooperative Agreement No. 14-35-0001-30622.

MMS. 1996. Beaufort Sea Planning Area oil and gas lease sale 144/Final Environmental Impact Statement. OCS EIS/EA MMS 96-0012. U.S. Minerals Manage. Serv., Alaska OCS Reg., Anchorage, AK. Two volumes. Var. pag.

MMS. 1998. Beaufort Sea Planning Area Oil and Gas Leas Sale 170 Final EIS. OCS EIS/EA, MMS 98-0007. Anchorage, AK: USDOI, MMS, Alaska OCS Region.

MMS. 2002. Liberty Development and Production Plan, Final Environmental Impact Statement. OCS EIS/EA, MMS 2002-019. Anchorage, AK: USDOI, MMS, Alaska OCS Region, 3 Vols.

MMS. 2003. Beaufort Sea Planning Area Sales 186, 195, and 202 Oil and Gas Lease Sale Final EIS. OCS EIS/EA, MMS 2003-001. Anchorage, AK: USDOI, MMS, Alaska OCS Region.MMS. 2006. Final Programmatic Environmental Assessment – Arctic Ocean Outer Continental Shelf Seismic Surveys – 2006. OCS EIS/EA MMS 2006-038. Department of the Interior, Minerals Management Service, Alaska OCS Region. 294 pp.

MMS. 2006. Final Programmatic Environmental Assessment – Arctic Ocean Outer Continental Shelf Seismic Surveys – 2006. OCS EIS/EA MMS 2006-038. Department of the Interior, Minerals Management Service, Alaska OCS Region. 294 pp.

MMS. 2007a. Seismic Surveys in the Beaufort and Chukchi Seas, Alaska - Draft Programmatic Environmental Impact Statement. OCS EIS/EA MMS 2007-001. Department of the Interior, Minerals Management Service, Alaska OCS Region.

MMS. 2008. Beaufort Sea and Chukchi Sea Planning Areas, Oil and Gas Lease Sales 209, 212, 217, and 221, Draft Environmental Impact Statement. November 2008. U.S. Department of the Interior Minerals Management Service November 2008 OCS EIS/EA MMS 2008-0055.

Mooney, T.A., P.E. Nachtigall, M. Breese, S. Vlachos and W.W.L. Au, 2009a. Predicting temporary threshold shifts in a bottlenose dolphin (*Tursiops truncatus*): the effects of noise level and duration. Journal of the Acoustical Society of America 125(3):1816-1826.

Mooney, T.A., P.E. Nachtigall and S. Vlachos. 2009b. Sonar-induced temporary hearing loss in dolphins. Biology Letters 4(4):565-567.

Moore, S.E. 1992. Summer records of bowhead whales in the northeastern Chukchi Sea. Arctic 45(4):398-400.

Moore, S.E. 2000. Variability in cetacean distribution and habitat section in the Alaskan Arctic, autumn 1982-91. Arctic 53(4):448-460.

Moore, S.E., and H.P. Huntington. 2008. Arctic marine mammals and climate change impacts and resilience. Ecological Applications 18(2):S157-S165.

Moore, S.E., and R.P. Angliss. 2006. Overview of planned seismic surveys offshore northern Alaska, July-October 2006. Paper SC/58/E6 presented to IWC Scientific Committee, IWC Annu. Meeting, 1-13 June, St Kitts.

Moore, S.E., and R. R. Reeves. 1993. Distribution and movement. Pp. 313-386 *In* J. J. Burns, J. J. Montague, and C. J. Cowles (*eds.*), The bowhead whale. Society for Marine Mammalogy, Special Publication No. 2.

Moore, S.E., and D. P. DeMaster. 2000. North Pacific right whale and bowhead whale habitat study: R/V Alpha Helix and CGC Laurier Cruises, July 1999. Annual Report. 3p.

Moore, S.E., K.M. Stafford, M.E. Dahlheim, C.G. Fox, H.W. Braham, J.J. Polovina and D.E. Bain. 1998. Seasonal variation in reception of fin whale calls at five geographic areas in the North Pacific. Marine Mammal Science 14(3):617-627.

Moore, S.E., J.M. Waite, L.L. Mazzuca and R.C. Hobbs. 2000a. Provisional estimates of mysticete whale abundance on the central Bering Sea shelf. Journal of Cetacean Research and Management 2(3):227-234.

Moore, S., D.P. DeMaster and P.K. Dayton. 2000b. Cetacean Habitat Selection in the Alaskan Arctic during Summer and Autumn. Arctic 53(4):432-447.

Moore, S.E., J. Urbán R., W.L. Perryman, F. Gulland, H. Pérez-Cortés M., P.R. Wade, L. Rojas-Bracho and T. Rowles. 2001. Are gray whales hitting 'K' hard? Marine Mammal Science 17(4):954-958.

Moore, S.E., J.M. Waite, N.A. Friday and T. Honkalehto. 2002. Distribution and comparative estimates of cetacean abundance on the central and south-eastern Bering Sea shelf with observations on bathymetric and prey associations. Progress in Oceanography 55(1-2):249-262.

Moore, S.E., K.M. Stafford, D.K. Mellinger and C.G. Hildebrand. 2006. Listening for large whales in the offshore waters of Alaska. BioScience 56(1):49-55.

Moreland, E.E., M.F. Cameron and P.L. Boveng. 2008. Densities of seals in the pack ice of the Bering Sea (Poster presentation). Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA.

Moriyasu, M., R. Allain, K. Benhalima and R. Clayton. 2004. Effects of seismic and marine noise on invertebrates: A literature Review. Canadian Department of Fisheries and Oceans. Research Document 2004/126.

Morton, A.B., and H.K. Symonds. 2002. Displacement of *Orcinus orca* (L.) by high amplitude sound in British Columbia, Canada. ICES Journal of Marine Science 59:71-80.

Moulton, F.D., W.J. Richardson, T.L. McDonald, R.E. Elliott and M.T. Williams. 2002. Factors influencing local abundance and haulout behavior of ringed seals (*Phoca hispida*) on landfast ice of the Alaskan Beaufort Sea. Canadian Journal of Zoology 80:1900-1917.

