UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

REQUEST FOR A LETTER OF AUTHORIZATION PURSUANT TO SECTION 101 (a) (5) OF THE MARINE MAMMAL PROTECTION ACT COVERING

Taking of Marine Mammals Incidental to Operation of Offshore Oil and Gas Facilities in the U.S. Beaufort Sea (50 C.F.R. Part 216, Subpart R)

---

submitted by

BP Exploration (Alaska) Inc.
Department of Health, Safety, and Environment
900 East Benson Blvd., P.O. Box 196612
Anchorage, AK 99519-6612

Biological Consultant:
LGL Alaska Research Associates, Inc.
1101 East 76th Avenue, Suite B
Anchorage, AK 99518

27 October 2009

Table of Contents

I. NATURE OF THE REQUEST

In 1999 and 2004, BP Exploration Alaska Inc. (BP) petitioned the National Marine Fisheries Service (NMFS) to issue regulations concerning the potential "taking" of small numbers of whales and seals incidental to oil and gas development and operations in arctic waters of the United States. These two petitions were submitted pursuant to Section 101 (a) 5 of the Marine Mammal Protection Act (MMPA or "the Act"), 16 U.S.C. § 1371.101 (a) (5), and 50 C.F.R. § 216, Subpart I. The regulations were promulgated by NMFS on 25 May 2000 and on 6 April 2006 at 50 C.F.R. § 216, subpart R. Those regulations allowed NMFS to issue Letters of Authorization (LoA) for the incidental, but not intentional, "taking" of small numbers of marine mammals of six species in the event that such "taking" occurred during construction and operation of Northstar oil and gas facilities in the Beaufort Sea offshore from Alaska[1]. The six species were the ringed seal (*Phoca hispida*), bearded seal (*Erignathus barbatus*), spotted seal (*Phoca largha*), bowhead whale (*Balaena mysticetus*), gray whale (*Eschrichtius robustus*), and beluga whale (*Delphinapterus leucas*). To date, five LoAs have been issued under the first regulations of 2000–2005 and four LoAs under the regulations of 2006–2011. The fourth and current LoA expires on 7 July 2010 and a fifth LoA will be requested by BP later in 2010 to cover the period from then through 6 April 2011, when the regulations expire.

The purpose of this request by BP is for NMFS to renew the Regulations and issue a new letter of authorization, effective 7 April 2011, for potential future incidental taking of small numbers of whales and seals during continued oil and gas operations in the arctic waters of the United States. Future LoAs will be requested at later dates, assuming that NMFS renews the regulations at 50 C.F.R. § 216, subpart R, for the period 7 April 2011 through 7 April 2016.

Aside from the aforementioned six species for which "take" authorization is again sought, other species that have occurred in small numbers in the Alaskan Beaufort Sea include the harbor porpoise (*Phocoena phocoena*), killer whale (*Orcinus orca*), narwhal (*Monodon monoceros*), and ribbon seal (*Histriophoca fasciata*). Because of the relative numerical insignificance of those species in the Beaufort Sea, they are not expected to be exposed to or affected by any activities associated with the planned Northstar activities and, therefore, are not discussed further. Two other species of marine mammals — Pacific walrus (*Odobenus rosmarus divergens*) and polar bear (*Ursus maritimus*) — are under the jurisdiction of the U.S. Fish and Wildlife Service and are thus subject to a separate application to that Agency.

BP does not anticipate that the operation of Northstar oil and gas production facilities will result in the "taking" of significant numbers of marine mammals. Moreover, these potential "takes" of small numbers of marine mammals are not likely to be lethal, and any impact on the species would be no more than negligible. Although some whales and seals are likely to occur near the planned activities, any disturbance effects that occur are not anticipated to have serious consequences for individuals or their populations. Furthermore, there would be no unmitigable adverse impact on the availability of seals or whales for subsistence uses. This request has been filed for the purpose of ensuring that there is no question that the activities described herein are conducted in compliance with the MMPA if small numbers of marine mammals are disturbed or otherwise "taken" incidentally and unintentionally during ongoing drilling, maintenance, and production operations.

[1] The MMPA defines "take" to mean to "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal." 16 U.S.C. § 1362 (13).

II. INFORMATION SUBMITTED IN RESPONSE TO THE REQUIREMENTS OF 50 C.F.R. § 216.104 and 216.207

The NMFS' regulations governing the issuance of letters of authorization permitting incidental takes under certain circumstances are codified at 50 C.F.R. Part 216, Subpart I (216.101 – 216.106). Section 216.104 sets out fourteen specific items that must be addressed in requests for rulemaking and renewal of regulations pursuant to Section 101(a) (5) of the MMPA. Section 216 Subpart R (216.200 – 216.210) describes the specific regulations for operation of oil and gas facilities in the U.S. Beaufort Sea. Section 216.207 references the fourteen requirements in section 216.104 in order to apply for a new Letter of Authorization. Each of these items is addressed in detail below.

1. OPERATIONS TO BE CONDUCTED

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

BP Exploration (Alaska) Inc. (BP) is currently producing oil from an offshore development in the Northstar Unit (Figure 1). 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 construction and operation of the Northstar development in the Beaufort Sea was approved via other permitting processes. This request for a Letter of Authorization concerning potential takes of small numbers of whales and seals is associated with plans for continued drilling and oil production activities at Northstar. Upon expiry of the LoA now being sought, additional requests for LoAs will be submitted for future operations of Northstar, assuming that regulations regarding incidental take of marine mammals in association with Northstar will be renewed.

Much of what already occurred during Northstar construction, drilling, and production provides a basis for what can be anticipated during the next five years of activity at Northstar. Construction was completed in 2001, and activities with similar intensity are not planned or expected for any date within the 5-year period from 2011 to 2016. Information about the levels of activity in prior years, however, is helpful in understanding the varying activity levels that could occur in the future. The following section summarizes past activities at Northstar during construction period and the subsequent periods of drilling and production. A detailed description of Northstar activities over the period 1999–2004 can be found in Rodrigues and Williams (2006) and for 2005–2008 in the respective annual reports (Richardson [ed.] 2006, 2007; Aerts and Richardson [eds.] 2008, 2009). The description of Northstar activities of previous years is followed by information about activities expected to occur during the next five year period.

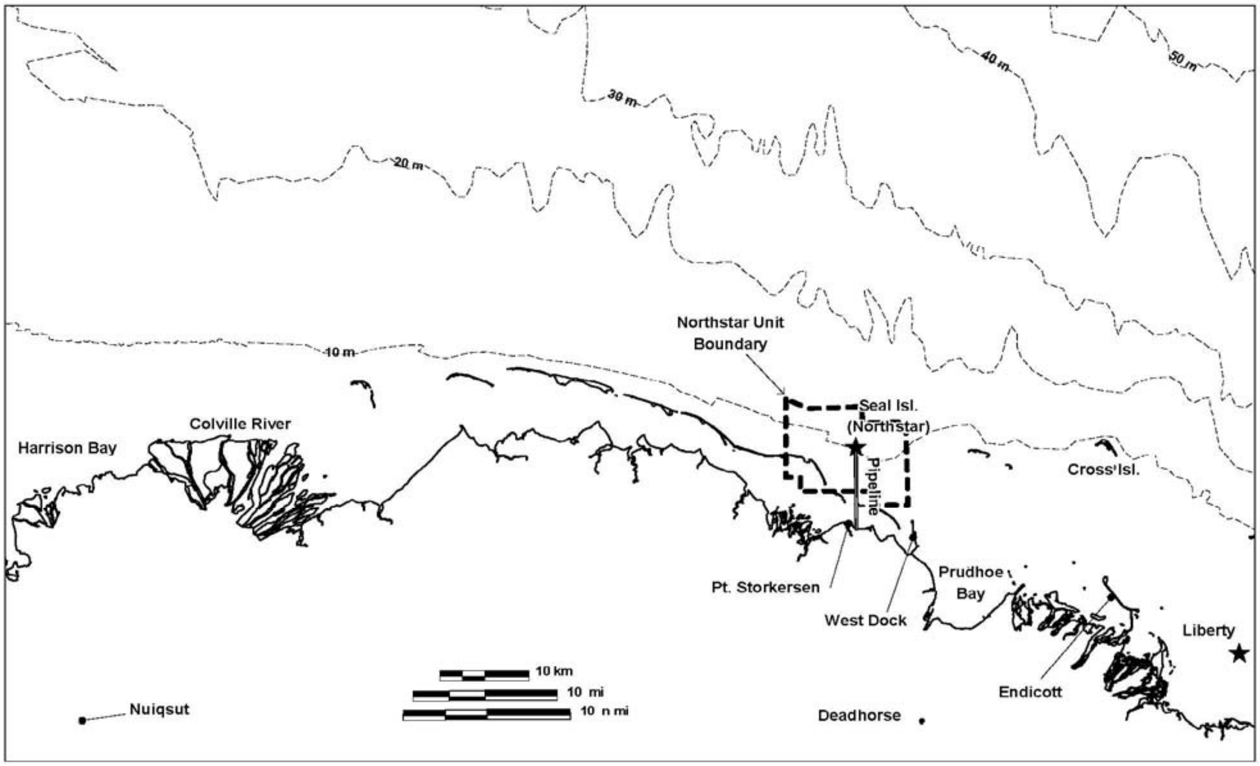

FIGURE 1. Location of the Northstar Development at Seal Island in the central Alaskan Beaufort Sea. Seal Island was an artificial gravel island constructed for exploration drilling in the 1980s. Northstar facilities were built on the eroded remnants of Seal Island in 2000.

Northstar Previous Activities—Construction, Drilling and Production

The Northstar Unit is located between 3.2 and 12.9 km (2 and 8 mi) offshore from Point Storkersen in the Beaufort Sea. The unit is adjacent to Prudhoe Bay, and is approximately 87 km (54 mi) northeast of Nuiqsut, an Inupiat community. The main facilities associated with Northstar include a gravel island work surface for drilling and oil production facilities, and two pipelines connecting the island to the existing infrastructure at Prudhoe Bay. One pipeline transports crude oil to shore, and the second imports gas from Prudhoe Bay for gas injection at Northstar. Permanent living quarters and supporting oil production facilities are also located on the island.

BP's original plans called for construction of Northstar to begin during early 1999 on the remnants of Seal Island, an old exploratory site. Ice roads to Seal Island were constructed in 1999 but island construction was cancelled that winter due to delays in the EIS process. Ice roads were again constructed during the ice-covered period 1999–2000 to allow reconstruction of Seal Island and installation of pipelines between the Northstar development and the shore. Trucks completed ~18,300 round trips to haul a total of ~548,000 cubic yards of gravel along the ice roads from the Kuparuk delta for the reconstruction of Seal Island. During this period a sheetpile wall was built around the entire working surface on the island to provide protection of island facilities in case of extreme ice ride-up during the winter. Two 10-inch pipelines were buried below the seafloor between the island and the mainland during the ice-covered period 1999–2000.

During the open-water period in 2000, construction of basic facilities on Northstar Island continued. Impact hammers were used to drive the well conductor pipes into the island, and permanent living quarters, a utility module, and pipe racks were delivered to the island by sealift barge. The living quarters and utility module were functional before the end of 2000. Helicopters, crew boats, and barges were used for transportation of personnel and equipment to and from the island. Alaska Clean Seas (ACS) conducted spill drills to train Northstar personnel in spill response techniques.

An ice road was constructed during the ice-covered period in late 2000 and early 2001 for transport of personnel, equipment, and construction material between Prudhoe Bay (West Dock) and Northstar Island. A path was cleared along the pipeline alignment to allow emplacement, at certain locations, of additional gravel fill over the sub-sea pipeline that had been installed during the previous winter. A total of 9 locations along the pipeline route required addition gravel backfill, necessitating 130 truckloads to haul ~3,640 cubic yards of stockpiled gravel. A third ice road was built along the coast from West Dock to the pipeline landfall; this provided access to the valve pad at the pipeline landfall and to the backfill sites south of Stump Island. Helicopters were used to transport personnel during periods when ice thickness was not sufficient to support vehicles or when ice roads were otherwise not suitable for vehicle use. Construction activities that occurred on Northstar Island during the ice-covered period of 2000–2001 included the following: completing assembly of the drilling rig, pipe rack, permanent living quarters, and grind and inject module; dock improvements; installation of the mini-injection effluent skid and the foundation blocks for modules housing the processing plant, compressor, and garage. Well drilling began during this period. Five wells were drilled from 14 December 2000 to 13 June 2001 when drilling was suspended until late 2001 to satisfy regulatory requirements. In December 2000 two ARKTOS emergency escape vehicles were driven to Northstar Island and subsequently tested on the sea ice.

The major activity that occurred at Northstar during the open-water period of 2001 was the arrival of the main production facilities via sealift during August, subsequent offloading, installation, and initial testing. As in 2000, helicopters and crew vessels were used for transportation of personnel to and from Northstar during the break up and broken-ice periods of 2001. Tugs and barges periodically traveled to and from Northstar delivering equipment and fuel. On 24 October 2001, the primary power supply for the island changed from the diesel generators used until then to gas-turbine-powered generators. Drilling operations resumed on 17 November 2001 (after being suspended since 13 June), and oil production commenced on 31 October 2001.

Oil production and associated gas injection occurred throughout the ice-covered season of 2001–2002. Also, a total of 7 wells were drilled between 17 November 2001 and 7 June 2002. Power was produced from gas-turbine generators, and additional gas turbine engines were operating to compress and inject gas. One ice road was constructed during the period and transportation to and from the island was by helicopter at the start and end of the ice-covered period, and by ice road during the remainder of the period. Three oil spill exercises were conducted during the period, 2 for containment of oil in water, and 1 for detection of oil under ice. No major construction or maintenance activities occurred during the ice-covered period in 2001–2002, although various test, training, and inspection activities occurred in the area on an intermittent basis through the winter and spring.

Oil production and gas injection continued during the 2002 open-water period and the gas-turbine generators continued to be used as a source of power for the island. No major sea lift occurred but the usual helicopter and vessel traffic took place for routine island support activities. Drilling occurred between 16 June and 28 October 2002 although all drilling during this period was above reservoir depths. During July through October 2002, ACS conducted 11 spill drill exercises.

Each year during the ice-covered season in the period 2003–2009 an ice-road was constructed between the Prudhoe Bay facilities at West Dock and Northstar Island to transport personnel, equipment, materials, and supplies. Helicopters and hovercraft were mainly used for transportation during freeze-up and during break-up. During the open-water periods, helicopters and the hovercraft were used for most of the transportation requirements. Vessels from Alaska Clean Seas (ACS) were used for transportation of personnel and equipment at times when weather, maintenance, or operational considerations prevented the use of helicopter and hovercraft. Round trip statistics of various transportation methods are summarized in Table 1. Normal oil production, gas injection and drilling activities continued during these years, including equipment testing, exercises for spill detection and emergency escape training. Construction and maintenance activities occurred annually on the protection barrier around Northstar due to ice and storm impacts. In 2003, from 10 through 25 August 2003, two barges made a total of 52 round-trips to haul 30,000 cubic yards of gravel from West Dock for berm construction. Depending on the actual damage, repair and maintenance in the following years consisted of activities such as creating a moat for divers access, removing concrete blocks in areas that had sustained erosion and/or block damage, installing a new layer of filter fabric, installing gravel bags of various sizes to build up and stabilize the subgrade, installing another layer of filter fabric and an overlying layer of geogrid to reduce the susceptibility of the fabric to abrasion, and installing concrete block armor. In 2008, BP installed large boulders at the NE corner of the barrier instead of replacing the lower concrete blocks that were removed during a storm. The boulders were transported with side-dump trucks from a quarry in the Brooks Range to Northstar Island. A total of 812 round trips were made during March–April, using the ice road for transport from West Dock to the island.

TABLE 1. Total number of round trips to Northstar Island for various transportation means each year since 2003 during the ice-covered and open-water seasons. A ½ round trip occurs when leaving prior to midnight, and returning after midnight or, occasionally, if the trip is not completed due to weather or other reasons. The hovercraft was first tested and used in spring 2003.

Year$^{\nabla}$	**Ice-covered season**		**Open-water season**			
	Helicopter	**Hovercraft**	**Helicopter**	**Hovercraft**	**Tugs/ Barges**	***ACS* boats**
2003	1122	na	277	202	82	392*
2004	253	141	189	302	24	22
2005	118	180	103	188	21	14
2006	465	249	271	560	64	106
2007	335	574	190	347	40	137
2008	222	426	119	445.5	45	55

$^{\nabla}$ refers to LOA reporting year from 1 November to 31 October
* records are from a dedicated crew boat

Equipment Used during Construction, Production, Drilling, and Maintenance Operations

Table 2 summarizes the vehicles and machinery used during BP's Northstar activities since the development of Northstar Island. Although all these activities are not planned to take place during 2011–2016 operational phase of Northstar, some of the equipment may be required to repair or replace existing structures or infrastructure on Northstar in the future. Specific vehicles and heavy equipment are mentioned where possible, but it in some cases these might be substituted by similar vehicles or heavy equipment.

TABLE 2. Equipment used during activities at and around Northstar since the development of the island.

Activity	**Vehicles/Equipment**	**Description**
Ice road construction	Ice Auger	*Blue Bird Rolligon* augers and pumps are used to bore holes into the sea ice and pump sea water onto the ice-road surface.
	Water Truck	Water trucks are used along ice road corridors to thicken the ice to a sufficient depth to support heavy equipment traffic, and to cap off the offshore roads for durability.
	Grader	*Caterpillar 14G or 16G* graders are used to maintain ice roads, as are small snow blowers and front-end loaders with snow blower attachments.
Pipeline Installation	Ditchwitch	*Ditchwitch R100s* are used to cut slots in the ice
	Backhoe	*Caterpillar 330s* are used to remove ice from the slots, *Hitachi EX-450s* are used for ice block removal from slotting and for pipeline trench excavation.
	Tractor Trailer	Standard tractor trailers are used to haul pipe sections to the trench location.
	Boom Tractor	*Caterpillar 583* side booms are used to lay the pipes into the trench.
Island Construction and Maintenance	Dozer	Various *D-3, D-4, D-5, D-8N and D-8K Caterpillars* are used for plowing snow along the ice-road corridors, removing ice rubble from Seal Island, moving gravel on the island, and various other island construction- and maintenance-related activities.
	Front-End Loaders	*Caterpillar 966* and *Volvo 150* loaders are used for island gravel placement, island slope grading, ice block handling, trench spoils handling, truck loading, trench spoils placement, snow removal, ice road maintenance, and various other island construction- and maintenance-related activities.
	Heavy Load Truck	*Euclid R-25*, *Volvo A-30,* and *Euclid B-70* dump trucks are used to haul gravel on grounded ice. *Kenworth Maxihauls* were used to haul gravel on the floating landfast ice
	Crane	A Manitowoc 888 crane was used to lift and place sheetpiles for island reinforcement and pilings for the dock face.
	Vibratory Hammer	*APE 200A* vibratory hammers are used to drive sheetpiles, dock piles, thermosiphons, and well casings.
	Impact Hammer	A *DELMAG D62-22 Diesel Impact Hammer* was used to install sheetpiles and well casings through frozen surfaces that can not be penetrated by the vibratory hammer.

TABLE 2. Continued.

Activity	Vehicles/Equipment	Description
Drilling activities	Drill Rig	Nabors 33e
Production operations	Gas Turbines	The turbines (*GE model LM-2500*) operate three *Solar* power generators and two high pressure compressors for gas injection.
	Pumps	Two electrically-powered crude stabilizer pumps and two electrically powered crude sales pumps operate almost continuously. Two electrically-powered water injection pumps operate sporadically.
	Various equipment	M777 truck crane, 82-ton link belt truck crane, Polaris 6-wheeler, Mechanic box truck, Compactors, Mobile aerial lifting platform, Scheuerle trailer model MPEK 5200.

Expected Activities—Continuation of Drilling, Production, Emergency Training Operations

Transportation of Personnel, Equipment, and Supplies

Transportation needs for the Northstar project include the ability to safely transport personnel, supplies, and equipment to and from the site during repairs or maintenance, drilling, and operations in an offshore environment. During proposed island renewal construction that may take place during the petition time period, quantities of pipes, VSMs, gravel, and a heavy module will be transported to the site. Drilling operations require movement of pipe materials, chemicals, and other supplies to the island. During ongoing field operations, equipment and supplies will need to be transported to the site. All phases of construction, drilling, and operation requires movement of personnel to and from the Northstar area.

During the operations phase from 2002–2009, fewer ice roads were required compared to the construction phase (2000–2001). The future scope of ice-road construction activities during the ongoing production is expected to be similar to the post-construction period of 2002 through 2009. The locations, dimensions, and construction techniques of these ice roads are described in the multi-year final comprehensive report (Richardson [ed.] 2008). The presence of ice roads allows the use of standard vehicles such as pick-up, SUVs, buses and trucks for transport of personnel and equipment to and from Northstar during the ice-covered period. Ice roads are planned to be constructed and used as a means of winter transportation for the duration of Northstar operations. The orientation of future ice roads is undetermined, but will not exceed the number of ice roads created during the winter of 2000/2001.

Barges and ACS vessels are used to transport personnel and equipment from the Prudhoe Bay area to Northstar during the open-water season, which extends from approximately mid- to late-July through early- to mid-October. Seagoing barges are used to transport large modules and other supplies and equipment during the construction period. To minimize the potential for conflicts with subsistence users, marine vessels transiting between Prudhoe Bay or West Dock and Northstar Island travel shoreward of the barrier islands as much as possible, and avoid the Cross Island area during the bowhead hunting season in autumn.

Helicopter access to Northstar Island continues to be an important transportation option during break-up and freeze-up of the sea ice when wind, ice conditions, or other operational considerations prevent or limit hovercraft travel. Helicopters will be used for movement of personnel and supplies in the fall after freeze-up begins and vessel traffic is not possible, but before ice roads have been constructed. Helicopters will also be used in the spring after ice roads are no longer safe for all-terrain vehicles but before enough open water is available for vessel traffic. Helicopters are also available for use at other times of year in emergency situations. Helicopters fly at an altitude of at least 305 m (1,000 ft), except for take-off, landing, and as dictated for safe aircraft operations as governed by the Federal Aviation Administration (FAA). Designated flight paths are assigned to minimize potential disturbance to wildlife and subsistence users.

A small hovercraft was first tested in June 2003 for use as an alternate means of transportation of personnel and supplies to and from Northstar during the open-water season and has been in use since then when weather conditions allowed. The hovercraft is used to transport personnel and supplies during break-up and freeze-up periods to reduce helicopter use. BP intends to continue the use of the hovercraft in future years. Specifications of the hovercraft and sound characteristics are described in Richardson ([ed.] 2008) and Blackwell and Greene (2005).

Production Operations

The process facilities for the Northstar project are primarily prefabricated sealift modules that were shipped to the island and installed in 2001. The operational aspects of the Northstar production facility include the following: two diesel generators (designated emergency generators), three turbine generators for the power plant, operating at 50 percent duty cycle (i.e., only two will be operating at any one time), two high pressure turbine compressors, one low pressure flare, and one high pressure flare. Both flares are located on the 66 m (215 ft) flare tower. Modules for the facility include permanent living quarters (i.e., housing, kitchen/dining, lavatories, medical, recreation, office, and laundry space), utility module (i.e., desalinization plant, emergency power, and wastewater treatment plant), warehouse/shop module, communications module, diesel and potable water storage, and chemical storage. The operational phase of Northstar began with initial drilling in late 2000. Oil production began on 31 October 2001. Operations have been continuing since that time and are expected to continue beyond 2016.

Drilling Operations

The drilling rig and associated equipment was moved by barge to Northstar Island from Prudhoe Bay during the open-water season in 2000. Drilling began in December 2000 using power supplied by the installed gas line. The first well drilled was the Underground Injection Control well, which was commissioned for disposal of permitted muds and cuttings on 26 January 2001. After Northstar facilities were commissioned, drilling above reservoir depth resumed, while drilling below that depth is allowed only during the ice covered period.

Twenty-three wells have been planned for Northstar, including 15 oil producing wells, 6 gas injection wells, and 2 waste injection wells. The planned well-drilling program was completed in May 2004. Drilling activities to drill new wells, conduct well maintenance, and drill well side-tracks continued in 2006 (6 wells), 2007 (2 wells) and 2008 (2 wells). The drill rig may be demobilized by barge during the 2010 open-water period. Although future drilling is not specifically planned, drilling of additional wells or well workover may be required at some time during 2011–2016 and it may be necessary to move a drilling rig to and/or from the island during those 5 years.

Pipeline Design, Inspection, and Maintenance

The Northstar pipelines have been designed, installed, and monitored to assure safety and leak prevention. Pipeline monitoring and surveillance activities have been conducted since oil production began and BP will conduct long-term monitoring of the pipeline system to assure design integrity and to detect any potential problems through the life of the Northstar development. The program will include visual inspections/aerial surveillance and pig inspections.

The Northstar pipelines include the following measures to assure safety and leak prevention:

- Under the pipeline design specifications, the tops of the pipes are 1.8 to 2.4 m (6 to 8 ft) below the original seabed (this is 2 times the deepest measured ice gouge).
- The oil pipeline uses higher yield steel than required by design codes as applied to internal pressure (by a factor of over 2.5 times). This adds weight and makes the pipe stronger. The 10-inch diameter Northstar oil pipeline has thicker walls than the 48-inch diameter Trans-Alaska Pipeline.
- The pipelines are designed to bend without leaking in the event of ice keel impingement or the maximum predicted subsidence from permafrost thaw.
- The pipelines are coated on the outside and protected with anodes to prevent corrosion.
- The shore transition is buried to protect against storms, ice pile-up, and coastal erosion. The shore transition valve pad is elevated and set back from the shoreline.

A best-available-technology leak detection system is being used during operations to monitor for any potential leaks. The Northstar pipeline incorporates two independent, computational leak detection systems: (1) the Pressure Point Analysis (PPA) system, which detects a sudden loss of pressure in the pipeline, and (2) the mass balance leak detection system, which supplements the PPA. Furthermore, an independent hydrocarbon sensor, the LEOS leak detection system, located between the two pipelines, can detect hydrocarbon vapors and further supplements the other systems.

- Intelligent inspection pigs are used during operations to monitor pipe conditions and measure any changes.
- The elevated overland pipeline section is composed of conventional, proven North Slope design.
- The line is constructed with no flanges, valves, or fittings in the subsea section to reduce the likelihood of equipment failure.

During operations, BP conducts aerial FLIR surveillance of the offshore and onshore pipeline corridors at least once per week (when conditions allow), to detect pipeline leaks. Pipeline isolation valves are inspected on a regular basis. In addition to FLIR observations/inspections, BP conducts a regular oil pipeline pig inspection program to assess continuing pipeline integrity. The LEOS Leak Detection System is used continuously to detect under-ice releases during the ice covered period.

The pipelines are also monitored annually to determine any potential sources of damage along the pipeline route. The monitoring work has been conducted in two phases: (1) a helicopter-based reconnaissance of strudel drainage features in early June, and (2) a vessel-based survey program in late July and early August. During the vessel-based surveys, a multi-beam sonar, a single-beam sonar, and a side scan sonar are used. These determine the locations and characteristics of ice gouges and strudel scour depressions in the sea bottom along the pipeline route, and at additional selected sites where strudel drainage features have been observed. If strudal scour depressions are identified, additional gravel fill is placed in the open water season to maintain the sea bottom to original pipeline construction depth.

Routine Repair and Maintenance

Various routine repair and maintenance activities have occurred since the construction of Northstar. Examples of some of these activities include completion and repair of the island slope protection berm, well cellar retrofit repairs, heat pipe and thermister installation, ARKTOS ramp repair, and modifications for a hovercraft landing area. Activities associated with these repairs or modifications are reported in the final comprehensive report (Rodrigues and Williams 2006) and since 2005 in the various Annual Reports (Rodrigues et al. 2006; Rodrigues and Richardson 2007; Aerts and Rodrigues 2008; Aerts 2009). Some of these activities, such as repair of the island slope protection berm, were major repairs that involved the use of barges and heavy equipment, while others were smaller-scale repairs involving small pieces of equipment and hand operated tools. The berm surrounding the island is designed to break waves and ice movement before they contact the island work surface, and is subjected to regular eroding action of these forces. The berm and sheet pile walls will require regular surveying and maintenance in future. Potential repair and maintenance activities that may be expected to occur at Northstar during the period 2011–2016 include pile driving, traffic, gravel transport, dock construction and maintenance, diving and other activities similar to those that have occurred in the past.

Emergency and Oil Spill Response Training

Emergency and oil spill response training activities are conducted at various times throughout the year at Northstar. Oil spill drill exercises are conducted by Alaska Clean Seas (ACS) during both the ice-covered and open-water periods. During the ice-covered periods, exercises are conducted for containment of oil in water and for detection of oil under ice. These spill drills have been conducted on mostly bottom-fast ice in an area 61 m × 61 m (200 ft × 200 ft) located just west of the island using snow machines and all-terrain vehicles. The spill drill includes the use of various types of equipment to cut ice slots or drill holes through the floating sea ice. Typically, the snow is cleared from the ice surface with a Bobcat loader and snow blower to allow access to the ice. Two portable generators are used to power light plants at the drill site. The locations and frequency of future spill drills or exercises will vary depending on the condition of the sea ice and training needs.

ACS conducts spill response training activities during the open-water season during late July through early October. Vessels used as part of the training typically include Zodiacs, Kiwi Noreens, and Bay-class boats that range in length from 3.7 to 13.7 m (12 to 45 ft). Future exercises could include other vessels and equipment.

ARKTOS amphibious emergency escape vehicles are stationed on Northstar Island. Each ARKTOS is capable of carrying 52 people. Training exercises with the ARKTOS are conducted monthly during the ice-covered period. ARKTOS training exercises are not conducted during the summer.

Equipment and techniques used during oil spill response exercises are continually updated, and some variations relative to the activities described here are to be expected.

Northstar Abandonment

Detailed plans for the decommissioning of Northstar will be prepared near the end of field life, which will not occur during the period addressed in this request. Decommissioning will be conducted in accordance with the provisions of Federal, State, and local laws, regulations, and permit conditions. In general, the applicable laws and regulations provide for discretion with respect to rehabilitation requirements. This flexibility allows for consideration of the environmental effects of decommissioning relative to leaving certain facilities in place and other site-specific factors.

Decommissioning may involve removal and salvage of offshore and onshore surface facilities and equipment. Subsurface pipelines may be purged, plugged, and left in place. The gravel island may be abandoned in place with some slope protection removed to allow erosion, or all slope protection in place to maintain low sediment release into the surrounding marine environment. The actual method of abandonment will be determined, in association with the responsible agencies, through an assessment of the environmental effects of the alternatives as judged at the future date when these decisions must be made.

2. DATES, DURATION AND REGION OF ACTIVITY

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

BP seeks authorization to continue operate the Northstar development during the period 7 April 2011 through 6 April 2016 as it was operated during the previous 5-year period. The geographic region encompasses the Northstar Oil and Gas Development area within state and/or Federal waters in the U.S. Beaufort Sea. The Northstar Development Unit is located between 3.2 and 12.9 km (2 and 8 mi) offshore from Point Storkersen in the Beaufort Sea. The unit is adjacent to Prudhoe Bay, and is approximately 87 km (54 mi) northeast of Nuiqsut, an Inupiat community (see Figure 1).

3. SPECIES AND NUMBERS OF MARINE MAMMALS IN AREA

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

The area where the Northstar production facilities are located is within or near the southern edge of the migration path, or within the range, of several species of marine mammals. These include six species under the jurisdiction of the National Marine Fisheries Service: ringed, bearded and spotted seals, and bowhead, gray and beluga whales. Other extralimital species that occasionally occur in very small numbers in the Alaskan Beaufort Sea include the harbor porpoise (*Phocoena phocoena*), killer whale (*Orcinus orca*), narwhal (*Monodon monoceros*), and ribbon seal (*Histriophoca fasciata*). Because of the rarity of the latter species in the Beaufort Sea, they are not expected to be exposed to or affected by any activities associated with the Northstar development and, therefore, are not discussed further. Some of these species are important subsistence resources used by the North Slope communities of Barrow, Nuiqsut and Kaktovik. To reduce redundancy, we have included the required information about species and numbers of marine mammals within the project area in Section 4.

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

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

The following six species of seals and cetaceans can be expected to occur in the region of proposed activity: ringed, spotted and bearded seals, and bowhead, gray and beluga whales. These six species are discussed in this section and are the species for which general regulations governing potential incidental takes of small numbers of marine mammals are sought. The descriptions provided in the original petition (BPXA 1999) and the 2004 submittal (BPXA 2004) are updated here to provide more recent information. Furthermore, NMFS annually publishes stock assessment reports for all marine mammals in Alaskan waters and those are referenced in the sections on individual species, below.

Two other marine mammal species found in this area, the Pacific walrus and polar bear, are managed by the U.S. Fish and Wildlife Service (USFWS). Potential incidental takes of those two species have been dealt with under a separate application for a Letter of Authorization from the USFWS.

Ringed Seal (Phoca hispida)

Ringed seals are year-round residents in the Beaufort Sea and will be the most frequently encountered seal species in the project area. During winter and early spring, ringed seals will be the only seals encountered near the development area within the landfast ice zone. No estimate for the size of the Alaska ringed seal stock is currently available (Angliss and Allen 2009). Past ringed seal population estimates in the Bering-Chukchi-Beaufort area ranged from 1–1.5 million (Frost 1985) to 3.3–3.6 million (Frost et al. 1988). Frost and Lowry (1981) estimated 80,000 ringed seals in the Beaufort Sea during summer and 40,000 during winter. The Alaska stock of ringed seals is not classified as a strategic stock by the NMFS. There is an increasing concern about the future of the ringed seals due to receding ice conditions and potential habitat loss. NMFS conducted a status review for the ringed seal in 2008, but failed to make a determination within a year and was sued for delaying protection of Arctic seals under the ESA. On 25 September 2009 a federal judge agreed to a settlement that requires NMFS to decide by 1 November 2010 whether ringed seals merit listing as a threatened or endangered species due to threats from global warming.

During winter, ringed seals occupy landfast ice and offshore pack ice of the Bering, Chukchi and Beaufort seas. In winter and spring, the highest densities of ringed seals are found on stable landfast ice. However, in some areas where there is limited landfast ice but wide expanses of pack ice, including the Chukchi Sea, Beaufort Sea, and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970; Stirling et al. 1982; Finley et al. 1983).

Based on studies of ringed seals in Alaska and the Canadian High Arctic, ringed seals start to use a series of breathing holes as soon as ice begins to form in late fall/early winter (Smith and Stirling 1975; Williams et al. 2002). As snow accumulates around these breathing holes, areas around some breathing holes become lairs, which afford protection from predators and weather (Smith and Stirling 1975; Frost and Burns 1989; Kelly and Quakenbush 1990). Ringed seals give birth in lairs from mid-March through April, nurse their pups in the lairs for 5–8 weeks, and mate in late April and May (Smith 1973; Hammill et al. 1991; Lydersen and Hammill 1993). They maintain some of the same breathing holes and lairs throughout the ice-covered period, but some are abandoned during the winter period even in the absence of human activities (Frost and Burns 1989; Hammill and Smith 1990). Williams et al. (2002) reported similar densities of structures (both abandoned and active) out to 3.5 km (2.2 mi) from Northstar Island and the ice road, and found that new structures were created by ringed seals throughout the ice-covered season. The area used by a single ringed seal may cover a relatively large area; Kelly and Quakenbush (1990) reported that mean distance between lairs was 2.0 km for male and 0.6 km for female ringed seals (maximum distance between 2 lairs was 3.4 km [2.1 mi]). Individual seals had as many as four lairs. Pups may use more holes than adults (mean 8.7, Lydersen and Hammill 1993), but these holes are closer together (maximum distance apart was 900 m [2952 ft]).

In 1997, BP began an intensive seal survey program in the Northstar/Prudhoe Bay area. The purpose was to establish a baseline prior to development at Northstar, and to continue the surveys during Northstar construction and initial operations for comparison with the baseline data. Seal counts through springtime aerial surveys, conducted prior to Northstar construction in the period 1997–1999 in Prudhoe Bay and Foggy Island Bay area, reported (uncorrected) ringed seal densities of 0.43, 0.39 and 0.63 seals/km^2, respectively, in water over 3 m (9.8 ft) in depth (Moulton et al. 2002). Similar surveys in the Prudhoe Bay area conducted during the years 1997–1999 estimated consistent higher densities of seals (0.73 versus 0.43 seals/km^2 in 1997; 0.64 vs. 0.39 seals/ km^2 in 1998 and 0.87 vs. 0.63 seals/km^2 in 1999; Frost et al. 2002, 2004). There are many natural factors that can contribute to variations in reported seal densities, e.g., time of year, time of day, snow conditions, air temperature, and cloud cover (Moulton et al. 2002). Early in the season a higher proportion of seals are still using their lairs and are unavailable to be counted by aerial surveyors, resulting in a lower estimated density (Kelly et al. 2004). However, it is not clear why such different results were obtained from similar surveys with considerable overlap in timing and methods. Ringed seal densities (uncorrected) on landfast ice during Northstar construction in the period 2000, 2001, and 2002 were 0.47, 0.54, and 0.83 seals/km^2, respectively (Moulton et al. 2005).

Although aerial surveys during spring are the standard method for documenting densities and distribution of ringed seals, the densities of seals estimated with this method underestimate actual seal densities. Not all seals are hauled out on the ice at any one time, and aerial surveyors, even under the best of survey conditions, miss some seals that are on the ice. Thus, the average density figures quoted above are minimum estimates. Although current reliable population estimates for ringed seals are not available, Frost et al. (2002) reported that a trend analysis suggested a marginally significant decline of 31% from 1980–87 to 1996–99; however this decline may be due to differences in survey timing rather than reflect an actual decline in abundance.