Moulton, L.L., and J.C. George. 2000. Freshwater Fishes in the Arctic Oil-Field Region and Coastal Plain of Alaska. In: The Natural History of an Arctic Oil Field: Development and the Biota., J.C. Truett and S.R. Johnson, eds. New York: Academic Press, pp. 327-348.

Moulton, V.D., and G.W. Miller. 2005. Marine mammal monitoring of a seismic survey on the Scotian Slope, 2003. Pp. 29-40, *In:* K. Lee, H. Bain and G.V. Hurley (*eds.*), Acoustic monitoring and marine

mammal surveys in the Gully and outer Scotian Shelf before and during active seismic programs. Environ. Stud. Res. Funds Rep. 151. 154 p (Published 2007).
Moulton, V.D., and J.W. Lawson. 2002. Seals, 2001. Pp. 3-1 to 3-48, *In:* W.J. Richardson (*ed.*), Marine mammal and acoustical monitoring of WesternGeco's open water seismic program in the Alaskan Beaufort Sea, 2001. LGL Rep. TA2564-4. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for WesternGeco, Houston, TX, and National Marine Fisheries Service, Anchorage, AK, and Silver Spring, MD. 95 p.
Murdoch, J. 1892. Ethnological Results of the Point Barrow Expedition in the Ninth Annual Report of the U.S. Bureau of Ethnology to the Secretary of the Smithsonian Institution, 1887-'88 by J.W. Powell. Washington: Government Printing Office.
Nachtigall, P.E., J.L. Pawloski and W.W.L. Au. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenose dolphin (*Tursiops truncatus*). Journal of the Acoustical Society of America 113(6):3425-3429.
Nachtigall, P.E., A.Y. Supin, J. Pawloski and W.W.L. Au. 2004. Temporary threshold shifts after noise exposure in the bottlenose dolphin (*Tursiops truncatus*) measured using evoked auditory potentials. Marine Mammal Science 20(4):673-687
National Academy of Sciences. 2005. Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. National Academies Press.
Nelson, C.H., R. L. Phillips, M. McRea, J. Barber, M.W. McLaughlin and J.L. Chin. 1993. Gray Whale and Pacific Walrus Benthic Feeding Grounds and Sea Floor Interaction in the Chukchi Sea. OCS MMS.
Nelson, R.K. 1981. Harvest of the sea: coastal subsistence in modern Wainwright. North Slope Borough, Barrow, Alaska. 125 pp
Nerini, M.K., H.W. Braham, W.M. Marquette and D.J. Rugh. 1984. Life History of the Bowhead Whale, *Balaena mysticetus*. Journal of Zoology 204:443-468.
Nieukirk, S.L., K.M. Stafford, D.K. Mellinger, R.P. Dziak and C.G. Fox. 2004. Low-Frequency Whale and Seismic Airgun Sounds Recorded in the Mid-Atlantic Ocean. Journal of the Acoustical Society of America 115(4):1832-1843.
Nieukirk, S.L., S.L. Heimlich, S.E. Moore, K.M. Stafford, R.P. Dziak, M. Fowler, J. Haxel, J. Goslin and D.K. Mellinger. 2009. Whales and airguns: an eight-year acoustic study in the central North Atlantic. p. 181-182 In: Abstract of the 18th Biennial Conference on the Biology of Marine Mammals, Québec, Oct. 2009. 306 p.
NMFS. 2003. Environmental Assessment for Issuing Annual Quotas to the Alaska Eskimo Whaling Commission for a Subsistence Hunt on Bowhead whales for the Years 2003 through 2007. Anchorage, AK: USDOC, NMFS, 67 pp. plus appendices.
NMFS. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. Juneau, AK: National Marine Fisheries Service, NOAA.
NMFS. 2008. Final Environmental Impact Statement for issuing annual quotas to the Alaska Eskimo Whaling Commission for a subsistence hunt on bowhead whles for the years 2008 through 2012. Prepared by U.S. Deprtment of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.
NOAA, 2006. State of the Arctic. U.S. Army ERDC – Cold Regions Research and Engineering Lab. Hanover, NH. October. 41 pages.
Nobmann, E.D. 1997. Nutritional Benefits of Subsistence Foods. University of Alaska Anchorage Institute of Social and Economic Research, Anchorage, AK.
Northern Economics, Inc. 2006. North Slope Economy 1965 to 2005 Final Report. Prepared for the U.S. Department of the Interior, Minerals Management Service, Alaska Region, Social and Economic Studies Program. Prepared by Northern Economics, Inc. in association with EDAW, Inc. April 2006
Nowacek, D.P., L.H. Thorne, D.W. Johnston and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Review 37(2):81-115.
NPFMC. 2009. Fishery Management Plan for Fish Resources of the Arctic Management Area. North Pacific Fishery Management Council, Anchorage, Alaska.
NRC. 1999. The Community Development Quota Program in Alaska. The National Academy Press Sale124: Environmental Impact Statement. OCAA WIS/EA MMS 90-0063. Washington, D.C.

NRC. 2001. Climate Change Science: An Analysis of Some Key Questions. Washington, DC: National Academy Press.

NRC. 2003a. Ocean Noise and Marine Mammals, Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals. The National Academies Press.

NRC. 2003b. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. www.nap.edu/openbook/0309087376/html/1.html. Washington, DC: The National Academies Press, 465 pp.

NSB. 2005. North Slope Borough Comprehensive Plan. Adopted by the NSB Assembly under Ordinance 75-6-48. Prepared by URS Corporation for North Slope Borough Planning Department, October 15, 2005. Barrow, AK.

NSF. 2009. Cruise Catalog: Healy. National Science Foundation. Rolling Deck to Repository (R2R) program. http://www.rvdata.us/catalog/Healy.

NWAB. 2009. Northwest Arctic Borough website: http://www.nwabor.org/aboutus.html.

Nystuen, J.A., and D.M. Farmer. 1987. The influence of wind on the underwater sound generated by light rain. Journal of the Acoustical Society of America 82: 270-274.

Ognev, S.I. 1935. Mammals of the U.S.S.R. and adjacent countries. vol. 3. Carnivora (Fissipedia and Pinnipedia). Gosudarst. Izdat. Biol. Med. Lit., Moscow. (Transl. from Russian by Israel Prog. Sci. Transl., 1962, 741 pp.).

Panikpak Edwardsen, D. 1993. Uqaluktuat: 1980 Elder's Conference Women's Session. Transcribed and translated by Dorothy Panikpak Edwardsen. Barrow: North Slope Borough Commission on Iñupiat History, Language and Culture.

Parkinson, C.L., and D.J. Cavalieri. 2002. A 21 year record of arctic sea-ice extents and their regional, seasonal, and monthly variability and trends. Annals of Glaciology 34: 441-446.

Parkinson, C.L., D.J. Cavalieri, P. Gloersen, H.J. Zwally and J.C. Cosimo. 1999. Arctic Sea Ice Extents, Areas, and Trends, 1978-1996. Journal of Geophysical Research 104C9:20,837-20, 856.

Parks, S.E., C.W. Clark and P.L. Tyack. 2007. Short- and long-term changes in right whale calling behavior: the potential effects of noise on acoustic communication. Journal of the Acoustical Society of America 122(6):3725-3731.

Paul, J.M., A.J. Paul and W.E. Barber. 1997. Reproductive biology and distribution of the snow crab from the northeastern Chukchi Sea. American Fisheries Society Symposium 19:287-294.

Petersen, N.M (ed.). 1981. The question of sound from icebreaker operations: The proceedings of a workshop. Arctic Pilot Project, Petro-Canada, Calgary, Alb. 350 p.

Pearson, W.H., J.R. Skalski and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on behavior of captive rockfish (*Sebaste*s spp.). Canadian Journal of Fisheries and Aquatic Science 49:1343-1356.

Petersen, M.R., J.B. Grand and C.P. Dau. 2000. Spectacled Eider (*Somateria fischeri*). *In*: A. Poole and F. Gill (*eds.*), The Birds of North America, No. 547. The Birds of North America, Inc., Philadelphia, PA.

Pickart, R.S. 2004. Shelfbreak Circulation in the Alaskan Beaufort Sea: Mean Structure and Variability. Journal of Geophysical Research 109:C04024.

Popov, L.A. 1976. Status of main ice forms of seals inhabiting waters of the U.S.S.R. and adjacent to the country marine areas. FAO ACMRR/MM/SC/51. 17 pp.

Popper, A.N., R.R. Fay, C. Platt and O. Sand. 2003. Sound Detection Mechanisms and Capabilities of Teleost Fishes. pp. 3-38, *In:* S.P. Collin and N.J. Marxhall (*eds.*). Sensory Processing in Aquatic Environments, New York: Springer-Verlag.

Porsild, A.E. 1945. Mammals of the Mackenzie Delta. Canadian Field-Naturalist 59:4-22.

Postma, L.D., L.P, Dueck, M.P. Heide-Jorgensen and S.E. Cosens. 2006. Molecular genetic support of a single population of bowhead whales (*Balaena mysticetus*) in Eastern Canadian Arctic and Western Greenland waters. Unpubl. paper submitted to the Scientific Committee of the International Whaling Commission. June 2006 (SC/58/BRG4). 15 pp.

Potter, J.R., M. Thillet, C. Douglas, M.A. Chitre, Z. Doborzynski and P.J. Seekings. 2007. Visual and passive acoustic marine mammal observations and high-frequency seismic source characteristics recorded during a seismic survey. IEEE Journal of Oceanic Engineering 32(2):469-483.

Quakenbush, L.T. 1988. Spotted seal, *Phoca largha*. Pp. 107-124, *In:* J.W. Lentfer (*ed.*), Selected marine mammals of Alaska. Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Quakenbush, L., B. Anderson, F. Pitelka and B. McCaffery. 2002. Historical and Present Breeding Season Distribution of Steller's Eiders in Alaska. Western Birds 33:99-120.

Quakenbush, L., R. Suydam, T. Obritschkewitsch and M. Deering. 2004. Breeding biology of Steller's eiders (*Polysticta stelleri*) near Barrow, Alaska, 1991-99. Arctic 57(2)166-182.

Quan, J. 2000. Summer Resident Gray Whales of Washington State: Policy, Biological and Management Implications of Makah Whaling. MS Thesis, Seattle: School of Marine Affairs, University of Washington.

Rahn, K.A. 1982. On the Causes, Characteristics and Potential Environmental Effects of Aerosol in the Arctic Atmosphere. In: The Arctic Ocean: The Hydrographic Environment and the Fate of Pollutants, L. Ray, ed. New York: John Wiley and Sons, pp. 163-195.

Ray, G.C., and B.P. Hayden. 1993. Marine biogeographic provinces of the Bering, Chukchi, and Beaufort Seas. Pages 175-184 in K. Sherman, L. M. Alexander, and B. D. Gold, editors. Large marine ecosystems: patterns, processes and yields. American Association for the Advancement of Science, Washington, D.C.

Reeves, R.R. 1990. An overview of the distribution, exploitation and conservation status of belugas, worldwide. Pp. 47-58, *In:* J. Prescott and M. Gauquelin (*eds.*), For the future of the beluga: Proceedings of the International Forum for the Future of the Beluga. University of Quebec Press, Canada.

Reeves, R.R., and M.F. Barto. 1985. Whaling in the Bay of Fundy. Whalewatcher 194:14-18.

Reeves, R.R., G.K. Silber and P.M. Payne. 1998. Draft Recovery Plan for the Fin Whale *Balaenoptera physalus* and Sei Whale *Balaenoptera borealis*. Silver Spring, MD: USDOC, NOAA, NMFS, Office of Protected Resources, 65 pp.

Reeves, R.R., B.S. Stewart, S. Leatherwood. 1992. The Sierra Club Handbook of Seals and Sirenians. Sierra Club Books, San Francisco, CA.