During summer, ringed seals are found dispersed throughout open water areas, although in some regions they move into coastal areas (Smith 1987; Harwood and Stirling 1992). During the open water period, ringed seals in the eastern Beaufort Sea are widely dispersed as single animals or small groups (Harwood and Stirling 1992). Marine mammal monitoring in the nearshore central Beaufort Sea confirms these generalities (Moulton and Lawson 2002; Williams et al. 2006a). Many groups consisting of >5 ringed seals were seen in September 1997 offshore from the Northstar area (Harris et al. 1998). These groups were in water 50–2,000 m (164–6,561 ft) deep, well offshore from the planned development area. A group of ~5 ringed seals was encountered ~15 nm offshore of Northstar Island mid/end September in waters of 25 m (82 ft) depth (L. Aerts, pers. communication). Large concentrations of ringed seals are not expected to be encountered near Northstar Island during the summer season. A summary of earlier data on summer sightings of ringed seals in the region can be found in BPXA (1999).

Spotted Seal (Phoca largha)

An early estimate of the size of the world population of spotted seals was 335,000–450,000 (Burns 1973), and the size of the Bering Sea population, including animals in Russian waters, was estimated to be 200,000–250,000 animals (Burns 1973). There is no reliable estimate of the total number of spotted seals in Alaskan waters (Angliss and Allen 2009), but the number of animals is most likely between several thousand and several tens of thousands (Rugh et al. 1997). The Alaska stock of spotted seals is not classified as a strategic stock by NMFS (Hill and DeMaster 1998). Similar to the ringed seal, there is a concern about the future of the spotted seal due to receding ice conditions and potential habitat loss. NMFS conducted a status review for the spotted seal in 2008, but failed to make a determination within a year and was sued for delaying protection of Arctic seals under the ESA. After an 18-month status review NMFS determined not to list the two spotted seal populations inhabiting US waters under the ESA, because they are currently not in danger of extinction or likely to become endangered in the foreseeable future.

During spring when pupping, breeding, and molting occur, spotted seals are found along the southern edge of the sea ice in the Okhotsk and Bering seas (Quakenbush 1988; Rugh et al. 1997). In late April and early May, adult spotted seals are often seen on the ice in female-pup or male-female pairs, or in male-female-pup triads. Subadults may be seen in larger groups of up to two hundred animals. During the summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998). At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. The seals are commonly seen in bays, lagoons and estuaries, but also range far offshore. In summer, they are rarely seen on the pack ice, except when the ice is very near to shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

A small number of spotted seal haul-outs are (or were) located in the central Beaufort Sea in the deltas of the Colville River and, previously, the Sagavanirktok River. Historically, these sites supported as many as 400–600 spotted seals, but in the late ‘90s <20 seals have been seen at any one site (Johnson et al. 1999). In total, there are probably no more than a few tens of spotted seals along the coast of the central Alaska Beaufort Sea during summer and early fall. No spotted seals were positively identified during BP’s Northstar marine mammal monitoring activities, although a few spotted seals might have been present. A total of 12 spotted seals were positively identified near the source vessel during open-water seismic programs in the central Alaskan Beaufort Sea generally near Northstar from 1996 to 2001 (Moulton and Lawson 2002). Numbers seen per year ranged from zero (in 1998 and 2000) to four (in 1999).

Given their seasonal distribution and low numbers in the nearshore waters of the central Alaskan Beaufort Sea, no spotted seals are expected in the Northstar area during late winter and spring, and a few individuals could be expected near Northstar during the summer or autumn.

Bearded Seal (Erignathus barbatus)

The Alaska stock of bearded seals, which occupy the Bering, Chukchi, and Beaufort seas, may consist of about 300,000–450,000 individuals (MMS 1996). No reliable estimate of bearded seal abundance is available for the Beaufort Sea (Angliss and Allen 2009). The Alaska stock of bearded seals is not classified by NMFS as a strategic stock. There is though an increasing concern about the future of the bearded seal due to receding ice conditions and potential habitat loss. NMFS conducted a status review for the bearded seal in 2008, but failed to make a determination within a year and was sued for delaying protection of Arctic seals under the ESA. On 25 September 2009 a federal judge agreed to a settlement that requires NMFS to decide by 1 November 2010 whether bearded seals merit listing as a threatened or endangered species due to threats from global warming.

The bearded seal is the largest in size of the northern phocids. It is primarily a bottom feeder. It prefers areas of water no deeper than 200 m (660 ft). Bearded seals have occasionally been reported to maintain breathing holes in the sea ice and they do occupy areas with pack ice, particularly if the water depth is <200 m (656 ft). Bearded seals apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas considerably more than 200 m (656 ft) deep.

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi and Beaufort seas, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter. From mid-April to June, as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer they are found near the widely fragmented margin of multi-year ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea. In the Beaufort Sea, bearded seals rarely use coastal haulouts.

In some areas, bearded seals are associated with the ice year-round; however, because they are primarily benthic feeders, they usually move shoreward into open water areas when the pack ice retreats to areas with water depths greater than 200 m (656 ft). During the summer, when the Bering Sea is ice-free, the most favorable bearded seal habitat is found in the central or northern Chukchi Sea along the margin of the pack ice. Suitable habitat is more limited in the Beaufort Sea where the continental shelf is narrower and the pack ice edge frequently occurs seaward of the shelf and over water too deep for feeding. The preferred habitat in the western and central Beaufort Sea during the open water period is the continental shelf seaward of the scour zone.

During the late winter/spring period, the Northstar area is covered by landfast ice which bearded seals tend to avoid, as they prefer areas of moving ice and open water in depths of less than 200 m (Mansfield 1967; Burns and Harbo 1972). However, bearded seals have been observed to maintain breathing holes in annual ice and have even been observed hauling out from the same holes as ringed seals (Mansfield 1967; Stirling and Smith 1977). Small numbers of bearded seals have been reported in the Northstar area. The number of bearded seals that were seen in the landfast ice around Northstar during spring aerial surveys from 1997 to 2002 ranged from zero to 15 (Moulton et al. 2003b).

Bowhead Whale (Balaena mysticetus)

The pre-exploitation population of bowhead whales in the Bering, Chukchi, and Beaufort seas is estimated to range between 10,400–23,000 whales, and was reduced by commercial whaling to perhaps 3,000 (Woodby and Botkin 1993). Up to the early 1990s, the population size was believed to be increasing at a rate of about 3.2% per year (Zeh et al. 1996; Angliss and Lodge 2002) despite annual subsistence harvests of 14–74 bowheads from 1973 to 1997 (Suydam et al. 1995; Section 8). This is consistent with an annual population growth rate of 3.4% (95% CL 1.75%) from 1978 to 2001 reported by George et al. (2004) who estimated the population in 2001 at approximately 10,545 animals (CV=0.128); 121 calves were reported in 2001, which was the highest number recorded and indicative of a healthy and increasing population. The large increases in population estimates that occurred from the late 1970s to the early 1990s were partly a result of actual population growth, but were also partly attributable to improved census techniques (Zeh et al. 1993). This bowhead population is currently listed as *Endangered* under the Endangered Species Act (ESA) and is classified as a strategic stock by the NMFS (Angliss and Allen 2009).

Bowheads winter in the central and western Bering Sea and summer in the Canadian Beaufort Sea (Moore and Reeves 1993). Spring migration through the Western Beaufort Sea occurs through offshore ice leads, generally from mid-April through mid-June (Braham et al. 1984; Moore and Reeves 1993). East of Point Barrow, the lead systems divide into numerous branches that vary in location and extent yearly, but are located well offshore of the Alaskan coast. The route follows a corridor centered at 71º30'N latitude, and broadly occurring between latitude 71º20'N and 71º45'N (Ljungblad et al. 1983; Braham et al. 1984; Richardson et al. 1995a). No bowhead whales are expected to occur within 75 km (46 mi) of Northstar during the spring migration period.

Bowheads arrive in coastal areas of the Canadian Beaufort Sea and Amundsen Gulf in late May and June. After feeding in the Canadian Beaufort Sea, bowheads migrate westward from late August through mid- or late October. Fall migration into Alaskan waters is primarily during September and October, with most bowheads passing by Northstar in September. A relatively small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; Greene 1997a; Greene et al. 1999; Blackwell et al. 2009). Consistent with this, Nuiqsut whalers have stated that the earliest arriving bowheads have apparently reached the Cross Island area earlier in recent years than formerly (T. Napageak, pers. comm.).

The Minerals Management Service (MMS) and its precursor the Bureau of Land Management have funded and/or conducted aerial surveys of the fall migration of bowhead whales in the Alaskan Beaufort Sea since 1979 (e.g., Ljungblad et al. 1986, 1987; Moore et al. 1989; Treacy 1988–1998, 2000, 2002a, b). One of the aims of this study is to better understand the annual bowhead fall migration, i.e., significant inter-year differences, and long-term trends in distance from shore and water depth at which whales migrate. Bowheads tend to migrate in deeper water offshore during years with higher than average ice coverage than in years with lower than average ice cover (Moore 2000). In addition, the sighting rate tends to be lower in heavy ice years (Treacy 1997). During fall migration, most bowheads migrate west in water ranging from 15 to 50 m (49 to 164 ft) deep. Some individuals enter shallower water, particularly in light ice years, but very few whales are ever seen shoreward of the barrier islands. Survey coverage far offshore in deep water is usually limited, and offshore movements may have been underestimated.

Since the start of construction and initial operations of BP's Northstar facilities in 2000 acoustic monitoring methods have been used to characterize the late summer/early autumn migration of bowheads past Northstar. An array of bottom-mounted acoustic recorders with direction-finding capability has been deployed 6–22 km (4–14 mi) seaward of Northstar in 2001–2004 (Greene et al. 2004; Blackwell et al. 2006). These recorders have determined the locations of large numbers of calling whales during the late summer/early autumn seasons in 2000–2004. The offshore distribution of calling bowheads has been analyzed in relation to the variable level of underwater sound emanating from Northstar itself and (especially) it's supporting vessels (Richardson et al. 2008a; McDonald et al. 2008). A confounding factor in using calling bowheads to determine changes in distribution in relation to sounds from Northstar is that any apparent displacement effect may be partly or wholly an effect of changes in calling behavior rather than an actual change in distribution. To the extent that there is offshore displacement of bowheads as a result of Northstar, it is challenging to detect and involves only a small proportion of the passing bowheads. Acoustic monitoring has continued since 2005, with increasing call detection rates during years with lower ice conditions when whales were migrating closer to shore (Richardson [ed.] 2007, 2008; Aerts and Richardson [eds.] 2008, 2009).

Gray Whale (Eschrichtius robustus)

Gray whales originally inhabited both the North Atlantic and North Pacific oceans. The Atlantic populations are believed to have become extinct by the early 1700s. A relic population survives in the Western Pacific. The eastern Pacific or California gray whale population has recovered significantly from commercial whaling. The most recent counts are based on survey data from 1997–98, 2000–01, and 2001–02, with population estimates of 29,758, 19,448 and 18,178, respectively (Rugh et al. 2005; Angliss and Allen 2009). The declining trend was believed to be related to limited food availability of a population that might have been approaching carrying capacity (Gulland et al. 2005; LeBoeuf et al. 2000; Moore et al. 2001). The eastern Pacific stock was removed from the Endangered Species List in 1994 and is not considered by NMFS to be a strategic stock.

The eastern Pacific gray whales breed and calve in the protected waters along the west coast of Baja California and the east coast of the Gulf of California from January to April (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the breeding and calving season, most of these gray whales migrate about 8,000 km (5,000 mi), generally along the west coast, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957; Rice and Wolman 1971; Braham 1984; Nerini 1984). Most summering eastern Pacific gray whales have historically congregated in the northern Bering Sea, particularly off St. Lawrence Island in the Chirikov Basin (Moore et al. 2000a), and in the southern Chukchi Sea. It is believed that changing oceanographic conditions, resulting in a decline of the benthic prey base for gray whales in the Chirikov Basin, moved feeding gray whales to areas north of the Bering Strait (Moore et al. 2003). A satellite tagging study conducted in 2005 revealed that a majority of the whales spent most of their time in the Chukchi Sea, and primarily in Russian waters. The most favored feeding area was NNW of the Bering Strait in the Chukchi Sea, where three whales spent August through mid-November. One of these whales traversed the Chukchi west to Wrangell Island, where it spent the month of August, with its route taking it to 72ºN (Mate 2006). In recent years gray whale sightings have increased at Point Barrow. Moore et al. (2000) reported that during the summer feeding season, 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. Gray whales were also observed clustered in near shore waters at Point Hope, southwest of Point Hope and between Icy Cape and Point Barrow, as well as in offshore waters northwest of Point Barrow at Hanna Shoal. In July 2005 tagged whales were observed to use the areas between Pt. Barrow and Icy Cape (Mate 2006). Acoustic data of whale calls recorded northeast of Barrow in October 2003 showed the presence of gray whale calls throughout the winter of 2003–04 (Stafford et al. 2007). It is therefore likely that at least some gray whales overwinter in the Beaufort Sea.

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). During the extensive aerial survey programs funded by MMS (BWASP surveys), only one gray whale was sighted in the central Alaskan Beaufort Sea from 1979 to 2007. Gray whales were mostly sighted around Point Barrow. Small numbers of gray whales were sighted on several occasions in the central Alaskan Beaufort, e.g., in the Harrison Bay area (Miller et al. 1999; Treacy 2000), in the Camden Bay area (Christie et al. 2009) and one single sighting near Northstar production island (Williams and Coltrane 2002). Several single gray whales have been seen farther east in the Canadian Beaufort Sea (Rugh and Fraker 1981; LGL Ltd., unpubl. data), indicating that small numbers must travel through the Alaskan Beaufort during some summers. Given the infrequent occurrence of gray whales in the Beaufort Sea east of Point Barrow, it is possible but unlikely that gray whales will be encountered near the Northstar area.

In summary, no gray whales will occur in the Northstar area during the winter and spring period, and given their rare occurrence in the central and eastern Beaufort Sea, no more than a few could be expected during the summer and fall.

Beluga Whale (Delphinapterus leucas)

The beluga whale is an arctic and subarctic species that has several populations that occur in Alaska. The Beaufort population was estimated to contain 39,258 individuals as of 1992 (Angliss and Allen 2009; Duval 1993). This estimate is based on the application of a sightability correction factor of 2× to the 1992 uncorrected census of 19,629 individuals. The Beaufort population is not considered by the NMFS to be a strategic stock.

Beluga whales of the Beaufort stock winter in the Bering Sea, migrate north and west into the eastern Beaufort Sea where they spend their summers (Angliss and Allen 2009). The majority of belugas in the Beaufort stock migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July. The westward spring migration in the Beaufort Sea occurs through ice leads far offshore, with belugas using some of the same leads used or created by bowhead whales in addition to cracks and leads farther offshore (Braham et al. 1984; Ljungblad et al. 1984; Richardson et al. 1995a). A portion of the Beaufort Sea seasonal population concentrates in the Mackenzie River estuary during July and August, but many of the belugas remain in offshore waters of the eastern Beaufort Sea and Amundsen Gulf (Davis and Evans 1982; Richard et al. 2001). Some belugas of the eastern Chukchi Sea stock are known to move into the Beaufort Sea during late summer (Suydam et al. 2001), but they also appear to occur predominantly in deep, offshore waters. A few migrating belugas were observed in nearshore waters of the central Alaskan Beaufort Sea by aerial and vessel-based surveyors during seismic monitoring programs from 1996 through 2001 (LGL and Greeneridge 1996a; Miller et al. 1997, 1998b, 1999). Results from aerial surveys conducted in 2006–2008 during seismic and shallow hazard surveys in the Harrison Bay and Camden Bay area also show that the majority of belugas occur along the shelf break, although there were quite some observations in near shore areas (Christie et al. 2009). Vessel-based surveyors observed a group of three belugas in Foggy Island Bay in July 2008 during BPs Liberty seismic survey (Aerts et al. 2008).

During late summer and autumn most belugas migrate westward far offshore near the pack ice (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1998b). The main fall migration corridor of beluga whales is believed to be ~100 km (62 mi) north of the Northstar development. Satellite-linked telemetry data show that some belugas migrate west considerably farther offshore, as far north as 76ºN to 78ºN latitude (Richard et al. 1997, 2001). However, small numbers of belugas were observed relatively close to shore (e.g., Johnson 1979). The proportion of the belugas that migrate west within 15 km (9 mi) of shore is not precisely known but is believed to be very small (Miller et al. 1997, 1998b, 1999). In recent years, small groups of westward traveling belugas have occasionally been sighted around Northstar and Endicott, mostly late July to early/mid August (John K. Dorsett, Todd Winkel pers. comm.).

No belugas are expected in or near the Northstar Project area during winter and spring, and only a few belugas are expected in nearshore waters during the summer and fall.

5. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

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

BP requests a Letter of Authorization for 2011 to authorize potential non-lethal incidental takes by harassment during its planned Northstar production, maintenance and training operations in the Beaufort Sea of Alaska in anticipation of renewed regulations for 2011–2016. The requested numbers of authorized “Level B” takes per year are discussed in Section 6 below. Although injury or mortality is unlikely during routine production activities, BP requests that the LoA authorize a small number (5) of incidental, non-intentional, injurious or lethal takes of ringed seals in the unlikely event that they might occur.

The Northstar production and maintenance activities outlined in Sections 1 and 2 have the potential to disturb or displace small numbers of marine mammals. These potential effects, as summarized in Section 7, will not exceed what is defined in the 1994 amendments to the MMPA as "Level B" harassment (behavioral disturbance). No take by serious injury or death is likely, given the nature of the activities and planned continuation of current monitoring and mitigation measures (Sections 11 and 13). No injurious or lethal takes have been documented during the intensive monitoring efforts that have occurred during the periods of Northstar construction and operations from 2000 to 2009 (Richardson [ed.] 2008; Richardson [ed.] 2006, 2007; Aerts and Richardson [eds.] 2008, 2009).

During continuing production activities at Northstar, sounds and non-acoustic stimuli will be generated by vehicle traffic, vessel operations, helicopter operations, drilling, and general operations of oil and gas facilities (e.g., generator sounds and gas flaring). The sounds generated from transportation activities will be detectable underwater and/or in air some distance away from the area of activity. The distance will depend on the nature of the sound source, ambient noise conditions, and the sensitivity of the receptor. At times, some of these sounds may be strong enough to cause localized avoidance or other disturbance reactions by small numbers of marine mammals. The type and significance of behavioral reaction is likely to depend on the species and activity of the animal at the time of reception of the stimulus, as well as the distance from the sound source and the level of the sound relative to ambient conditions. Monitoring studies conducted since 2000 near and offshore of Northstar have shown that any disturbance and displacement effects on seals and whales that do occur are subtle and localized (Moulton et al. 2003a, 2005; Blackwell et al. 2004a, 2008; Williams et al. 2006b, c; McDonald et al. 2008; Richardson et al. 2008a). These very limited effects would not have biologically significant consequences for many (if any) individual seals and whales, and would have no population consequences.

In winter, during ice road construction, and in spring, flooding on the sea ice may displace some ringed seals along the ice road corridor. No other species of marine mammal under the jurisdiction of the NMFS, except possibly a few bearded seals, is expected to be present near the planned activities during winter or spring. With the monitoring and mitigation measures that are planned (see Sections 11 and 13), and the ice conditions that prevail between Northstar and the shore, it is unlikely that any seals will be injured or killed during winter or spring. However, there is the possibility of injury or death of a seal pup in a lair, and it is requested that this possibility be covered by the regulations and associated LoA.

During the open water season, all six species of seals and whales discussed in Section 4 could theoretically be exposed to vessel or island noise, as well as other stimuli associated with the planned operations. Vessel traffic is known to cause avoidance reactions by whales at certain times (Richardson et al. 1995b). Helicopter operations, and perhaps some other summer activities may also lead to disturbance of small numbers of seals or whales (although helicopter traffic associated with Northstar is largely confined to areas from Northstar southward, where bowheads and belugas are rare). In addition to disturbance, some limited masking of whale calls or other low-frequency sounds potentially relevant to bowhead whales could occur. However, as evident from monitoring studies conducted in 2001–2004, any effects of sounds from Northstar on whales traveling near the southern (proximal) edge of the bowhead migration corridor are, at most, subtle (Blackwell et al. 2008; McDonald et al. 2008; Richardson et al. 2008a).

If an oil spill occurs, marine mammals may be unintentionally disturbed as a result of spill response measures. Response measures for the ice-covered and open-water season may be markedly different, resulting in varying risk of Level A taking (i.e., injury or death) depending on the season.

Potential takes of marine mammals by incidental ("Level B") harassment could occur for the duration of the requested Letter of Authorization, and for the duration of regulations, upon renewal. Ringed seals will be in the area throughout this period. Small numbers of bearded and spotted seals may be present during the open water seasons, and a very small number of bearded seals might also be present during winter in some years. Few whales are likely to be in the area before late August, and whales will be absent near Northstar after freeze-up, which typically occurs by late October. The numbers of marine mammals that may potentially be taken are estimated and discussed in the next section.

6. NUMBERS OF MARINE MAMMALS THAT MAY POTENTIALLY BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section 5], and the number of times such takings by each type of taking are likely to occur.

General Considerations

BP seeks authorization for potential "taking" of small numbers of marine mammals under the jurisdiction of the NMFS in the Northstar/Prudhoe Bay area. Species for which authorization is sought are ringed, spotted, and bearded seals, and bowhead, gray, and beluga whales. Potential takes are most likely to result from operational noise and vehicle, vessel, or aircraft activity. This section summarizes the numbers of marine mammals that might potentially be "taken" during operation of Northstar.

The Northstar facility is located ~5 km (3 mi) north of the closest barrier islands. Northstar is not expected to "take" more than small numbers of marine mammals, nor to have more than a negligible effect on their populations. In addition, Northstar is not expected to adversely impact subsistence hunting of marine mammal species that are important to the Alaskan Native communities of the Beaufort Sea (see Section 8). Any effects that Northstar production activities may have on pinnipeds or cetaceans is expected to be minor, short-term, and localized, with no consequences for the populations.

In the unlikely event of an oil spill, there is the possibility of serious injury or mortality to some unpredictable number of marine mammals; even then, population effects are expected to be negligible. Regarding "takes" related to oil spills NMFS has previously stated (in NMFS 1997) the following policy: "*…NMFS finds that a negligible impact determination may be appropriate if the probability of occurrence is low, but the potential effects may be significant. In this case, the probability of occurrence of impacts must be balanced with the potential severity of harm to the species or stock when determining negligible impact. In applying this balancing test, NMFS evaluates the risks involved and the potential impacts on marine mammal populations and habitat.*" This policy was clarified in NMFS (2000) where taking by an oil spill was not authorized.

Potential Numbers of "Takes"

The estimated annual numbers of potential level B "takes" for each seal and whale species during the ice-covered and open water seasons for the Northstar oil production period are presented and discussed below, and summarized in Table 4 at the end of this section (p 32). These numbers take into account that the potential for marine mammal "takes" during drilling and production related activities is reduced compared to the construction period in 2000–2001.

Although injury or mortality is unlikely during routine production activities, BP requests that the renewed regulations and associated Letters of Authorization authorize a small number (5) of incidental, non-intentional, injurious or lethal takes of ringed seals in the unlikely event that they might occur.

In requesting "take" authorization it should be noted that to date, the MMPA and its implementing regulations have not had a clear operational definition of "take by harassment". As a result, there has been much debate concerning how substantial and prolonged a change in behavior must be before it constitutes a "take by harassment". There is general recognition that minor and brief changes in behavior generally do not have biologically significant consequences for marine mammals and do not "rise to the level of taking" (NMFS 2000, p. 60409; NRC 2005). Criteria and procedures for estimating numbers of marine mammals present and potentially affected are still being developed and improved (NMFS 2005; Southall et al. 2007), and a variety of plausible estimates can be presented depending on assumptions.

Ice-Covered Season

Potential sources of disturbance to marine mammals from the Northstar project during the ice-covered period consist primarily of vehicle traffic along the ice-road, helicopter traffic, and the ongoing production and drilling operations on the island. During the ice-covered season, the only seal or whale species that occurs regularly in the area of landfast ice surrounding Northstar is the ringed seal. Spotted seals do not occur in the Beaufort Sea in the ice-covered season. Small numbers of bearded seals occur occasionally in the landfast ice in some years. Bowhead and beluga whales are absent from the Beaufort Sea in winter (or at least from the landfast ice portions of the Beaufort Sea), and in spring their eastward migrations are through offshore areas north of the landfast ice, which excludes whales from areas close to Northstar. Therefore, this section discusses only the estimated number of potential "takes" of ringed and bearded seals.

Potential displacement of ringed seals was more closely related to physical alteration of sea ice by industry than to exposure to detectable levels of low-frequency industrial sound during winter and spring (Williams et al. 2006; Richardson et al. 2008b; Moulton et al. MS). The distance within which displacement of ringed seals might occur near a development like Northstar was defined as the physically affected area plus a 100 m (328 ft) buffer zone. A study from a drill site in the Canadian Beaufort Sea provided similar results (Harwood et al. 2007). The Northstar ice road is typically flooded and thickened, and/or cleared of snow. The physically affected ice road area is about 400 m (1312 ft) wide, and this is extended with 100 m (328 ft) on either side to a total width of 600 m (1968 ft) to derive at the zone of displacement. This zone of displacement (or impact zone) around physically affected areas such as the ice road, work areas on the ice, and Northstar Island itself, is used to calculate the number of seals potentially affected (Richardson et al. 2008b).

Bearded Seal

The few bearded seals that remain in the area during winter and spring are generally found north of Northstar in association with the pack ice or the edge of the landfast ice. Bearded seals were not observed on the fast ice during the 1997 or 1998 BP/LGL surveys (G. Miller, LGL Ltd., pers. comm.), but small numbers were noted there in 1999, 2000, 2001 and 2002 (Moulton et al. 2003b). No bearded seals were seen during spring aerial surveys from Oliktok Point to Flaxman Island (Frost et al. 1997, 1998). The large size of this phocid makes it conspicuous to observers, reducing the likelihood of missing animals on the ice and hence underestimating abundance. Based on available data, and the ecology of bearded seals, it is unlikely that more than a few bearded seals (and most likely none) will be present in close proximity (<100 m [328 ft]) to the ice road and Northstar itself during the ice-covered season. The most probable number of bearded seals predicted to be potentially impacted by Northstar activities during the ice-covered season in any one year is zero. However, to allow for unexpected circumstances that might lead to "take" of bearded seals when they are present, BP requests a "Level B Harassment" authorization for a maximum of ***2 bearded seals*** per year during the ice-covered period.

Ringed Seal

Individual ringed seals in the Northstar area during the ice-covered season may be displaced a short distance away from the ice road corridors connecting the production islands to the mainland. However, traffic along the ice roads was at a maximum during the initial construction period in 2000, and there was no more than very localized displacement (Williams et al. 2002, 2006c; Moulton et al. 2003a, 2005, MS). Seal densities near Northstar during spring were not significantly affected by industrial activities in 2000–2004 (Moulton et al. 2005, MS). Seal monitoring each spring since 2005, based on visual observations from the Northstar module in the 15 May – 15 July period, have showed continued occurrence of ringed seals near Northstar facilities, though with large variations within and between years (Aerts 2009). During most of the year, all age and sex classes, except for newborn pups, could occur in the Northstar area. In late March and April, ringed seals give birth; therefore, at that time of year young pups may also be encountered. Mitigation measures (see Section 11) will be used to minimize the possibility that any seal pups in lairs will be injured or killed.

Detailed monitoring of ringed seals near Northstar was done during spring and (in some years) winter of 1997 to 2002, including three years of Northstar construction and initial oil production (2000–2002). During the 2003–04 and 2004–05 ice-covered and break-up periods, no intensive ringed seal monitoring was required and seal sightings were recorded opportunistically from Northstar Island. Since 2005 these observations from Northstar have occurred in a more systematic fashion from mid May through mid July each year, with the main objective to document seasonal and annual variations in seals present in an area of 1 km (0.62 mi) around Northstar (Rodrigues and Williams 2006; Rodrigues and Richardson 2007; Aerts and Rodrigues 2008; Aerts 2009). Estimated annual numbers of potential ringed seal "takes" are based on data collected from the intensive aerial monitoring program conducted in 1997–2002.

The numbers of seals present and potentially affected by Northstar activities were estimated using the 1997–2002 seal data according to the following steps (see Richardson et al. 2008b for more detail):

1. Defining a potential impact zone, i.e., the area within which seals might have been affected by Northstar activities. This zone consisted of a 100 m (328 ft) buffer around the ice road, work areas on the ice, and Northstar Island and covered a total area of ~4 km^2 (1.5 mi^2).
2. Defining a reference zone, i.e., the area without influence of industrial activities. This zone was defined as an area at distances of 4–10 km (2.5–6.2 mi) from the ice road, work areas on the ice, and Northstar Island. The reference zone was used to calculate the number and density of ringed seals that one would expect in the potential impact zone if there was no industrial activity. Because seal density is related to water depth, densities within the reference zone were calculated for four categories of water depth. Expected density near Northstar was a weighted average of those values (weighting by the proportions of the potential impact zone that were within each depth stratum).

3. Calculating the expected number of seals present in the potential impact zone in the absence of industrial activities (based on data from the reference zone) for each year separately. The seal density of the reference zone was multiplied by the total area of the potential impact zone (4 km^2 [1.5 mi^2]) to obtain the maximum number of seals that could be present and potentially affected.
4. Multiplying the number of seals calculated under step 3 with a correction factor of 2.84 (to correct for the "detection bias" and "availability bias"). "Detection bias" refers to the fact that aerial surveyors do not see every seal that is on the ice and potentially sightable. "Availability bias" refers to the fact that seals are not always hauled out above the ice and snow, and thus "available' to be seen by aerial surveyors. Those two correction factors are based, respectively, on Frost et al. (1988) and Kelly and Quakenbush (1990).

Results of these calculations show that 3–8 seals could be present in the potential impact zone (Table 3). The period 1997–1999 can be considered as a pre-construction period, and 2000–2002 as construction period, with the most intensive construction activities occurring in 2000 and 2001. This means that, if there was some displacement of ringed seals away from Northstar in the ice-covered season due to construction activities, we would have expected fewer seals within the potential impact zone during 2000–2002 than in 1997–1999. That was not observed, although inter-year comparisons should be treated cautiously given the possibility of year-to-year differences in environmental conditions and sightability of seals during aerial surveys. The presence of numerous seals near the Northstar facilities during late spring of 2000, 2001 and 2002 indicates that any displacement effect was localized and, if it occurred at all, involved only a small fraction of the seals that would otherwise have been present. There has been no indication that seals were affected in a meaningful way during the production years 2003–2009. However, for the purpose of the current application, covering production years 2011–2016, BP requests a "Level B Harassment" authorization for a maximum of ***8 ringed seals*** for the ice-covered period of each year to cover for any unexpected circumstances that might lead to a harassment "take".

Break-Up Season

Potential sources of disturbance to marine mammals from the Northstar project during the break-up period consist primarily of hovercraft and helicopter traffic, plus the ongoing production and drilling operations on the island. Spotted seals, bowhead whales, gray whales, and beluga whales are expected to be absent during the break-up period. Therefore, there is no potential for "taking" of those species during the break-up period. Similar to the ice-covered season, we predict that only very few bearded seals (and most likely none) could be present within the potential impact zone around the ice road and Northstar facilities. The most probable number of bearded seals predicted to be potentially impacted by Northstar activities during break-up in any one year is zero.

No more than a few ringed seals showed subtle, short term, localized responses to Northstar activities during winter or spring, and there is no reason to believe that effects would be different during the subsequent break-up period. The number of seals present within the potential impact zone during the break-up period is expected to be similar as for the ice-covered season. It is possible that some of these seals are the same individuals already counted as present during the latter stages of the ice-covered season (B. Kelly, pers. comm.). Thus, if any seals were affected during break-up in some subtle way, it is probable that some of these would be the same individuals. The requested

TABLE 3. Numbers of ringed seals expected to occur in spring 1997–2002 within the "Potential Impact Zone" in the absence of any Northstar impact, based on observed seal densities in a reference area 4–10 km (2.5–6.2 mi) away from Northstar. The potential impact zone included areas within 100 m (328 ft) of the ice road and Northstar/Seal Island (Richardson et al. 2008b).

BP/LGL Survey	Expected Density [a] (seals/km^2)	Expected Number of Seals Within Potential Impact Zone	
		Uncorrected	Corrected [b]
1997	0.54	2	6
1998	0.36	1	4
1999	0.29	1	3
2000	0.59	2	7
2001	0.56	2	6
2002	0.67	3	8
Average 1997–2002	0.50	2	6

a. This is the average uncorrected densities based on data from the zone 4–10 km away from the 2004 development zone, controlling for water depth by weighting density based on the proportions of the potential impact zone within the various depth strata.

b. This is the "uncorrected" number multiplied by the 1.22 correction factor for seals hauled out but not seen by observers (Frost et al. 1988), and by the 2.33 correction factor for seals not hauled out (Kelly and Quakenbush 1990).

Level B take authorization of 8 seals per year during the ice-covered periods of 2011–2016 (see preceding subsection) is expected to also cover potentially affected seals during break-up.

Open-Water Season

Potential sources of disturbance to marine mammals from the Northstar project during the open-water period consist primarily of hovercraft and ACS vessels used for transfers of crew and supplies, barge and tugboat traffic, helicopter traffic, and the ongoing production and drilling operations on the island. During the open-water season all six species for which take authorization is sought can be present in the Northstar area. Estimated annual numbers of potential open-water "takes" for each of these six species are summarized below.

Spotted Seal

Pupping and mating occur in the spring when spotted seals are not in the Beaufort Sea. Hence, young pups will not be encountered. All other sex and age classes may be encountered in small numbers during late summer/autumn. Spotted seals are most often found in waters adjacent to river deltas during the open-water season in the Beaufort Sea, and major haul-out concentrations are absent close to the project area. It is therefore unlikely that any spotted seals will be "taken" during Northstar operations.

Bearded Seal

During the open-water season, bearded seals are widely and sparsely distributed in areas of pack ice and open water, including some individuals in relatively shallow water as far south as

Northstar. Studies indicate that pups and other young bearded seals up to 3 years of age comprise 40–45% of the population (Nelson et al. n.d.), and that younger animals tend to occur closer to shore. Therefore, although all age and sex classes could be encountered, bearded seals encountered in the Northstar project area during the open-water period are likely to be young, non-reproductive animals. Bearded seals, if present, may be exposed to noise and other stimuli from production activities, vessel and aircraft traffic on and around the island. It is possible that some individuals may be briefly disturbed or show localized avoidance, but this will not have any biologically significant impact on the species. We assume that simple exposure to sounds or brief reactions that do not disrupt behavioral patterns in a biological significant manner (i.e., looking at a passing vessel or helicopter) do not constitute harassment (NMFS 2000, 2001). Given that and the low number of bearded seals potentially present, the estimated number of bearded seal "takes" during the open-water season is zero. However, to allow for unexpected circumstances, Level B "take" authorization is requested for ***1 bearded seal*** per year.

Ringed Seal

Because ringed seal is resident in the Beaufort Sea, they are the most abundant and most frequently encountered seal species in the Northstar area. During the open-water period all sex and age classes (except neonates) can be encountered. The estimated number of seals that potentially might be harassed by noise from Northstar production activities or from vessel and aircraft traffic are based on the following three assumptions:

1. Seals present within a 1 km distance (3.11 km^2 area) of Northstar might be potentially disturbed by construction and other activities on the island.
2. The density of seals within that area would be no more than 2x the density observed during boat-based surveys for seals within the general Prudhoe Bay area in 1996–2001 (0.19 seals/ km^2 × 2 = 0.38 seals/ km^2; Moulton and Lawson 2002).
3. Individual seals within the affected area are replaced once for each of thirteen 7-day intervals during the open-water period (mid July–mid October).

The first of these points assumes that seals in open water are not significantly affected by passing vessels (or helicopters) that they could occasionally encounter in areas >1 km (0.62 mi) from Northstar. Passing boats and helicopters might cause startle reactions and other short-term effects. However, NMFS has indicated that short-term behavioral effects having no negative consequences for biologically important activities are not relevant in estimating the number of ringed seals potentially affected (NMFS 2000, 2001).

Based on the above assumptions, an estimated 15 seals might be present and potentially affected during the open-water season (i.e., 3.11 km^2 × 0.38 seals/ km^2 × 13 weeks). This estimate is subject to wide uncertainty (in either direction) given the uncertainties in each of the three assumptions listed above. There is no specific evidence that any of the seals occurring near Northstar during the 1997–2009 open-water seasons were disturbed appreciably or otherwise affected by BP's activities (Williams et al. 2006a; Moulton et al. 2003a, 2005; Rodrigues et al. 2006; Rodrigues and Richardson 2007; Aerts and Rodrigues 2008; Aerts 2009). However, for the purpose of the current application, covering production years 2011–2016, BP requests a "Level B Harassment" authorization for a maximum of ***15 ringed seals*** per year to allow for any unexpected circumstances during the open-water season that might lead to a harassment "take".

Bowhead Whales

Bowhead whales are not resident in the region of activity. During the open-water season, relatively few westward migrating bowheads occur within 10 km (6 mi) of Northstar during most years. However, in some years (especially years with relatively low ice cover) a larger percentage of the bowhead population migrates within 10–15 km (6–9 mi) of Northstar (Treacy 1998; Blackwell et al. 2007, 2009). The bowhead whale population in the Bering-Chukchi-Beaufort area was estimated to include approximately 10,545 animals (CV=0.128) in 2001. A total of 121 calves were reported in 2001, the highest number yet recorded and indicative of a healthy and increasing population (George et al. 2004). To estimate the 2011 population size for purposes of calculating potential "takes", the annual rate of increase was assumed to be steady at 3.4% (George et al. 2004). Based on these figures, the 2011 population size could be approximately 14,625 bowhead whales.

About 43.7% of the bowheads in the Bering-Chukchi-Beaufort stock are sexually mature (Koski et al. 2004), and about 25% of the mature females are pregnant during autumn migration (Zeh et al. 1993). About 50.5% of the whales in this stock are juveniles (excluding calves), and 5.8% are calves (Koski et al. 2004). The sex ratio is close to 1:1; about half of each category would be males and half females. There are few data on the age and sex composition of bowhead whales that have been sighted near the Prudhoe Bay area. The few data from the area and more extensive data from more easterly parts of the Alaskan Beaufort Sea in late summer/autumn (Koski and Johnson 1987; Koski and Miller 2002, 2009) suggest that almost all age and sex categories of bowheads could be encountered, i.e., males, non-pregnant females, pregnant females, and calves (mostly 3–6 months old). Newly born calves (<1 month old) are not likely to be encountered during the fall (Nerini et al. 1984; Koski et al. 1993). Koski and Miller (2009) found that, at least in the more easterly part of the Beaufort Sea, subadults were disproportionately present in water <200 m (656 ft) deep, and that small subadult whales were the dominant group in shallow (<20 m [66 ft]) nearshore habitats with the size of whales increasing with increasing water depth. The potential take would be limited to "Level B Harassment" (including avoidance reactions and other behavioral changes). Most bowheads that could be encountered would be migrating, so it is unlikely that an individual bowhead would be potentially "taken by harassment" more than once.