Reeves, R.R., R.J. Hofman, G.K. Silber and D. Wilkinson. 1996. Acoustic deterrence of harmful marine mammalfishery interactions: proceedings of a workshop held in Seattle, Washington, 20-22 March 1996. NOAA Tech. Memo. NMFS-OPR-10. Nat. Mar. Fish. Serv., Northwest Fisheries Sci. Cent., Seattle, WA. 70 p.

Regehr, E.V., S.C. Amstrup and I. Stirling. 2006. Polar bear population status in the southern Beaufort Sea. US Geological Survey Open File Report 2006-1337, USGS, Anchorage: USGS, 20.

Reiser, C.M., B. Haley, J. Beland, D.M. Savarese, D.S. Ireland and D.W. Funk. 2009. Evidence of short-range movements by phocid species in reaction to marine seismic surveys in the Alaskan Chukchi and Beaufort seas. p. 211 *In:* Abstrats 18th Biennial Conference for the Biology of Marine Mammals, Québec, Canada, Oct. 2009. 306 p.

Reiser, C., D. Funk, R. Rodrigues and D. Hannay (*eds.*). 2010. Marine Mammal Monitoring and Mitigation during Open Water Shallow Hazards and Site Clearance Survey by Shell Offshore Inc. in the Alaskan Chukchi Sea, July - October 2009: 90-Day Report. LG Report P1112-1. LGL Alaska Research Associates, Inc., Anchorage, AK, and JASCO Research Ltd., Victoria, BC, for Shell Offshore, Inc. Houston, TX, National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD, and U.S. Fish and Wildlife Service, Marine Mammal Management, Anchorage, AK.

Rice, D.W. 1974. Whales and whale research in the eastern North Pacific. Pp. 170-195. *In:* W.E. Schevill (*ed.*). The whale problem: A status report. Harvard Press, Cambridge, MA.

Rice, D.W. 1981. Status of the Eastern Pacific (California) Stock of the Gray Whale. In: Food and Agriculture Organization, 181-187. Rome: Food and Agriculture Organization.

Rice, D.W. 1998. Marine Mammals of the World: Systematics and Distribution. Society Marine Mammalogy, Spec. Publ. No. 4.

Rice, D.W., and A.A. Wolman. 1971. The life history and ecology of the gray whale, *Eschrichtius robustus*. International Whaling Commission.

Rice, D.W., A.A. Wolman, D.E. Withrow and L.A. Fleischer. 1981. Gray Whales on the Winter Grounds in Baja California. International Whaling Commission (International Whaling Commission) 31:477-493.

Richard, P.R., A.R. Martin and J.R. Orr. 1998. Study of Late Summer and Fall Movements and Dive Behavior of Beaufort Sea Belugas, Using Satellite Telemetry: 1997. Anchorage: MMS, 1998.

Richardson, W.J., B. Würsig and C.R. Greene. 1986. Reactions of bowhead whales, Balaena mysticetus, to seismic exploration in the Canadian Beaufort Sea. Journal of the Acoustical Society of America 79(4):1117-1128.

Richardson, W.J., R.A. Davis, C.R. Evans, D.K. Ljungblad and P. Norton. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-84. Arctic 40(2):93-104.

Richardson, W.J., C.R. Greene, C.I. Malme, D.H. Thomson, S.E. Moore and B. Wűrsig. 1991. Effects of Noise on Marine Mammals. OCS Study, MMS 90-0093. Herndon, VA: USDOI, MMS, Atlantic OCS Region, 462 pp.

Richardson, W.J., and C.I. Malme. 1993. Man-made noise and behavioral responses. Pp. 631-700, *In:* J.J. Burns, J.J. Montague and C.J. Cowles (*eds.*), The Bowhead Whale. Special Publication 2, Society for Marine Mammalogy, Lawrence, KS. 787 p.

Richardson, W.J., C.R. Greene, C.I. Malme and D.H. Thomson. 1995a. Marine Mammals and Noise. Academic Press. San Diego, California.

Richardson, W.J., C.R. Greene Jr., J.S. Hanna, W.R. Koski, G.W. Miller, N.J. Patenaude and M.A. Smultea, with R. Blaylock, R. Elliott and B. Würsig. 1995b. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska – 1991 and 1994 phases. OCS Study MMS 95-0051; LGL Rep. TA954. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Herndon, VA. 539 p.

Richardson, W.J., G.W. Miller and C.R. Greene, Jr. 1999. Displacement of migrating bowhead whales by sounds from seismic surveys in shallow waters of the Beaufort Sea. Journal of the Acoustical Society of America 106(4, Pt. 2):2281 (Abstract).

Richardson, W.J. and M.T. Williams. 2003. Monitoring of Industrial Sounds, Seals, and Bowhead Whales near BP’s Northstar Oil Development, Alaskan Beaufort Sea, 1999-2002. Anchorage, AK: BPXA and USDOC, NMFS.

Richardson, W.J., and M.T. Williams. 2004. Monitoring of Industrial Sounds, Seals, and Bowhead Whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 1999-2003. Annual and Comprehensive Report. LGL Report TA 4001. Anchorage, AK: BPXA.

Richardson, W.J., M. Holst, W.R. Koski and M. Cummings. 2009. Responses of cetaceans to large-source seismic surveys by Lamont-Doherty Earth Observatory. p. 213 *In:* Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Québec, Oct. 2009. 306 p.

Rolland, R.M., S.E. Parks, K.E. Hunt, M. Castellote, P.J. Corkeron, D.P. Nowacek, S.K. Wasser and S.D. Kraus. 2012. Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B: Biological Sciences. *doi: 10.1098/rspb.2001.2429*.

Romano, T.A., M.J. Keogh, C.Kelly, P. Feng, L. Berk, C.E. Schlundt, D.A. Carder and J.J. Finneran. 2004. Anthropogenic sound and marine mammal health: measures of the nervous and immune systems before and after intense sound exposure. Canadian Journal of Fisheries and Aquatic Science 61(7):1124-1134.

Ross, D. 1976. Mechanics of underwater noise. Pergamon, New York. 375 p. (Reprinted 1987, Peninsula Publ., Los Altos, CA).

Ross, W.G. 1993. Commercial whaling the North Atlantic sector. Pp. 511-561 *In:* J.J. Burns, J.J. Montague and C.J. Cowles (*eds.*). The Bowhead Whale. Society for Marine Mammalogy, Special Publication No. 2.

Roth, E.H, and V. Schmidt. 2010. Noise levels generated by research icebreakers and marine seismic sources in the deep-water, Arctic Ocean. MPL Tech. Memorandum. 527.

Rugh, D.J., K.E.W. Shelden, D.E. Withrow, H.W. Braham and R.P. Angliss. 1993. Spotted seal (*Phoca largha*) distribution and abundance in Alaska, 1992. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Rugh, D.J., K.E.W. Shelden and D.E. Withrow. 1994. Spotted seals in Alaska, 1993 annual report. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Rugh, D.J., K.E.W. Shelden and D.E. Withrow. 1995. Spotted seal sightings in Alaska 1992-93: Final Report. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Rugh, D., D. DeMaster, A. Rooney, J. Breiwick, K. Shelden and S. Moore. 2003. A review of bowhead whale (*Balaena mysticetus*) stock identity. Journal of Cetacean Research and Management 5(3):267-279.

Rugh, D.J., R.C. Hobbs, J.A. Lerczak and J.M. Breiwick. 2005. Estimates of abundance of the eastern North Pacific stock of gray whales 1997-2002. Journal of Cetacean Research and Management 7(1):1-12.

Savarese, D.M., C.R. Reiser, D.S. Ireland and R. Rodrigues. 2009. Beaufort Sea vessel-based monitoring program. Chapter 6. *In:* Funk, D.W., D.S. Ireland, R. Rodrigues, and W.R. Koski (*eds.*). Joint monitoring program in the Chukchi and Beaufort seas, July–November 2006-2008. LGL Alaska Report P1050-1. Report from LGL Alaska Research Associates, Inc., Anchorage, AK, LGL Ltd., environmental research associates, King City, Ont., Greeneridge Sciences, Inc., Goleta, CA, and JASCO Research, Victoria, B.C., for Shell Offshore, Inc. and other Industry contributors, National Marine Fisheries Service, and U.S. Fish and Wildlife Service. 488 p. plus appendices.

SACLANT. 1998. Estimation of cetacean hearing criteria levels. Section II, Chapter 7 *In:* SACLANTCEN Bioacoustics Panel Summary Record and Report. Report from NATO Undersea Res. Center. Available at http://enterprise.spawar.navy.mil/nepa/whales/pdf/doc2-7.pdf

Schlundt, C.E., J.J. Finneran, D.A. Carder and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds (MTTS) of bottlenose dolphins and white whales after exposure to intense tones. Journal of the Acoustical Society of America 107:3496-3508.

Schmitt, F.P., C. de Jong and F.W. Winter. 1980. Thomas Welcome Roys. America's Pioneer of Modern Whaling. Charlottesville, VA: University of Virginia, University Press, 253 pp.

Schorger, A.W. 1952. Ducks killed during a storm at Hot Springs, South Dakota. Wilson Bulletin 64:113-114.

Schreiner, A. E., C. G. Fox and R. P. Dziak. 1995. Spectra and magnitudes of T-waves from the 1993 earthquake swarm on the Juan de Fuca ridge. Geophysical Research Letters 22(2): 139-142.

Scribner, K.T., S. Hills, S.R. Fain and M.A. Cronin. 1997. Population genetics studies of the walrus (*Odobenus rosmarus*): a summary and interpretation of results and research needs. *In:* A.E. Dizon, S.J. Chivers and W.F. Perrin (*eds.*), Molecular Genetics of Marine Mammals. Marine Mammal Science, Special publication 3:173-184.

Seaman, G.A., K.J. Frost and L.F. Lowry. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska. Part I. Distribution, abundance and movements. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 56:153-220. (available from NOAA-OMA-OAD, Alaska Office, 701 C. Street, P.O. Box 56, Anchorage, AK 99513).

Sergeant, D.E., and P.F. Brodie. 1969. Body size in white whales, *Delphinapterus leucas*. Journal of Fisheries Research Board of Canada 26:2561-2580.

Serreze, M.C., J.A. Maslanik, T.A. Scambos, F. Fetterer, J. Stroeve, K. Knowles, C. Fowler, S. Drobot, R.G. Barry and T. M. Haran. 2003. A RecordMinimum Arctic Sea Ice Extent and Area in 2002. Geophysical Research Letters 303:10-1.

Shaughnessy, P.D., and F.H. Fay. 1977. A review of the taxonomy and nomenclature of North Pacific harbour seals. Journal of Zoology (London) 182:385-419.

Shelden, K.E.W. 1994. Beluga whales (*Delphinapterus leucas*) in Cook Inlet - A review. Appendix *In:* Withrow, D.E., K.E.W. Shelden and D. J. Rugh. Beluga whale (Delphinapterus leucas) distribution and abundance in Cook Inlet, summer 1993. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Shelden, K.E.W., and D.J. Rugh. 1995. The bowhead whale (*Balaena mysticetus*): status review. Marine Fisheries Review 57(3-4):1-20.

Shelden, K.E.W., D.P. DeMaster, D.J. Rugh and A.M. Olson. 2001. Developing classification criteria under the U.S. Endangered Species Act: Bowhead whales as a case study. Conservation Biology 15(5):1300-1307.

Shell. 2010. Application for Incidental Harassment Authorization for the Non-Lethal Taking of Whales and Seals in Conjunction with a Proposed Open Water Marine Survey Program in the Beaufort and Chukchi Seas, Alaska, During 2010. Prepared by Shell Exploration and Production, Inc. and LGL Alaska Research Associates, Inc. April 2010.

Sherrod, G.K. 1982. Eskimo Walrus Commission's 1981 Research Report: The Harvest and Use of Marine Mammals in Fifteen Eskimo Communities. Kawerak, Inc., Nome.