The acoustic monitoring of the bowhead whale migration during the early years of Northstar operations is described in the final Comprehensive Report of 1999–2004 (Richardson [ed.] 2008: Chapters 7–12). The monitoring was designed to determine whether the southern edge of the distribution of calling bowhead whales tended to be farther offshore with increased levels of underwater sounds from Northstar construction and operational activities. If the southernmost calling bowheads detected by the acoustic monitoring system tended to be farther offshore when Northstar operations were noisy than when they were quieter, this was to be taken as evidence of a Northstar effect. The initial monitoring objectives did not call for estimating the numbers of bowhead whales that were affected based on the acoustic localization data, but this was added as an objective in an updated monitoring plan (LGL and Greeneridge 2000) prepared subsequent to issuance of the initial 5-yr regulations. It was anticipated that the geographic scale of any documented effect, as a function of Northstar sound level, would provide a basis for estimating the number of whales affected. As early as 2001, it was noted that–given the difficulty in separating displacement effects from effects on calling behavior–the estimates of numbers affected would concern numbers of whales whose movements and/or calling behavior were affected by Northstar activities (BPXA 2001).

In fact, the monitoring results provided evidence ($P < 0.01$ each year) of an effect on the southern part of the migration corridor during all four of the autumn migration seasons for which detailed data were acquired, i.e., 2001–04 (McDonald et al. 2008; Richardson and Mc Donald 2008). In 2001, the apparent southern edge of the distribution of calling whales was an estimated 1.53 km (0.95 mi) farther offshore when sound at industrial frequencies (28–90 Hz), measured 440 m (1,443 ft) from Northstar and averaged over 45 min preceding the call, increased from 94.3 to 103.7 dB re 1 μPa. In 2002, the apparent southern edge of the call distribution was an estimated 2.35 km (1.5 mi) farther offshore during times when transient sounds associated with boat traffic were present during the preceding 2 hr. In 2003 and 2004, the apparent southern edge was estimated to be farther offshore when tones were recorded in the 10–450 Hz band just prior to the call. In 2003, the apparent offshore shift was by an estimated 0.76 km (0.47 mi) when tones were present within the preceding 15 min. In 2004, the apparent shift was 2.24 km (1.39 mi) when tones were present within the preceding 2 hr.

Much effort has been given to the problem of estimating the numbers of bowhead whales passing Northstar whose distribution or calling behavior was affected. From the outset, this process has been treated with caution because of the possibility that effects of Northstar sound on distances offshore might be confounded by effects on bowhead calling behavior. Given the recent evidence that some aspects of calling behavior are correlated with levels of underwater sound being emitted by Northstar and its associated vessels (Blackwell et al. 2008), along with other complications (McDonald and Richardson 2008), we are not satisfied that reliable or defensible estimates of numbers affected by Northstar sound can be derived from acoustic localization data.

There is no established criterion for determining how large a displacement or change in calling behavior would need to occur before a bowhead whale should be considered "taken by harassment". NMFS has concluded that minor and brief changes in behavior generally do not "rise to the level of taking" (NMFS 2000, p. 60409). It seems improbable that the apparent displacements or changes in calling behavior evident in the southern part of the migration corridor at the higher-noise times during 2001–2004 would have negative consequences for the individual whales involved, let alone their population. There is considerable natural variation in the distances of bowheads from shore both within and between years (Treacy 2002a, b; Treacy et al. 2006). The displacement would need to be by many kilometers before the whales could be said to be following a migration route outside the normal range of routes. Offshore displacement of the migration route of a given whale by 2 or 3 km (1.2 or 1.9 mi), or even 5 km (3.1 mi), is well within the natural range of variability, and is unlikely to have negative consequences for the individual whale. An exception could occur if the whales were displaced from a localized area of particular significance to bowheads. However, bowheads did not show any special tendency to congregate or feed near Northstar prior to or after the construction of Northstar Island in 2000 (e.g., Miller et al. 1996; Treacy 2002b; Treacy et al. 2006).

For the bowhead whales in the southern part of the migration corridor that exhibit "apparent offshore displacement", it is not known how long the effect (whether actual offshore displacement or altered calling behavior) persisted. It was not within the scope of this study to address how far east or west of Northstar any effect extends. Even if this effect were prolonged, it is unlikely that a slight offshore displacement or a change in calling behavior among whales traveling through largely open water would result in long-term negative effects on biologically important activities of those individuals. Potential implications for subsistence hunting are addressed in Section 8.

In discussing how to identify effects on marine mammals that would and would not be biologically significant, NRC (2005, p. 82) suggested that, for migrating animals, biologically significant effects might be possible if either the path length or the duration of migration were increased into the upper quartile of the normal time or distance of migration. NRC (2005) further noted that, if the effect of the activity extends for only a small duration or along only a small part of the migration path, such data alone might be sufficient to determine that the effect is not biologically significant. Apparent displacements of the scale evident at Northstar (at most a few kilometers) would increase the duration or distance of migration by only a very small percentage. Also, NRC (2005) notes that fully one-fourth of the population have migration durations or distances in the upper quartile normally, so the suggested criterion is likely to be a conservative (i.e., precautionary) one. Similarly, Southall et al. (2007) emphasize the need to distinguish minor short-term changes in behavior with no lasting biological consequences from biologically significant effects on critical life functions such as growth, survival, and reproduction. Southall et al. (2007) note that "a reaction lasting less than 24 h and not recurring on subsequent days is not regarded as particularly severe unless it could directly affect survival or reproduction".

Based on these considerations, it is doubtful that the apparent Northstar effects found in the Northstar studies would have had biologically significant consequences for any individual bowheads or for the population and as such the limited observed effects would not constitute a "take" under the definition of NMFS (2000, 2001). However, for the purpose of the current application, covering production years 2011–2016, BP requests a "Level B Harassment" authorization for an annual maximum of ***15 bowhead whales*** (~0.1% of the estimated 2011 population size) to cover for any unexpected circumstances that might lead to a "take". The concern that (even small) displacements of bowheads would reduce the accessibility to subsistence hunters remains. That is a separate issue and is discussed in Section 8 of this application.

Gray Whales

Gray whales are uncommon in the Prudhoe Bay area, with no more than a few sightings in summer or early autumn in any one year, and usually no sightings (Miller et al. 1999; Treacy 2000, 2002a, b). During the extensive aerial survey programs funded by MMS (BWASP surveys), only one gray whale was sighted in the central Alaskan Beaufort Sea from 1979 to 2007. Gray whales were mostly sighted around Point Barrow. Small numbers of gray whales were sighted on several occasions in the central Alaskan Beaufort, e.g., in the Harrison Bay area (Miller et al. 1999; Treacy 2000), in the Camden Bay area (Christie et al. 2009) and one single sighting near Northstar production island (Williams and Coltrane 2002). Several single gray whales have been seen farther east in the Canadian Beaufort Sea (Rugh and Fraker 1981; LGL Ltd., unpubl. data), indicating that small numbers must travel through the Alaskan Beaufort during some summers. Gray whale calls have been recorded northeast of Barrow during the winter, indicating that some whales overwinter in the western Beaufort Sea (Stafford et al. 2007). Gray whales do not call very often when on their summer feeding grounds, and the infrequent calls are not very strong (M. Dahlheim and S. Moore, NMFS, pers. comm.). No gray whale calls were recognized in the data from the acoustic monitoring system near Northstar in 2000–08. No specific data on age or sex composition are available for the few gray whales that move east into the Beaufort Sea. All sex and age classes (including pregnant females) could be found, with the exception of calves less than six months of age.

If a few gray whales occur in the Prudhoe Bay area in 2011–16, it is unlikely that they would be affected significantly by Northstar sounds. Gray whales typically do not show avoidance of sources of continuous industrial sound unless the received broadband level exceeds ca. 120 dB re 1 μPa (Malme et al. 1984, 1988; Richardson et al. 1995b). The broadband received level ca. 450 m (1,476 ft) seaward from Northstar did not exceeded 120 dB 1 μPa in the operational period 2004–2008 (95th percentiles), except when a vessel was passing close to Northstar or the acoustic recorders (maximum levels). It is possible that one or more gray whales, if present, might have been disturbed briefly during close approach by a vessel, but no such occurrences were documented in the past. It is most likely that no gray whales will be affected in any biologically significant way by activities at Northstar during any one year. However, for the purpose of the current application, covering production years 2011–2016, BP requests a "Level B Harassment" authorization for a maximum of ***2 gray whales*** per year to allow for any unexpected circumstances that might lead to a harassment "take".

Beluga Whales

The Beaufort Sea beluga population was estimated at 39,258 individuals in 1992, with a maximum annual rate of increase of 4.0% (Hill and DeMaster 1998; Angliss and Allen 2009). Assuming a continued 4% annual growth rate, the population size could be approximately 79,650 beluga whales in 2011. However, the 4.0% estimate is a maximum value and does not include loss of animals due to subsistence harvest or natural mortality factors. Angliss and Allen (2009) consider the current annual rate of increase to be unknown. Thus, the population size in 2011 may be less than the estimated value. Additionally, the southern edge of the main fall migration corridor is approximately 100 km (62 mi) north of the Northstar region. A few migrating belugas were observed in nearshore waters of the central Alaskan Beaufort Sea by aerial and vessel-based surveyors during seismic monitoring programs from 1996 through 2001 (LGL and Greeneridge 1996a; Miller et al. 1997, 1998b, 1999). Results from aerial surveys conducted in 2006–2008 during seismic and shallow hazard surveys in the Harrison Bay and Camden Bay area, also show that the majority of belugas occur along the shelf break, although there were quite some observations in nearshore areas (Christie et al. 2009). Vessel-based surveyors observed a group of three belugas in Foggy Island Bay in July 2008 during BPs Liberty seismic survey (Aerts et al. 2008) and small groups of westward traveling belugas have occasionally been sighted around Northstar and Endicott, mostly late July to early/mid August (John K. Dorsett, Todd Winkel, BP, pers. comm.). Any potential take of these beluga whales in nearshore waters is expected to involve a very small percentage of the population, and to be limited to "Level B harassment". Belugas from the Chukchi stock occur in the Alaskan Beaufort Sea in summer, but are even less likely than the Beaufort stock to be encountered in the nearshore areas where sounds from Northstar will be audible.

The few animals involved could include all age and sex classes. Calving probably occurs in June to August in the Beaufort Sea region and calves 1–4 months of age could be encountered in summer or autumn. Most of the few belugas that could be encountered would be engaged in migration, so it is unlikely that a given beluga would be repeatedly "taken by harassment".

Based on available information on the presence and abundance of beluga whales, the following data and assumptions were used to estimate the number of belugas that could be present and potentially disturbed by Northstar activities:

- Aerial survey data from 1979 to 2000, including both MMS and LGL surveys, were used to estimate the proportion of belugas migrating through waters ≤4 km (2.5 mi) seaward of Northstar. Of the belugas traveling through the surveyed waters (generally inshore of the 100-m contour), the overall percentage observed in waters offshore of Northstar during 1997–2000 was 0.62% (8 of 1,289 belugas). The maximum percentage for any one year was for 1996, when 6 of 153 (3.9%) were ≤4 km (2.5 mi) offshore of Northstar. These figures are based on beluga sightings within the area 147°00’ to 150°30’W.
- Most beluga whales migrate far offshore; the proportion migrating through the surveyed area is unknown but was assumed by Miller et al. (1999) to be ≤20%, which is probably an overestimate.
- The disturbance radius for belugas exposed to construction and operational activities in the Beaufort Sea is not well defined (Richardson et al. 1995a), but BPXA (1999) assumed that the potential radius of disturbance was ≤1 km (0.62 mi) around the island. (There are no Northstar-specific data that could be used to obtain a better estimate than this ≤1 km [0.62 mi] figure.) Based on the assumed 1 km radius, we would expect that no more than 20% of the belugas migrating ≤4 km (2.5 mi) seaward of Northstar would approach within 1 km of the Northstar Island in the absence of any industrial activity there.
- The size of the Beaufort Sea population of beluga whales as estimated for 2011, i.e., 79,650 (see above).
- Satellite-tagging data show that some members of the Chukchi Sea stock of belugas could also occur in the Beaufort Sea generally near Northstar during late summer and autumn (Suydam et al. 2001, 2003). However, they (like the Beaufort belugas) tend to remain at or beyond the shelf break when in the Alaskan Beaufort Sea during that season. That, combined with the small size of the Chukchi stock, means that consideration of Chukchi belugas would not appreciably change the estimated numbers of belugas that might occur near Northstar.

From these values, the number of belugas that might approach within 1 km of Northstar (in the absence of industrial activities) during the open water season is ~20 belugas based on the average distribution: $0.0062 \times 0.2 \times 0.2 \times 79{,}650$. If some belugas did exhibit behavioral reactions to Northstar, it is unlikely that any of these incurred biologically significant effects in the sense of NRC (2005) or Southall et al. (2007). However, for the purpose of the current application, BP requests a “Level B Harassment” authorization for a maximum of ***10 beluga whales*** (~0.01% of the estimated population size) per year to allow for any unexpected circumstances that might lead to a harassment “take”.

Summary of Potential Take Estimates and Authorization Requested

Table 4 summarizes the results of the potential Level B harassment “take” estimates described above for the period of the requested LoA, and in anticipation of renewed regulations for 2011–2016. No allowance has been made for possible changes in population sizes of the species.

Although injury or mortality is unlikely during routine production activities, BP requests an authorization of five (5) incidental, non-intentional, injurious or lethal takes of ringed seals in the unlikely event that they might occur.

In requesting Level B "take" authorization it should be noted that to date, the MMPA and its implementing regulations have not had a clear operational definition of "take by harassment". As a result, there has been much debate concerning how substantial and prolonged a change in behavior must be before it constitutes a "take by harassment". There is general recognition that minor and brief changes in behavior generally do not have biologically significant consequences for marine mammals and do not "rise to the level of taking" (NMFS 2000, p. 60409; NRC 2005). Criteria and procedures for estimating numbers of marine mammals present and potentially affected are still being developed and improved (NMFS 2005; Southall et al. 2007), and a variety of plausible estimates can be presented depending on assumptions. Based on the available information gathered over the past decade by the various Northstar related studies, it seems that most potential impacts occurred in the form of short-term behavioral effects without any negative consequences for biologically important activities, such as feeding, breeding, migrating, nursing, and sheltering. Anticipated changes in the behavior of some individuals are generally well within the range of variability that occurs under natural conditions. It is therefore debatable if Northstar activities have had any marine mammal Level B harassment "takes" as interpreted by NMFS (NMFS 2001, p9293). However, for the period of the current application and foreseen renewal of the regulations for 2011–2016, BP requests "take" authorizations as a precautionary measure to allow for unexpected circumstances that may lead to marine mammal "takes" in the unlikely event that they occur.

TABLE 4. Estimated annual potential Level B "takes" for marine mammals during the ice-covered and open water seasons during the Northstar operation period with requested harassment authorization for each species in parentheses (see text for details).

Season	Ringed Seal	Spotted Seal	Bearded Seal	Bowhead Whale	Gray Whale	Beluga Whale
Ice-covered and break-up	0 (8)	0	0 (2)	0	0	0
Open Water	0 (15)	0	0(1)	0 (15)	0 (2)	0 (10)

7. ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

The likely or possible impacts of the planned offshore oil developments at Northstar on marine mammals involve both non-acoustic and acoustic effects. Potential non-acoustic effects could result from the physical presence of personnel, structures and equipment, construction or maintenance activities, and the occurrence of oil spills. There is a small chance that a seal pup might be injured or killed by on-ice construction or transportation activities. A major oil spill is unlikely and, if it occurred, its effects are difficult to predict. A major oil spill might cause serious injury or mortality to small numbers of marine mammals. Petroleum development and associated activities in marine waters introduce sound into the environment, produced by island construction, maintenance, and drilling as well as vehicles operating on the ice, vessels, aircraft, generators, production machinery, gas flaring, and camp operations. The acoustic sense of marine mammals probably constitutes their most important distance receptor system, and oil industry sounds could (at least in theory) have several types of effects on marine mammals. These effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995b):

1. The noise may be too weak to be heard at the location of the animal, i.e. lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both.
2. The noise may be audible but not strong enough to elicit any overt behavioral response. This has been demonstrated upon exposure of bowhead whales to low levels of seismic, drilling, dredge, or icebreaker sounds (Richardson et al. 1986, 1990, 1995a, 1995b).
3. The noise may elicit reactions of variable conspicuousness and variable relevance to the well-being of the animal. These can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions.
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist or exhibit increasing responsiveness (sensitization). The latter are most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat.
5. Any anthropogenic noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies including calls from conspecifics, echolocation sounds of odontocetes (used for navigation and other functions), and environmental sounds such as ice or surf noise. Intermittent sounds, such as those from impact hammers, will cause strong masking for only a fraction of the time when compared to continuous sounds.
6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity. Effects of strong sounds of varying durations on hearing thresholds of pinnipeds and odontocete cetaceans have received considerable study in recent years (e.g., Kastak et al. 1999; Schlundt et al. 2000, 2006; Finneran et al. 2002, 2003, 2005, 2007; Kastak et al. 2005; Nachtigall et al. 2003, 2004; Southall et al. 2007; Gedamke et al. 2008; Lucke et al. 2009). Received sound levels must far exceed the animal's hearing threshold for there to be any temporary threshold shift (TTS). The TTS threshold depends on duration of exposure; the sound level necessary to cause TTS is higher for short sound exposures than for long sound exposures. Received levels must be even higher to risk permanent hearing impairment, especially for non-impulse noise.

In the sections below a detailed overview is provided of the type of sounds produced by Northstar, the sound characteristics, propagation and also ambient sounds in the area. This is followed by potential effects of sounds and oil spills on pinnipeds and cetaceans that occur in the Northstar/Prudhoe Bay area.

Northstar Sound Characteristics

Construction Sounds

Sounds associated with construction of Seal Island in 1982 were studied and described by Greene (1983a) and summarized in the previous petition for regulations submitted by BP (BPXA 1999). Underwater and in-air sounds and iceborne vibrations of various activities associated with the final construction phases of Northstar were recorded in the winter of 2000–2002 (Greene et al. 2008). The main purpose of these measurements was to characterize the properties of island construction sounds and to use this information in assessing their possible impacts on wildlife. Activities recorded included ice augering, pumping sea water to flood the ice and build an ice road, a bulldozer plowing snow, a Ditchwitch cutting ice, trucks hauling gravel over an ice road to the island site, a backhoe trenching the sea bottom for a pipeline, and both vibratory and impact sheet pile driving. Table 5 presents a summary of the levels of construction sounds and vibrations measured around the Northstar prospect. For each sound source, the distance is presented at which the level in the strongest one-third octave band equals the median background level in the corresponding one-third octave band. The distances were calculated using the slope of the logarithmic regression obtained from broadband levels of each respective sound source.

Ice road construction was an activity that was difficult to separate into its individual components, as one or more bulldozers and several rolligons were normally working concurrently. Of the construction activities reported, those related to ice road construction (bulldozers, augering and pumping) produced the least amount of sound, in all three media. The distance to median background for the strongest one-third octave bands for bulldozers, augering, and pumping was <2 km (1.24 mi) for underwater sounds, <1 km (0.62 mi) for in-air sounds, and <4 km (2.49 mi) for iceborne vibrations (Table 5). Vibratory sheet pile driving produced the strongest sounds, with broadband underwater levels of 143 dB re 1µPa at 100 m (328 ft). Most of the sound energy was in a tone close to 25 Hz. Distances to background levels of underwater sounds (~3 km [~1.86 mi]) were somewhat smaller than expected. Shepard et al. (2001) recorded sound near Northstar in April 2001 during construction and reported that the noisiest conditions occurred during sheet pile installation with a vibrating hammer. Our estimates were 8–10 dB higher at 150 m (492 ft) and 5–8 dB lower at 2 km (1.24 mi) than the measurements by Shepard et al. (2001).

Operational Sounds

Drilling operations started in December 2000 and were the first sound-producing activities associated with the operational phase at Northstar. The four principal operations that occur during drilling are drilling per se, tripping (extracting and lowering the drillstring), cleaning, and well-logging (lowering instruments on a cable down the hole). Drilling activities can be categorized as non-continuous sounds, i.e., they contribute to Northstar sounds intermittently. Other non-continuous sounds are those from heavy equipment operation for snow removal, berm maintenance, and island surface maintenance. Sounds from occasional movements of a "pig" through the pipeline may also propagate into the marine or nearshore environment.

TABLE 5. Summary of levels of sounds and vibrations from seven principal sound sources, for three parameters: (1) Broadband levels at 100 m; (2) The center frequency of the strongest one-third octave band for each sound source, as determined from the closest recording (usually 100 m or less); (3) The distance from the source at which the level in the strongest one-third octave band was equal to the median level of background sound in the same one-third octave band. Source: Table IV in Greene et al. 2008.

	Hydrophone (10–10,000 Hz)			Microphone (10–10,000 Hz)			Geophone (10–500 Hz)		
Sound Source	Broadband @ 100 m (dB re 1 μPa)	Center of strongest 1/3 OB (Hz)	Distance to 0 dB S/N in 1/3 OB (m)	Broadband @ 100 m (dB re 20 μPa)	Center of strongest 1/3 OB (Hz)	Distance to 0 dB S/N in 1/3 OB (m)	Broadband @ 100 m (dB re 1 pm/s)	Center of strongest 1/3 OB (Hz)	Distance to 0 dB S/N in 1/3 OB (m)
Bulldozer	114.2	63	1163	64.7	10	73	129.8	10	3613
Augering	103.3	250	1702	67.9	20	389	104.3	10	338
Pumping	108.1	800	1832	72.0	12.5	168	111.1	12.5	582
					50	631			
Ditchwitch	122.0	20	7292	76.3	12.5	612	121.9	16	9963
Trucks	123.2	160	3256	74.8	80	828	126.2	10	3310
Backhoe	124.8	10	3275	NA	NA	NA	145.7	12.5	2500
Vibr.sheet	142.9	25	2930	81.0	50	2,822	146.1	25	1207

Sounds from generators, process operations (e.g., flaring, seawater treatment, oil processing, gas injection), and island lighting are more continuous and contribute to the operational sounds from Northstar. Drilling and operational sounds underwater, in air, and of ice-borne vibrations were obtained at Northstar Island and summarized below (Blackwell et al. 2004b; Blackwell and Greene 2006).

Drilling

During the ice covered seasons from 1999 to 2002, drilling sounds were measured and readily identifiable underwater, with a marked increase in received levels at 60–250 Hz and 700–1400 Hz relative to no-drilling times. The higher-frequency peak, which was distinct enough to be used as a drilling "signature", was clearly detectible 5 km (3.1 mi) from the drill rig, but had fallen to background values by 9.4 km (5.8 mi). Distances at which background levels were reached were defined as the distance beyond which broadband levels remained constant with increasing distance from the source. Beyond that distance, measured levels were dominated by natural (or at least non-Northstar) sound or vibration. On a windy day, recorded levels would diminish to background levels closer to Northstar than on a calm day. This method defines the distance at which broadband levels from the measured sound source equal background levels, but certain tones from the sound source may still be audible to greater distances. The lower-frequency peak straddled the range of frequencies involved in power generation on the island, which have been common in recordings since the beginning of construction at Northstar. It is reasonable that, during drilling, an increase in the level of sound and vibration would occur from any equipment that is required to work harder, such as the machinery for power generation or drilling. Sound pressure density levels of island production with and without drilling activities measured at ~500 m (1,640 ft) from Northstar are similar, with most of the sound energy below 100 Hz. The broadband (10–10,000 Hz) level was ~2 dB higher during drilling than without, but relatively low in both cases (99 vs. 97 dB re 1μPa; Blackwell and Greene 2006).

In air, drilling sounds were not distinguishable from overall island sounds based on spectral characteristics or on broadband levels (Blackwell et al. 2004b). A similar result was found for recordings from geophones: broadband levels of iceborne vibrations with or without drilling were indistinguishable (Blackwell et al. 2004b). Thus, airborne sounds and iceborne vibrations were not strong enough during drilling to have much influence on overall Northstar sound, in contrast to underwater sounds, which were higher during drilling (Blackwell and Greene 2006).

Richardson et al. (1995b) summarized then-available data by stating that sounds associated with drilling activities vary considerably, depending on the nature of the ongoing operations and the type of drilling platform (island, ship, etc.). Underwater sound associated with drilling from natural barrier islands or an artificial island built mainly of gravel is generally weak and is inaudible at ranges beyond several kilometers. The results from the Northstar monitoring work in more recent years are generally consistent with the earlier evidence.

Other Operational Sounds

Ice-covered season – Both with and without drilling, underwater broadband levels recorded north of the island during the ice-covered season were similar with and without production (Blackwell et al. 2004b). Although the broadband underwater levels did not seem to be affected appreciably by production activities, a peak at 125–160 Hz could be related to production. This peak was no longer detectable 5 km (3.1 mi) from the island, either with or without simultaneous drilling (Blackwell et al. 2004b). Thus, oil production at Northstar during the ice-covered season did not appear to cause any substantial increase in overall levels of underwater sound relative to the levels with the island present but without active oil production. However, production probably caused a change in frequency composition. This is to be expected for two reasons (1) “No production” recordings were obtained while diesel generators provided the island’s power source (2001), whereas “production” recordings were obtained after the island had shifted to gas turbines (2002). (2) Production implies the use of compressors, which were a new sound source. The transition did not seem to result in detectable changes in broadband levels of island sounds in the water or in the ice, although the in-air levels might have increased by a few dB (Blackwell et al. 2004b).

Open-water season – Underwater and in-air production sounds from Northstar Island were recorded and characterized during nine open-water seasons from 2000 to 2008 (Blackwell and Greene 2006; Blackwell et al. 2009). Data on underwater sounds were obtained during the fall whale migration (late August–early October) via

1. boat-based recordings 0.3–37 km (0.2–23 mi) from the island (2000–2003),
2. a cabled hydrophone (2000–2003) and autonomous directional seafloor acoustic recorders (DASARs; 2003–2008) deployed ~450 m (0.3 mi) north of Northstar, and
3. DASARs deployed within a range of 6.5–38.5 km (4–24 mi) north of Northstar.

Island activity sounds recorded during 2000–2003 included construction of the island, installation of facilities, a large sealift transported by several barges and associated Ocean, River, and Point Class tugs, conversion of power generation from diesel-powered generators to Solar gas turbines, drilling, production, and reconstruction of an underwater berm for protection against ice. From 2003–2008 island activities mainly consisted of production related sounds and maintenance activities of the protection barrier. During the open water season, vessels were the main contributors to the underwater sound field at Northstar (Blackwell and Greene 2006). Vessel noise is discussed in the next subsection.

During both the construction phase in 2000 and the drilling and production phase, island sounds underwater reached background values at distances of 2–4 km (1.2–2.5 mi; Blackwell and Greene 2006). For each year, percentile levels of broadband sound (maximum, 95th, 50th, and 5th percentile, and minimum) were computed over the entire field season. The range of broadband levels recorded over 2001–2008 for all percentiles is 80.8–141 dB re 1 µPa. The maximum levels are mainly determined by the presence of vessels and can be governed by one specific event. The 95th percentile represents the sound level generated at Northstar during 95% of the time. From 2004 to 2008 these levels ranged from 110 to 119.5 dB re 1 µPa at ~450 m (0.3 mi) from Northstar. Much of the variation in received levels was dependent on sea state, which is correlated with wind speed. The lowest sound levels in the time series are indicative of the quietest times in the water near the island, and generally correspond to times with low wind speeds. Conversely, times of high wind speed usually correspond to increased broadband levels in the DASAR record (Blackwell et al. 2009). The short-term variability in broadband sound levels in 2008 was higher than in previous years. This was attributed to the presence of a new type of impulsive sound on the records of the near-island DASARs, referred to as “pops”. Bearings pointed to the northeastern part of Northstar Island, but to date the source is not known. Pops were broadband in nature, of short duration (~0.05 s), and with received sound pressure levels at the near-island DASAR ranging from 107 to 144 dB re 1 µPa. This sound was also present on the 2009 records. Presently, the source of this sound is not known.

Percentile distributions of one-third octave band levels and spectral density levels were calculated to characterize the frequency composition of sounds near Northstar. Overall, the spectra for Northstar are very similar between years. For example, peaks were present at 30 Hz and 60 Hz. These peaks have been present every year of monitoring and are associated with generation of 60 Hz power. There was also a peak at 87 Hz, which has been present since 2003 and which we attribute to the LP compressor of compressor Module L1 (Spence 2006).

Airborne sounds were recorded concurrently with the boat-based recordings in 2000–2003 (Blackwell and Greene 2006). The strongest broadband airborne sounds were recorded ~300 m (1,000 ft) from Northstar Island in the presence of vessels, and reached 61–62 dBA re 20µPa. These values are expressed as A-weighted levels on the scale normally used for in-air sounds. In-air sounds generally reached a minimum 1–4 km (0.6–2.5 mi) from the island, with or without the presence of boats.

Transportation Sounds

Sounds related to winter construction activities of Seal Island in 1982 were reported by Greene (1983a) and information on this topic is included in the previous petition submitted by BP (BPXA 1999). During the construction and operation of Northstar Island from 2000 to 2002, underwater sound from vehicles constructing and traveling along the ice road diminished to background levels at distances ranging from 4.6 to 9.5 km (2.9 to 5.9 mi). In-air sound levels of these activities reached background levels at distances ranging from 100–600 m (328–1,969 ft; Table 5).

Sounds and vibrations from vehicles traveling along an ice-road constructed across the grounded sea ice and along Flaxman Island (a barrier Island east of Prudhoe Bay) were recorded in air and within artificially constructed polar bear dens in March 2002 (MacGillivray et al. 2003). Underwater recordings were not made. Sounds from vehicles traveling along the ice-road were attenuated strongly by the snow cover of the artificial dens; broadband vehicle traffic noise was reduced by 30–42 dB. Sound also diminished with increasing distance from the station. Most vehicle noise was indistinguishable from background (ambient) noise at 500 m (1,640 ft), although some vehicles were detectable to more than 2,000 m (1.2 mi). Ground vibrations (measured as velocity) were undetectable for most vehicles at a distance of 100 m (328 ft), but were detectable to 200 m (656 ft) for a Hägglunds tracked vehicle (MacGillivray et al. 2003).

Helicopters were used for personnel and equipment transport to and from Northstar during the unstable ice periods in spring and fall. Helicopters flying to and from Northstar generally maintain straight-line routes at altitudes of 300 m (1,000 ft) ASL, thereby limiting the received levels at and below the surface. Helicopter sounds contain numerous prominent tones at frequencies up to about 350 Hz, with the strongest measured tone at 20–22 Hz. Received peak sound levels of a Bell 212 passing over a hydrophone at an altitude of ~300 m (1,000 ft), which is the minimum allowed altitude for the Northstar helicopter under normal operating conditions, varied between 106 and 111 dB re 1µPa at 9 and 18 m (30 and 59 ft) water depth (Greene 1982, 1985). Harmonics of the main rotor and tail rotor usually dominate the sound from helicopters; however, many additional tones associated with the engines and other rotating parts are sometimes present (Patenaude et al. 2002).

Under calm conditions, rotor and engine sounds are coupled into the water within a 26º cone beneath the aircraft. Some of the sound transmits beyond the immediate area, and some sound enters the water outside the 26º cone when the sea surface is rough. However, scattering and absorption limit lateral propagation in shallow water. For these reasons, helicopter and fixed-wing aircraft flyovers are not heard underwater for very long, especially when compared to how long they are heard in air as the aircraft approaches, passes and moves away from an observer. Tones from helicopter traffic were detected underwater at a horizontal distance ~450 m (1,476 ft) from Northstar, but only during helicopter departures from Northstar (Blackwell et al. 2009). The duration of the detectable tones, when present, was short (20–50 s) and the received sound levels were weak, sometimes barely detectable. The lack of detectable tones during 65% of the investigated helicopter departures and arrivals supports the importance of the aircraft's path in determining whether tones will be detectable underwater. Helicopter tones were not detectable underwater at the most southern DASAR location ~6.5 km (4 mi) north of Northstar.

Vessels − principally the crew boat, tugs, and self-propelled barges − were the main contributors to the underwater sound field at Northstar during the construction and production periods (Blackwell and Greene 2006). Vessel sounds are a concern due to the potential disturbance to marine mammals (Richardson et al. 1995b). Characteristics of underwater sounds from boats and vessels have been reported extensively, including specific measurements near Northstar (Greene and Moore 1995; Blackwell and Greene 2006). Broadband source levels for most small ships (lengths about 55–85 m [180–279 ft]) are ~160–180 dB re 1 µPa. Both the crew boat and the tugs produced substantial broadband sound in the 50–2000 Hz range, which could at least in part be accounted for by propeller cavitation (Ross 1976). Several tones were also apparent in the vessel sounds, including one at 17.5 Hz, corresponding to the propeller blade rate of Ocean Class tugs. Two tones were identified for the crew boat: one at 52–55 Hz, which corresponds to the blade rate, and one at 22–26 Hz, which correspond to a harmonic of the shaft rate.

The presence of boats considerably expanded the distances to which Northstar-related sound was detectable. On days with average levels of background sounds, sound from tug boats were detectable on offshore DASAR recordings to at least 21.5 km (13.4 mi) from Northstar (Blackwell et al. 2009). On other occasions, vessel sounds from crew boat, tugs, and self-propelled barges were often detectable underwater as much as ~30 km (18.6 mi) offshore (Blackwell and Greene 2006). BP therefore looked into options to reduce vessel use. During the summer of 2003 a small, diesel-powered hovercraft (Griffon 2000TD) was tested to transport crew and supplies between the mainland and Northstar Island. Acoustic measurements showed that the hovercraft was considerably quieter underwater than similar-sized conventional vessels (Blackwell and Greene 2005). Received underwater broadband sound levels at 6.5 m (21.3 ft) from the hovercraft reached 133 and 131 dB re 1 µPa for hydrophone depths 1 m and 7 m (3 ft and 23 ft), respectively. In-air unweighted and A-weighted broadband (10–10,000 Hz) levels reached 104 and 97 dB re 20 µPa, respectively. Use of the hovercraft for Northstar transport resulted in a decreased number of periods of elevated vessel noise ("vessel spikes") in the acoustic records of the near-island DASARs (Blackwell et al. 2009).

Sound Propagation

Underwater Propagation

Overall sound levels at Northstar during the open-water season were highly influenced by the presence or absence of vessels (Blackwell and Greene 2006). A simple sound propagation model was fitted to data recorded at various distances from Northstar on several dates in 2000 and 2002. With vessels, received levels continued to decrease until the farthest distance sampled (~30 km [18.6 mi]), indicating that background levels were not reached at that distance. Spreading loss terms were 18.3 and 14.4 dB / tenfold change in distance on two dates in 2000 (Blackwell and Greene 2006) and 22–24.8 dB / tenfold change in distance for six vessel spikes recorded on two dates in 2008 (Blackwell et al. 2009). Variations in spreading loss are in part related to the background noise conditions during the measurements, with higher spreading loss terms at times when background levels are higher.

Propagation of underwater sounds at Northstar during the ice-covered season was studied in 2000–2002. Most analyses were on data from 2002, during production, rather than during construction activities (Blackwell et al. 2004b). Northstar sounds during the ice-covered season reached background levels underwater by 9.4 km (5.8 mi) with drilling and 3–4 km (1.9–2.5 mi) without drilling. At times with higher background noise (e.g., windy periods) Northstar sounds disappeared below ambient levels at closer distances, as expected. Spreading loss terms were about 22.0 dB / tenfold change in distance.

In winter, acoustic transmission loss near Liberty has been measured based on received levels of drilling sounds under the ice at different distances from Tern Island (Greene 1997b). At ranges between 0.2 and 2+ km (0.1 and 1.2+ mi) and at frequencies below 150 Hz, transmission loss was rapid: about 35 dB / tenfold change in distance plus an addition linear absorption term of 2–9 dB per kilometer. This rapid attenuation is as expected for waters only 6 to 7 m deep (19.7 to 23 ft; approx. half the depth at Northstar). Attenuation rates could not be measured at higher frequencies, but were also expected to be high (Greene 1997b).

In-Air Propagation

Airborne sounds from Northstar Island were recorded on several dates during the open-water seasons of 2001–2003. The strongest broadband airborne sounds were recorded ~300 m (~1,000 ft) from Northstar Island in the presence of vessels, and reached 61–62 dBA re 20 µPa. In-air sounds generally reached a minimum 1–4 km (0.6–2.5 mi) from the island, with or without the presence of boats. Beyond those distances, in-air sounds were principally affected by wind. A tone at 81 Hz that diminished with increasing distance from Northstar was detected on nearly every in-air recording, but its source is not known.

During the ice-covered season the strongest broadband airborne sounds were 74 and 80 dBA re 20 μPa during production without and with drilling, respectively, as recorded 470 m and 220 m (1,541 ft and 722 ft) from the island, respectively. Airborne sounds diminished to background levels at 5 and 9.4 km (3.1 and 5.8 mi) without and with drilling, respectively. Spreading loss terms were 19.6 and 20.5 dB / tenfold change in distance without, and with drilling.

To our knowledge, no other studies of in-air sound propagation from industrial sources along the Alaskan Beaufort Sea coast have been conducted. However, some relevant general principles are described in the original petition (BPXA 1999; see also section 4.6 in Richardson et al. 1995b).

Ambient Noise

Ambient noise is the background sound of physical and biological origin, excluding sounds from specific identifiable sources. Marine mammals are unable to detect industrial noise and sounds from other mammals if these signals are much weaker than the ambient noise levels at corresponding frequencies. Natural ambient noise can mask weak sound signals of either natural or human origin. Marine mammals must be adapted to the natural ambient noise levels that prevail in their environment. Ambient levels are thus important for understanding the natural environmental constraints on an animal's ability to detect mammal calls, anthropogenic sounds, and other relevant sounds.