Shapiro, L., and R. Metzner. 1979. Ice Conditions on Alaska's Sea Coast: Extending the Observations. The Northern Engineer 112:22-27, 35.

Shepro, C. E., D.C. Maas and D.G. Callaway. 2003. North Slope Borough 20003 Economic Profile and Census Report. Department of Planning and Community Services, 2003. Barrow, AK.

Simpkins, M.A., L.M. Hiruki-Raring, G. Sheffield, J.M. Grebmeier and J.L. Bengtson. 2003. Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska in March 2001. Polar Biology 26:577-586.

Smith, T.G. 1980. Polar bear predation of ringed and bearded seals in the landfast sea ice habitat. Canadian Journal of Zoology 58:2201-2209.

Smith, T.G., and M.O. Hammill. 1981. Ecology of the ringed seal, *Phoca hispida*, in its fast ice breeding habitat. Canadian Journal of Zoology 59:966-981.

Smith, T.G., and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). the birth lair and associated structures. Canadian Journal of Zoology. 53(9):1297-1305.

Smith, T.G., M.O. Hammill and G. Taugbol. 1991. A review of the developmental, behavioral and physiological adaptations of the ringed seal, *Phoca hispida*, to life in the Arctic winter. Arctic 44:124-131.

Smultea, M.A., M. Holst, W.R. Koski and S. Stoltz. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, April-June 2004. LGL Rep. TA2822-26. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nationla Marine Fisheries Service, Silver Spring, MD. 106 p.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33(4):411-522.

SRBA (Braund, Stephen R. and Associates). 1993a. The North Slope Subsistence Study: Barrow, 1987, 1988, 1989. Submitted to the US Department of Interior, Minerals management Service, Alaska OCS Region, Anchorage, Alaska.

SRBA (Braund, Stephen R. and Associates). 1993b. The North Slope Subsistence Study: Wainwright, 1988 and 1989. Submitted to the US Department of Interior, Minerals management Service, Alaska OCS Region, Anchorage, Alaska.

Stafford, K.M., D.K. Mellinger, S.E. Moore and C.G Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999–2002. Journal of the Acoustical Society of America 122(6):3378-3390.

Statoil. 2010. Environmental Evaluation Document Statoil 2010 Chukchi Marine Seismic Survey Chukchi Sea, Alaska. Prepared by ASRC Energy Services, Anchorage, Alaska. April 2010.

Stehn, R.A., C.P. Dau, B. Conant and W.I. Butler, Jr. 1993. Decline of spectacled eiders nesting in western Alaska. Arctic 46(3):264-277.

Stemp, R. 1985. Observations on the Effects of Seismic Exploration on Seabirds. pp. 217-233, *In:* G.D. Greene, F.R. Engelhardt and R.J. Paterson, (*eds.*). Proceedings of the Workshop on Effects of Explosives Use in the Marine Environment. Halifax, NS, Canada: Energy, Mines and Resources Canada and Indian and Northern Affairs.

Stirling, I., and A.E. Derocher. 1990. Factors affecting the evolution and behavioral ecology of the modern bears. International Conference on Bear Research and Management 8. 189-204.

Stocker, M. 2002. Fish, Mollusks, and other Sea Animals' use of Sound, and the Impact of Anthropogenic Noise in the Marine Acoustic Environment. Earth Island Institute.

Stoker, S.W., and I.I. Krupnik., 1993. Subsistence Whaling. Pp. 579-629. *In:* J.J. Burns, J.J. Montague and C.J. Cowles (*eds.*). The Bowhead Whale. Special Publications of the Society for Marine Mammalogy Publications, No. 2. Lawrence, KS: Society for Marine Mammalogy.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. JNCC Rep. 323. Joint Nature Conserv. Commit., Aberdeen, Scotland. 43 p.

Stone, C.J., and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. Journal of Cetacean Research and Management 8(3):255-263.

Stroeve, J.C., M. C. Serreze, F. Fetterer, T. Arbetter, W. Meier, J. Maslanik and K. Knowles. 2005. Tracking the Arctic's Shrinking Ice Cover: Another extreme September Minimum in 2004. Geophysical Research Letters 32:L04501.

Suydam, R.S. 1997. Threats to the Recovery of Rare, Threatened, and Endangered Birds: Steller's Eider. In: NPR-A Symposium Proceedings, Apr. 16-17, 1997. Anchorage, AK: USDOI, BLM.

Suydam, R.S., K.J. Frost and L. Lowry. 2005. Distribution and Movements of Beluga Whales form the Eastern Chukchi Sea Stock During Summer and Early Autumn. OCS MMS.

Tavolga, W.N. 1977, Sound Production in Fishes. Benchmark Papers in Animal Behavior V.9. Dowden, Hutchinson & Ross, Inc.

Taylor, B., R. LeDuc, J.C. George, R. Suydam, S. Moore and D. Rugh. 2007 Synthesis of lines of evidence for population structure for bowhead whales in the Bering-Chukchi-Beaufort region. Unpublished report submitted to International Whaling Commission (SC/59/BRG35). 12 pp.

TERA. 1997. Distribution and abundance of spectacled eiders in the vicinity of Prudhoe Bay, Alaska: 1997 status report. Unpublished report prepared by Troy Environmental Research Associates, Anchorage, AK.

TERA. 1999. Spectacled eiders in the Beaufort Sea: distribution and timing of use. Unpublished report prepared by Troy Ecological Research Associates, Anchorage, AK.

Thiele, L. 1984. Preliminary results of underwater noise measurements on the icebreaker "John A. MacDonald". Note 84.108. Report from Ødegaard & Daneskiold-Samsøe K/S, Copenhagen, for Greenland Fish. Invest., Copenhagen, Denmark. 21 p.

Thiele, L. 1988. Underwater noise study from the icebreaker "John a. MacDonald". Report 85.133. Report from Ødegaard & Daneskiold-Samsøe ApS, Clpenhagen, Denmark. 133 p.

Thomas, J.A., R.A. Kastelein and F.T. Awbrey. 1990. Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. Zoo Biology 9(5):393-402.