Ambient noise levels in air over the Beaufort Sea are expected to be dominated by wind noise during the ice-covered and broken ice season, and by noise from wind and breaking waves during the open water season. However, there has been no specific effort to measure in-air ambient noise in this region.

Primary sources of underwater ambient noise near the Northstar area are wind and waves, ice, and sounds of biological origin (e.g., bearded seals, bowhead whales, and to a much lesser extent ringed seals and belugas). Of these sources, wind is the primary influence on ambient noise level in the absence of human activities, directly and through its effects on ice and waves. In spring, bearded seal calls are also a prominent contributor to ambient noise at many times, and bowhead calls are common in late summer and autumn. During winter and spring, when the Northstar area is covered by landfast ice, natural ambient noise levels below the ice are low. Levels in these conditions are often below those typical of calm conditions in open water (Greene and Buck 1964; Milne and Ganton 1964).

Ambient noise in waters near Prudhoe Bay during the open-water season has been measured systematically during several studies. For example, measurements with a bottom hydrophone 2.4 km (1.5 mi) from Seal Island spanned nine days (21–29 September 1984) when a drill rig on the island was not operating (Davis et al. 1985). Measurements with a hydrophone 0.46 km (0.29 mi) from Sandpiper Island spanned 14 days (28 September–11 October 1985) while a rig on that island was inactive (Johnson et al. 1986). The results of analyses of these data are summarized in LGL and Greeneridge (1996a) and in Table 6.

The median ambient noise levels measured at the two islands are the same. The median spectra for these measurements agree closely with the spectrum for Knudsen's Sea State One (Knudsen et al. 1948), which corresponds to wind speeds from 4–6 knots (Beaufort wind force 2).

The environment during the measurement periods in 1984 and 1985 was reasonably quiet. However, the natural ambient noise level was quite variable as is illustrated by comparing the 5th and 95th percentile levels.

A large quantity of additional ambient noise data were collected in the Prudhoe Bay region during the open water seasons of 1995–98. Sonobuoy data from August 1995 showed 5th, 50th and 95th percentile ambient levels in the 20–1000 Hz band of 77, 95, and 104 dB re 1 μPa (LGL and Greeneridge 1996a). The median was similar to the 1984–85 median, but the 5th and 95th percentiles were lower in 1995. At low frequencies (20–100 Hz), median levels of natural ambient noise measured in these shallow waters were similar to the levels expected in deep waters of the North Atlantic and North Pacific oceans.

Levels of natural ambient noise during the open water seasons at Northstar are expected to be within the same general range of variability described above. Marine mammals inhabiting this region are likely accustomed to this range of natural sound levels. In the absence of boats, underwater sounds from Northstar Island (during construction, drilling, and production) were at background values at distances beyond 2–4 km (1.2–2.5 mi) away from Northstar in low to moderate wind conditions (Blackwell and Greene 2006). However, when vessels were present at Northstar Island, received levels within at least 20–30 km (12.4–18.6 mi) of the island were above background levels (Blackwell and Greene 2006).

TABLE 6. Percentile broadband (20–1000 Hz) ambient noise levels in dB re 1 μPa in the Beaufort Sea of Alaska.

Percentiles	Seal Island ’84	Sandpiper Island ’85	Prudhoe Bay region ‘95
5%	84	87	77
50%	94	94	95
95%	111	113	104

Potential Impacts on Pinnipeds

Possible impacts on pinnipeds from activities at and near Northstar involve both acoustic and non-acoustic effects. This section describes the potential impacts from sounds generated by Northstar and from oil spills on pinniped species.

Effects of Sound on Pinnipeds

To determine the effects of man-made sounds on marine mammal species it is important to understand the characteristics of the sound sources, sound propagation, and the ambient or natural sound levels. For Northstar related activities these aspects of the sounds are described above. In addition it is relevant to understand the hearing abilities and sound production of the receiver, in this case pinnipeds. The possible categories of noise effects on marine mammals in general were summarized earlier in this section. The categories relevant here are behavioral disturbance and associated habituation effects, masking, and possible effects on hearing sensitivity.

Pinniped Hearing Abilities and Sound Production

The hearing abilities of pinnipeds (and other animals) are functions of the following (Richardson et al. 1995b):

1. Absolute hearing threshold, i.e., the level of sound barely audible in the absence of ambient noise.
2. Critical ratio, i.e., the signal-to-noise ratio required to detect a tonal sound in the presence of background noise.
3. The ability to localize sound direction at the frequencies under consideration.
4. The ability to discriminate among sounds of different frequencies and intensities.

Underwater audiograms have been obtained using behavioral methods for four species of phocinid seals: the ringed, harbor (*Phoca vitulina*), harp (*Pagophilus groenlandicus*), and northern elephant (*Mirounga angustirostris*) seals (reviewed in Richardson et al. 1995b; Kastak and Schusterman 1998). Below 30–50 kHz, the hearing threshold of phocinids is essentially flat down to at least 1 kHz, and ranges between 60 and 85 dB re 1 μPa. There are few published data on in-water hearing sensitivity of phocid seals below 1 kHz. However, measurements for one harbor seal indicated that, below 1 kHz, its thresholds deteriorated gradually to 96 dB re 1 μPa at 100 Hz (Kastak and Schusterman 1998). More recent data suggest that harbor seal hearing at low frequencies may be more sensitive than that, and that earlier data were confounded by excessive background noise (Kastelein et al. 2009a, 2009b). If so, harbor seals have considerably better underwater hearing sensitivity at low frequencies than do small odontocetes like belugas (for which the threshold at 100 Hz is about 125 dB). In air, the upper frequency limit of phocid seals is lower (about 20 kHz).

The acoustic discrimination and localization abilities of pinnipeds appear to be less sensitive than those of odontocetes. Critical ratios tend to increase with increasing frequency and are probably similar to those of other mammals. Pinnipeds occurring in the Northstar area are all members of the same functional hearing group: pinnipeds in water as recognized by Miller et al. (2005) and Southall et al. (2007).

Pinniped call characteristics are relevant when assessing potential masking effects of man-made sounds. In addition, for those species whose hearing has not been tested, call characteristics are useful in assessing the frequency range within which hearing is likely to be most sensitive. The three species of seals present in the study area, all of which are in the phocid seal group, are all most vocal during the spring mating season and much less so during late summer. In each species, the calls are at frequencies from several hundred to several thousand hertz—above the frequency range of the dominant noise components from most of the proposed oil production and operational activities. Information on the calls of ringed, spotted, and bearded seals can be found in BPXA (1999).

Possible Effects on Hearing Sensitivity

Temporary or permanent hearing impairment is a possibility (although rarely demonstrated) when marine mammals are exposed to very strong sounds. This impairment is known as a Temporary Threshold Shift (TTS) when the condition is short-term, and Permanent Threshold Shift (PTS) when the condition is chronic. There is no direct evidence that free-ranging marine mammals suffer TTS or PTS. However, it is now possible to predict, to a first approximation, situations where

TTS would and would not occur in free-ranging pinnipeds based on systematic TTS studies on captive pinnipeds (Bowles et al. 1999; Kastak et al. 1999, 2005, 2007; Schusterman et al. 2000; Finneran et al. 2003; Southall et al. 2007). Kastak et al. (1999) reported TTS of approximately 4–5 dB in three species of pinnipeds (harbor seal, Californian sea lion, and northern elephant seal) after underwater exposure for ~20 minutes to noise with frequencies ranging from 100 Hz to 2,000 Hz at received levels 60–75 dB above hearing threshold. This approach allowed similar effective exposure conditions to each of the subjects, but resulted in variable absolute exposure values depending on subject and test frequency. Recovery to near baseline levels was reported within 24 hours of noise exposure (Kastak et al. 1999). Kastak et al. (2005) followed up on their previous work using higher sensitive levels and longer exposure times (up to 50-minutes) and corroborated their previous findings. The sound exposures necessary to cause slight threshold shifts were also determined for two California sea lions (*Zalophus californianus*) and a juvenile elephant seal (*Mirounga angustirostris*) exposed to underwater sound for similar duration. The sound level necessary to cause TTS in pinnipeds depends on exposure duration, as in other mammals; with longer exposure, the level necessary to elicit TTS is reduced (Schusterman et al. 2000; Kastak et al. 2005, 2007). For very short exposures (e.g., to a single sound pulse), the level necessary to cause TTS is very high (Finneran et al. 2003). For pinnipeds exposed to in-air sounds, auditory fatigue has been measured in response to single pulses and to nonpulse noise (see Southall et al. 2007), although high exposure levels were required to induce TTS-onset (SEL: 129 dB re: [20 µPa]2-s; Bowles et al. unpub. data).

For pulsed underwater sounds, NMFS has taken the position that pinnipeds should not be exposed to received levels exceeding 190 dB re 1 µPa (NMFS 1995). That criterion, on an "rms over duration of pulse basis", was established before there were any data on levels of sounds that do and do not elicit TTS in pinnipeds. It also did not consider the effects of sound duration on TTS and PTS thresholds. There has not been any specific "do not exceed" criterion for pinnipeds exposed to prolonged or continuous sounds. However, it is accepted that any such criterion should be lower than that for pulsed sounds given the effects of exposure duration on the level at which TTS (and presumably PTS) becomes evident (Richardson et al. 1995b; Kastak et al. 2005, 2007). Southall et al. (2007) proposed new noise impact criteria based on a wide-ranging review of existing data, summarized for pinnipeds in Table 7.

TABLE 7. Proposed injury criteria for pinnipeds exposed to discrete noise events (either single pulses, multiple pulses, or non-pulses within a 24-hr period). See Southall et al. 2007 for more details. For each category of sound, they concluded that there is risk of auditory damage if the exposure exceeds either the specified sound pressure level (flat weighted) or the specified sound exposure level (M-weighted).

	Single pulses	**Multiple pulses**	**Non pulses**
Pinnipeds (in water)			
Sound pressure level	218 dB re 1 µPa (peak) (flat)	218 dB re 1 µPa (peak) (flat)	218 dB re 1 µPa (peak) (flat)
Sound exposure level	186 dB re 1 μPa^2-s (M_{pw})	186 dB re 1 μPa^2-s (M_{pw})	203 dB re 1 μPa^2-s (M_{pw})
Pinnipeds (in air)			
Sound pressure level	149 dB re 20 µPa (peak) (flat)	149 dB re 20 µPa (peak) (flat)	149 dB re 20 µPa (peak) (flat)
Sound exposure level	144 dB re $(20\ \mu Pa)^2$-s (M_{pa})	144 dB re $(20\ \mu Pa)^2$-s (M_{pa})	144.5 dB re $(20\ \mu Pa)^2$-s (M_{pa})

In any case, levels of underwater sound from production and drilling activities that occur continuously over extended periods are not very high (Blackwell and Greene 2006). For example, received levels of prolonged drilling sounds are expected to diminish below 140 dB re 1 µPa at a distance of about 40 m (131 ft) from the center of activity. Sound levels during other production activities aside from drilling usually would diminish below 140 dB re 1 µPa at a closer distance. The 140 dB re 1 µPa radius for drilling noise is within the island and drilling sounds are attenuated to levels below 140 dB re 1 µPa in the water near Northstar. Neither TTS nor permanent hearing damage are expected from the operations at Northstar.

Masking

Masking of calls or other natural sounds would not extend beyond the maximum distance where the construction or operational sounds are detectable, and at that distance only the weakest sounds would be masked. The maximum distances for masking will vary greatly depending on ambient noise and sound propagation conditions, but will typically be about 2–5 km (1.2–3.1 mi) in air and 3–10 km (1.9–6.2 mi) underwater. Also, some types of Northstar sounds (especially the stronger ones) vary over time, and at quieter times masking would be absent or limited to closer distances.

Behavioral Reactions to Noise and Disturbance

Disturbance is the main concern in this project. In the terminology of the 1994 amendments to the MMPA, oil field construction or operation noise could cause “Level B” harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

When the received level of noise exceeds some behavioral reaction threshold, some pinnipeds will exhibit disturbance reactions. The levels, frequencies and types of noise that elicit a response vary among and within species, individuals, locations and seasons. Behavioral changes may be an upright posture for hauled out seals, movement away from the sound source, or complete avoidance of the area. The reaction threshold and degree of response are related to the activity of the animal at the time of the disturbance.

Behavioral reactions do not occur throughout the zone ensonified by industrial activity. In most cases that have been studied, including recent work on ringed seals, the actual radius of effect is considerably smaller than the radius of detectability (reviewed in Richardson et al. 1995b; Moulton et al. 2003a, 2005; Blackwell et al. 2004a).

Effects of Construction, Drilling and Production Activity

Systematic aerial surveys to assess ringed seal responses to the construction of Seal Island were done both for Shell Oil (Green and Johnson 1983) and for the Minerals Management Service (Frost and Burns 1989; Kelly et al. 1988). Green and Johnson (1983) found that some seals within several kilometers of Seal Island were apparently displaced by construction of the island during the winter of 1981–82. Similarly, Frost and Lowry (1988) found lower densities of seals within 3.7 km (2 nmi) of artificial islands than 3.7–7.4 km (2–4 nmi) away when exploration activity was high. During years with construction or drilling activities, there was apparently a 38–40% reduction in seal densities near the islands (Frost and Lowry 1988). It is important to note that these early analyses did not account for non-industrial factors known to influence basking activity of seals (Moulton et al. 2002, 2005). Also, the numbers of sightings were small relative to the variation in the data.

Kelly et al. (1988) used trained dogs to study the use by seals of breathing holes and lairs in relation to exposure to industrial activities. They reported that the proportion of structures abandoned within 8 km (5 mi) of Seal Island was similar to that within 150 m (492 ft) of on-ice seismic lines. There were no differences in abandonment rate within vs. beyond 150 m (492 ft) from Seal Island. Kelly et al. (1988) indicated that the data were not adequate to evaluate at what distances from the island abandonment of structures began to decrease. In a final analysis of those data, Frost and Burns (1989) reported that the proportion of abandoned structures was significantly higher within 2 km (1.2 mi) of Seal Island than 2–10 km (1.2–6.2 mi) away. Complicating the interpretation is that dog-based searches were conducted where structures were expected to be found, rather than over the entire study area, and multiple searches over a given area were not conducted. Hammill and Smith (1990) found that dogs missed as many as 73% of the structures during the first search of an area. Frost and Burns (1989) also noted that the analyses of disturbance and abandonment as a result of Seal Island construction were complicated by other noise sources active simultaneously. These included on-ice seismic exploration, excavation of structures by their investigations, and snow machine traffic. They suspected that, overall; there was no area-wide increase in abandonment of structures. Finally, it is unknown whether there are differences in detection rates by dogs for open vs. abandoned structures or for areas of different structure density. This detection bias potentially confounds interpretation of the data.

Utilizing radio telemetry to examine the short-term behavioral responses of ringed seals to human activities, Kelly et al. (1988) found that some ringed seals temporarily departed from lairs when various sources of noise were within 97–3,000 m (0.06–1.9 mi) of an occupied structure. Radio-tagged ringed seals did return to re-occupy those lairs. The durations of haul-out bouts during periods with and without disturbance were not significantly different. Also, the time ringed seals spent in the water after disturbance did not differ significantly from that during periods of no disturbance (Kelly et al. 1988).

Moulton et al. (2003a, 2005) conducted intensive and replicated aerial surveys during the springs of 1997–99 ("pre-Northstar") and 2000–02 (with Northstar activities) to study the distribution and abundance of ringed seals within an ~4,140 km^2 (1,598 mi^2) area around the Northstar Development. The main objective was to determine whether, and to what extent, oil development affected the local distribution and abundance of ringed seals. The 1997–1999 surveys were conducted coincident with aerial surveys over a larger area of the central Beaufort Sea (Frost et al. 2004). Moulton et al. (2003a, 2005) determined that the raw density of ringed seals over their study area ranged from 0.39 to 0.83 seals/ km^2, while Frost et al. (2004) obtained raw densities of 0.64 to 0.87 seals/ km^2 in similar area at about the same times. There was no evidence that construction, drilling, and production activities at Northstar in 2000–2002 significantly affected local ringed seal distribution and abundance relative to the baseline years (1997–99). Additionally, after natural variables that affect haul-out behavior were considered (Moulton et al. 2003a, 2005), there was no significant evidence of reduced seal densities close to Northstar as compared with farther away during the springs of 2000, 2001, and 2002. The survey methods and associated analyses were shown to have high statistical power to detect such changes if they occurred. Environmental factors such as date, water depth, degree of ice deformation, presence of meltwater, and percent cloud cover had more conspicuous and statistically-significant effects on seal sighting rates than did any human-related factors (Moulton et al. 2003a, 2005).

To complement the aerial survey program on a finer scale, specially-trained dogs were used to find seal structures and to monitor the fate of structures in relation to distance from industrial activities (Williams et al. 2006c). In late 2000, surveys began before construction of ice roads but concurrent with drilling and other island activities.

In the winter of 2000–2001, a total of 181 structures were located, of which 118 (65%) were actively used by late May 2001. However, there was no relationship between structure survival or the proportion of structures abandoned and distance to Northstar-related activities. The most important factors predicting structure survival were time of year when found, and ice deformation. The covariate distance to the ice road improved the fit of the model, but the relationship indicated that structure survival was lower farther away from the ice road, contrary to expectation. However, new structures found after the ice-road was constructed were, on average, farther from the ice-road than were structures found before construction (though this was marginally statistically significant). This may have been related to the active flooding of the ice road, which effectively removed some of the ice as potential ringed seal habitat.

Blackwell et al. (2004a) investigated the effects of noise from pipe-driving and other construction activities on Northstar to ringed seals in June and July 2000, during and just after break-up of the landfast ice. None of the ringed seals seen during monitoring showed any strong reactions to the pipe-driving or other construction activities on Northstar. Eleven of the seals (48%) appeared either indifferent or curious when exposed to construction or pipe-driving sounds. One seal approached within 3 m (9.8 ft) of the island's edge during pipe-driving and others swam in the 3–15 m (9.8–49.2 ft) moat around the island. Seals in the moat may have been exposed to sound levels up to 153–160 dB re 1 µPa (rms) when they dove close to the bottom.

Consistent with Blackwell et al. (2004a), seals are often very tolerant of exposure to other types of pulsed sounds. For example, seals tolerate high received levels of sounds from airgun arrays (Arnold 1996; Harris et al. 2001; Moulton and Lawson 2002). Monitoring work in the Alaskan Beaufort Sea during 1996–2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 0.01 to 0.03 m^3 (560 to 1,500 in^3). The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating than when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to a few hundreds of meters, and many seals remained within 100–200 m (328–656 ft) of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997. Similarly, seals are often very tolerant of pulsed sounds from seal-scaring devices (Mate and Harvey 1987; Jefferson and Curry 1994; Richardson et al. 1995b). Thus, it is not especially surprising that avoidance reactions to impulsive pile driving sounds did not extend very far from the pile driving operations on Northstar, if reactions occurred at all.

Effects of Aircraft Activity

Helicopters are the only aircraft associated with Northstar oil production activities. Helicopter traffic occurs primarily during late spring and autumn when travel by ice road, hovercraft or vessel is not possible.

Blackwell et al. (2004a) observed 12 ringed seals during low-altitude overflights of a Bell 212 helicopter at Northstar in June and July 2000 (9 observations took place concurrent with pipe-driving activities, see above). One seal showed no reaction to the aircraft while the remaining 11 (92%) reacted, either by looking at the helicopter or by departing from their basking site. Blackwell et al. (2004a) concluded that none of the reactions to helicopters were strong or long lasting, and that seals near Northstar in June and July 2000 probably had habituated to industrial sounds and visible activities that had occurred often during the preceding winter and spring. There have been few systematic studies of pinniped reactions to aircraft overflights, and most of the available data concern pinnipeds hauled out on land or ice rather than pinnipeds in the water (Richardson et al. 1995b; Born et al. 1999). Any reactions to helicopter overflights can be prevented by maintaining a minimum altitude of 305 m (1,000 ft) when weather allows.

Spotted seals hauled out on land in summer are unusually sensitive to aircraft overflights compared to other species. They often rush into the water when an aircraft flies by at altitudes up to 300–750 m (984–2,460 ft). They occasionally react to aircraft flying as high as 1370 m (4495 ft) and at lateral distances as far as 2 km (1.2 mi) or more (Frost and Lowry 1990; Rugh et al. 1997). However, no spotted seal haul-outs are located near Northstar.

Effects of Vessel Activity

Few authors have specifically described the responses of pinnipeds to boats, and most of the available information on reactions to boats concerns pinnipeds hauled out on land or ice. Ringed seals hauled out on ice pans often showed short-term escape reactions when a ship came within 0.25 to 0.5 km (0.15 to 0.3 mi; Brueggeman et al. 1992). Jansen et al. (2006) reported that harbor seals approached by vessels to 100 m (328 ft) were 25 times more likely to enter the water than were seals approached at 500 m (1,640 ft). However, during the open water season in the Beaufort Sea, ringed and bearded seals are commonly observed close to vessels (e.g., Harris et al. 2001; Moulton and Lawson 2002). In places where boat traffic is heavy, there have been cases where seals have habituated to vessel disturbance. In England, harbor and gray (*Halichoerus grypus*) seals at specific haul-outs appear to have habituated to close approaches by tour boats (Bonner 1982). Jansen et al. (2006) found that harbor seals in Disenchantment Bay, Alaska increased in abundance during the summer as ship traffic also increased. In Maine, Lelli and Harris (2001) found that boat traffic was the best predictor of variability in harbor seal haulout behavior, followed by wave height and percent sunshine utilizing multiple regressions. Lelli and Harris (2001) reported that increasing boat traffic reduced the number of seals counted on the haul-out. Southall et al. (2007) report that pinnipeds exposed to ~110 to 120 dB re 1 µPa in air, tended to respond by leaving their haulouts and seeking refuge in the water, while animals exposed to in-air sounds of ~60 to 70 dB re 20 µPa often did not respond at all.

Effects of Oil on Pinnipeds

Ringed, bearded and spotted seals are present in open water areas during summer and early autumn, and ringed seals remain in the area through the ice-covered season. During the spring periods in 1997–2002, the observed densities of ringed seals on the fast-ice in areas ≥3 m (9.8 ft) deep ranged from 0.35 to 0.72 seals/ km^2. After allowance for seals not seen by aerial surveyors, actual densities may have been about 2.84 times higher (see Sections 4 and 6; also Moulton et al.

2003a). Therefore, an oil spill from the Northstar development or its pipeline could affect seals. Any oil spilled under the ice also has the potential to directly contact seals.

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

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

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

Oiling of External Surfaces

Adult seals rely on a layer of blubber for insulation and oiling of the external surface does not appear to have adverse thermoregulatory effects (Kooyman et al. 1976, 1977; St. Aubin 1990). Contact with oil on the external surfaces can cause increased stress and can irritate the eyes of ringed seals (Geraci and Smith 1976; St. Aubin 1990). These effects seemed to be temporary and reversible, but continued exposure of eyes to oil could cause permanent damage (St. Aubin 1990).

New-born seal pups rely on their fur for insulation. New-born ringed seal pups in lairs on the ice could be contaminated through contact with oiled mothers. New-born ringed seal pups that were contaminated with oil would probably die from hypothermia.

Ingestion

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

Avoidance and Behavioral Effects

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

Factors Affecting the Severity of Effects

Seals that are under natural stress, such as lack of food or a heavy infestation by parasites, could die because of the additional stress of oiling (Geraci and Smith 1976; St. Aubin 1990; Spraker et al. 1994). Female seals that are nursing young would be under natural stress, as would molting seals. In both cases, the seals would have reduced food stores and may be less resistant to effects of oil than seals that are not under some type of natural stress. Seals that are not under natural stress (e.g., fasting, molting) would be more likely to survive oiling.

In general, seals do not exhibit large behavioral or physiological reactions to limited surface oiling or incidental exposure to contaminated food or vapors (St. Aubin 1990; Williams et al. 1994). Effects could be severe if seals surface in heavy oil slicks in leads, or if oil accumulates near haul-out sites (St. Aubin 1990). An oil spill in open water is likely to have only minor impacts on seals.

Seals exposed to heavy doses of oil for prolonged periods could die. This type of prolonged exposure could occur if fuel or crude oil was spilled in or reached nearshore waters, was spilled in a lead used by seals, or was spilled under the ice in winter when seals have limited mobility. Seals residing in these habitats may not be able to avoid prolonged contamination and some would die. Impacts on regional populations of seals would be minor.

Effects of Oil-Spill Cleanup Activities

Oil spill cleanup activities could increase disturbance effects on either whales or seals, causing temporary disruption and possible displacement (MMS 1996). The Northstar Oil Discharge Prevention and Contingency Plan (ODPCP; BPXA 1998a, b) includes a scenario of a production well blowout to the open water in August. In this scenario, approximately 177,900 barrels of North Slope crude oil will reach the open water. It is estimated that response activities will require 186 staff (93 per shift) using 33 vessels (Table 1.6.1-3; BPXA 1998b) for about 15 days to recover oil in open water. Shoreline cleanup will occur for ~45 days employing low pressure, cold water deluge on the soiled shorelines. In a similar scenario during solid ice conditions, it is estimated that 97 pieces of equipment along with 246 staff (123 per shift) will be required for response activities (BPXA 1998a).

In the event of a large spill contacting and extensively oiling coastal habitats, the presence of response staff, equipment, and the many aircraft involved in the cleanup will (depending on the time of the spill and the cleanup), potentially displace seals and other marine mammals. If extensive cleanup operations occur in the spring, they could cause increased stress and reduced pup survival of ringed seals. Oil spill cleanup activity could exacerbate and increase disturbance effects on subsistence species, cause localized displacement of subsistence species, and alter or reduce access to those species by hunters. On the other hand, the displacement of marine mammals away from oil-contaminated areas by cleanup activities would reduce the likelihood of direct contact with oil.

Conclusions Regarding Effects on Pinnipeds

Disturbance ("potential take by harassment") was the main concern during the construction phase of Northstar, and one of the main concerns during the initial production phase. Responses of seals to acoustic disturbance vary highly, with the most conspicuous changes in behavior occurring when seals are hauled out on ice or land when exposed to human activities. Seals in open water do not appear to react as strongly. In some earlier Northstar monitoring reports, it was suggested that the number of seals potentially affected by Northstar activities on an annual basis during 1999–2002 was about 110 to 145 ringed seals plus 1 bearded seal (but no spotted seals). The numbers of ringed seals potentially affected during the ice-covered and break-up periods in November 2002 through October 2003 have been estimated based on a re-evaluation of the criteria used in previous years. This re-evaluation takes account of the results of aerial and on-ice studies indicating that the areas from which seals were displaced were quite small (Williams et al. 2002, 2006b, 2006c; Moulton et al. 2003a, 2005; Richardson et al. 2008b).

The number of seals potentially affected probably includes only those seals excluded from physically-disturbed areas. Those areas include the artificial island and ice road plus a 100 m (0.06 mi) zone around these areas. Updated totals for the numbers of seals expected within the potential impact zone from 1997 through 2002 range from 3 to 8 seals (see Section 6). Seal monitoring in an area extending out to ~950 m (3,116 ft) around Northstar as conducted from the process module during the break-up period (15 May–15 July) showed high variation in the numbers of ringed seals observed, with a total of 229 in 2005, 59 in 2006, 3 in 2007, and 415 in 2008 (Aerts 2009). These totals of near-daily counts are believed to include (for most years) a large number of resightings of the same individual seals. The overall results suggest that any effects of Northstar production activities on seals were minor and localized, with no consequences for the seal populations. There is a small possibility of injury or mortality to a very small number of ringed seal pups during on-ice construction and transportation activities, although no injuries or mortalities were detected during monitoring from 1999 to 2008.

In the unlikely event of a large oil spill, there is the possibility that a small number of seals could be oiled. Of these, most would not be seriously injured. However, there is the possibility that a small number of seals could be seriously injured or killed by oiling.

Potential Impacts on Cetaceans

Cetacean species that occur in the Northstar/Prudhoe Bay area and have the potential to be impacted by Northstar related activities are bowhead, gray and beluga whale. Production activities, aircraft and vessel traffic, and oil spills can potentially have an effect on cetacean behavior, lead to disturbance or (in the case of oil spills) physically affect whales.

Effect of Sound on Cetaceans

The possible categories of noise effects on marine mammals in general were summarized earlier in this section. The categories relevant here are behavioral disturbance and associated habituation effects, masking, and possible effects on hearing sensitivity. To assess the potential effects of sound on cetaceans it is important to understand the sound characteristics produced by the different industrial activities, and the hearing abilities of the receiver, in this case the cetaceans occurring in the area: bowhead, gray and beluga whale. Hearing abilities have not been measured directly in many cetaceans (e.g., for any baleen whale), and in these cases understanding the call characteristics is relevant in assessing the likely frequency range of best hearing. Also, the characteristics of marine mammal calls are relevant in assessing the potential masking effects of man-made sounds. Before discussing possible impacts on cetaceans to man made sounds we briefly discuss their hearing abilities and sound production.

Cetacean Hearing Abilities and Sound Production

Cetacean hearing has been studied in relatively few species and individuals. Based on current knowledge of functional hearing in marine mammals, three distinct, functional hearing categories were defined for cetacean species (Southall et al. 2007): (1) low-frequency cetaceans (baleen whales); (2) “mid”-frequency cetaceans (most odontocetes, including beluga whale), and (3) high-frequency cetaceans (most small odontocetes, e.g., porpoises, river dolphins, pygmy sperm whale).

The auditory sensitivity of bowheads, gray whales, and other baleen whales has not been measured, but relevant anatomical and behavioral evidence is available. These whales appear to be specialized for low frequency hearing, with some directional hearing ability (reviewed in Richardson et al. 1995b; Ketten 2000). Their auditory bandwidth (estimated lower to upper frequency hearing cut-off) is believed to range from 7 Hz to 22 kHz (Southall et al. 2007), or perhaps higher in the minke whale (Berta et al. 2009). This means that their optimum hearing overlaps broadly with the low frequency range where production activities and associated vessel traffic emit most of their energy.

The beluga whale is one of the better-studied species in terms of its hearing ability. Belugas can hear sounds over a very wide range of frequencies, from 40 Hz to above 100 kHz (White et al. 1978; Awbrey et al. 1988; Johnson et al. 1989). The auditory bandwidth (estimated lower to upper frequency hearing cut-off) in mid-frequency odontocetes in general is believed to range from 150 Hz to 160 kHz (Southall et al. 2007), however, belugas are most sensitive above 10 kHz. They have relatively poor sensitivity at the low frequencies (reviewed in Richardson et al. 1995b) that dominate the sound from industrial activities and associated vessels. Nonetheless, the noise from strong low frequency sources is detectable by belugas many kilometers away (Richardson and Würsig 1997). Also, beluga hearing at low frequencies in open water conditions is apparently somewhat better than in the captive situations where most hearing studies were done (Ridgway and Carder 1995; Au

1997). If so, low frequency sounds emanating from production activities may be detectable somewhat farther away than previously estimated.

Call characteristics of cetaceans provide some limited information on their hearing abilities, although the auditory range often extends beyond the range of frequencies contained in the calls. Also, understanding the frequencies at which different marine mammal species communicate is relevant for the assessment of potential impacts from man made sounds. Information on the call characteristics is provided below for each cetacean species that is known to occur in the Northstar area.

Bowhead Whale

Most bowhead calls are tonal, frequency-modulated sounds at frequencies of 50 to 400 Hz. These calls overlap broadly in frequency with the underwater sounds emitted by many construction and operational activities (Richardson et al. 1995b). Some bowhead calls contain energy up to 1200 Hz (Clark and Johnson 1984; Würsig and Clark 1993), but most of the energy is below 500 Hz. Bowhead "songs" occur in late winter and spring but have not been reported in late summer or autumn. Functions of bowhead calls are not positively known, but are believed to include maintenance of contact among widely separated individuals, mother-calf interactions, and various other social functions. Calls may be especially important during migration through ice. Source levels are quite variable, with the stronger calls having source levels up to about 180 dB re 1 µPa-m. Some bowhead calls are detectable more than 20 km (12.5 mi) away, but the ability to detect calls at long range diminishes with increasing background noise level (Greene et al. 2004).

Gray Whale

Gray whales make a wide variety of calls at frequencies from <100 to 2000 Hz; many calls are described as "knocks" and pulses (Dahlheim et al. 1984; Moore and Ljungblad 1984; Dahlheim 1987). Gray whales are less vocal in their summer feeding grounds than during migration or (especially) when on their winter breeding/calving grounds (Dahlheim 1987). Gray whales feeding in groups may keep in acoustic contact when separated by distances >800 m (0.5 mi; Bogoslovskaya 1986).

Beluga Whale

The beluga's extensive vocal repertoire includes trills, whistles, clicks, bangs, chirps and other sounds (Schevill and Lawrence 1949; Ouellet 1979; Sjare and Smith 1986a). Beluga whistles have dominant frequencies in the 2 to 6 kHz range (Sjare and Smith 1986a). This is above the frequency range of most of the sound energy produced by the planned Northstar production activities and associated vessels. Other beluga call types reported by Sjare and Smith (1986a, b) included sounds at mean frequencies ranging upward from 1.0 kHz.

The beluga also has a very well developed high frequency echolocation system, as reviewed by Au (1993). Echolocation signals have peak frequencies from 40 to 120 kHz and broadband source levels of up to 219 dB re 1 µPa-m (zero-peak). Echolocation calls are far above the frequency range of the sounds from the planned Northstar activities. Those industrial sounds are not expected to interfere with echolocation.

Possible Effects on Hearing Sensitivity

Temporary or permanent hearing impairment is a possibility (although rarely demonstrated) when marine mammals are exposed to very strong sounds. There are no data on received sound levels necessary to cause TTS in baleen whales. For toothed whales, there are data concerning TTS thresholds for bottlenose dolphins and belugas exposed to a single short noise pulse (Schlundt et al. 2000, 2006; Finneran et al. 2002, 2005, 2007) as well as dolphins exposed to more prolonged sounds (Nachtigall et al. 2003, 2004). The lowest received level that elicited mild TTS was 192 dB re 1 μPa for a 1-s pulse, and about 175 dB for a prolonged (~55 min) exposure. Permanent hearing impairment would not be expected in belugas unless sound levels were substantially higher than those required to induce TTS (Southall et al. 2007). Such exposures will not occur near Northstar, given the empirical data on sound levels near the operations. Cetaceans will not occur near Northstar during the ice-covered season.

Pressure pulses from explosions can cause permanent auditory damage and, if the cetacean is close to the blast, other injuries or death (Todd et al. 1996). However, explosions are not planned to occur as part of the ongoing Northstar operations.

Overall, TTS and permanent hearing damage are not expected to occur in cetaceans during the drilling and production activities at Northstar.

Masking

No masking effects on cetaceans will occur during the ice-covered season because cetaceans will not occur near Northstar at those seasons. The sounds from oil production and any drilling activities are not expected to be detectable beyond several kilometers from the source (Greene 1983; Blackwell et al. 2004b; Blackwell and Greene 2006; Blackwell and Greene 2005). Sounds from vessel activity, however, were detectable to distances as far as ~30 km (18.6 mi) from Northstar (Blackwell and Greene 2006). Because of the transient nature of vessel noise, it will not cause significant masking effects. Only vessels under power to maintain position can be a significant source of continuous noise (Blackwell et al. 2004b; Blackwell and Greene 2006), with potential to cause some degree of masking.

Small numbers of bowheads, belugas and (rarely) gray whales could be present near Northstar during the open-water season. Almost all energy in the sounds emitted by drilling and other operational activities is at low frequencies, predominantly below 250 Hz with another peak centered around 1000 Hz. Most energy in the sounds from the vessels and aircraft to be used during this project is below 1 kHz (Moore et al. 1984; Greene and Moore 1995; Blackwell et al. 2004b; Blackwell and Greene 2006). These frequencies are mainly used by mysticetes like bowhead and gray whales, but not by odontocetes like the beluga.

An industrial sound source will reduce the effective communication or echolocation distance only if its frequency is close to that of the cetacean signal and if its received level is appreciably above the then-prevailing ambient noise level. If little or no overlap occurs between the industrial noise and the frequencies used, as in the case of belugas, communication and echo location are not expected to be disrupted. Furthermore, the relatively low effective source levels and rapid attenuation of drilling and production sounds from artificial islands in shallow water makes significant masking effects unlikely even for mysticetes that are within several kilometers of Northstar Island. Because of the transient nature of moving boat noise, it will not cause significant masking effects. However, docking vessels or other vessels under power to maintain position can be a significant source of continuous noise (Blackwell et al. 2004b; Blackwell and Greene 2006), with potential to cause some degree of masking.

Certain cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or possibly to shift their peak frequencies in response to strong ambient signals (Dahlheim 1987; Au 1993; Lesage et al. 1993, 1999; review in Richardson et al. 1995b; Foote et al. 2004; Scheifele et al. 2005; Di Iorio and Clark 2009; Holt et al. 2009; Parks et al. 2009). These adaptations, along with directional hearing, pre-adaptation to tolerate some masking by natural sounds, and the brief periods when most individual whales occur near Northstar, would all reduce the potential impacts of masking. Overall, masking effects from underwater sounds associated with project activities will have negligible effects on the abilities of cetaceans to hear other sounds.

Behavioral Reactions to Noise and Disturbance

Disturbance is the main concern in this project. In the terminology of the 1994 amendments to the MMPA, construction noise could cause “Level B” harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

When the received level of noise exceeds some behavioral reaction threshold, cetaceans will show disturbance reactions. The levels, frequencies and types of noise that elicit a response vary among and within species, individuals, locations and seasons. Behavioral changes may be subtle alterations in surface-respiration-dive cycles, more conspicuous responses such as changes in activity or aerial displays, movement away from the sound source, or (at least in theory) complete avoidance of the area. The reaction threshold and degree of response are related to the activity of the animal at the time of the disturbance. Whales engaged in active behaviors such as feeding, socializing or mating are less likely than resting animals to show overt behavioral reactions. However, they may do so if the received noise level is high or the source of disturbance is directly threatening.

Behavioral reactions do not occur throughout the zone ensonified by industrial activity. In most cases that have been studied, including work on bowhead, gray and beluga whales, the actual radius of effect is considerably smaller than the radius of detectability (reviewed in Richardson and Malme 1993; Richardson et al. 1995b; Nowacek et al. 2007; Southall et al. 2007).

Effects of Construction, Drilling and Production

Spring migration of bowheads and belugas through the western and central Beaufort Sea occurs from April to June. Their spring migration corridors are far north of the barrier islands and of the Northstar project area. Whales, including bowhead, beluga, and gray whales, will not be within the Northstar project area during winter or spring. In addition, industrial sounds from Northstar are unlikely to be detectable far enough offshore to be heard by spring-migrating whales. In rare cases where these sounds might be audible to cetaceans in spring, the received levels would be weak and very unlikely to elicit behavioral reactions. Consequently, noise from construction and operational activities at Northstar during the ice-covered season would have no effects on whales.

During the open-water season, sound propagation from sources on the island is reduced because of poor coupling of sound through the gravel island into the shallow waters. In the absence of boats, underwater sounds from Northstar Island during construction, drilling, and production reached background values 2–4 km (1.2–2.5 mi) away in quiet conditions (Blackwell and Greene 2006). However, when Northstar-related vessels were present, levels were higher and faint vessel sound was often still evident 20–30 km (12.4–18.6 mi) away.

Bowhead Whales – Information about the reactions of cetaceans to construction or heavy equipment activity on artificial (or natural) islands is limited (Richardson et al. 1995b). During the construction of artificial islands and other oil-industry facilities in the Canadian Beaufort Sea during late summers of 1980–84, bowheads were at times observed as close as 800 m (0.5 mi) from the construction sites (Richardson et al. 1985, 1990). Richardson et al. (1990) showed that, at least in summer, bowheads generally tolerated playbacks of low-frequency construction and dredging noise at received broadband levels up to about 115 dB re 1 μPa. At received levels higher than about 115 dB, some avoidance reactions were observed. Bowheads apparently reacted in only a limited and localized way (if at all) to construction of Seal Island, the precursor of Northstar (Hickie and Davis 1983).

There are no specific data on reactions of bowhead (or gray) whales to noise from drilling on an artificial island. However, playback studies have shown that both species begin to show overt behavioral responses to various low-frequency industrial sounds when received levels exceed 115–120 dB re 1 μPa (Malme et al. 1984; Richardson et al. 1990, 1995a, 1995b). The overall received level of drilling sound from Northstar Island generally diminished to 115 dB within 1 km (0.62 mi; Blackwell et al. 2004b). Any reactions by bowhead (or gray) whales to drilling at Northstar were, therefore, expected to be highly localized and would involve few whales.

Prior to construction of Northstar, it was expected (based on early data mentioned above) that some bowheads would avoid areas where noise levels exceeded 115 dB re 1 μPa (Richardson et al. 1990). It was expected that, during most autumn migration seasons, few bowheads would come close enough to shore to receive sound levels that high from Northstar. Thus disturbance effects from continuous construction and operational noise were expected to be limited to the closest whales and the times with highest sound emissions.

In 2000–2004 bowhead whales were monitored acoustically to determine the number of whales that might have been exposed to Northstar related sounds. Data from 2001–2004 were useable for this purpose. The results showed that, during late summer and early autumn of 2001, a small number of bowhead whales in the southern part of the migration corridor (closest to Northstar) were apparently affected by vessel or Northstar operations. At these times, most "Northstar sound" was from maneuvering vessels, not the island itself. The distribution of calling whales was analyzed and the results indicated that the apparent southern (proximal) edge of the call distribution was significantly associated with the level of industrial sound output each year, with the southern edge of the call distribution varying by 0.76 km to 2.35 km (0.47 mi to 1.46 mi; depending on year) farther offshore when underwater sound levels from Northstar and associated vessels were above average (Richardson et al. 2008a). It is possible that the apparent deflection effect was, at least in part, attributable to a change in calling behavior rather than actual deflection. In either case, there was a change in the behavior of some bowhead whales.

Migrating bowheads whose paths are deflected offshore by no more than a few kilometers would not, in most cases, incur biologically significant effects. A deflection by (at most) a few kilometers is well within the range of normal variability in the offshore distances of migrating bowheads. Given that, no significant effects on individual health and overall population would be expected.

Gray Whales – There are no data on the reactions of gray whales to production activities similar to those in operation at Northstar. Oil production platforms of a very different type have been in place off California for many years. Gray whales regularly migrate through that area (Brownell 1971), but no detailed data on distances of closest approach or possible noise disturbance have been published. Oil industry personnel have reported seeing whales near platforms, and that the animals approach more closely during low-noise periods (Gales 1982; McCarty 1982). Playbacks of recorded production platform noise indicate that gray whales react if received levels exceed ~123 dB re 1 µPa—similar to the levels of drilling noise that elicit avoidance (Malme et al. 1984).

A typical migrating gray whale tolerates steady, low-frequency industrial sounds at received levels up to about 120 dB re 1 µPa (Malme et al. 1984). Gray whales may tolerate higher-level sounds if the sound source is offset to the side of the migration path (Tyack and Clark 1998). Also, gray whales generally tolerate repeated low-frequency seismic pulses at received levels up to about 163−170 dB re 1 µPa measured on an (approximate) rms basis. Above those levels avoidance is common. Because the reaction thresholds to both steady and pulsed sounds are slightly higher than corresponding values for bowheads, reaction distances for gray whales would be slightly less than those for bowheads. In the unlikely event that gray whales occur near Northstar, disturbance effects would be highly localized and would have no biological consequences for individual whales or the population. Given the infrequent occurrence and low numbers of gray whales in the area, it is most likely that there would be no disturbance effects from sound sources on or associated with the island.

Beluga Whales – In the Canadian Beaufort Sea, beluga whales were seen within several feet of an artificial island. During the island's construction, belugas were displaced from the immediate vicinity of the island, but not from the general area (Fraker 1977a). Belugas in the Mackenzie River estuary showed less response to a stationary dredge than to moving tug/barge traffic. They approached as close as 400 m (1,312 ft) from stationary dredges. Underwater sounds from Northstar Island are weaker than those from the dredge. In addition, belugas occur only infrequently in nearshore waters in the Prudhoe Bay region. They also have relatively poor hearing sensitivity at the low frequencies of most construction noises. Therefore, effects of construction and related sounds on belugas would be expected to be negligible.

Responses of beluga whales to drilling operations are described in Richardson et al. (1995a) and summarized here. In the Mackenzie Estuary during summer, belugas have been seen regularly within 100 to 150 m (328 to 492 ft) of artificial islands (Fraker 1977a, b; Fraker and Fraker 1979). However, in the Northstar area, belugas are present only during late summer and autumn, and almost all of them are migrating through offshore waters far seaward of Northstar. Only a very small proportion of the population enters nearshore waters. In spring, migrating belugas showed no overt reactions to recorded drilling noise (< 350 Hz) until within 200 to 400 m (656 to 1,312 ft) of the source, even though the sounds were measurable up to 5 km away (3.1 mi; Richardson et al. 1991). During another drilling noise playback study, overt reactions by belugas within 50 to 300 m (164 to 984 ft) involved increased swimming speed (Stewart et al. 1983). The short reaction distances are probably partly a consequence of the poor hearing sensitivity of belugas at low frequencies (Richardson et al. 1995b). In general, very few belugas are expected to approach Northstar Island, and any such occurrences would be restricted to the late summer/autumn period. Even those few belugas would show no more than localized and brief avoidance reactions, limited to the area within several hundred meters of the island.

There are no specific data on the reactions of beluga whales to production operations similar to those at Northstar. Personnel from production platforms in Cook Inlet, Alaska, report that belugas are seen within 9 m (30 ft) of some rigs, and that steady noise is non-disturbing to belugas (Gales 1982; McCarty 1982). Beluga whales are regularly observed near the Port of Anchorage and the extensive dredging/maintenance activities that operate there regularly (NMFS 2003). Pilot whales, killer whales, and unidentified dolphins were also reported near Cook Inlet platforms. In that area, flare booms might attract belugas, possibly because the flares attract salmon in that area. Attraction of belugas to prey concentrations is not likely to occur at Northstar because belugas are predominantly migrating rather than feeding when in that area, and because only a very small proportion of the beluga population occurs in nearshore waters. Overall, effects of routine production activities on belugas are expected to be negligible.

Effects of Aircraft Activity

Helicopters are the only aircraft associated with Northstar drilling and oil production operations for crew transfer and supply and support. Helicopter traffic occurs during late spring/summer and fall/early winter when travel by ice roads, hovercraft or vessels is not possible. Twin otters are used for routine pipeline inspections.

Low passes by aircraft over a cetacean, including a bowhead, gray or beluga whale, result in short-term responses or no discernible reaction. Responses can include sudden dives, churning the water with the flippers and/or flukes, or rapidly swimming away from the aircraft track (reviewed in Richardson et al. 1995b; see also Patenaude et al. 2002). Belugas often roll and apparently look upward at the aircraft. The activity of the animal at the time of the overflight tends to be related to the "severity" of the reaction, with feeding or socializing animals the least likely to respond. Responses range from no overt reaction to a dramatic disruption of activities. Known or suspected reasons for this variation include aircraft altitude, engine setting changes, type of aircraft, weather conditions, and whale activity at the time. Whales appear less disturbed by quiet aircraft flying at slow speeds and reduced engine power. Single overflights may elicit a sudden dive, which probably represents a startle reaction to the visual appearance or sudden noise of the aircraft. Reactions tend to be more common when aircraft altitude is low (e.g., 75–150 m or 250–500 ft) and infrequent when higher (300–450 m or 1,000–1,500 ft), but there is much variability. Continued disturbance by an aircraft, such as prolonged circling overhead at low altitude, often results in dispersal of the individuals and departure from the area.

There is little likelihood of project-related helicopter and aircraft traffic over bowheads during the fall migration. Helicopter and aircraft traffic is between the shore and Northstar Island. Almost all bowhead whales migrate west in waters farther north. Helicopters maintain an altitude of 305 m (1,000 ft) above sea level while traveling over water to and from Northstar whenever weather conditions allow. It is unlikely that there will be any need for helicopters or aircraft to circle or hover over the open water other than when landing or taking off. Gray whales are uncommon in the area and there is little likelihood that any will be overflown by a helicopter or aircraft. The 305+ m (1,000+ ft) planned flight altitude will minimize any disturbance that might occur if a gray whale is encountered. Even if several bowheads or (less likely) gray whales did react to a single helicopter or aircraft overflight, the reaction would be brief and of no long-term consequence to the whales.

Likewise, there is little likelihood of helicopter disturbance to belugas. Brief reactions by belugas are common when a helicopter is low (e.g., at 75 to 150 m or 250 to 500 ft altitude) but uncommon when it is higher (300 to 450 m or 1,000 to 1,500 ft). However, there is much variability (Richardson et al. 1995b; Patenaude et al. 2002). Because of the predominantly offshore migration route of belugas, very few (if any) will be overflown during helicopter flights over nearshore waters. Any overflights are most likely to be at an altitude of 305 m (1,000 ft) or more. Therefore, few belugas will react to helicopters. Any such reactions will be brief and of no long-term significance to individuals or the population.

Effects of Vessel Activity

Reactions of cetaceans to vessels often include changes in general activity (e.g., from resting or feeding to active avoidance), changes in surfacing-respiration-dive cycles, and changes in speed and direction of movement. As with aircraft, responses to vessel approaches tend to be reduced if the animals are actively involved in a specific activity such as feeding or socializing (reviewed in Richardson et al. 1995b). Past experiences of the animals with vessels are important in determining the degree and type of response elicited from a whale-vessel encounter.

Whales react most noticeably to erratically moving vessels with varying engine speeds and gear changes, and to vessels in active pursuit. Avoidance reactions by bowheads sometimes begin as subtle alterations in whale activity, speed and heading as far as 4 km (2.5 mi) from the vessel. Consequently, the closest point of approach is farther from the vessel than if the cetacean had not altered course. Bowheads sometimes begin to swim actively away from approaching vessels when they come within 2–4 km (1.2–2.5 mi). If the vessel approaches to within several hundred meters, the response becomes more noticeable and whales sometimes change direction to swim perpendicularly away from the vessel path (Richardson et al. 1985, 1995b; Richardson and Malme 1993).

During the drilling and oil production phase of the Northstar development, most vessel traffic involves slow-moving tugs and barges and smaller faster-moving vessels providing local transport of equipment, supplies and personnel. Much of this traffic will occur during August and early September before many whales are in the area. Some vessel traffic during the broken ice periods in the spring and fall may also occur. Alternatively, small hovercraft may be used during the spring and fall when the ice is too thin to allow safe passage by large vehicles over the ice road.

Whale reactions to slow-moving vessels are less dramatic than are their reactions to faster and/or erratic vessel movements. Bowhead, gray and beluga whales often tolerate the approach of slow-moving vessels within several hundred meters. This is especially so when the vessel is not directed toward the whale and when there are no sudden changes in direction or engine speed (Wartzok et al. 1989; Richardson et al. 1995b; Heide-Jørgensen et al. 2003).

Most vessel traffic associated with Northstar will be inshore of the bowhead and beluga migration corridor, and/or prior to the migration season of bowhead and beluga whales. Underwater sounds from hovercraft are generally lower than for standard vessels since the sound is generated in air, rather than underwater. If vessels or hovercraft do approach whales, a small number of individuals may show short-term avoidance reactions. These will be of no long-term significance to individuals and the population.

The highest levels of underwater sound produced by routine Northstar operations are generally associated with Northstar-related vessel operations. These vessel operations around Northstar sometimes result in sound levels high enough that a small number of the bowheads in the southern part of the migration corridor appear to be deflected slightly offshore (see above). To the extent that offshore deflection occurs as a result of Northstar, it is mainly attributable to Northstar-related vessel operations. As previously described, this deflection is expected to involve few whales and generally small deflections, and is unlikely to have important consequences for individual bowheads or their populations.

Most vessel traffic associated with Northstar will be south and west of Cross Island. The vessel traffic is not expected to affect subsistence activities at Cross Island.

Effects of Oil on Cetaceans

Bowhead and beluga whales migrate through the Alaskan Beaufort Sea, and a limited number of gray whales sometimes occur in the area during some years. Almost all of these whales are north of the barrier islands, and most of the belugas follow a far-offshore migration corridor.

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

In the case of an oil spill occurring during migration periods, disturbance of the migrating cetaceans from cleanup activities may have more of an impact than the oil itself. Human activity associated with cleanup efforts could deflect whales away from the path of the oil. However, noise created from cleanup activities likely will be short term and localized with no long-term consequences for individuals or populations. In fact, whale avoidance of clean-up activities may benefit whales by displacing them from the oil spill area.

There is no concrete evidence that oil spills, including the much studied Santa Barbara Channel and Exxon Valdez spills, have caused the death of cetaceans (Geraci 1990; Brownell 1971; Harvey and Dahlheim 1994). It is suspected that some individually identified killer whales that disappeared from Prince William Sound during the time of the Exxon Valdez spill were casualties of that spill. However, no clear cause and effect relationship between the spill and the disappearance could be established (Dahlheim and Matkin 1994). The AT-1 pod of transient killer whales that sometimes inhabits Prince William Sound has continued to decline after the Exxon Valdez oil spill, and has been nominated for listing on the Endangered Species List. No effects on humpback whales in Prince William Sound were evident after the Exxon Valdez spill (von Ziegesar et al. 1994). There was some temporary displacement of humpback whales out of Prince William Sound, but this could have been caused by oil contamination, boat and aircraft disturbance, displacement of food sources, or other causes.

Migrating gray whales were apparently not greatly affected by the Santa Barbara spill. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill represented increased survey effort

(Brownell 1971; Geraci 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci 1990).

Oiling of External Surfaces

Whales rely on a layer of blubber for insulation, so oil would have little if any effect on thermoregulation by whales. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's heath (Geraci 1990). It can be assumed that if oil contacted the eyes, effects would be similar to those observed in ringed seals; continued exposure of the eyes to oil could cause permanent damage (St. Aubin 1990).

Ingestion

Whales could ingest oil if their food is contaminated, or oil could also be absorbed through the respiratory tract. Some of the ingested oil is voided in vomit or feces but some is absorbed and can cause toxic effects (Geraci 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978, 1982). Whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980, 1982) and this kind of damage has not been reported (Geraci 1990).

Fouling of Baleen

Baleen itself is not damaged by exposure to oil and is resistant to effects of oil (St. Aubin et al. 1984). Crude oil could coat the baleen and reduce filtration efficiency; however, effects may be temporary (Braithwaite 1983; St. Aubin et al. 1984). Most of the oil that would coat the baleen is removed after 30 min and less than 5% would remain after 24 h (Bratton et al. 1993). Effects of oiling of the baleen on feeding efficiency appear to be minor (Geraci 1990).

Avoidance

Some cetaceans can detect oil and sometimes avoid it, but others enter and swim through slicks without apparent effects (Geraci 1990; Harvey and Dahlheim 1994). Bottlenose dolphins apparently could detect and avoid slicks and mousse but did not avoid light sheens on the surface (Smultea and Würsig 1995). After the Regal Sword spill, various species of baleen and toothed whales were observed swimming and feeding in areas containing spilled oil southeast of Cape Cod, MA (Goodale et al. 1981).

Factors Affecting the Severity of Effects

Effects of oil on whales in open water are likely to be negligible, but there could be effects on whales where both the oil and the whales are at least partly confined in leads or at ice edges (Geraci 1990). In spring migrating bowhead and beluga whales migrate through leads in the ice. At this time, the migration can be concentrated in narrow corridors defined by the leads. However, given the probable alongshore trajectory of oil spilled from Northstar in relation to the whale migration route through offshore waters, interactions between oil slicks and whales are unlikely in spring.

In fall, the migration route of bowheads can be close to shore (Blackwell et al. 2009). If fall migrants were moving through leads in the pack ice, or were concentrated in nearshore waters, some bowhead whales might not be able to avoid oil slicks and could be subject to prolonged contamination. However, the autumn migration past the Northstar area extends over several weeks and most of the whales travel along routes well north of Northstar. Thus, only a small minority of the whales are likely to approach patches of spilled oil. Additionally, vessel activity associated with spill cleanup efforts may deflect the small number of whales traveling nearshore farther offshore, and thereby reduce the likelihood of contact with spilled oil. Also, during years when movements of oil and whales might be partially confined by ice, the bowhead migration corridor tends to be farther offshore (Treacy 1997; LGL and Greeneridge 1996a; Moore 2000).

Effects of Oil-Spill Cleanup Activities

General issues related to oil-spill cleanup activities are discussed under "Pinnipeds", above. The potential effects on cetaceans are expected to be less than those on seals. Cetaceans tend to occur well offshore where cleanup activities (in the open-water season) are unlikely to be as concentrated. Also, cetaceans are transient and, during the majority of the year, absent from the area. However, if intensive cleanup activities were necessary during the autumn whale hunt, this could affect subsistence hunting (see Section 8, below).

Conclusions Regarding Effects on Cetaceans

The proposed activity will consist of oil production and associated gas injection, minor construction operations (i.e., island maintenance and repair), and possible drilling activity during two main periods: the ice-covered season and the open-water season. During the ice-covered season, cetaceans will not be in the Northstar areas. The planned activities will have no effect on bowhead or beluga whales migrating east through offshore waters of the Beaufort Sea during the spring. In the event of an oil spill during winter or spring, it is unlikely that much oil would be carried into the whale migration corridor.

In the open-water period, the principal activities will be related to oil production, and associated helicopter and vessel traffic. Underwater sounds from continuous production activities on the islands are not expected to be detectable more than about 2–4 km (1.2–2.5 mi) offshore of Northstar Island. Sounds of transient nature, such as vessel traffic can be detectable to distances of ~30 km (18.6 mi) from the island. Disturbance to bowhead, gray and beluga whales by on-island activities will be limited to substantially less than that distance. Helicopter traffic will be limited to nearshore areas between the mainland and the islands, and is very unlikely to approach or disturb whales. Barge and vessel traffic will be located mainly inshore of the whales, and will involve vessels moving slowly, in a straight line, and at constant speed. Little disturbance or displacement of whales by vessel traffic is expected. Vessels operating for prolonged periods around Northstar may at times produce sufficient underwater sound to cause slight offshore deflection or other behavioral changes in a small minority of the bowheads passing Northstar at those times. No biologically significant consequences are expected either for individual bowheads or for the population.

8. ANTICIPATED IMPACT ON SUBSISTENCE

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

Inupiat hunters emphasize that all marine mammals are sensitive to noise, and take pains to make as little extraneous noise as possible when hunting. Seals are also said to be cautious of any unusual visual stimulus, especially if it is in motion. At the same time, seals are said to be curious and will sometimes investigate unusual objects, and can be attracted by imitating the normal, non-vocal sounds that seals make on the ice. In general, seals are sensitive to their surroundings, are especially responsive to sound, and may avoid unusual sounds.

Bowhead whales often show avoidance or other behavioral reactions to underwater noise from industrial activities, but often tolerate the weaker noise received when the same activities are occurring farther away. Various studies have provided information about these sound levels and distances (e.g., Richardson and Malme 1993; Richardson et al. 1995a, b; Miller et al. 1999). However, scientific studies done to date have limitations, as discussed in part by Moore and Clarke (1992) and in MMS (1997). Inupiat whalers believe that some migrating bowheads are diverted by noises at greater distances than have been demonstrated by scientific studies (e.g., Rexford 1996; MMS 1997). The whalers have also mentioned that bowheads sometimes seem more "skittish" and more difficult to approach when industrial activities are underway in the area (Galginaitis 2006). There is also concern about the persistence of any deflection of the bowhead migration corridor, and the possibility that sustained deflection might influence subsistence farther “downstream” during the fall migration.

Recently, there has been concern among Inupiat hunters that barges and other vessels operating within or near the bowhead migration corridor may deflect whales for an extended period (J.C. George, NSB-DWM, pers. comm.). It has been suggested that, if the headings of migrating bowheads are altered through avoidance of vessels, the whales may subsequently maintain the “affected” heading well past the direct zone of influence of the vessel. This might result in progressively increasing deflection as the whale progresses west. However, crew boats and barges supporting Northstar remain well inshore of the main migration corridor, so this type of effect is unlikely to occur in response to these types of Northstar-related vessel traffic.

Monitoring studies conducted under the provisions of incidental take authorizations can provide some of the data needed to resolve questions about the radius of influence of industrial activities on bowheads (e.g., Richardson [ed.] 1999, 2008). Monitoring studies during the Northstar project were designed in consultation with representatives of the whalers to help ensure consensus on the methods and on the meaning of the results (Section 13). In addition, BP developed a plan of cooperation with the whalers in previous years (see Section 12) to reduce any potential interference with the hunt.

Potential effects on subsistence could result from direct actions of oil development upon the biological resources or from associated changes in human behavior. For example, the perception that marine mammals might be contaminated or “tainted” by an oil spill could affect subsistence patterns whether or not many mammals are actually contaminated. The following discussion addresses both aspects.

Marine Mammal Harvests in the Project Area

Residents of the village of Nuiqsut are the primary subsistence users in the project area. The communities of Barrow and Kaktovik also harvest resources that pass through the area of interest but do not hunt in or near the Northstar area. Subsistence hunters from all three communities conduct an annual hunt for autumn-migrating bowhead whales. Barrow also conducts a bowhead hunt in spring. Residents of all three communities hunt seals. Other subsistence activities include fishing, waterfowl and seaduck harvests, and hunting for walrus and beluga, polar bears, caribou, and moose. Relevant harvest data are summarized in Tables 8 and 9.

The annual take of bowhead whales has varied due to (a) changes in the allowable quota level and (b) year-to-year variability in ice and weather conditions, which strongly influence the success of the hunt. Locations of bowhead whale strikes and kills are available through the North Slope Borough, Alaska Eskimo Whaling Commission, Galginaitis (2009), and EDAW/AECOM 2007.

Nuiqsut is the community closest to the Northstar development (~87 km or 54 mi southwest from Northstar). Nuiqsut hunters harvest bowhead whales only during the fall whaling season (Long 1996). In recent years, Nuiqsut whalers have typically landed three or four whales per year (Table 9). Nuiqsut whalers concentrate their efforts on areas north and east of Cross Island, generally in water depths greater than 20 m (65 ft; Galginaitis 2009). Cross Island is the principal base for Nuiqsut whalers while they are hunting bowheads (Long 1996). Cross Island is located approximately 27 km (16.8 mi) east of Northstar.

Kaktovik whalers search for whales east, north and occasionally west of Kaktovik. Kaktovik is located approximately 200 km (124 mi) east of Northstar Island. The western-most reported harvest location was about 21 km (13 mi) west of Kaktovik, near 70º10'N, 144º11'W (Kaleak 1996). That site is about 180 km (112 mi) east of Northstar Island.

Barrow whalers search for whales much farther from the Northstar construction area—about 250+ km (175+ mi) to the west. However, given the westward migration of bowheads in autumn, Barrow (unlike Kaktovik) is "downstream" from the Northstar region during that season. Barrow hunters have expressed concern about the possibility that bowheads might be deflected offshore by Northstar and then remain offshore as they pass Barrow.

TABLE 8. Subsistence harvest data (as percent of total harvest) by species, total harvest and Per Capita harvest. Source: Table 7.3 in Braund and Kruse (2009). The footnotes in the Table refer to more detailed source information summarized by Braund and Kruse (2009).

	Point Lay[1]	Barrow[2]		Wainwright[3]	Nuiqsut[4]	Kaktovik[4]	
Resource	**1987**	**1962-82[1]**	**1987-89**	**1988-89**	**1993**	**1962-82**	**1992-93**
Bowhead Whale	—	21%	38%	35%	29%	28%	63%
Caribou	16	58	27	23	31	16	11
Walrus	4	5	9	27	—	3	—
Bearded Seal	2	3	4	5	—	7	2
Hair Seals	4	4	2	1	3	4	1
Beluga Whales	64	1	—	1	—	6	—
Polar Bears	<1%	—	2	2	—	3	1
Moose	2	—	3	<1%	2	4	1
Dall Sheep	—	—	<1%	<1%	—	4	3
Muskox	—	—	<1%	<1%	—	—	2
Grizzly Bear	<1%	—	—	—	<1%	—	—
Small Land Mammals	<1%	—	<1%	<1%	<1%	—	—
Birds	5	1	4	2	2	—	2
Fishes	3	7	11	5	34	22	13
Vegetation	<1%	—	<1%	<1%	<1%	—	—
Total	100%	100%	100%	100%	100%	100%	100%
Total Harvest (lb)	100,681	928,205	702,660	304,047	267,818	32,408	170,939
Per Capita Harvest (lb)	819	540	233	638	742	219	886

TABLE 9. Bowhead landings at Barrow, Nuiqsut and Kaktovik, 1978–2005 (from Burns et al. 1993; IWC Reports SC/59/BRG4, SC/60/BRG10, SC61/BRG6; Alaska Eskimo Waling Commission [AEWC]; J.C. George, NSB DWM; and EDAW/AECOM 2007).

Year	IWC Quota for whaling villages in Alaska	Barrow		Kaktovik		Nuiqsut	
		Quota	Landed	Quota	Landed	Quota	Landed
1973	N/A	N/A	17	N/A	3	N/A	1
1974	N/A	N/A	9	N/A	2	N/A	0
1975	N/A	N/A	10	N/A	0	N/A	0
1976	N/A	N/A	23	N/A	2	N/A	0
1977	N/A	N/A	20	N/A	2	N/A	0
1978	14 landed or 20 struck	3 landed or 5 struck	4	1 landed or 2 struck	2	1 landed or 2 struck	0
1979	18 landed or 27 struck	5 landed or 7 struck	3	2 landed or 3 struck	5	1 landed or 3 struck	0
1980	18 landed or 26 struck	6 landed or 7 struck	9	2 landed or 3 struck	1	1 landed or 1 struck	0
1981	16 landed or 27 struck	9	4	3	3	1	0
1982	17 landed or 27 struck	5	0	2	1	1	1
1983	18 landed or 27 struck	4	2	2	1	1	0
1984	27 struck	8	4	3	1	1	0
1985	27 struck	4	5	2	0	1	0
1986	32 struck	9	8	3	3	2	1
1987	32 struck	9	7	3	0	2	1
1988	35 struck	11	11	2	1	2	0
1989	41 landed or 44 struck	15	10	2+1	3	2	2
1990	41 landed or 47 struck	15	11	2	2	2	0
1991	41 landed or 44 struck	15	12	2	1	2	1
1992	41 landed or 54 struck	18	22	3	3	3	2
1993	41 landed or 54 struck	18 (+5)	23	3	3	3	3
1994	41 landed or 52 struck	18	16	3	3	3	0
1995	68 struck	22 (+2)	19	3+1	4	4	4
1996	77 struck	22	24	3	1	4	2
1997	76 struck	22 (+8)	30	3+1	4	4	3
1998	77 struck	22	16	3	3	4	4
1999	75 struck	22	24	3	3	4	3
2000	75 struck	22	18	3	3	4	4
2001	75 struck	22	27	3	4	4	3
2002	75 struck	22	22	3	3	4	4
2003	75 struck	22	16	3	3	4	4
2004	75 struck	22	21	3	3	4	3
2005	75 struck	22	29	3	3	4	1
2006	75 struck	22	22	3	3	4	4
2007	75 struck	22	20	3	3	4	3
2008	75 struck	22	21	3	3	4	4

Effects of Routine Production Operations, Repair and Maintenance

Bowhead Whale Harvest

The disturbance and potential displacement of bowhead whales and other marine mammals by sounds from vessel traffic or on-island activities are the principal concerns related to subsistence use of the area. The harvest of marine mammals is central to the culture and subsistence economies of the coastal North Slope communities. In particular, if elevated noise levels displace migrating bowhead whales farther offshore, this could make harvest of these whales more difficult and dangerous for hunters. The harvest could also be affected if bowheads are more "skittish" when exposed to vessels or impact hammering noise.

Few bowhead whales approach the project area before the end of August, and autumn whaling at Cross Island generally does not begin until after 1 September. Whaling at Cross Island is usually completed by late September, and the bowhead migration usually ends by late October. Insofar as possible, BP's vessel traffic near areas of particular concern for whaling will be completed before the end of August.

Drilling at Northstar began in December 2000 and production operations began in late October 2001. The planned well-drilling program was completed in May 2004. Drilling activities to drill new wells, conduct well maintenance, and drill well side-tracks continued in 2006 (6 wells), 2007 (2 wells) and 2008 (2 wells). The drill rig is expected to be demobilized by barge during the 2010 open-water period. Although future drilling is not specifically planned, drilling of additional wells or well workover may be required at some time during 2011–2016. Production will continue for the foreseeable future at Northstar.

Underwater sounds from drilling and production operations on an artificial gravel island are not very strong, and are not expected to travel more than about 10 km (6.2 mi; Table 5). Vessel sounds account for the highest sound levels at Northstar, and at times they are detectable considerably farther away (Blackwell and Greene 2006). Harvests have remained high at Cross Island in recent years despite sounds from Northstar, and in most recent years the quota has been filled quickly (Galginaitis 2007, 2008, 2009).

Northstar is west of the main hunting area for Nuiqsut hunters. On most occasions, even the bowheads traveling along the southern edge of the migration corridor are not expected to hear sounds from Northstar until the whales are well west of the main hunting area. (Times with considerable vessel activity at Northstar would be the exception.) As noted above, when industrial sounds at Northstar were high, some bowheads traveling in the southern part of the migration corridor appeared to have been deflected a few kilometers farther offshore or to have called less often (McDonald et al. 2008; Richardson et al. 2008a). This effect would not be expected to occur offshore of Cross Island, 27 km (16.8 mi) east of Northstar.

In addition to activities at Northstar, drilling and production operations will include slow-moving vessels, a hovercraft, and limited helicopter activity. Overt whale reactions to slow-moving vessels and to helicopters traveling in a straight line are limited to close distances and short durations. In addition, whenever possible, helicopters will fly at a minimum altitude of 305 m (1,000 ft). Most vessel and helicopter traffic will be well inshore of the bowhead migration corridor. Bowhead whales will rarely be approached by these vessels and helicopters, any such approaches will not be within the area where Nuiqsut hunters usually search for bowheads, and any whale reactions to these approaches will be brief and localized.

The monitoring implemented during 2000–2004 (Richardson [ed.] 2008) has provided data that resolve many of the previous uncertainties about the characteristics and propagation of construction and operational noises, and about their effects on bowhead whales. Sounds from important BP activities associated with Northstar have been recorded and the resulting acoustic data have been described in the final comprehensive report (Richardson [ed.] 2008), various annual reports (Richardson [ed.] 2006, 2007; Aerts and Richardson [eds.] 2008, 2009) and papers (e.g., Blackwell and Greene 2004, 2005, 2006; Greene et al. 2008). The whale migration in the area just west of Cross Island and offshore of Northstar has been monitored, and the migration corridor has been found to be no more than slightly and locally affected by Northstar. These results from intensive monitoring, along with the successful harvests at Cross Island in recent years, indicate that any effects of Northstar on bowheads have not reduced the availability of bowheads for the Nuiqsut subsistence hunters.

In summary, it is not expected that routine production activities will affect the accessibility of bowhead whales to hunters. Nonetheless, BP recognizes that it is difficult to determine the maximum distance at which whale reactions to industry activities occur, and that effects may extend to distances somewhat greater than those demonstrated in the scientific studies. As in previous years, BP will discuss a plan of cooperation with the whalers (Section 12) to reduce any potential interference with the hunt. The timing and characteristics of production, drilling and other operations at Northstar, and of barge and aircraft traffic west and south of Cross Island, will be addressed in that agreement. In addition, BP recognizes that the presence of Northstar instills a sense of anxiety among the hunters with regard to potential impacts, even though these potential impacts do not appear to be occurring.

Pinniped and Beluga Harvests

Coastal communities in the Beaufort Sea also take seals plus small numbers of walruses and beluga whales. The seal harvest during winter and spring is principally of ringed seals. During the open water period both ringed and bearded seals are commonly taken. Belugas are not a significant subsistence resource at Nuiqsut, given the offshore migration routes and the lack of any coastal concentrations in that area. Subsistence issues relating to walruses (and polar bears) are considered in separate incidental take regulations of the U.S. Fish and Wildlife Service and are not discussed further here.

Nuiqsut hunters may hunt seals year-round, but during recent years most of the seal harvest has been during the early summer in open water (the late Thomas Napageak, pers. comm.). In summer, boat crews hunt ringed, spotted and bearded seals. The most important seal hunting area for Nuiqsut hunters is off the Colville Delta, extending as far west as Fish Creek and as far east as Pingok Island (149º40’W). Pingok Island, the closest edge of the main sealing area, is ~17 mi (27 km) west of Northstar. Sealing occurs in this area by snow machine before break-up and by boat during the summer. Cross Island is a productive area for seals, but is too far from Nuiqsut to be used on a regular basis. During the whaling season, the hunters at Cross Island concentrate on bowhead whales, not seals.

Drilling and oil production activities at Northstar have little potential to influence seal hunting activities by residents of Nuiqsut, given the distance of these development sites from areas where

Nuiqsut residents usually hunt seals. In winter and spring, a small number of ringed seals may be disturbed and possibly displaced from areas near Northstar, and from locations near ice roads. During the open water season, displacement of seals would also be highly localized. Effects of support traffic (vessels and helicopters) on seals are expected to be minor and to be limited to the areas along the routes of travel, most of which will be well to the east of the main hunting area. Thus, it is unlikely that drilling and production activity, or associated traffic, would have a significant negative impact on Nuiqsut seal hunting. Concerns about this are addressed in the plan of cooperation (Section 12).

Effects of Oil Spills

Oil spills might affect the hunt for bowhead whales. The harvest period for bowhead whales is probably the time of greatest risk that a relatively large-scale spill would reduce the availability of bowhead whales for subsistence uses. Pipeline spills are possible for the total production period of Northstar. Spills could occur at any time of the year. However, spills at most times of year would not affect bowheads, as bowheads are present near Northstar for only several weeks during late summer and early autumn. Bowheads travel along migration corridors that are far offshore of the planned production islands and pipelines during spring, and somewhat offshore of those facilities during autumn. Under the prevailing east-wind conditions, oil spills from Northstar would not move directly into the main hunting area east and north of Cross Island. However, oil spills could extend into the hunting area under certain wind and current regimes (Anderson et al. 1999).

Even in case of a major spill, it is unlikely that more than a small minority of the bowheads encountered by hunters would be contaminated by oil. However, disturbance associated with reconnaissance and cleanup activities could affect whales and thus accessibility of whales to hunters. In the very unlikely event that a major spill incident occurred during the relatively short fall whaling season, it is possible that hunting would be affected significantly.

Ringed seals are more likely than bowheads to be affected by spill incidents, because they occur in the development areas throughout the year and are more likely than whales to occur close to Northstar. Small numbers of bearded seals could also be affected, especially by a spill during the open-water season. Potential effects on subsistence use of seals will still be relatively low, as the areas most likely to be affected are not areas heavily used for seal hunting. However, wind and currents could carry spilled oil west from Northstar to areas where seal hunting occurs. It is possible that oil-contaminated seals could be harvested.

Oil spill cleanup activity could exacerbate and increase disturbance effects on subsistence species, cause localized displacement of subsistence species, and alter or reduce access to those species by hunters. On the other hand, the displacement of marine mammals away from oil-contaminated areas by cleanup activities would reduce the likelihood of direct contact with oil and thus tainting or other impacts on the mammals.