Thomas, T.A., W.R. Koski and W.J. Richardson. 2002. Correction factors to calculate bowhead whale numbers form aerial surveys of the Beaufort Sea. Chapter 15. *In:* W.J. Richardson and D.H. Thomson (*eds.*). Bowhead whale feeding in the eastern Alaskan Beaufort Sea: Update of Scientific and Traditional Information. 28pp. OCS Study MMS 2002-012.

Thomson, D., and R. Davis. 2001. Review of the Potential Effects of Seismic Exploration on Marine Animals in the Beaufort Sea. Unpublished Report for Department of Fisheries and Oceans by LGL Ltd, Ontario, Canada.

Tolstoy, M.J., B. Diebold, S.C. Webb, D.R. Bohnenstiehl, E. Chapp, R.C. Holmes and M. Rawson. 2004. Broadband calibration of the R/V Ewing seismic sources. Geophysical Research Letters 31:L14310.

Tolstoy, M., J. Diebold, L. Doermann, S. Nooner, S.C. Webb, D.R. Bohnenstiehl, T.J. Crone and R.C. Holmes. 2009. Broadband calibration of the R/V Marcus G. Langseth four-string seismic sources. Geochem. Geophys. Geosyst. 10(8):1-15. Q08011.

Treacy, S.D. 1993. Aerial surveys of endangered whales in the Beaufort Sea, fall 1992. OCS Study MMS 93-0023. U.S. Minerals Manage. Serv., Anchorage, AK. 136 p.

Treacy, S.D. 2002a. Aerial surveys of endangered whales in the Beaufort Sea, fall 2000. OCS Study MMS 2002-014. U.S. Minerals Management Service., Anchorage, AK. 111 p.

Treacy, S.D. 2002b. Aerial surveys of endangered whales in the Beaufort Sea, fall 2001. OCS Study MMS 2002-061. U.S. Minerals Management Service, Anchorage, AK. 117 p.

Troy, D.M. 2003. Molt migration of spectacled eiders in the Beaufort Sea region. Unpublished report prepared by Troy Ecological Research Associates, Anchorage, AK, for BP Exploration (Alaska) Inc., Anchorage, AK. 17p.

Turnpenny, A.W.H., and J.R. Nedwell. 1994. The Effects on Marine Fish, Diving Mammals and Birds of Underwater Sound Generated by Seismic Surveys. FCR 089/94. Consultancy Report. Fawley Aquatic Research Laboratories Ltd.

Tyack, P., M. Johnson and P. Miller. 2003. Tracking responses of sperm whales to experimental exposures of airguns. Pp. 115-120, *In:* A.E. Jochens and D.C. Biggs (*eds.*), Sperm whale seismic study in the Gulf of Mexico/Annual Report: Year 1. OCS Study MMS 2003-069. Rep. from Texas A&M University, College Station, TX, for U.S. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Tyack, P.L., M.P. Johnson, P.T. Madsen, P.J. Miller and J. Lynch. 2006. Biological significance of acoustic impacts on marine mammals: examples using an acoustic recording tag to define acoustic exposure of sperm whales, Physeter catodon, exposed to airgun sounds in controlled exposure experiments. Eos, Trans. Am. Geophys. Union 87(36), Joint Assembly Suppl., Abstract OS42A-02. 23-26 May, Baltimore, MD.

Tynan, C.T., and D.P. DeMaster. 1997. Observations and predictions of arctic climate change: potential effects on marine mammals. Arctic 50(4):308-322.

Udevitz, M.S., D.M. Burn and M.A. Webber. 2008. Estimation of walrus populations on sea ice with infrared imagery and aerial photography. Marine Mammal Science 24(1):57-70.

Urick, R.J. 1983. Principles of Underwater Sound. Third Edition. McGraw-Hill Book Company.

U.S. Army Corps of Engineers. 2000. Ouzinke Harbor Trip Report, Steller's Eider Survey Nos. 1 and 2. Unpublished Memorandum for the Record. CEPOA-EN-CW-ER. Anchorage, AK: U.S. Army Corps of Engineers, Alaska District.

USCG. 2008a. Coast Guard Magazine, Issue 4:40-42. http://www.uscg.mil/mag/

USCG. 2008b. The Emerging Arctic. A New Maritime Frontier. United States Coast Guard.

USDOI/BLM. 2005. Northwest National Petroleum Reserve – Alaska; Final Amended Integrated Activity Plan/Environmental Impact Statement.

USFWS. 1996. Spectacled eider recovery plan. Anchorage, Alaska. 157 p.

USFWS. 2002. Steller's Eider Recovery Plan. Fairbanks, Alaska.

USFWS. 2007. Biological Opinion for Chukchi Sea Planning Area Oil and Gas Lease Sale 193 and associated seismic surveys and exploratory drilling. Consultation with the Minerals Management Service–Alaska OCS Region, Anchorage, AK.

USFWS. 2009a. Final Biological Opinion for Beaufort and Chukchi Sea Program Area Lease Sales and Associated Seismic Surveys and Exploratory Drilling. Section 7 Consultation with MMS – Alaska OSC Region, Anchorage, AK.

USFWS. 2009b. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Polar Bear (*Ursus maritimus*) in the United States; Proposed Rule. Federal Register, 74 FR 56057-56086, October 29, 2009.

Walters, V. 1955. Fishes of Western Arctic America and Eastern Arctic Siberia: Taxonomy and Zoogeography. Bulletin of the American Museum of Natural History 106 Article 5:255-368.

Webb, C., and N. Kempf. 1998. The Impact of Shallow-Water Seismic in Sensitive Areas. Society of Petroleum Engineers Technical Paper. SPE 46722. Caracas, Venezuela.

Weingartner, T.J., D.J. Cavalieri, K. Aagaard, and S. Yasunori. 1998. Circulation, Dense Water Formation and Outflow on the Northeast Chukchi Shelf. Journal of Geophysical Research 103C4:7647-7661.

Weir, C.R. 2008. Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. Aquatic Mammals 34(1):71-83.