One of the most persistent effects of EVOS was the reduced harvest and consumption of subsistence resources, due to the local perception that they had been tainted by oil (Fall and Utermohle 1995). The concentrations of petroleum-related aromatic compound (AC) metabolites in the bile of harbor seals were greatly elevated in harbor seals from oiled areas of Prince William Sound. Mean concentrations of phenanthrene (PHN) equivalents for oiled seals from PWS was over 70 times greater than for control areas, and over 20 times higher than for presumably unoiled areas of

PWS (Frost et al. 1994b). Concentrations of hydrocarbons in harbor seal tissues collected in PWS one year after EVOS were not significantly different from seals collected in non-oiled areas; however, average concentrations of AC metabolites in bile were still significantly higher than those observed in un-oiled areas (Frost et al. 1994b). The pattern of reduced consumption of marine subsistence resources by the local population persisted for at least a year. Most affected communities had returned to documented pre-spill harvest levels by the third year after the spill. Even then, some households in these communities still reported that subsistence resources had not recovered to pre-spill levels. Harvest levels of subsistence resources for the three communities most affected by the spill still were below pre-spill averages even after three years. By then, the concern was mainly about smaller numbers of animals rather than contamination. However, contamination remained an important concern for some households (Fall and Utermohle 1995). As an example, an elder stopped eating local salmon after the spill, even though salmon is the most important subsistence resource and he ate it every day up to that point. Similar effects could be expected after a spill on the North Slope, with the extent of the decline in harvest and use, and the temporal duration of the effect, dependent upon the size and location of the spill. This analysis reflects the local perception that oil spills pose the greatest potential danger associated with offshore oil production.

Summary

In summary, direct effects of routine drilling and oil production activities upon subsistence uses of marine mammals (mainly ringed seals and bowhead whales) will be minimal. In winter, the ringed seal is the only relevant species present. Winter use of the development areas by subsistence hunters is limited or nil. No seal hunting or harvests were observed during the intensive marine mammals monitoring from 1997–2002 or subsequent observations of seals by island personnel. Seals are also present near Northstar throughout the open water season, but are not hunted in those locations to any significant extent. Bowhead whales are absent in the early part of the open water season. Bowheads migrate through the general area during late summer and autumn, mainly offshore of Northstar. Ongoing production and maintenance activities, and possible resumption of drilling activities, are not expected to affect the bowhead migration corridor or bowhead behavior in the hunting areas used by Nuiqsut, Kaktovik, or Barrow whalers.

Local concerns about these issues will be addressed in the updated Plan of Cooperation (Section 12) and by ongoing monitoring (Section 13). An acoustic and marine mammal monitoring program is planned for 2011–2016. This program will measure underwater sounds from Northstar and provide a basis for determining if there are major changes in utilization of the Northstar area by marine mammals (which are not expected). The future monitoring program will be revised as necessary based on guidance from the NMFS and NSB-DWM.

The only situation in which there could be direct, major effects on subsistence would be in the unlikely event of a large oil spill during whaling. The probability of such a spill occurring over the life of the field is low (S.L. Ross Environmental Research Ltd. 1998). However, because subsistence harvests are socio-culturally based, perception is an important component that cannot be adequately addressed by biological studies alone (Fall and Utermohle 1995).

9. ANTICIPATED IMPACT ON HABITAT

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

Food of Seals and Whales

The ringed seal, the most common seal near Northstar, feeds on fish and a variety of benthic species, including crabs and shrimp. Bearded seals feed mainly on benthic organisms, primarily crabs, shrimp, and clams. Spotted seals feed on pelagic and demersal fish, as well as shrimp and cephalopods. They are known to feed on a variety of fish including herring, capelin, sand lance, Arctic cod, saffron cod, and sculpins.

Bowhead whales feed in the eastern Beaufort Sea during summer and early autumn, but continue feeding to varying degrees while on their migration through the central and western Beaufort Sea in the late summer and fall (Richardson and Thomson [eds.] 2002). When feeding in relatively shallow areas such as those where oil development may occur, bowheads feed throughout the water column. However, feeding is concentrated at depths where zooplankton is concentrated (Würsig et al. 1984, 1989; Richardson [ed.] 1987; Griffiths et al. 2002). Lowry and Sheffield (2002) found that copepods and euphausiids were the most common prey found in stomach samples from bowhead whales harvested in the Kaktovik area from 1979 to 2000. Areas to the east of Barter Island appear to be used regularly for feeding as bowhead whales migrate slowly westward across the Beaufort Sea (Thomson and Richardson 1987; Richardson and Thomson [eds.] 2002). However, in some years, sizable groups of bowhead whales have been seen feeding as far west as the waters just east of Point Barrow near the Plover Islands (Braham et al. 1984; Ljungblad et al. 1985; Landino et al. 1994). The situation in September–October 1997 was unusual in that bowheads fed widely across the Alaskan Beaufort Sea, including higher numbers in the area east of Barrow than reported in any previous year (S. Treacy and D. Hansen, MMS, pers. comm.).

Beluga whales feed on a variety of fish, shrimp, squid and octopus (Burns and Seaman 1985). Very few beluga whales occur near Northstar; their main migration route is much further offshore.

Gray whales are primarily bottom feeders, and benthic amphipods and isopods form the majority of their summer diet, at least in the main summering areas west of Alaska (Oliver et al. 1983; Oliver and Slattery 1985). Farther south, gray whales have also been observed feeding around kelp beds, presumably on mysid crustaceans, and on pelagic prey such as small schooling fish and crab larvae (Hatler and Darling 1974).

Marine Fish

Two kinds of fish inhabit marine waters in the study area: (1) true marine fish that spend all of their lives in salt water, and (2) anadromous species that reproduce in fresh water and spend parts of their life cycles in salt water.

Most arctic marine fish species are small, benthic forms that do not feed high in the water column. The majority of these species are circumpolar and are found in habitats ranging from deep offshore water to water as shallow as 5–10 m (16–30 ft; Fechhelm et al. 1995). The most important pelagic species, and the only abundant pelagic species, is the Arctic cod. The Arctic cod is a major vector for the transfer of energy from lower to higher trophic levels (Bradstreet et al. 1986). In summer, Arctic cod can form very large schools in both nearshore and offshore waters (Craig et al. 1982; Bradstreet et al. 1986). Locations and areas frequented by large schools of Arctic cod cannot be predicted, but can be almost anywhere. The Arctic cod is a major food source for beluga whales, ringed seals, and numerous species of seabirds (Frost and Lowry 1984; Bradstreet et al. 1986).

Anadromous Dolly Varden char and some species of whitefish winter in rivers and lakes, migrate to the sea in spring and summer, and return to fresh water in autumn. Anadromous fish form the basis of subsistence, commercial, and small regional sport fisheries. Dolly Varden char migrate to the sea from May through mid-June (Johnson 1980) and spend about 1.5 to 2.5 months there (Craig 1989). They return to rivers beginning in late July or early August with the peak return migration occurring between mid-August and early September (Johnson 1980). At sea, most anadromous corregonids (whitefish) remain in nearshore waters within several kilometers of shore (Craig 1984, 1989). They are often termed "amphidromous" fish in that they make repeated annual migrations into marine waters to feed, returning each fall to overwinter in fresh water.

Marine Invertebrates

Benthic organisms are defined as bottom dwelling creatures. Infaunal organisms are benthic organisms that live within the substrate and are often sedentary or sessile (bivalves, polychaetes). Epibenthic organisms live on or near the bottom surface sediments and are mobile (amphipods, isopods, mysids, and some polychaetes). Epifauna, which live attached to hard substrates, are rare in the Beaufort Sea because hard substrates are scarce there. A small community of epifauna, the Boulder Patch, occurs in Stefansson Sound.

The benthic environment near Northstar appears similar to that reported in various other parts of the Arctic (Ellis 1960, 1962, 1966; Dunbar 1968; Wacasey 1975). Many of the nearshore benthic marine invertebrates of the Arctic are circumpolar and are found over a wide range of water depths (Carey et al. 1975). Species identified include polychaetes (*Spio filicornis*, *Chaetozone setosa*, *Eteone longa*), bivalves (*Cryrtodaria kurriana*, *Nucula tenuis*, *Liocyma fluctuosa*), an isopod (*Saduria entomon*), and amphipods (*Pontoporeia femorata*, *P. affinis*).

Nearshore benthic fauna have been studied in lagoons west of Northstar and near the mouth of the Colville River (Kinney et al. 1971, 1972; Crane and Cooney 1975). The waters of Simpson Lagoon, Harrison Bay, and the nearshore region support a number of infaunal species including crustaceans, mollusks and polychaetes. In areas influenced by river discharge, seasonal changes in salinity can greatly influence the distribution and abundance of benthic organisms. Large fluctuations in salinity and temperature that occur over a very short time period, or on a seasonal basis, allow only the very adaptable, opportunistic species to survive (Alexander et al. 1974). Since shorefast ice is present for many months, the distribution and abundance of most species depends on annual (or more frequent) recolonization from deeper offshore waters (Woodward Clyde Consultants 1995). Due to ice scouring, particularly in water depths of <2.4 m (8 ft), infaunal communities tend to be patchily distributed. Diversity increases with water depth until the shear zone is reached at 15–25 m (50–80 ft; Carey 1978). Biodiversity then declines due to ice gouging between the landfast ice and the polar pack ice (Woodward Clyde Consultants 1995).

Effects of Routine Production Operations

Noise Effects on Food of Seals and Whales

Construction activities produced both impulsive sounds (e.g., pile driving) and longer-duration sounds. Short, sharp sounds can cause overt or subtle changes in fish behavior. Chapman and Hawkins (1969) tested the reactions of whiting (hake) in the field to an airgun. When the airgun was fired, the fish dove from 25 to 55 m (80 to 180 ft) depth and formed a compact layer. The whiting dove when received sound levels were higher than 178 dB re 1 µPa (Pearson et al. 1992).

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

- startle responses at received levels of 200–205 dB re 1 µPa and above for two sensitive species, but not for two other species exposed to levels up to 207 dB;
- alarm responses at 177–180 dB for the two sensitive species, and at 186 to 199 dB for other species;
- an overall threshold for the above behavioral response at about 180 dB;
- an extrapolated threshold of about 161 dB for subtle changes in the behavior of rockfish; and
- a return to pre-exposure behaviors within the 20-60 minute exposure period.

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

The reactions of fish to research vessel sounds have been measured in the field with forward-looking echosounders. Sound produced by a ship varies with aspect and is lowest directly ahead of the ship and highest within butterfly-shaped lobes to the side of the ship (Misund et al. 1996). Because of this directivity, fish that react to ship sounds by swimming in the same direction as the ship may be guided ahead of it (Misund 1997). Fish in front of a ship that show avoidance reactions may do so at ranges of 50 to 350 m (164 to 1148 ft; Misund 1997), though reactions probably will depend on the species of fish. In some instances, fish will avoid the ship by swimming away from the path and will become relatively concentrated to the side of the ship (Misund 1997). Most schools of fish will show avoidance if they are not in the path of the vessel. When the vessel passes over fish, some species, in some cases, show sudden escape responses that include lateral avoidance and/or downward compression of the school (Misund 1997). Some fish show no reaction. Avoidance reactions are quite variable and depend on species, life history stage, behavior, time of day, whether the fish have fed, and sound propagation characteristics of the water (Misund 1997).

Behavior of zooplankters is not expected to be affected by drilling and production operations at Northstar. These animals have exoskeletons and no air bladders. Many crustaceans can make sounds and some crustacea and other invertebrates have some type of sound receptor. However, the reactions of zooplankters and benthic animals 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. Impacts on zooplankton behavior are predicted to be negligible and this would translate into negligible impacts on feeding bowheads.

Habitat Disruption

The main impact issues associated with drilling and production activity will be temporarily elevated noise levels, as other emissions are strictly controlled, and bottom disturbance is a natural phenomenon in this region. Sea floor surface disruption associated with island construction and pipeline trenching likely resulted in disturbance to benthic communities within the island and pipeline footprint. These communities have a naturally patchy distribution. In nearshore areas such as the Northstar development and along the pipeline route, these communities are subject to natural seasonal disruption by ice scour and ice gouging of the sea floor and transport of significant amounts of suspended sediments due to river outflow and coastal erosion (MBC 2003). This suggests that recovery of disturbed areas will occur in a manner similar to that occurring after natural disturbance, except for those areas buried by island construction. Effects of pipeline trenching on total suspended sediments in the water column were localized within ~500 m (1,640 ft) and effects are likely indistinguishable from naturally occurring disturbances to the benthos by sea ice, river outflow, and coastal erosion (MBC 2003). In addition, the island slope protection system introduced hard bottom structures for possible colonization by arctic kelp species, some invertebrates and fish.

Oil Spills

Oil spill probabilities for the Northstar project have been calculated based on historic oil spill data. Probabilities vary depending on assumptions and method of calculation. A recent reanalysis of worldwide oil spill data indicates the probability of a large oil spill (>1,000 barrels) during the lifetime of Northstar is low (S.L. Ross Environmental Research Ltd. 1998). That report uses standardized units such as well-years and pipeline mile-years to develop oil spill probabilities for the Northstar project. Well-years represent the summed number of years that the various wells will be producing, and mile-years represent the length of pipeline times the amount of time the pipeline is in service. The calculated probability of a large oil spill allows for the state-of-the-art engineering and procedures used at Northstar. That probability is far lower than previously-estimated probabilities (23-26%), which were based on MMS studies of offshore oil field experience in the Gulf of Mexico and California (USACE 1998a).

Oil Effects on Foods of Seals and Whales

Arctic cod and other fishes are a principal food item for beluga whales and seals in the Beaufort Sea. Anadromous fish are more sensitive to oil when in the marine environment than when in the fresh water environment (Moles et al. 1979). Generally, arctic fish are more sensitive to oil than are temperate species (Rice et al. 1983). However, fish in the open sea are unlikely to be affected by an oil spill. Fish in shallow nearshore waters could sustain heavy mortality if an oil slick were to remain in the area for several days or longer. Fish concentrations in shallow nearshore areas that are used as feeding habitat for seals and whales could be unavailable as prey. Because the animals are mobile, effects would be minor during the ice-free period.

Effects of oil on zooplankton as food for bowhead whales were discussed by Richardson ([ed.] 1987). Zooplankton populations in the open sea are unlikely to be depleted by the effects of an oil spill. Oil concentrations in water under a slick are low and unlikely to have anything but very minor effects on zooplankton. Zooplankton populations in near surface waters could be depleted; however, concentrations of zooplankton in near-surface waters generally are low compared to those in deeper water (Bradstreet et al. 1987; Griffiths et al. 2002).

Some bowheads feed in shallow nearshore waters (Bradstreet et al. 1987; Richardson and Thomson [eds.] 2002). Wave action in nearshore waters could cause high concentrations of oil to be found throughout the water column. Oil slicks in nearshore feeding areas could contaminate food and render the site unusable as a feeding area. However, bowhead feeding is uncommon along the coast near the Northstar Development area, and contamination of certain areas would have only a minor impact on bowhead feeding.

Effects of oil spills on zooplankton as food for seals would be similar to those described above for bowhead whales. Effects would be restricted to nearshore waters. During the ice-free period, effects on seal feeding would be minor.

Bearded seals consume benthic animals. Wave action in nearshore waters could cause oil to reach the bottom through adherence to suspended sediments (Sanders et al. 1990). There could be mortality of benthic animals and elimination of some benthic feeding habitat. During the ice-free period, effects on seal feeding would be minor.

Effects on availability of feeding habitat would be restricted to shallow nearshore waters. During the ice-free period, seals and whales could find alternate feeding habitats.

The ringed seal is the only marine mammal present near Northstar in significant numbers during the winter. An oil spill in shallow waters could affect habitat availability for ringed seals during winter. The oil could kill ringed seal food and/or drive away mobile species such as the arctic cod.

Effects of an oil spill on food supply and habitat would be locally significant for ringed seals in shallow nearshore waters in the immediate vicinity of the spill and oil slick in winter. Effects of an oil spill on marine mammal foods and habitat under other circumstances would be negligible.

Oil Effects on Habitat Availability

The subtidal marine plants and animals associated with the Boulder Patch community of Stefansson Sound are not likely to be affected directly by an oil spill from Northstar Island, seaward of the barrier islands and farther west. The only type of oil that can reach the subtidal organisms (located in 5 to 10 m [16 to 33 ft] of water) will be highly dispersed oil created by heavy wave action and vertical mixing. Such oil has no measurable toxicity (MMS 1996). The amount and toxicity of oil reaching the subtidal marine community is expected to be so low as to have no measurable effect. However, oil spilled under the ice during winter, if it reached the relevant habitat, could act to reduce the amount of light available to the kelp species and other organisms directly beneath the spill. This could be an indirect effect of a spill. Due to the highly variable winter lighting conditions, any reduction in light penetration resulting from an oil spill would not be expected to have a significant impact on the growth of the kelp communities.

Depending on the timing of a spill, planktonic larval forms of organisms in arctic kelp communities such as annelids, mollusks, and crustaceans may be affected by floating oil. The contact may occur anywhere near the surface of the water column (MMS 1996). Due to their wide distribution, large numbers, and rapid rate of regeneration, the recovery of marine invertebrate populations is expected to occur soon after the surface oil passes. Spill response activities are not likely to disturb the prey items of whales or seals sufficiently to cause more than negligible effects.

Summary

Overall, the continuation of ongoing Northstar activities is not expected to cause significant impacts on habitats used by marine mammals, or on the food sources that marine mammals utilize. No observations of impacted habitat or food were made during the construction phase and none are anticipated during continued operations. A major oil spill is unlikely, but if it occurred it could have at least local and short-to-medium term effects on habitat availability, especially for seals occupying nearshore waters near the development site where the spill occurred.

10. ANTICIPATED IMPACT OF HABITAT LOSS OR MODIFICATION

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

The footprint for Northstar Island covers ~25 acres of benthic habitat and ~21 acres of seabed were excavated for the two pipelines. Much of the island footprint was in place prior to the beginning of Northstar construction in 2000 as a result of the construction of Seal Island at the same site in 1982. The small additional area covered and excavated was not known to influence marine mammal use.

Ice habitat for ringed seal breathing holes and lairs (especially for mothers and pups) is normally associated with pressure ridges or cracks (Smith and Stirling 1975). The amount of habitat altered by Northstar ice-road construction is minimal compared to the overall habitat available in the region. Densities of ringed seals on the ice near Northstar during late spring are similar to those elsewhere in the region (Miller et al. 1998b; Link et al. 1999; Moulton et al. 2002, 2005). Ringed seals use multiple breathing holes (Smith and Stirling 1975; Kelly and Quakenbush 1990), and are not expected to be adversely affected by the loss of 1–2 breathing holes within the thickened ice road. Ringed seals near Northstar appear to have the ability to open new holes and create new structures throughout the winter, and ringed seal use of landfast ice near Northstar did not appear to be much different than that of ice 2–3.5 km away (1.2–2.2 mi; Williams et al. 2002). Active seal structures were found within 10s of meters of thickened ice (Williams et al. 2006b, c). A few ringed seals occur within areas of artificially thickened ice if cracks that can be exploited by seals form in that thickened ice.

Bowheads are not present near Northstar during the winter and are not normally found in the development area during July through mid-August. Starting in late August and continuing until late October, bowheads may travel close enough to Northstar to hear sounds from Northstar Island or to encounter vessel traffic to and from the island. Some of these migrating bowhead whales might be displaced seaward by the planned activities. To the extent that there is offshore displacement of bowheads as a result of Northstar, it is a subtle and inconsistent effect involving no more than a small proportion of the passing bowheads (Richardson et al. 2008b). Feeding does not appear to be an important activity by bowheads migrating through the central part of the Alaskan Beaufort Sea in most years. In the absence of important feeding areas, the potential diversion of a small number of bowheads from parts of the Northstar development area is not expected to have any significant or long-term consequences for individual bowheads or their population. Bowheads or other whales are not predicted to be excluded from any habitat.

11. MITIGATION MEASURES

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

To minimize the likelihood that impacts will occur to the species, stocks and subsistence use of marine mammals, all activities associated with the Northstar development will be conducted in accordance with all Federal, state and local regulations. BP will coordinate important activities with the relevant Federal and state agencies. These will include the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Minerals Management Service, Biological Resources Division of the U.S. Geological Survey, and Alaska Department of Fish and Game. BP will also coordinate important activities with local authorities (North Slope Borough), representatives of communities (Barrow, Nuiqsut, and Kaktovik), and representatives of whaling captains (Alaska Eskimo Whaling Association (AEWC), and the Barrow (BWCA), Nuiqsut (NWCA), and Kaktovik (KWCA) Whaling Captains Associations. A plan of cooperation was developed between BP and the subsistence users in the region during the previous 5-yr regulations. We anticipate annual renewal/renegotiation of these documents during the subsequent period. This will ensure efforts have been made by BP to minimize the possibility that operational, maintenance, and training activities interfere with the fall hunt for bowheads, and that all activities are conducted safely.

BP has participated in all peer-review workshops convened by NMFS in Seattle and Anchorage since 1998 to discuss ringed seal and bowhead whale mitigation and monitoring methods and results of studies. BP plans to participate in future peer-review workshops sponsored by NMFS.

Mitigation during Production, Facilities Repair and Maintenance

Ice-covered Season

During winter and spring activities on the sea ice, the ringed seal is the only marine mammal species under the jurisdiction of NMFS that is likely to be encountered near Northstar. Winter activities are planned to commence on the sea ice as early as practical before female ringed seals have established their birth lairs and before pups are born. The most likely effects of these early winter activities will be temporary and localized disturbance to a small number of adult and subadult ringed seals. This disturbance will result from ice road construction, traffic on the ice, spill response training, emergency evacuation training, and exposure to noise and vibration from island activities.

Seals may be displaced for a few hours from the immediate area of some activities (Kelly et al. 1986). However, if displacement occurs it is limited to a distance of, at most, 100 m (320 ft) from activities such as those proposed for Northstar (Williams et al. 2006b, c).

Female ringed seals establish their birth lairs before pupping in late March to April. It was thought that female seals would avoid establishing birth lairs in close proximity to on-going activities associated with Northstar. However, the closest suspected birth lairs were found ~1,600 m (1 mi) from the island and 54 m (177 ft) from the ice road in 2001 (Williams et al. 2006b, c). Results of all studies of structure location and seal distribution indicate that no more than limited displacement of ringed seals has occurred.

In the event that construction activities are required after 1 March in a previously undisturbed area of floating landfast ice (i.e., in waters deeper than 3 m [9.8 ft]), a survey with dogs will be completed to delineate an area where activities may proceed without disturbing seal structures or, alternatively, another suitable approach will be taken in consultation with NMFS. In case of dog surveys, trained dogs will search all floating sea ice for any ringed seal structures. Those surveys will be done prior to the new proposed activity on the floating sea ice, to provide information needed to prevent injury or mortality of young seals. Seal structures will be avoided by 150 m (429 ft) during subsequent BP activities, when practicable. Since 2001, no BP's activities took place after 1 March in previously undisturbed areas during late winter and as such no on-ice searches were conducted.

A report will be prepared describing the area searched, activities that occurred, and methods of any surveys with dogs that BP conducts to locate ringed seal lairs that are to be avoided by on-ice activities initiated after mid-March. A report will be submitted to NMFS in preliminary form 90 days after the proposed activity is complete, and in its entirety (methods, results, and discussion) as described for the annual reporting requirement in Section 13.

Broken Ice and Open-water Season

All non-essential boat, hovercraft, barge, and air traffic will be scheduled to avoid periods when whales are migrating through the area. Helicopter operations have the potential to disturb marine mammals. Helicopter flights will be primarily during ice breakup or freeze-up. Unless limited by weather conditions, a minimum flight altitude of 305 m (1,000 ft) ASL will be maintained, except during takeoff and landing. No flights over whales or subsistence hunters are anticipated. Helicopter flights to Northstar will occur in a corridor from the mainland. Essential traffic has been and will continue to be closely coordinated with the NSB and AEWC to avoid disrupting subsistence activities.

The number of marine mammals that are likely to be exposed to activities related to ongoing Northstar operations and maintenance is small relative to their regional populations. Past monitoring has indicated that effects of Northstar activities (with mitigation measures in place) have been limited, when they occur, to short-term behavioral changes by a small number of individual ringed seals and bowhead whales. (Similar short-term behavioral effects might possibly occur in very small numbers of bearded and spotted seals, and beluga or gray whales, though there is no indication of effects on those species as a result of Northstar activities to date.) These behavioral changes have resulted in no greater than negligible impacts on individuals or on the species or stocks. Effects of future (2011–2016) Northstar activities are expected to be no greater than those during initial and continued production in 2002–2009, and less than during the construction period in 2000–2001. No specific rookeries, areas of concentrated feeding or mating, or other areas of special significance for marine mammals occur in or near the planned operational area, although some ringed seal breeding occurs in the general area during the ice covered season.

Impact hammering activities may occur at any time of year to repair sheetpile or dock damage due to ice impingement. Impact hammering is most likely to occur during the ice-covered season or break-up period and would not be scheduled during the fall bowhead migration. Based on studies by Blackwell et al. (2004a), it is predicted that only impact driving of sheet piles or pipes that are in the water (i.e., those on the dock) could produce received levels of 190 dB re 1 μPa (rms), and then only in immediate proximity to the pile. The impact pipe driving in June and July 2000 did not produce received levels as high as 180 dB re 1 μPa (rms) at any location in the water. This was attributable to attenuation by the gravel and sheetpile walls (Blackwell et al. 2004a). We anticipate that received levels for any pile driving that might occur within the sheetpile walls of the island in future would also be less than 180 dB_{rms} at all locations in the water around the island. If impact pile driving were planned in areas outside the sheetpile walls, it is possible that received levels underwater might exceed the 180 dB re 1 μPa (rms) level. Under present NMFS criteria, pinnipeds are not to be exposed to pulses with received levels above 190 dB, and whales are not be exposed to levels above 180 dB re 1 μPa_{rms} (NMFS 2000). Mild and infrequent TTS does not have long-term negative effects on hearing. However, to prevent or at least minimize exposure to sound levels that might elicit TTS, a safety zone will be established and monitored for presence of seals and whales. Establishment of the safety zone of any source predicted to result in received levels underwater above 180 dB_{rms} will be analyzed using existing data collected in the waters of the Northstar facility (see Section 13).

If observations and mitigation are required, a marine mammal observer stationed at an appropriate viewing location on the island will conduct watches commencing 30 minutes prior to the onset of impact hammering or other identified activity. See Section 13 for a detailed description of the observer program. If pinnipeds are seen within the 190 dB re 1 μPa contour (the "safety zone"), then operations will be shut down immediately until the mammals move beyond outside the "safety zone". Whales are very unlikely to be present; however, if they are observed within the 180 dB re 1 μPa (rms) zone, operations will shut down. If no mammal is seen within the “safety zone” for 20 minutes, it will be assumed to have moved beyond the "safety zone", and the activity can resume. During the lifetime of the requested Letter of Authorization, safety criteria different from the provisional 180 and 190 dB criteria of NMFS (2000) may be accepted by NMFS. If so, the new criteria would apply.

A Communications Plan and Conflict Avoidance Agreement (see Section 12) have been negotiated with subsistence hunters and their representatives, and implemented, in previous years. BP expects that these plans will be further discussed and refined in subsequent years. This will confirm that efforts have been made by BP to minimize the possibility that Northstar operations, including vessels, helicopters and other ancillary operations, interfere with the subsistence hunt of bowhead whales.

Contingency Plan for Oil Spills

An oil spill prevention and contingency response plan was developed and approved by the Alaska Department of Environmental Conservation, U.S. Department of Transportation, U.S. Coast Guard, and U.S. Minerals Management Service. The plan has been amended since its initial approval. Major changes since 1999 include the following: seasonal drilling restrictions from June 1 to July 20 and from October 1 until ice becomes 18 inches thick; changes to the response planning standard for a well blowout as a result of reductions in well production rates; and deletion of ice auguring for monitoring potential sub-sea oil pipeline leaks during winter following demonstration of the LEOS leak detection system. Future changes to the response planning standards may be expected in response to declines in well production rates and pipeline throughput.

The plan consists of five parts:

1. Response Action Plan: provides initial emergency response actions and oil spill response scenarios.
2. Prevention Plan: describes facility prevention measures.
3. Supplemental Information: provides background information on the facility, including descriptions of the facility, the receiving environment for potential spills, the incident command system, maximum response operating limitations, response resources (personnel and equipment), response training and drills, and protection of environmentally sensitive areas.
4. Best Available Technology (BAT): provides a rationale for the prevention technology in place at the facility and a determination of whether or not it is BAT.
5. Response Planning Standard: provides calculations of the applicable response planning standards for Northstar, including a detailed basis for the calculation reductions to be applied to the response planning standards.

The plan incorporates by reference a detailed map atlas that summarizes the resources that might be at risk from an oil spill on a seasonal basis, sensitive shoreline types, and key hydrographic, topographic and facility information.

12. PLAN OF COOPERATION

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

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

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

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

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

The AEWC and BP established a conflict avoidance agreement to mitigate the noise and/or traffic impacts of offshore oil and gas production related activities on subsistence whaling.

In addition, the NSB and residents from Barrow, Nuiqsut, and Kaktovik participated in the development of the Final Environmental Impact Statement (FEIS) for the Northstar project. Local residents provided traditional knowledge of the physical, biological, and human environment that has been incorporated into the Northstar FEIS. Also included in the Northstar FEIS is information gathered from the 1996 community data collection, along with relevant testimony during past public hearings in the communities of Barrow, Nuiqsut, and Kaktovik. This data collection has helped ensure that the concerns of NSB residents about marine mammals and subsistence are taken into account in the development of the project designs, permit stipulations, monitoring programs, and mitigation measures.

BP meets annually with communities on the North Slope to discuss the Northstar Development project. Stakeholder and peer review meetings convened by NMFS have been held at least annually from 1998 to the present to discuss proposed monitoring and mitigation plans, and results of completed monitoring and mitigation. Those meetings have included representatives of the concerned communities, the AEWC, the NSB, federal, state, and university biologists, the Marine Mammal Commission, and other interested parties. One function of those meetings has been to coordinate planned construction and operational activities with subsistence whaling activity. The conflict avoidance agreement may address the following:

- Operational agreement and communications procedures
- Where/when agreement becomes effective
- General communications scheme, by season
- Northstar Island operations, by season
- Conflict avoidance
- Seasonally sensitive areas
- Vessel navigation
- Air navigation
- Marine mammal and acoustic monitoring activities
- Measures to avoid impacts to marine mammals
- Measures to avoid conflicts in areas of active whaling
- Emergency assistance
- Dispute resolution process

13. MONITORING AND REPORTING PLAN

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

The proposed monitoring program is based on continuation of previous monitoring conducted at Northstar. However, BP is aware that changes to the plan can be made through consultation with the NSB, NMFS, and AEWC while this application is being processed and during the process of renewal of the regulations for the period 2011–2016.

A comprehensive analysis of the results of the acoustical and marine mammal monitoring program to date has recently been completed (Richardson [ed.] 2008). Results of this intensive monitoring suggest that (1) there are no measurable effects on seals from Northstar activities, and (2) there are limited but measurable effects on movement patterns of calling bowhead whales passing Northstar. The effects on bowheads are limited to the southernmost part of the migration corridor during periods with relatively noisy operations (generally boat and barge operations). The new monitoring plan proposes annual monitoring for changes in (I) the relative numbers of ringed seals near Northstar, (II) the relative numbers of bowhead whale calls near Northstar during September, and (III) sound levels emanating from Northstar during September. The September monitoring effort for bowheads and sound levels will coincide with the bulk of the bowhead whale migration past

Northstar, terminating before the onset of freeze-up. Also, BP proposes additional monitoring as a contingency under two conditions, described below. Results from monitoring will be reported in a single annual report. In addition, a five-year comprehensive report will be prepared in 2015.

No monitoring is proposed specifically for bearded or spotted seals or for gray or beluga whales, as their occurrence near Northstar is extremely limited. Few, if any, observations of these species were made during the intensive monitoring from 1999 to 2004 and biological effects are not expected. However, if sightings of these (or other) species are made, those observations will be included in the monitoring reports that will be prepared.

Annual Monitoring

Ringed Seal Monitoring

BP proposes to continue the long-term observer program, conducted by island personnel, of ringed seals during the spring, summer, and early autumn. This program is intended to assess the continued long-term stability of ringed seal abundance and habitat use near Northstar as indexed by counts obtained on a regular and long-term basis. The proposed approach is to continue the Northstar seal count that is conducted during the period 15 May–15 July from the 33 m (109 ft) high process module by Northstar staff following a standardized protocol since 2005. Counts are made on a daily basis (weather permitting), between 11:00–19:00, in an area of ~950 m (3,116 ft) around the island, for a duration of ~15 minutes. Counts will only be made during periods with visibility of 1 km (0.62 mi) or more and with a cloud ceiling of more than 90 m (300 ft).

Bowhead Whale Monitoring

BP proposes to continue monitoring the bowhead migration in 2011 and subsequent years for ~30 days each September through the recording of bowhead calls. BP proposes to deploy a DASAR (Directional Autonomous Seafloor Acoustic Recorder; Greene et al. 2004) or similar recorder about 15 km or 9 mi north of Northstar, consistent with a location used in past years (as far as conditions allow). The data of the offshore recorder can provide information on the total number of calls detected, the temporal pattern of calling during the recording period, and possibly the bearing to calls, and call types. These data can be compared with corresponding data from the same site in previous years (this is location EB in 2001–2007 and C in 2008–2009). If substantially higher or lower numbers of calls are recorded than were recorded at that site in previous years, further analyses and additional monitoring will be considered in consultation with NMFS and North Slope Borough representatives. A second DASAR, or similar recorder, will be deployed at the same location to provide a reasonable level of redundancy.

Acoustic Monitoring of Northstar Sounds

BP proposes to install an acoustic recorder about 450 m (1,476 ft) north of Northstar, in the same area where sounds have been recorded since 2001. This recorder will be installed for ~30 days each September, corresponding with the deployment of the offshore DASAR (or similar recorder). The near-island recorder will be used to record and quantify sound levels emanating from Northstar. If island sounds are found to be significantly stronger or more variable than in the past, and if it is expected that the stronger sounds will continue in subsequent years, then further consultation with

NMFS and NSB will occur to determine if more analyses or changes in monitoring strategy are appropriate. A second acoustic recorder will be deployed to provide a reasonable level of redundancy.

Contingency Monitoring

If BP needs to conduct an activity capable of producing pulsed underwater sound with levels ≥180 or ≥190 dB re 1 µPa (rms) at locations where whales or seals could be exposed, BP proposes to monitor safety zones defined by those levels. One or more on-island observers, as necessary to scan the area of concern, will be stationed at location(s) providing an unobstructed view of the predicted safety zone. The observer(s) will scan the safety zone continuously for marine mammals for 30 minutes prior to the operation of the strong source. Observations will continue during all periods of operation. If whales and seals are detected within the (respective) 180 or 190 dB distances, a shutdown or other appropriate mitigation measure (as agreed upon with NMFS) would be implemented. The sound source will be allowed to operate again when the marine mammals were observed to leave the safety zone or if the observer has determined that no marine mammals have been within the safety zone for 15 minutes. If marine mammal safety criteria recognized by NMFS change before or during the 5-year period under consideration, BP will adopt new monitoring and mitigation measures in consultation with NMFS.

If BP initiates significant on-ice activities (e.g., construction of new ice roads, trenching for pipeline repair, or projects of similar magnitude) in previously undisturbed areas after 1 March, trained dogs, or a comparable method, will be used to search for seal structures. If seal structures are found within 150 m (492 ft) of the proposed area of operations, BP will adjust the area of operations or adopt appropriate mitigation measures. Those mitigation measures will be defined in consultation with NMFS and North Slope Borough Biologists.

Reports

BP proposes the submission of a single annual monitoring report, with the first report to cover the activities from April through October 2011, and subsequent reports to cover activities from November of one year through October of the next year. It is proposed that the first report, concerning April–October 2011, and the annual report for subsequent years (to cover monitoring during a 12-month November–October period) would be submitted by 1 June of the following year.

The annual reports will provide summaries of BP's Northstar activities. These summaries will include the following: dates and locations of ice-road construction, on-ice activities, vessel/hovercraft operations, oil spills, emergency training, and major repair or maintenance activities thought to alter the variability or composition of sounds in a way that might have detectable effects on ringed seals or bowhead whales. The annual reports will also provide details of ringed seal and bowhead whale monitoring, the monitoring of Northstar sound via the nearshore DASAR, descriptions of any observed reactions, and documentation concerning any apparent effects on accessibility of marine mammals to subsistence hunters.

BP also proposes to submit a single comprehensive report on the monitoring results from 2011 to mid-2015 no later than 240 days prior to expiry of the renewed Regulations.

If specific mitigation is required for activities on the sea ice initiated after 1 March (requiring searches with dogs for lairs), or during the operation of strong sound sources (requiring visual observations and shut-down), then a preliminary summary of the activity, method of monitoring, and preliminary results will be submitted within 90 days after the cessation of that activity. The complete description of methods, results and discussion will be submitted as part of the annual report.

Any observations concerning possible injuries, mortality, or an unusual marine mammal mortality event will be transmitted to NMFS within 48 hours.

14. COORDINATING RESEARCH TO REDUCE AND EVALUATE POTENTIAL INCIDENTAL TAKE

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

BP coordinated the past marine mammal monitoring programs for the open-water and ice-covered seasons during operation of Northstar with MMS, NMFS, ADF&G, University of Alaska, and other industrial groups conducting related work. Provided that an acceptable methodology and business relationship can be worked out in advance, BP will continue to work with any number of external entities, including other energy companies, agencies, universities, and NGOs, in its efforts to manage, understand, and fully communicate information about environmental impacts related to Northstar activities.

BP is also interested in better understanding cumulative effects. In the past, BP has been an active participant in the National Academy's cumulative effects study. In addition, BP sponsored workshops intended to design better approaches to cumulative effects studies. The challenge in this case is determining a responsible approach to considering cumulative effects from sound. We are open to ideas and discussion and welcome comments from stakeholders with regard to assessment of cumulative effects from sound. BP currently plans to sponsor a series of workshops intended to develop methods for assessing cumulative effects associated with underwater sound, tentatively starting in 2010.

BP has contributed to studies of ringed seals through the Coastal Marine Institute of the University of Alaska (Kelly et al. 2004). BP will coordinate its proposed seal monitoring during the ice-covered season with any ongoing monitoring of on-ice work or any other related research on seals in the area surrounding Northstar.

BP plans to involve Inupiat personnel as well as biologists and acousticians in the monitoring and research programs proposed here. This will provide more opportunities for exchange of traditional and scientific knowledge.

BP anticipates that NMFS and peer reviewers will comment on the draft final reports on the marine mammal and acoustical monitoring work. BP will provide copies of draft monitoring reports to the North Slope Borough, the Alaska Eskimo Whaling Commission, and the Minerals Management Service for their review. Comments received as a result of the review processes will provide additional opportunities for input from and coordination with other groups with interests and experience in the area.

III. LITERATURE CITED

Aerts, L.A.M. 2009. Introduction, description of BP's activities, and record of seal sightings, 2008. p1-1 to p1-19 *In*: L.A.M Aerts and W.J. Richardson (eds., 2009, q.v.).

Aerts, L.A.M. and W.J. Richardson [eds.]. 2008. 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 Res. Assoc. Inc. (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA) and Applied Sociocultural Res. (Anchorage, AK) for BP Exploration (Alaska) Inc., Anchorage, AK.

Aerts, L.A.M. and R. Rodrigues. 2008. Introduction, description of BP's activities, and record of seal sightings, 2007. p1-1 to p1-18 *In*: L.A.M Aerts and W.J. Richardson (eds., 2008, q.v.).

Aerts, L.A.M. and W.J. Richardson [eds.]. 2009. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2008: Annual Summary Report. LGL Rep. P1081. Rep. from LGL Alaska Res. Assoc. Inc. (Anchorage, AK), Greeneridge Sciences Inc. (Santa Barbara, CA) and Applied Sociocultural Res. (Anchorage, AK) for BP Exploration (Alaska) Inc., Anchorage, AK.

Aerts, L.A.M., M. Blees, S.B. Blackwell, C.R Greene Jr., K.H Kim, D. Hannay and M. Austin. 2008. Marine mammal monitoring and mitigation during BP Liberty OBC seismic survey in Foggy Island Bay, Beaufort Sea, July-August 2008: 90-day report. LGL Rep. P1011-1. Rep. from LGL Alaska Research Associates Inc., LGL Ltd., Greeneridge Sciences Inc. and JASCO Research Ltd. for BP Exploration Alaska.

Alexander, V., D.C. Burrell, J. Chang, T.R. Cooney, C. Coulon, J.J. Crane, J.A. Dygas, G.E. Hall, P.J. Kinney, D. Kogl, T.C. Mowatt, A.S. Naidu, T.E. Osterkamp, D.M. Schell, R.D. Seifert, and R.W. Tucker. 1974. Environmental studies of an arctic estuarine system: final report. R74-1. Sea Grant Report 73-16. Inst. Marine Sci., Univ. Alaska, Fairbanks, AK.

Anderson, E., K. Jayko, C. Galagan and H. Rines. 1999. Oil spill model application for the Beaufort Sea. ASA 99-090. Rep. from Applied Science Assoc. Inc., Narragansett, RI, for BP Explor. (Alaska) Inc., Anchorage, AK. 16 p.

Angliss, R.P., and K.L. Lodge. 2002. Alaska marine mammal stock assessments, 2002. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-133, 224 p.

Angliss, R.P., and B.M. Allen. 2009. Alaska marine mammal stock assessments, 2008. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-193, 258 p.

Arnold, B.W. 1996. Visual monitoring of marine mammal activity during the Exxon 3-D seismic survey/Santa Ynez Unit, offshore California/9 November to 12 December 1995. Rep. from Impact Sciences Inc., San Diego, CA, for Exxon Co. U.S.A., Thousand Oaks, CA. 25 p.

Au, W.W.L. 1993. The sonar of dolphins. Springer-Verlag, New York, NY. 277 p.

Au, W.W.L. 1997. Some hot topics in animal bioacoustics. J. Acoust. Soc. Am. 101(5, Pt. 1):2433-2441.

Awbrey, F.T., J.A. Thomas and R.A. Kastelein. 1988. Low-frequency underwater hearing sensitivity in belugas, *Delphinapterus leucas*. J. Acoust. Soc. Am. 84(6):2273-2275

Berta, A., R. Racicot and T. Deméré 2009. The comparative anatomy and evolution of the ear in Balaenoptera mysticetes. Abstr. 18th Bienn. Conf. Biol. Mar. Mamm., Quebec, Oct. 2009, p. 33.

Blackwell, S.B. and C.R. Greene. 2002. Acoustic measurements in Cook Inlet, Alaska, during August 2001. Report from Greeneridge Sciences Inc., Santa Barbara, CA, for Nat. Mar. Fish. Serv., Anchorage AK.

Blackwell, S.B. and C.R. Greene, Jr. 2005. Underwater and in-air sounds from a small hovercraft. **J. Acoust. Soc. Am.** 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. **J. Acoust. Soc. Am.** 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. J. Acoust. Soc. Am. 115 (5):2346-2357.

Blackwell, S.B., C.R. Greene Jr., and W.J. Richardson. 2004b. Drilling and operational sounds from an oil production island in the ice-covered Beaufort Sea. **J. Acoust. Soc. Am.** 116(5): 3199-3211.

Blackwell, S.B., R.G. Norman, C.R. Greene Jr., M.W. McLennan, T.L. McDonald and W.J. Richardson. 2006. Acoustic monitoring of bowhead whale migration, autumn 2003. p. 7-1 to 7-48 *In*: W.J. Richardson (ed., 2008, q.v.). LGL Rep. P1004.

Blackwell, S.B., T.L. McDonald, R.M. Nielson, C.S. Nations, C.R. Greene, Jr., and W.J. Richardson. 2008. Effect of Northstar on bowhead calls. P12-1 to 12-44 *In*: W.J. Richardson (ed., 2008, q.v., LGL Rep. P1004).

Blackwell, S.B., W.C. Burgess, K.H. Kim, R.G. Norman, C.R. Greene, Jr., M.Wm. McLennan and L.A.M. Aerts. 2009. Sounds recorded at Northstar and in the offshore DASAR array, Autumn 2008. p3-1 to 3-37 *In:* Aerts, L.A.M. and W.J. Richardson (eds., 2009, q.v.). LGL Report 1081.

Bogoslovskaya, L.S. 1986. On the social behaviour of gray whales off Chukotka and Koryaka. Rep. Int. Whal. Comm., Spec. Iss. 8:243-251.

Bonner, W.N. 1982. Seals and man/a study of interactions. University of Washington Press, Seattle, WA. 170 p.

Born, E.W., F.F. Riget, R. Dietz and D. Andriashek. 1999. Escape responses of hauled out ringed seals (*Phoca hispida*) to aircraft disturbance. Polar Biol. 21(3):171-178.

Bowles, A.E., L. Wolski, E. Berg and P.K. Yochem. 1999. Measurement of impulse noise-induced temporary threshold shift in endangered and protected animals--two case studies. J. Acoust. Soc. Am. 105(2, Pt. 2):932.

BPXA. 1998a. Oil Discharge Prevention and Contingency Plan, Northstar Operations, North Slope, Alaska. Draft Plan (June). Prepared by BPXA. Available at BPXA, P.O. Box 196612, Anchorage, Alaska, 99519-6612.

BPXA. 1998b. Addendum. Oil Discharge Prevention and Contingency Plan, Northstar Operations, North Slope, Alaska. Draft Plan (September). Prepared by BPXA. Available at BPXA, P.O. Box 196612, Anchorage, Alaska, 99519-6612.

BPXA. 1999. Petition for regulations pursuant to section 101 (a) (5) of the Marine Mammal Protection Act covering taking of marine mammals incidental to offshore oil and gas development and production in the Beaufort Sea, Sept. 1999 ed. Submitted by BP Explor. (Alaska) Inc., Anchorage, AK, to Nat. Mar. Fish. Serv. [Silver Spring, MD]. Prepared by LGL Alaska Res. Assoc., Anchorage, AK. 121 p.

BPXA. 2001. Monitoring and reporting plan. Section 13 In: Request for a Letter of Authorization covering taking of marine mammals incidental to construction and operation of offshore oil and gas facilities in the U.S. Beaufort Sea, Alaska (50 C.F.R. Part 216, Subpart R). Request from BP Exploration (Alaska) Inc., Anchorage, AK, to Nat. Mar. Fish. Serv. [Silver Spring, MD]. Prepared by LGL Alaska Res. Assoc. Inc., Anchorage, AK.

BPXA. 2004. Request for a Letter of Authorization pursuant to section 101 (a) (5) of the Marine Mammal Protection Act covering taking of marine mammals incidental to operation of the Northstar facility in the U.S. Beaufort Sea. Submitted by BP Explor. (Alaska) Inc., Anchorage, AK, to Nat. Mar. Fish. Serv. [Silver Spring, MD]. Prepared by LGL Alaska Res. Assoc., Anchorage, AK. 103 p.

Bradstreet, M.S.W., D.H. Thomson and D.B. Fissel. 1987. Zooplankton and bowhead whale feeding in the Canadian Beaufort Sea, 1986. (Sect. 1, 204 p.) In: Bowhead whale food availability characteristics in the Southern Beaufort Sea: 1985 and 1986. Environmental Studies. 50. Indian and Northern Affairs Canada, Northern Affairs Program, Ottawa.

Bradstreet, M.S.W., K.J. Finley, A.D. Sekerak, W.B. Griffiths, C.R. Evans, M.F. Fabijan and H.E. Stallard. 1986. Aspects of the biology of arctic cod (*Boreogadus saida*) in arctic marine waters. Can. Tech. Rep. Fish. Aquat. Sci. 1491:193.

Braham, H. W. 1984. Distribution and migration of gray whales in Alaska. p. 249-266 In: The Gray Whale. M. L. Jones, S. L. Swartz, and S. Leatherwood (eds.). Academic Press, New York. 600 p.

Braham, H.W., D.B. Krogman, and G.M. Carroll. 1984. Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi, and Beaufort seas, 1975-78. NOAA Tech. Rep. NMFS SSRF-778. USDOC/NOAA/NMFS.

Braithwaith, L.F. 1983. The effects of oil on the on the feeding mechanism of the bowhead whale. Rep. By Brigham Young Univ., Provo, UT for Minerals Management Service, Alaska OCS Region and Bureau of Land Management, Anchorage, AK. AA-851-CTO-55. NTIS No. PCA04/MFA01. 51 p.

Bratton, G.R., Spainhour.CB, W. Flory, M. Reed and K. Jayko. 1993. Presence and potential effects of contaminants. p 701-744 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Special Publications of the Society for Marine Mammalogy. No. 2. Allen Press, Lawrence, KA.

Braund, S.R., K. Brewster, L. Moorehead, T.P. Holmes and J.A. 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.

Braund, S.R. and J. Kruse (eds.). 2009. Synthesis: Three decades of research on socioeconomic effects related to offshore petroleum development in coastal Alaska. MMS OCS Study 2009-006. Rep. from Stephen R. Braund & Assoc., Anchorage, AK, for U.S. Minerals Manage. Serv., Anchorage, AK. xxii + 439 p.

Brownell, J., RL. 1971. Whales, dolphins and oil pollution. p 255-276 In: D. Straughan (ed.), Biological and oceanographical survey of the Santa Barbara oil spill 1969-1970. Vol. 1. Biology and bacteriology. Allan Hancock Foundation, University of Southern California, Los Angeles, CA.

Brueggeman, J.J., G.A. Green, R.A. Grotefendt, M.A. Smultea, D.P. Volsen, R.A. Rowlett, C.C. Swanson, C.I. Malme, R. Mlawski and J.J. Burns. 1992. 1991 marine mammal monitoring program (seals and whales) Crackerjack and Diamond prospects Chukchi Sea. Rep. from EBASCO Environmental, Bellevue, WA, for Shell Western E & P Inc. and Chevron U.S.A. Inc. Var. pag.

Burns, J.J. 1970. Remarks on the distribution and natural history of pagophilic pinnipeds in the Bering and Chukchi seas. J. Mammal. 51(3):445-454.

Burns, J.J. and S.J. Harbo, Jr. 1972. An aerial census of ringed seals, northern coast of Alaska. Arctic 25(4):279-290.

Burns, J. J. 1973. Marine mammal report. Alaska Dep. Fish and Game, Pittman-Robertson Proj. Rep. W-17-3, W-17-4, and W-17-5.Burns, J.J. and G.A. Seaman. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska. II. Biology and ecology. R.U. 612, contract NA 81 RAC 00049. Rep. from Alaska Dep. Fish & Game, Fairbanks, AK, for U.S. Nat. Oceanic & Atmos. Admin. 129 p.

Burns, J.J., J.J. Montague and C.J. Cowles (eds.). 1993. The bowhead whale. Spec. Publ. 2, Soc. Mar. Mamm., Lawrence, KS. 787 p.

Calkins, D.G., E. Becker, T.R. Spraker and T.R. Loughlin. 1994. Impacts on Steller sea lions. p 119-139 In: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego.

Carey, A.G., Jr. (ed.). 1978. Marine biota (plankton, benthos, fish). Pages 174-237 in Environmental Assessment of the Alaskan Continental Shelf, Interim Synthesis: Beaufort/Chukchi. Outer Continental Shelf Environmental Assessment Program, Boulder, CO.

Carey, A.G., Jr., R.E. Ruff, J.G. Castillo, and J.J. Dickinson. 1975. Benthic ecology of the western Beaufort Sea continental margin: preliminary results. p. 665-680 In: J. C. Reed and J. E. Safer (eds.), The coast and shelf of the Beaufort Sea. Arctic Institute of North America, Arlington, VA.

Chapman, C.J. and A.D. Hawkins. 1969. The importance of sound in fish behaviour in relation to capture by trawls. p. 717-729 In: Proc. FAO conference on fish behaviour in relation to fishing techniques and tactics. FAO Fish. Rep. 62, Vol. 3, Rome.

Christie, K., C. Lyons and W.R. Koski. 2009. Beaufort Sea Aerial Monitoring Program. Chapter 7 *In:* D.W. Funk, D.S. Ireland, R. Rodrigues, and W.R. Koski (eds.). 2009. Joint Monitoring Program in the Chukchi and Beaufort seas, open-water season 2006–2008. LGL Alaska Report P1050-1, Rep. from LGL Alaska Research Associates, Inc., Greeneridge Sciences, Inc., and JASCO Research, Ltd., for Shell Offshore, Inc. and Other Industry Contributors, and National Marine Fisheries Service, U.S. Fish and Wildlike Service. 488 p plus Appendices.

Clark, C.W. and J.H. Johnson. 1984. The sounds of the bowhead whale, *Balaena mysticetus*, during the spring migrations of 1979 and 1980. Can. J. Zool. 62(7):1436-1441.

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. Rep. Int. Whal. Comm. 43:387-396.

Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: A review. Trans. Amer. Fish. Soc. 113:265-282.

Craig, P.C. 1989. An introduction to anadromous fishes in the Alaskan Arctic. In: D.W. Norton (ed.) Researches on anadromous fish in arctic Alaska and Canada. Biol. Pap. Univ. Alaska 24:27-54.

Craig, P.C., W.B. Griffiths, L. Halderson and H. McElderry. 1982. Ecological studies of arctic cod (*Boreogadus saida*) in Beaufort Sea coastal waters, Alaska. Can. J. Fish. Aquat. Sci. 39:396-406.

Crane, J.J. and R.T. Cooney. 1975. The nearshore benthos. In: Environmental Studies of an Arctic Estuarine System. U.S. EPA Grant R801124-03.

Dahlheim, M.E. 1987. Bio-acoustics of the gray whale (*Eschrichtius robustus*). Ph.D. thesis, Univ. Brit. Columbia, Vancouver, B.C. 315 p.

Dahlheim, M.E. and C.O. Matkin. 1994. Assessment of injuries to Prince William Sound killer whales. p 163-171 In: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego.

Dahlheim, M.E., H.D. Fisher and J.D. Schempp. 1984. Sound production by the gray whale and ambient noise levels in Laguna San Ignacio, Baja California Sur, Mexico. p. 511-541 In: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Davis, R.A. and C.R. Evans. 1982. Offshore distribution and numbers of white whales in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. Rep. from LGL Ltd., Toronto, Ont., for Sohio Alaska Petrol. Co., Anchorage, AK, and Dome Petrol. Ltd., Calgary, Alb. (co-managers). 76 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.

Di Iorio, L. and C.W. Clark. 2009. Exposure to seismic survey alters blue whale acoustic communication. Biol. Lett. doi: 10.1098/rsbl.2009.0651.

Dunbar, M.J. 1968. Ecological development in polar regions. A study in evolution. Prentice-Hall, Inc. Englewood Cliffs, N.J.

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.

Ellis, D.V. 1960. Marine infaunal benthos in arctic North America. Arctic Institute of North America. Technical Paper 5.

Ellis, D.V. 1962. Observations on the distribution and ecology of some arctic fish. Arctic 15:179-190.

Ellis, D.V. 1966. Some observations on the shore fauna of Baffin Island. Arctic 8:224-236.

Engelhardt, F.R. 1978. Petroleum hydrocarbons in arctic ringed seals, *Phoca hispida*, following experimental oil exposure. p. 614-628 In: Proc. Conf. on Assessment of Ecological Impacts of Oil Spills, 14-17 June 1978, Keystone, CO. Am. Inst. Biol. Sci.

Engelhardt, F.R. 1981. Oil pollution in polar bears: exposure and clinical effects. p. 139-179 In: Proc. 4th Arctic Marine Oilspill Program technical seminar, Edmonton Alta. Envir. Protect. Serv, Ottawa. 741 p.

Engelhardt, F.R. 1982. Hydrocarbon metabolism and cortisol balance in oil-exposed ringed seals, *Phoca hispida*. Comp. Biochem. Physiol. 72C:133-136.

Engelhardt, F.R. 1985. Effects of petroleum on marine mammals. p. 217-243 In: F.R. Engelhardt (ed.), Petroleum effects in the arctic environment. Elsevier, London, U.K. 281 p.

Engelhardt, F.R., J.R. Geraci and T.G. Smith. 1977. Uptake and clearance of petroleum hydrocarbons in the ringed seal, *Phoca hispida*. J. Fish. Res. Board Can. 34:1143-1147.

EWAC/AECOM 2007. Quantitative Description of Potential Impacts of OCS Activities on Bowhead Whale Hunting Activites in the Beaufort Sea. Prepared by EDAW, Inc. and Adams/Russell Consulting for U.S. Department of the Interior, Minerals Management Service.

Fall, J.A., and C.J. Utermohle (eds.). 1995. An Investigation of the Sociocultural Consequences of Outer Continental Shelf Development in Alaska II: Prince William Sound. Minerals Management Service, Technical Report 160, Anchorage, AK.

Fechhelm, R.G., W.B. Griffiths, J.D. Bryan, B.J. Gallaway, and W.J. Wilson. 1995. Application of an in situ growth model: Inferred instance of trophic competition between anadromous fishes of Prudhoe Bay, Alaska. Trans. Am. Fish. Soc. 124:55-69.

Finley, K.J., G.W. Miller, R.A. Davis and W.R. Koski. 1983. A distinctive large breeding population of ringed seals (*Phoca hispida*) inhabiting the Baffin Bay pack ice. Arctic 36(2):162-173.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. J. Acoust. Soc. Am. 111(6):2929-2940.

Finneran, J.J., R. Dear, D.A. Carder and S.H. Ridgway. 2003. Auditory and behavioral responses of California sea lions (*Zalophus californianus*) to single underwater impulses from an arc-gap transducer. J. Acoust. Soc. Am. 114(3):1667-1677.

Finneran, J. J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift (TTS) in bottlenose dolphins (Tursiops truncatus) exposed to mid- frequency tones. Journal of the Acoustical Society of America, 118, 2696-2705.

Finneran, J. J., C.E. Schlundt, B. Branstetter, and R.L. Dear. 2007. Assessing temporary threshold shift in a bottlenose dolphin (Tursiops truncatus) using multiple simultaneous auditory evoked potentials. Journal of the Acoustical Society of America, 122, 1249-1264.

Foote, A.D., R.W. Osborne and A.R. Hoelzel. 2004. Whale-call response to masking boat noise. Nature 428(6986):910.

Fraker, M.A. 1977a. The 1976 white whale monitoring program, MacKenzie Estuary, N.W.T. Rep. from F.F. Slaney & Co. Ltd., Vancouver, B.C., for Imperial Oil Ltd., Calgary, Alb. 76p. + maps, tables, append.

Fraker, M.A. 1977b. The 1977 white whale monitoring program/MacKenzie Estuary, N.W.T. Rep. from F.F. Slaney & Co. Ltd., Vancouver, B.C., for Imperial Oil Ltd., Calgary, Alb. 53p. + maps, photos.

Fraker, M.A. and P.N. Fraker. 1979. The 1979 whale monitoring program Mackenzie Estuary. Rep. from LGL Ltd., Sidney, B.C., for Esso Resour. Can. Ltd., Calgary, Alb. 51 p.

Frost, K.J. 1985. The ringed seal. Unpubl. Rep., Alaska Dep. Fish. and Game, Fairbanks, Alaska. 14 p.

Frost, K.J. and J.J. Burns. 1989. Winter ecology of ringed seals (*Phoca hispida*) in Alaska. Outer Cont. Shelf Environ. Assess. Progr., Final Rep., NOAA Proj. RU-232, Anchorage, AK (1989). 108 p. Contract NA-81-RAC-00045.

Frost, K.J. and L.F. Lowry. 1981. Feeding and trophic relationship of bowhead whales and other vertebrate consumers in the Beaufort Sea. Draft report submitted to the National Marine Fisheries Service, National Marine Mammal Laboratory, Seattle, WA.

Frost, K.J. and L.F. Lowry. 1984. Trophic relationships of vertebrate consumers in the Alaskan Beaufort Sea. p. 381-401 In: P.W. Barnes, D.M. Schell and E. Reimnitz (eds.), The Alaskan Beaufort Sea ecosystems and environments. Academic Press, Orlando, FL. 466 p.

Frost, K.J. and L.F. Lowry. 1988. Effects of industrial activities on ringed seals in Alaska, as indicated by aerial surveys. p. 15-25 In: W.M. Sackinger, M.O. Jeffries, J.L. Imm and S.D. Treacy (eds.), Port and Ocean Engineering under arctic conditions, vol. II. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111p.

Frost, K.J. and L.F. Lowry. 1990. Use of Kasegaluk Lagoon by marine mammals. p. 93-100 In: Alaska OCS Reg. Third Info. Transfer Meet. Conf. Proc. OCS Study MMS 90-0041. Rep. from MBC Appl. Environ. Sci., Costa Mesa, CA, for U.S. Minerals Manage. Serv., Anchorage, AK. 233 p.

Frost, K.J., L.F. Lowry and J.J. Burns. 1988. Distribution, abundance, migration, harvest, and stock identity of belukha whales in the Beaufort Sea. p. 27-40 In: P.R. Becker (ed.), Beaufort Sea (Sale 97) information update. OCS Study MMS 86-0047. Nat. Oceanic & Atmos. Admin., Ocean Assess. Div., Anchorage, AK. 87 p.

Frost, K.J., L.F. Lowry, E.H. Sinclair, J. Ver Hoef and D.C. McAllister. 1994a. Impacts on distribution, abundance and productivity of harbour seals. p 97-118 In: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego.

Frost, K.J., C-A. Manen, T.L. Wade. 1994b. Petroleum hydrocarbons in tissues of harbor seals from Prince William Sound and the Gulf of Alaska. p. 331-358 In Loughlin, T.R. (ed.)., Marine Mammals and the Exxon Valdez. Academic Press. San Diego, CA.

Frost, K.J., L.F. Lowry, S. Hills, G. Pendleton and D. DeMaster. 1997. Monitoring distribution and abundance of ringed seals in northern Alaska/Final interim report, May 1996-March 1997. Rep. from Alaska Dep. Fish & Game, Fairbanks, AK, for U.S. Minerals Manage. Serv., Anchorage, AK. 42 p.

Frost, K.J., L.F. Lowry, C. Hessinger, G. Pendleton, D. DeMaster and S. Hills. 1998. Monitoring distribution and abundance of ringed seals in northern Alaska/Interim report, April 1997-March 1998. Rep. from Alaska Dep. Fish & Game, Fairbanks, AK, for U.S. Minerals Manage. Serv., Anchorage, AK. 48 p.

Frost, J.J., L.F. Lowry, J.M. Ver Hoef. 1999. Monitoring the trend of harbor seals in Price William Sound, Alaska, after the Exxon Valdez oil spill. Mar. Mamm. Sci. 15(2):494-506.

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 2002-043. Final Rep. prepared by State of Alaska Department of Fish and Game, Juneau, AK, for U.S. Department of Interior, Minerals Management Service, Anchorage, AK. 66 p. + 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(2):115-128.

Gales, R.S. 1982. Effects of noise of offshore oil and gas operations on marine mammals--an introductory assessment. NOSC Tech. Rep. 844. Rep. from Naval Ocean Systems Center, San Diego, CA, for U.S. Bur. Land Manage., New York, NY. 79 + 300 p. 2 volumes. NTIS AD-A123699 + AD-A123700.

Galginaitis, M.S. 2006. Summary of the 2005 subsistence whaling season at Cross Island. P3-1 to 3-26 *In:* W.J. Richardson (ed., 2006, q.v.). LGL Rep. TA4209.

Galginaitis, M.S. 2007. Summary of the 2006 subsistence whaling season at Cross Island. P3-1 to 3-22 *In:* W.J. Richardson (ed., 2007, q.v.). LGL Rep. TA4441.

Galginaitis, M.S. 2008. Summary of the 2007 subsistence whaling season at Cross Island. P3-1 to 3-18 *In:* L.A.M. Aerts and W.J. Richardson (eds., 2008, q.v.). LGL Rep. 1005b.

Galginaitis, M.S. 2009. Summary of the 2008 subsistence whaling season at Cross Island. P5-1 to 5-26 *In:* L.A.M. Aerts and W.J. Richardson (eds., 2009, q.v.). LGL Rep. 1081.

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. Intern. Whal. Comm. Working Pap. SC/60/E9. 10 p.

George, J.C., J. Zeh, R. Suydam and C. Clark. 2004. Population size of the Bering-Chukchi-Beaufort Seas stock of bowhead whales, *Balaena mysticetus*, based on the 2001 census off Point Barrow, Alaska. Mar. Mamm. Sci. (in press). Draft available as SC/54/BRG5, Intern. Whal. Comm., Cambridge, U.K.

Geraci, J.R. 1990. Cetaceans and oil: Physiologic and toxic effects. p 167-197 In: J.R. Geraci and D.J. St. Aubin (eds.), Sea mammals and oil confronting the risks. Academic Press, Inc., San Diego. 282 p.

Geraci, J.R. and T.G. Smith. 1976. Direct and indirect effects of oil on ringed seals (*Phoca hispida*) of the Beaufort Sea. Can. J. Fish. Aquat. Sci. 33:1976-1984.

Geraci, J.R. and D.J. St. Aubin. 1980. Offshore petroleum resource development and marine mammals: a review and research recommendations. Mar. Fish. Rev. 42(11):1-12.

Geraci, J.R. and D.J. St. Aubin. 1982. Study of the effects of oil on cetaceans. Final report. Rep. from University of Guelph for U.S. Bur. Land Manage., Washington, DC. 274 p. NTIS PB83-152991.

Geraci, J.R., and D.J. St. Aubin. 1990. Sea Mammals and Oil: Confronting the Risk. Academic Press, Academic Press, Inc., San Diego. 282 p.

Goodale, D.R., M.A.M. Hyman and H.E. Winn. 1981. Cetacean responses in association with the Regal Sword spill. p XI 1-15 In: Cetacean and Turtle Assessment Program (ed.), A characterization of marine mammals and turtles in the mid and north Atlantic areas of the U.S. outer continental shelf. Report from University of Rhode Island, Kingston, RI, for U.S. Dep. Int. Bureau Land Manage., Washington, DC.

Green, J.E. and S.R. Johnson. 1983. The distribution and abundance of ringed seals in relation to gravel island construction in the Alaskan Beaufort Sea. p. 1-28 In: B.J. Gallaway (ed.), Biological studies and monitoring at Seal Island, Beaufort Sea, Alaska 1982. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for Shell Oil Co., Houston, TX. 150 p.

Greene, C.R. 1982. Characteristics of waterborne industrial noise. P249-346 In: W.J. Richardson (ed.). Behavior, disturbance responses and feeding of bowhead whales Balaena mysticetus in the Beaufort Sea, 1980-81. Chapter by Polar Res. Lab., Inc., in Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX for US Bureau of Land Management, Washington. 456 p. NTIS PB86-152170.

Greene, C.R. 1983. Characteristics of underwater noise during construction of Seal Island, Alaska, 1982. p. 118-150 In: B.J. Gallaway (ed.), Biological studies and monitoring at Seal Island, Beaufort Sea, Alaska 1982. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for Shell Oil Co., Houston, TX. 150 p.

Greene, C.R. 1985. Characteristics of waterborne industrial noise, 1980-84. p197-253 In: W.J. Richardson (ed.). Behavior, disturbance responses and feeding of bowhead whales Balaena mysticetus in the Beaufort Sea, 1980-84. Chapter by Greeneridge Sciences, Inc., in Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX for US Minerals Management Service, Reston, VA. 306 p. NTIS PB87-124376.

Greene, C.R., Jr. 1997a. 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. 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. 245 p.

Greene, C.R., Jr. 1997b. Underice drillrig sound, sound transmission loss, and ambient noise near Tern Island, Foggy Island Bay, Alaska, February 1997. Rep. from Greeneridge Sciences Inc., Santa Barbara, CA, and LGL Alaska Res. Assoc. Inc., Anchorage, AK, for BP Explor. (Alaska) Inc., Anchorage, AK. 22 p.

Greene, C.R., Jr. 1998. Underwater acoustic noise and transmission loss during summer at BP's Liberty prospect in Foggy Island Bay, Alaskan Beaufort Sea. Rep. from Greeneridge Sciences Inc., Santa Barbara, CA, and LGL Ltd., environ. res. assoc., King City, Ont., for BP Explor. (Alaska) Inc., Anchorage, AK. 39 p.

Greene, C.R. and B.M. Buck. 1964. Arctic Ocean ambient noise. J. Acoust. Soc. Am. 36(6): 1218-1220.

Greene, C.R., Jr. and Moore. 1995. Man-made noise. p. 101-158 In: W.J. Richardson et al., Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Greene, C.R., Jr., N.S. Altman and W.J. Richardson. 1999. Bowhead whale calls [1998]. p. 6-1 to 6-23 In: W.J. Richardson (ed., 1999, q.v.).

Greene, C.R., Jr., M.W. McLennan, R.G. Norman, T.L. McDonald, R.S. Jakubczak and W.J. Richardson. 2004. Directional Frequency and Recording (DIFAR) sensors in seafloor recorders to locate calling bowhead whales during their fall migration. J. Acoust. Soc. Am. 116(2):799-813.

Greene, C.R. Jr., S.B. Blackwell, and M.W. McLennan. 2008. Sounds and vibrations in the frozen Beaufort Sea during gravel island construction. **J. Acoust. Soc. Am.** 123(2): 687–695.

Griffiths, W.B., D.H. Thomson, and M.S.W. Bradstreet. 2002. Zooplankton and water masses at bowhead whale feeding locations in the eastern Beaufort Sea. p. 6-1 to 6-42 In: W.J. Richardson and D.H. Thomson (eds.). Bowhead whale feeding in the eastern 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.

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. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-150, 33 pp.

Hammill, M.O. and T.G. Smith. 1990. Application of removal sampling to estimate the density of ringed seals (*Phoca hispida*) in Barrow Strait, Northwest Territories. Can. J. Fish. Aquatic Sci. 47(2):244-250.

Hammill, M.O., C. Lydersen, M. Ryg and T.G. Smith. 1991. Lactation in the ringed seal (*Phoca hispida*). Can. J. Fish. Aquatic Sci. 48(12):2471-2476.

Harris, R.E., A.N. Balla-Holden, S.A. MacLean and W.J. Richardson. 1998. Seals. (Chap. 4) In: W.J. Richardson (ed.), 1998 (q.v.).

Harris, R.E., G.W. Miller and W.J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. Mar. Mamm. Sci. 17(4):795-812.

Harvey, J.T. and M.E. Dahlheim. 1994. Cetaceans in oil. p 257-264 In: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego.

Harwood, L.A., T.G. Smith, and H. Melling. 2007. Assessing the potential effects of near shore hydrocarbon exploration on ringed seals in the Beaufort Sea region 2003-2006. Environmental Studies Research Funds Report No. 162. Available at http://www.esrfunds.org/documents/ESRF162_000.pdf.

Harwood, L.A. and I. Stirling. 1992. Distribution of ringed seals in the southeastern Beaufort Sea during late summer. Can. J. Zool. 70(5):891-900.

Hatler, D.F. and J.D. Darling. 1974. Recent observations of the gray whale in British Columbia. Can. Field Nat. 88(4):449-459.

Hazard, K. 1988. Beluga whale, *Delphinapterus leucas*. p. 195-235 In: J.W. Lentfer (ed.), Selected marine mammals of Alaska. Mar. Mamm. Comm., Washington, DC. 275 p. NTIS PB88-178462.

Heide-Jørgensen, M.P., K.L. Laidre, Ø. Wiig, M.V. Jensen, L. Dueck, L.D. Maiers, H.C. Schmidt, and R.C. Hobbs. 2003. From Greenland to Canada in ten days: Tracks of bowhead whales, *Balaena mysticetus*, across Baffin Bay. Arctic 56(1):21-31.

Hickie, J. and R.A. Davis. 1983. Distribution and movements of bowhead whales and other marine mammals in the Prudhoe Bay region, Alaska, 26 September to 13 October 1982. p. 84-117 In: B.J. Gallaway (ed.), Biological studies and monitoring at Seal Island, Beaufort Sea, Alaska 1982. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for Shell Oil Co., Houston, TX. 150 p.

Hill, P.S. and D.P. DeMaster. 1998. Draft Alaska marine mammal stock assessments 1998. U.S. Nat. Mar. Fish. Serv., Nat. Mar. Mamm. Lab., Seattle, WA.

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. JASA Expr. Lett. 125(1):EL27-EL32.

Hoover-Miller, A., K.R. Parker, and J.J. Burns. 2001. A reassessment of the impact of the Exxon Valdez oil spill on harbor seals (*Phoca vitulina richardsi*) in Prince William Sound, Alaska. Mar. Mamm. Sci. 17(1):94-110.

Jansen J.K., J.L. Bengtson, P.L. Boveng, S.P. Dahle S.P. and J.M. Ver Hoef. 2006. Disturbance of harbor seals by cruise ships in Disenchantment Bay, Alaska: an investigation at three spatial and temporal scales. AFSC Processed Rep. 2006-02. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle WA 98115.

Jefferson, T.A. and B.E. Curry. 1994. Review and evaluation of potential acoustic methods of reducing or eliminating marine mammal–fishery interactions. Rep. from Mar. Mamm. Res. Progr., Texas A & M Univ., College Station, TX, for U.S. Mar. Mamm. Comm., Washington, DC. 59 p. NTIS PB95-100384.

Johnson, C.B., B.E. Lawhead, J.R. Rose, M.D. Smith, A.A. Stickney, A.M. Wildman. 1999. Wildlife studies on the Colville River Delta, Alaska, 1998. Rep. from ABR, Inc., Fairbanks, AK, for ARCO Alaska, Inc., Anchorage, AK.

Johnson, C.S., M.W. McManus and D. Skaar. 1989. Masked tonal hearing thresholds in the beluga whale. J. Acoust. Soc. Am. 85(6):2651-2654.

Johnson, L. 1980. The arctic char, *Salvelinus alpinus*. p. 15-98 In: E.K. Balon (ed.), Charrs: Salmonid fishes of the genus *Salvelinus*. Perspectives in Vertebrate Science. Vol. 1. Dr. W. Junk bv Publ., The Hague.

Johnson, S.R. 1979. Fall observations of westward migrating white whales (*Delphinapterus leucas*) along the central Alaskan Beaufort Sea coast. Arctic 32(3):275-276.

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. Rep. from LGL Ltd., King City, Ont., for Shell Western E & P Inc., Anchorage, AK. 130 p.

Jones, M.L. and S.L. Swartz. 1984. Demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico. p. 309-374 In: M. L. Jones et al. (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Kaleak, J. 1996. History of whaling by Kaktovik village. p. 69-71 In: Proceedings of the 1995 Arctic Synthesis Meeting. U.S. Minerals Manage. Serv., Alaska OCS Region, Anchorage, AK. 222 p.

Kastak, D. and R.J. Schusterman. 1998. Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise, and ecology. J. Acoust. Soc. Am. 103(4):2216-2228.

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. J. Acoust. Soc. Am. 106(2): 1142-1148.

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. J. Acoust. Soc. Am. 118(5): 3154-3163.

Kastak, D., C. Reichmuth, M.M. Holt, J. Mulsow, B.L. Southall and R.J. Schusterman. 2007. Onset, growth, and recovery of in-air temporary threshold shift in a California sea lion (*Zalophus californianus*). J. Acoust. Soc. Am. 122(5): 2916-2924.

Kastelein, R.A., P. Wensveen, L. Hoek and J.M. Terhune. 2009a. Underwater hearing sensitivity of harbor seals (*Phoca vitulina*) for narrow noise bands between 0.2 and 80 kHz. J. Acoust. Soc. Am. 126(1):476-483.

Kastelein, R.A., P.J. Wensveen, L. Hoek, W.C. Verboom and J.M. Terhune. 2009b. Underwater detection of tonal signals between 0.125 and 100 kHz by harbor seals (*Phoca vitulina*). J. Acoust. Soc. Am. 125(2): 1222-1229.

Kelly, B.P. 1988. Bearded seal, *Erignathus barbatus*. p. 77-94 In: J.W. Lentfer (ed.), Selected Marine Mammals of Alaska/Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, DC. 275 p.

Kelly, B.P. and L. Quakenbush. 1990. Spatiotemporal use of lairs by ringed seals (*Phoca hispida*). Can. J. Zool. 68(12):2503-2512.

Kelly, B.P., O.R. Harding, and M. Kunnasranta. 2004. Timing and re-interpretation of ringed seal surveys. p. 32-37 In: V. Alexander (ed.), Coastal Marine Institute, Annual Report No. 10. OCS Study MMS 2004-002. 119 p.

Kelly, B.P., L. Quakenbush and J.R. Rose. 1986. Ringed seal winter ecology and effects of noise disturbance. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 61(1989):447-536. 536p. OCS Study MMS 89-0026, NTIS PB89-234645.

Kelly, B.P., J.J. Burns and L.T. Quakenbush. 1988. Responses of ringed seals (*Phoca hispida*) to noise disturbance. p. 27-38 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. Geophysical Inst., Univ. Alaska, Fairbanks, AK. 111 p.