Weir, R. 1976. Annotated Bibliography of Bird Kills at Man-Made Obstacles: A Review of the State of the Art and Solutions. Unpublished report. Ottawa, Ontario, Canada: Canadian Wildlife Service, Fisheries and Environment.

Wenz, G.M. 1962. Acoustic ambient noise in the ocean: Spectra and sources. Journal of the Acoustical Society of America 34(12):1936–1956.

Wiese, K. 1996. Sensory Capacities of Euphausiids in the Context of Schooling. Marine Freshwater Behavior Physiology 28:183–194.

Williams, M.T., and J.A. Coltrane. 2002. Marine mammal and acoustical monitoring of the Alaska Gas Producers Pipeline Team's open water pipeline route survey and shallow hazards program in the Alaskan Beaufort Sea, 2001. LGL Rep. P643. Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, for BP Explor. (Alaska) Inc., ExxonMobil Production, Phillips Alaska Inc., and NMFS. 103 p.

Williams, R., A.W. Trites and D.E. Bain. 2002. Behavioural Responses of Killer Whales (*Orcinus orca*) to Whale-watching Boats: Opportunistic Observations and Experimental Approaches. Journal of Zoology 256:255-270.

Winsor, M.H., and B.R. Mate. 2006. Seismic survey activity and the proximity of satellite tagged sperm whales. International Whaling Commssion Working Paper SC/58/E16. 8 p.

Wolfe, R., and L.B. Hutchinson-Scarbrough. 1999. The subsistence harvest of harbor seals and sea lions by Alaska Natives in 1998. Technical paper No. 250. Draft Final report for year five, subsistence study and monitor system (no. 50ABNF400080). Prepared for NMFS by Alaska Dep. Fish and Game, Juneau, Alaska, 72 pp. + appendices.

Wong, C.K. 1996. Effects of diazinon on the demographic parameters of *Moina macrocopa*. Water, Air and Soil Pollution 393: 393-399

Woodby, D.A., and D.B. Botkin. 1993. Stock sizes prior to commercial whaling. Pp. 387-407 *In:* J.J. Burns, J.J. Montague and C.J. Cowles (*eds.*), The bowhead whale. Society for Marine Mammalogy, Special Publication No. 2.

Woody, D.A., and D.B. Botkin. 1993. Stock Sizes Prior to Commercial Whaling. pp. 387-407. *In:* J.J. Burns, J.J. Montague and C.J. Cowles (*eds.*). The Bowhead Whale, Special Publication, The Society for Marine Mammalogy, 2. Lawrence, KS: The Society for Marine Mammalogy.

Woodgate, R.A., K. Aagaard and T.J.O. Weingartner. 2005. A Year in the Physical Oceanography of the Chukchi Sea: Moored Measurements from Autumn 1990-1991. Deep Sea Reseach.

Wright, A.J., N. Aguilar Soto, A.L. Baldwin, M. Bateson, C.M. Beale, C. Clark, T. Deak, E.F. Edwards, A. Fernández, A. Godinho, L.T. Hatch, A. Kakuschke, D. Lusseau, D. Martineau, L.M. Romero, L.S. Weilgart, B.A. Wintle, G. Notarbartolo-di-Sciara and V. Martin. 2007a. Do marine mammals experience stress related to anthropogenic noise? International Journal of Comparative Psychology 20(2-3):274-316.

Wright, A.J., N. Aguilar Soto, A.L. Baldwin, M. Bateson, C.M. Beale, C. Clark, T. Deak, E.F. Edwards, A. Fernández, A. Godinho, L.T. Hatch, A. Kakuschke, D. Lusseau, D. Martineau, L.M. Romero, L.S. Weilgart, B.A. Wintle, G. Notarbartolo-di-Sciara and V. Martin. 2007b. Anthropogenic noise as a stressor in animals: A multidisciplinary perspective. International Journal of Comparative Psychology 20(2-3): 250-273.

Würsig, B., and C. Clark. 1993. The Bowhead Whale. J. J. Burns, J. J. Montague and C. J. Cowles (*eds.*). Society for Marine Mammalogy, Allen, Lawrence, KS, Special Publicatoin No. 2, pp. 157–199.

Yanchunas, D. 2009. Opening the Arctic. Professional Mariner. www.professionalmariner.com.

Yazvenko, S.B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, S.K. Meier, H.R. Melton, M.W. Newcomer, R.M. Nielson, V.L. Vladimirov and P.W. Wainwright. 2007a. Distribution and abundance of western gray whales during a seismic survey near Sakhalin Island, Russia. Environmental Monitoring and Assessment 134(1-3):45-73.

Yazvenko, S. B., T.L. McDonald, S.A. Blokhin, S.R. Johnson, H.R. Melton and M.W. Newcomer. 2007b. Feeding activity of western gray whales during a seismic survey near Sakhalin Island, Russia. Environmental Monitoring and Assessment 134(1-3):93-106.

Zeh, J.E., and A.E. Punt. 2004. Updated 1978-2001 abundance estimates and their correlations for the Bering-Chukchi-Beaufort Seas stock of bowhead whales. Unpublished report submitted to International Whaling Commission. (SC/56/BRG1). 10 pp.

Zeh, J.E., C.W.Clark, J.C. George, D. Withrow, G.M. Carroll and W.R. Koski. 1993. Current Population Size and Dynamics. In: The Bowhead Whale. J.J. Montague, C.J. Cowles and J.J. Burns (eds.). pp 409-489. Lawrense: The Society for Marine Mammalogy.

Zelick, R., Mann, D. and Popper, A.N. 1999, Acoustic communication in fishes and frogs. Pp 363-411, *In:* R.R. Fay and A.N. Popper (*eds.*). Comparative Hearing: Fish and Amphibians Springer-Verlag, New York.

Zykov, M., T. Deveau and D. Hannay, 2010. Modeling of Underwater Sound from GXT's Beaufort 4 Source in the Alaskan Beaufort Sea, Version 2.2. Report by JASCO Applied Sciences Ltd. for LGL, Alaska.