Ketten, D.R. 2000. Cetacean ears. p. 43-108 In: W.W.L. Au, A.N. Popper and R.R. Fay (eds.), Hearing by whales and dolphins. Springer-Verlag, New York, NY. 485 p.

Kinney, P., D. Schell, V. Alexander, A.S. Naidu, C.P. McRoy, and D.C. Burnell. 1971. Baseline data study of the Alaskan arctic aquatic environment. Eight-month progress report 1970. Inst. Mar. Sci, Univ. Alaska. R71-4. Fairbanks, AK.

Kinney, P., D. Schell, V. Alexander, D.C. Burnell, R. Cooney, and A.S. Naidu. 1972. Baseline data study of the Alaskan arctic aquatic environment. Inst. Mar. Sci., Univ. Alaska. R72-3. Fairbanks, AK.

Knudsen, V.O., R.S. Alford and J.W. Emling. 1948. Underwater ambient noise. J. Mar. Res. 7(3):410-429.

Kooyman, G.L., R.L. Gentry and W.B. McAlister. 1976. Physiological impact of oil on pinnipeds. Unpubl. Final Rep., Res. Unit 71, to Outer Cont. Shelf Envir. Assess. Program, BLM/NOAA. 26 p.

Kooyman, G.L., R.W. Davis and M.A. Castellini. 1977. Thermal conductance of immersed pinniped and sea otter pelts before and after oiling with Prudhoe Bay crude. p. 151-157 In: D.A. Wolfe (ed.), Fate and effects of petroleum hydrocarbons in marine ecosystems and organisms. Pergamon Press, Oxford.

Koski, W.R. and S.R. Johnson. 1987. Behavioral studies and aerial photogrammetry. Section 4 in 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 Exploration and Production Inc., Anchorage, AK.

Koski, W.R. and G.W. Miller. 2002. Habitat use by different size classes of bowhead whales in the eastern Alaskan Beaufort Sea during late summer and autumn. p. 10-1 to 10-21 (Chap. 10) 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 Manage. Serv., Anchorage, AK, and Herndon, VA. 420 p.

Koski, W.R. and G.W. Miller. 2009. Habitat use by different size classes of bowhead whales in the Central Beaufort Sea during late summer and autumn. Arctic 62(2):137-150.

Koski, W.R., R.A. Davis, G.W. Miller and D.E. Withrow. 1993. Reproduction. p. 239-274 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mamm., Lawrence, KS. 787 p.

Koski, W.R., D.J. Rugh, A.E. Punt and J. Zeh. 2004. A new approach to estimating the length-frequency distribution of the Bering-Chukchi-Beaufort bowhead whale population using aerial photogrammetry and a summary of other life-history parameters estimated from photoidentification / photogrammetry data. Working Paper SC/56/BRG2. Int. Whal. Comm., Cambridge, U.K. 25 p.

Landino, S.W., S.D. Treacy, S.A. Zerwick and J.B. Dunlap. 1994. A large aggregation of bowhead whales (*Balaena mysticetus*) feeding near Barrow, Alaska, in late October 1992. Arctic 47(3):232-235.

Le Boeuf, B.J., H. Pérez-Cortés M., J. Urbán R., B.R. Mate and F. Ollervides U. 2000. High gray whale mortality and low recruitment in 1999: potential causes and implications. Journal of Cetacean Research and Management 2:85-99.

Lelli, B. and D.E. Harris. 2001. Human disturbances affect harbor seal haul-out behavior: can the law protect these seals from boaters? Macalester Environmental Review. 23 October 2001. www.macalester.edu/~envirost/MacEnvReview/harbor_seal.htm

Lerczak, J.A., K.E.W. Shelden, and R.C. Hobbs. 2000. Application of suction-cup-attached VHF Transmitters to the study of beluga, *Delphinapterus leucas*, surfacing behavior in Cook Inlet, Alaska. Marine Fisheries Review 62(3):99-111.

Lesage, V., C. Barrette and M.C.S. Kingsley. 1993. The effect of noise from an outboard motor and a ferry on the vocal activity of beluga (*Delphinapterus leucas*) in the St. Lawrence estuary, Canada. Abstr. 10th Bienn. Conf. Biol. Mar. Mamm., Galveston, TX, Nov. 1993:70. 130 p.

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. Mar. Mamm. Sci. 15(1):65-84.

LGL and Greeneridge. 1996a. Northstar Marine Mammal Monitoring Program, 1995: Baseline surveys and retrospective analyses of marine mammal and ambient noise data from the Central Alaskan Beaufort Sea. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK. 104 p.

LGL and Greeneridge. 2000. Technical plan for marine mammal and acoustic monitoring during construction of BP's Northstar Oil Development in the Alaskan Beaufort Sea, 2000-2001, August 2000 ed. Rep. from LGL Alaska Res. Assoc. Inc. (Anchorage), LGL Ltd. (King City, Ont.), and Greeneridge Sciences Inc. (Santa Barbara, CA), for BP Explor. (Alaska) Inc., Anchorage, AK. 80 p.

Link, M.R., T.L. Olson and M.T. Williams. 1999. Ringed seal distribution and abundance near potential oil development sites in the central Alaskan Beaufort Sea, spring 1998. LGL Rep. P-430. Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, for BP Explor. (Alaska) Inc., Anchorage, AK. 58 p.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1983. Aerial surveys of endangered whales in the Beaufort, eastern Chukchi, and northern Bering Seas, 1982. NOSC Tech Doc. 605. Rep. from Naval Ocean Systems Center, San Diego, CA for U.S. Minerals Manage. Serv., Anchorage, AK. 382 p. NTIS AD-A134 772/3.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1984. Aerial surveys of endangered whales in the Beaufort, eastern Chukchi, and northern Bering Seas, 1983: with a five year review, 1979-1983. NOSC Tech Rep. 955. Rep. from Naval Ocean Systems Center, San Diego, CA for U.S. Minerals Manage. Serv., Anchorage, AK. 356 p. NTIS AD-A146 373/6.

Ljungblad, D.K., B. Würsig, S.L. Swartz and J.M. Keene. 1985. Observations on the behavior of bowhead whales (*Balaena mysticetus*) in the presence of operating seismic exploration vessels in the Alaskan Beaufort Sea. OCS Study MMS 85-0076. Rep. from SEACO Inc., San Diego, CA, for U.S. Minerals Manage. Serv., Anchorage, AK. 78 p. NTIS PB87-129318.

Ljungblad, D.K., S.E. Moore and D.R. Van Schoik. 1986. Seasonal patterns of distribution, abundance, migration and behavior of the Western Arctic stock of bowhead whales, Balaena mysticetus in Alaskan seas. Rep. Int. Whal. Comm., Spec. Iss. 8:177-205.

Ljungblad, D.K., S.E. Moore, J.T. Clarke and J.C. Bennett. 1987. Distribution, abundance, behavior and bioacoustics of endangered whales in the Alaskan Beaufort and eastern Chukchi Seas, 1979-86. NOSC Tech. Rep. 1177; OCS Study MMS 87-0039. Rep. from Naval Ocean Systems Center, San Diego, CA, for U.S. Minerals Manage. Serv., Anchorage, AK. 391 p. NTIS PB88-116470.

Long, F., Jr. 1996. History of subsistence whaling by Nuiqsut. p. 73-76 In: Proceedings of the 1995 Arctic Synthesis Meeting. U.S. Minerals Manage. Serv., Alaska OCS Region, Anchorage, AK. 222 p.

Lowry, L.F. and G. Sheffield. 2002. Stomach contents of bowhead whales harvested in the Alaskan Beaufort Sea. p. 18-1 to 18-28 (Chap. 18) 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. 2. 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. 277 p.

Lowry, L.F., K.J. Frost, R. Davis, D.P. DeMaster and R.S. Suydam. 1998. Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. Polar Biol. 19(4):221-230.

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. J. Acoust. Soc. Am. 125(6): 4060-4070.

Lydersen, C. and M.O. Hammill. 1993. Diving in ringed seal (*Phoca hispida*) pups during the nursing period. Can. J. Zool. 71(5):991-996.

MacGillivray, A.O., D.E. Hannay, R.G. Racca, C.J. Perham, S.A. MacLean, M.T. Williams. 2003. Assessment of industrial sounds and vibrations received in artificial polar bear dens, Flaxman Island, Alaska. Final report to ExxonMobil Production Co. by JASCO Research Ltd., Victoria, British Columbia and LGL Alaska Research Associates, Inc., Anchorage, Alaska. 60 p.

Maher, W.J. 1960. Recent records of the California gray whale (*Eschrichtius glaucus*) along the north coast of Alaska. Arctic 13(4):257-265.

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 Rep. 5586. Rep. from Bolt Beranek & Newman Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218377.

Malme, C.I., B. Würsig, 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. Jefferies, J.L. Imm, S.D. Treacy (eds.) Port and Ocean Engineering Under Arctic Conditions, Volume II. University of Alaska, Fairbanks, Alaska. 111pp.

Mansfield, A.W. 1967. Seals of arctic and eastern Canada. Fish. Res. Board Can. Bul. 137. 35 p.

Mate, B.R. 2006. The Spring Northward Migration and Summer Feeding of Mother Gray Whales in the Eastern North Pacific Ocean, Bering Sea and Chukchi Sea. Report to LGL Ltd. (Sidney, B.C. Canada) on the Tagging of Eastern North Pacific Gray Whales—2005. Agreement Number EA1666.10A

Mate, B.R. and J.T. Harvey (eds.) 1987. Acoustic deterrents in marine mammal conflicts with fisheries. ORESU-W-86-001. Oregon State Univ., Sea Grant Coll. Progr., Corvallis, OR. 116 p.

MBC Applied Environmental Sciences. 2003. Proceedings of the Ninth Information Transfer Meeting. OCS Study MMS 2003-42. by MBC Applied Environmental Sciences, Costa Mesa, CA. for U.S. Dept. Int., Minerals Management Service, Alaska OCS Region, Anchorage, AK. 93 pp. plus attachments.

McCarty, S.L. 1982. Survey of the effect of outer continental shelf platforms on cetacean behavior. p. C-1 to C-31 In: R.S. Gales (ed.), Effects of noise of offshore oil and gas operations on marine mammals--an introductory assessment, vol. 2. App. 3 in NOSC Tech. Rep. 844. Naval Ocean Systems Cent., San Diego, CA. 300 p. NTIS AD-A123700.

McDonald, T.L., W.J. Richardson, C.R. Greene, Jr., S.B. Blackwell, C. Nations, and R. Nielson. 2008. Detecting changes in distribution of calling bowhead whales exposed to fluctuating anthropogenic sounds. p. 9 1 to 9 45 *In*: W.J. Richardson (ed., 2008, q.v.). LGL Rep. P1004.

Miller, G.W., R.E. Elliott and W.J. Richardson. 1996. Marine mammal distribution, numbers and movements. p. 3-72 In: LGL and Greeneridge, Northstar marine mammal monitoring program, 1995: Baseline surveys and retrospective analyses of marine mammal and ambient noise data from the central Alaskan Beaufort Sea. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK. 104 p.

Miller, G.W., R.E. Elliott, W.R. Koski and W.J. Richardson. 1997. Whales [1996]. (Chap. 5, 115 p.) In: W.J. Richardson (ed.), 1997 (q.v.).

Miller, G.W., R.E. Elliott and W.J. Richardson. 1998b. Whales. [1997]. (Chap. 5) In: W.J. Richardson (ed., 1998, q.v.).

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton and W.J. Richardson. 1999. Whales [1998]. p. 5-1 to 5-109 In: W.J. Richardson (ed.), 1999 (q.v.).

Miller, G.W., Moulton, V.D., Davis, R.A., Holst, M., Millman, P., MacGillivray, A., Hannay, D., 2005. Monitoring seismic effects on marine mammals– southeastern Beaufort Sea, 2001–2002. In: Armsworthy, S.L., Cranford, P.J., Lee, K. (Eds.), Offshore Oil and Gas Environmental Effects Monitoring: Approaches and Technologies. Battelle Press, Columbus, Ohio, pp. 511–542.

Milne, A.R. and J.H. Ganton. 1964. Ambient noise under Arctic-Sea ice. J. Acoust. Soc. Am. 36(5):855-863.

Misund, O.A. 1997. Underwater acoustics in marine fisheries and fisheries research. Review of Fish Biology and Fisheries 7(1):1-34.

Misund, O.A., J.T. Øvredal, and M.T. Hafsteinsson. 1996. Reactions of herring schools to the sound field of a survey vessel. Aquatic Living Resources 9(1):5-11.

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. 1997. Arctic seismic synthesis and mitigating measures workshop/Proceedings. OCS Study MMS 97-0014. U.S. Minerals Manage. Serv., Anchorage, AK. 165 p.

Moles, A., S.D. Rice and S. Korn. 1979. Sensitivity of Alaskan freshwater and anadromous fishes to Prudhoe Bay crude oil and benzene. Trans. Amer. Fish. Soc. 108:408-414.

Moore, S.E. 2000. Variability in cetacean distribution and habitat selection in the Alaskan Arctic, Autumn 1982-91. Arctic 53(4)448-460.

Moore, S.E. and J.T. Clarke. 1992. Patterns of bowhead whale distribution and abundance near Barrow, Alaska, in fall 1982-1989. Mar. Mamm. Sci. 8(1):27-36.

Moore, S.E. and D.K. Ljungblad. 1984. Gray whales in the Beaufort, Chukchi, and Bering seas: distribution and sound production. p. 543-559 In: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Moore, S.E. and R.R. Reeves. 1993. Distribution and movement. p. 313-386 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mamm., Lawrence, KS. 787 p.

Moore, S.E., D.K. Ljungblad and D.R. Schmidt. 1984. Ambient, industrial and biological sounds recorded in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas during the seasonal migrations of the bowhead whale (*Balaena mysticetus*), 1979-1982. Rep. from SEACO Inc., San Diego, CA, for U.S. Minerals Manage. Serv., Anchorage, AK. 111 p. NTIS PB86-168887.

Moore, S.E., J.T. Clarke and D.K. Ljungblad. 1989. Bowhead whale (*Balaena mysticetus*) spatial and temporal distribution in the central Beaufort Sea during late summer and early fall 1979-86. Rep. Int. Whal. Comm. 39:283-290.

Moore, S.E., D.P. DeMaster, and P.K. Dayton. 2000. Cetacean habitat selection in the Alaskan Arctic during summer and Autumn. Arctic 53(4)432-447.

Moore S.E., W.L. Perryman, F. Gulland, H. Perez-Cortes, 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. Grebmeier, and J.R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. Can. J. Zool. 81:734-742.

Moulton, V.D. and J.W. Lawson. 2002. Seals, 2001. p. 3-1 to 3-48 In: W.J. Richardson and J.W. Lawson (eds.), Marine mammal 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., for WesternGeco LLC, Anchorage, AK; BP Explor. (Alaska) Inc., Anchorage, AK; and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 95 p.

Moulton, V.D., W.J. Richardson, T.L. McDonald, R.E. Elliott and M.T. Williams. 2002. Factors influencing local abundance and haulout behaviour of ringed seals (*Phoca hispida*) on landfast ice of the Alaskan Beaufort Sea. Can. J. Zool. 80(11):1900-1917.

Moulton, V.D., W.J. Richardson, M.T. Williams and S.B. Blackwell. 2003a. Ringed seal densities and noise near an icebound artificial island with construction and drilling. Acoust. Res. Let. Online. 4(4):112–117.

Moulton, V.D., R.E. Elliott and M.T. Williams. 2003b. Fixed-wing aerial surveys of seals near BP's Northstar and Liberty sites, 2002. p. 4-1 to 4-35 In: W.J. Richardson and M.T. Williams (eds., 2003, q.v.). LGL Rep. TA2702-2.

Moulton, V.D., W.J. Richardson, T.L. McDonald, R.E. Elliott, M.T. Williams and C. Nations. 2005. Effects of an offshore oil development on local abundance and distribution of ringed seals (*Phoca hispida*) of the Alaskan Beaufort Sea. **Marine Mammal Science** 21(2): 217-242.

Moulton, V.D., M.T. Williams, S.B. Blackwell, W.J. Richardson, R.E. Elliot and B. Streever. MS. Zone of displacement for ringed seals (*Pusa hispida*) wintering around offshore oil-industry operations in the Alaskan Beaufort Sea.

Nachtigall, P.E., J.L. Pawloski and W.W.L. Au. 2003. Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncatus*). J. Acoust. Soc. Am. 113(6):3425-3429.

Nachtigall, P. E., A. Ya. Supin, J.L. Pawloski, and W.W. L. Au. 2004. Temporary threshold shifts after noise exposure in the bottlenose dolphin (*Tursiops truncatus*) measured using auditory evoked potentials. Marine Mammal Science, 20, 673-687.

Nelson, R.R., J.J. Burns, and K.J. Frost. n.d. The Bearded Seal (*Erignathus barbatus*). Alaska Department of Fish and Game.

Nerini, M. 1984. A review of gray whale feeding ecology. p. 423-450 In: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.), The gray whale *Eschrichtius robustus*. Academic Press, Orlando, FL. 600 p.

Nerini, M.K., H.W. Braham, W.M. Marquette and D.J. Rugh. 1984. Life history of the bowhead whale, *Balaena mysticetus* (Mammalia: Cetacea). J. Zool., Lond. 204:443-468.

NMFS (National Marine Fisheries Service). 1995. Small takes of marine mammals incidental to specified activities; offshore seismic activities in southern California/Notice of issuance of an Incidental Harassment Authorization. Fed. Regist. 60(200, 17 Oct.):53753-53760.

NMFS. 1997. Small takes of marine mammals incidental to specified activities; oil and gas exploration drilling activities in the Beaufort Sea/Notice of issuance of an Incidental Harassment Authorization. Fed. Regist. 62(191, 2 Oct.):51637-51643.

NMFS. 2000. Taking marine mammals incidental to construction and operation of offshore oil and gas facilities in the Beaufort Sea/Final rule. Fed. Regist. 65(102, 25 May):34014-34032.

NMFS. 2001. Small takes of marine mammals incidental to specified activities; oil and gas exploration drilling activities in the Beaufort Sea/Notice of issuance of an incidental harassment authorization. Fed. Regist. 66(26, 7 Feb.):9291-9298

NMFS. 2003. Subsistence harvest management of Cook Inlet beluga whales Final Environmental Impact Statement. July 2003. 197 pp.

NMFS. 2005. Endangered fish and wildlife; Notice of Intent to prepare an Environmental Impact Statement. Fed. Regist. 70(7, 11 Jan.): 1871-1875.

NRC. 2005. Marine mamma populations and ocean noise: determining when noise causes biologically significant effects. Committee on characterizing biologically significant marine mammal behaviour, National Research Council. ISBN: 0-309-54667-2, 142 p.

Nowacek, D.P., L.H. Thorne, D.W. Johnston and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mamm. Rev. 37(2):81-115.

Oliver, J.S. and P.N. Slattery. 1985. Destruction and opportunity on the sea floor: effects of gray whale feeding. Ecology 66(6):1965-1975.

Oliver, J.S., P.N. Slattery, M.A. Silberstein and E.F. O'Connor. 1983. A comparison of gray whale, *Eschrichtius robustus*, feeding in the Bering Sea and Baja California. Fish. Bull. 81(3):513-522.

Ouellet, P. 1979. Northern whales [LP phonograph record]. Cat. No. 19. Music Gallery Editions, Toronto, Ont.

Parks, S.E., I. Urazghildiiev and C.W. Clark. 2009. Variability in ambient noise levels and call parameters of North Atlantic right whales in three habitat areas. J. Acoust. Soc. Am. 125(2):1230-1239.

Patenaude, N.J., W.J. Richardson, M.A. Smultea, W.R. Koski, G.W. Miller, B. Würsig and C.R. Greene Jr. 2002. Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. Mar. Mamm. Sci. 18(2):309-335.

Pearson, W.H., J.R. Skalski and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on behavior of captive rockfish (*Sebastes spp*). Can. J. Fish. Aquatic Sci. 49:1343-1356.

Quakenbush, L.T. 1988. Spotted seal, *Phoca largha*. p. 107-124 In: J.W. Lentfer (ed.), Selected Marine Mammals of Alaska/Species Accounts with Research and Management Recommendations. Marine Mammal Commis., Washington, DC. 275 p.

Rexford, B. 1996. The Alaska Eskimo Whaling Commission and history of subsistence whaling off Point Barrow "Nuvuk" (including General Discussion). p. 77-85 In: Proceedings of the 1995 Arctic Synthesis Meeting. U.S. Minerals Manage. Serv., Alaska OCS Region, Anchorage, AK. 222 p.

Rice, D.W. and A.A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Am. Soc. Mamm. Spec. Publ. 3. 142 p.

Rice, S.D., A. Moles, J.F. Karinen, S. Korn, M.G. Carls, C. Brodersen, J.A. Gharrett and M.M. Babcock 1983. Effects of petroleum hydrocarbons on Alaskan aquatic organisms. Final Rep. to OCEAP by NW Alaska Fisheries Centre, Auke Bay Laboratory, NMFS, NOAA, Auk Bay AK. 145 p.

Richard, P.R., A.R. Martin and J.R. Orr. 1997. Study of summer and fall movements and dive behaviour of Beaufort Sea belugas, using satellite telemetry: 1992-1995. ESRF Rep. 134. Environ. Stud. Res. Funds, Calgary, Alb. 38 p.

Richard, P.R., A.R. Martin and J.R. Orr. 2001. Summer and autumn movements of belugas of the eastern Beaufort Sea stock. Arctic 54(3):223-236.

Richardson, W.J. (ed.). 1987. Importance of the eastern Alaskan Beaufort Sea to feeding bowhead whales, 1985-86. OCS Study MMS 87-0037. Rep. from LGL Ecol. Res. Assoc. Inc., Bryan, TX, for U.S. Minerals Manage. Serv., Reston, VA. 547 p. NTIS PB88-150271.

Richardson, W.J. (ed.). 1999. Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Richardson, W.J. [ed.]. 2006. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2005: Annual Summary Report. LGL Rep. TA4209 (rev.). Rep. from LGL Ltd. (King City, Ont.) and Greeneridge Sciences Inc. (Santa Barbara, CA) for BP Explor. (Alaska) Inc., Anchorage, AK. 79 p.

Richardson, W.J. [ed.]. 2007. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 2006: Annual Summary Report. LGL Rep. TA4441. Rep. from LGL Ltd. (King City, Ont.) and Greeneridge Sciences Inc. (Santa Barbara, CA) for BP Explor. (Alaska) Inc., Anchorage, AK. 78 p.

Richardson, W.J. [ed.]. 2008. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar Oil Development, Alaskan Beaufort Sea, 1999–2004. Comprehensive Report, 3rd Update, Feb. 2008. LGL Rep. P1004. Rep. from LGL Ltd. (King City, Ont.), Greeneridge Sciences Inc. (Santa Barbara, CA), WEST Inc. (Cheyenne, WY), and Applied Sociocultural Research (Anchorage, AK) for BP Exploration (Alaska) Inc., Anchorage, AK.

Richardson, W.J. and C.I. Malme. 1993. Man-made noise and behavioral responses. p. 631-700 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mamm., Lawrence, KS. 787 p.

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 volumes. NTIS PB2004-101568. Available from www.mms.gov/alaska/ref/AKPUBS.HTM#2002.

Richardson, W.J. and B. Würsig. 1997. Influences of man-made noise and other human actions on cetacean behaviour. Mar. Freshwat. Behav. Physiol. 29(1-4):183-209.

Richardson, W.J., M.A. Fraker, B. Würsig and R.S. Wells. 1985. Behaviour of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea: reactions to industrial activities. Biol. Conserv. 32(3):195-230.

Richardson, W.J., B. Würsig and C.R. Greene, Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79:1117-1128.

Richardson, W.J., B. Würsig and C.R. Greene Jr. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. Mar. Environ. Res. 29(2):135-160.

Richardson, W.J., C.R. Greene Jr., W.R. Koski, M.A. Smultea, with G. Cameron, C. Holdsworth, G. Miller, T. Woodley and B. Würsig. 1991. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska--1990 phase. OCS Study MMS 91-0037. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Herndon, VA. 311 p. NTIS PB92-170430.

Richardson, W.J., C.R. Greene Jr., J.S. Hanna, W.R. Koski, G.W. Miller, N.J. Patenaude and M.A. Smultea. 1995a. 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. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Herndon, VA. 539 p.

Richardson, W.J., C.R. Greene Jr., C.I. Malme and D.H. Thomson. 1995b. Marine mammals and noise. Academic Press, San Diego, CA. 576 p.

Richardson, W.J., T.L. McDonald, C.R. Greene Jr., and S.B. Blackwell. 2008a. Effects of Northstar on distribution of calling bowhead whales, 2001-2004. P10-1 to 10-44 *In*: W.J. Richardson (ed., 2008, q.v.). LGL Rep. P1004.

Richardson W.J., V.D. Moulton and T.L. McDonald. 2008b. Potential effects of Northstar activities on marine mammals and on their availability for subsistence. P. 14-1 to 14-23 *In:* W.J. Richardson (ed., 2008, q.v.). LGL Rep. P1004.

Ridgway, S.H. and D.A. Carder. 1995. Deep hearing and sonar studies of conditioned white whales *Delphinapterus leucas*. Abstr. 11th Bienn. Conf. Biol. Mar. Mamm., Orlando, FL, Dec. 1995:96. 148 p.

Rodrigues, R. and M.T. Williams. 2006. BP's activities at Northstar, 1999–2004. p. 2-1 to 2-45 In: W.J. Richardson (ed., 2008, q.v.).

Rodrigues, R. and W.J. Richardson. 2007. Introduction, description of BP's activities, and record of seal sightings, 2006. p1-1 to p1-20 *In:*W.J. Richardson (ed., 2007, q.v.).

Rodrigues, R., C.C Kaplan, and W.J. Richardson. 2006. Introduction, description of BP's activities, and record of seal sightings, 2005. p1-1 to p1-13 *In:*W.J. Richardson (ed., 2006 q.v.).

Ross, D. 1976. Mechanics of underwater noise. Pergamon, New York, NY. 375 p. Reprinted 1987, Peninsula Publ., Los Altos, CA.

Rugh, D.J. and M.A. Fraker. 1981. Gray whale (*Eschrichtius robustus*) sightings in eastern Beaufort Sea. Arctic 34(2):186-187.

Rugh, D.J., K.E.W. Shelden and D.E. Withrow. 1997. Spotted seals, *Phoca largha*, in Alaska. Mar. Fish. Rev. 59(1):1-18.

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 to 2002. J. Cetacean Res. Manage. 7(1):1-12.Scheifele, P.M., S. Andrew, R.A. Cooper, M. Darre, F.E. Musiek and L. Max. 2005. Indication of a Lombard vocal response in the St. Lawrence River beluga. J. Acoust. Soc. Am. 117(3, Pt. 1):1486-1492.

S.L. Ross Environmental Research Ltd. 1998. Blowout and spill probability assessment for the Northstar and Liberty oil development projects in the Alaskan North Slope. Final Rep. (November 1998). Prepared for BP Exploration (Alaska) Inc. by S.L. Ross Environmental Research Ltd., Ottawa, Ontario. Available at BPXA, P.O. Box 196612, Anchorage, Alaska, 99519-6612.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, 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): 415-521.

Stafford, K.M., S.E. Moore, M. Spillane, and S. Wiggins. 2007. Gray whale calls recorded near Barrow, Alaska, throughout the winter of 2003-04. Arctic 60(2): 167-172.

St. Aubin, D.J. 1990. Physiologic and toxic effects on pinnipeds. p 103-127 In: J.R. Geraci and D.J. St. Aubin (eds.), Sea mammals and oil confronting the risks. Academic Press, Inc., San Diego.

St. Aubin, D.J., R.H. Stinson and J.R. Geraci. 1984. Aspects of the structure of baleen, and some effects of exposure to petroleum hydrocarbons. Can. J. Zool. 62:193-198.

Sanders, H.L., J.F. Grassle, G.R. Hampson, L.S. Morse, S. Garner-Price and C.C. Jones. 1990. Anatomy of an oil spill: long-term effects from the grounding of the barge Florida off West Falmouth, Massachusetts. J. Mar. Res. 38:265-380.

Schevill, W.E. and B. Lawrence. 1949. Underwater listening to the white porpoise (*Delphinapterus leucas*). Science 109(2824):143-144.

Schlundt, C.E., J.J. Finneran, D.A. Carder and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. J. Acoust. Soc. Am. 107(6):3496-3508.

Schlundt, C. E., R.L. Dear, D.A. Carder, and J.J. Finneran, 2006. Growth and recovery of temporary threshold shifts in a dolphin exposed to midfrequency tones with durations up to 128 s. J. Acoust. Soc. Am. 120, 3227.

Schusterman, R., D. Kastak, B. Southall and C. Kastak. 2000. Underwater temporary threshold shifts in pinnipeds: tradeoffs between noise intensity and duration. J. Acoust. Soc. Am. 108(5, Pt. 2):2515-2516.

Shepard, G.W., P.A. Kuumhansl, M.L. Knack, and C.I. Malme. 2001. ANIMIDA Phase I: Ambient and industrial noise measurements near the Northstar and Liberty sites during April 2000. BBN Technical Memorandum No. 1270 prepared for U.S. Department of Interior, Minerals Management Service, Alaska OCS Office.

Sjare, B.L. and T.G. Smith. 1986a. The relationship between behavioral activity and underwater vocalizations of the white whale, *Delphinapterus leucas*. Can. J. Zool. 64(12):2824-2831.

Sjare, B.L. and T.G. Smith. 1986b. The vocal repertoire of white whales, *Delphinapterus leucas*, summering in Cunningham Inlet, Northwest Territories. Can. J. Zool. 64(2):407-415.

Skalski, J.R., W.H. Pearson and C.I. Malme. 1992. Effects of sounds from a geophysical survey device on catch-per-unit-effort in a hook-and-line fishery for rockfish (*Sebastes spp*). Can. J. Fish. Aquatic Sci. 49:1357-1365.

Smith, T.G. 1973. Population dynamics of the ringed seal in the Canadian eastern arctic. Fish. Res. Board Can. Bull. 181. 55 p.

Smith, T.G. 1987. The ringed seal, *Phoca hispida*, of the Canadian Western Arctic. Can. Bull. Fish. Aquat. Sci. 216: 81 p.

Smith, T.G. and I. Stirling. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Can. J. Zool. 53:1297-1305.

Smultea, M.A. and B. Würsig. 1995. Behavioral reactions of bottlenose dolphins to the Mega borg oil spill, Gulf of Mexico 1990. Aquat. Mamm. 21:171-181.

Spence, J. 2006. Controlling underwater noise from offshore gravel islands during production activities. NCE Report 06-003. Rep. from Noise Control Engineering Inc., Billerica, MA, for Minerals Management Service, Herndon, VA. MMS Noise Project #538.

Spraker, T.R., L.F. Lowry, and K.J. Frost. 1994. Gross necropsy and histopathological lesions found in harbor seals. p. 281-312 In: T.R. Loughlin (ed.), Marine mammals and the Exxon Valdez. Academic Press, San Diego, CA.

Stewart, B.S., F.T. Awbrey and W.E. Evans. 1983. Belukha whale (*Delphinapterus leucas*) responses to industrial noise in Nushagak Bay, Alaska: 1983. Outer Cont. Shelf Environ. Assess. Progr., Final Rep. Princ. Invest., NOAA, Anchorage, AK 43(1986):587-616. 702 p. OCS Study MMS 86-0057; NTIS PB87-192118.

Stirling, I. and T.G. Smith. 1977. Interrelationships of Arctic Ocean mammals in the sea ice habitat. p. 129-136 In: Proceedings of the Circumpolar Conference on Northern Ecology. Sect. II. Nat. Res. Counc. Can., Ottawa, Ont.

Stirling, I., M. Kingsley and W. Calvert. 1982. The distribution and abundance of seals in the eastern Beaufort Sea, 1974-79. Can. Wildl. Serv. Occas. Pap. 47. 25 p.

Suydam, R.S., R.P. Angliss, J.C. George, S.R. Braund and D.P. DeMaster. 1995. Revised data on the subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaska eskimos, 1973-1993. Rep. Int. Whal. Comm. 45:335-338.

Suydam, R.S., L.F. Lowry, K.J. Frost, G.M. O'Corry-Crowe and D. Pikok Jr. 2001. Satellite tracking of eastern Chukchi Sea beluga whales into the Arctic Ocean. Arctic 54(3):237-243.

Suydam, R., L. Lowry, K. Frost, G. O'Corry-Crowe and G. VanBlaricom. 2003. Satellite tracking of eastern Chukchi Sea beluga whales in the Beaufort Sea and Arctic Ocean, 1998-2002. Abstr. 15th Bienn. Conf. Biol. Mar. Mamm., Greensboro, NC, Dec. 2003:159.

Swartz, S.L. and M.L. Jones. 1981. Demographic studies and habitat assessment of gray whales, Eschrichtius robustus, in Laguna San Ignacio, Baja California, Mexico. U.S. Mar. Mamm. Comm. Rep. MMC-78/03. 34 p. NTIS PB-289737.

Thomson, D.H. and W.J. Richardson. 1987. Integration. p. 449-479 In: W. J. Richardson (ed.) Importance of the eastern Alaskan Beaufort Sea to feeding Bowhead whales, 1985-86. OCS Study MMS 87-0037. Rep. from LGL Ecological Research Associates, Inc., Bryan, TX, for U. S. Minerals Management Service. 547 p. NTIS PB88-150271.

Todd, S., P. Stevick, J. Lien, F. Marques, D. Ketten. 1996. Behavioral effects of exposure to underwater explosions in humpback whales (*Megaptera novaeangliae*). Can. J. Zool. 74:1661-1672.

Tomilin, A.G. 1957. Mammals of the U.S.S.R. and adjacent countries. Vol. 9. Cetaceans. Israel Progr. Sci. Transl. (1967), Jerusalem. 717 p. NTIS TT 65-50086.

Treacy, S.D. 1988. Aerial surveys of endangered whales in the Beaufort Sea, fall 1987. OCS Study MMS 88-0030. U.S. Minerals Manage. Serv., Anchorage, AK. 142 p. NTIS PB89-168785.

Treacy, S.D. 1989. Aerial surveys of endangered whales in the Beaufort Sea, fall 1988. OCS Study MMS 89-0033. U.S. Minerals Manage. Serv., Anchorage, AK. 102 p. NTIS PB90-161464.

Treacy, S.D. 1990. Aerial surveys of endangered whales in the Beaufort Sea, fall 1989. OCS Study MMS 90-0047. U.S. Minerals Manage. Serv., Anchorage, AK. 105 p. NTIS PB91-235218.

Treacy, S.D. 1991. Aerial surveys of endangered whales in the Beaufort Sea, fall 1990. OCS Study MMS 91-0055. U.S. Minerals Manage. Serv., Anchorage, AK. 108 p. NTIS PB92-176106.

Treacy, S.D. 1992. Aerial surveys of endangered whales in the Beaufort Sea, fall 1991. OCS Study MMS 92-0017. U.S. Minerals Manage. Serv., Anchorage, AK. 93 p.

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. 1994. Aerial surveys of endangered whales in the Beaufort Sea, fall 1993. OCS Study MMS 94-0032. U.S. Minerals Manage. Serv., Anchorage, AK. 133 p.

Treacy, S.D. 1995. Aerial surveys of endangered whales in the Beaufort Sea, fall 1994. OCS Study MMS 95-0033. U.S. Minerals Manage. Serv., Anchorage, AK. 116 p.

Treacy, S.D. 1996. Aerial surveys of endangered whales in the Beaufort Sea, fall 1995. OCS Study MMS 96-0006. U.S. Minerals Manage. Serv., Anchorage, AK. 121 p. NTIS PB97-115752

Treacy, S.D. 1997. Aerial surveys of endangered whales in the Beaufort Sea, fall 1996. OCS Study MMS 97-0016. U.S. Minerals Manage. Serv., Anchorage, AK. 115 p. NTIS PB97-194690

Treacy, S.D. 1998. Aerial surveys of endangered whales in the Beaufort Sea, fall 1997. OCS Study MMS 98-0059. U.S. Minerals Manage. Serv., Anchorage, AK. 143 p. Published 1999.

Treacy, S.D. 2000. Aerial surveys of endangered whales in the Beaufort Sea, fall 1998-1999. OCS Study MMS 2000-066. U.S. Minerals Manage. Serv., Anchorage, AK. 135 p.

Treacy, S.D. 2002a. Aerial surveys of endangered whales in the Beaufort Sea, fall 2000. OCS Study MMS 2002-014. U.S. Minerals Manage. Serv., 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 Manage. Serv., Anchorage, AK. 117 p.

Treacy, S.D., Gleason, J.S., and Cowles, C.J. 2006. Offshore distances of bowhead whales (*Balaena mysticetus*) observed during fall in the Beaufort Sea, 1982–2000: An alternative interpretation. Arctic 59(1):83–90.

Tyack, P.L. and C.W. Clark. 1998. Quick look -- Playback of low frequency sound to gray whales migrating past the central California coast - January, 1998. Rep. from Woods Hole Oceanogr. Inst., Woods Hole, MA; and Bioacoustics Res. Prog., Cornell Univ., Ithaca, NY. 34 p. + Figures & Tables.

USACE. 1998a. Beaufort oil and gas development/Northstar Project: Environmental impact statement. Volume IV – Chapters 8-13. U.S. Army Corps of Engineers, Alaska. Anchorage AK.

USACE. 1998b. Beaufort oil and gas development/Northstar Project: Environmental impact statement. Appendix B - Biological Assessment. U.S. Army Corps of Engineers, Alaska. Anchorage AK.

von Ziegesar, O., E. Miller and M.E. Dahlheim. 1994. Impacts on humpback whales in Prince William Sound. p 173-191 In: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego.

Wacasey, J. W. 1975. Biological productivity of the southern Beaufort Sea: zoobenthic studies. Tech. Rep. 12b. Can. Dep. Environ., Beaufort Sea Proj. Victoria, B.C.

Wartzok, D., W.A. Watkins, B. Würsig and C.I. Malme. 1989. Movements and behaviors of bowhead whales in response to repeated exposures to noises associated with industrial activities in the Beaufort Sea. Rep. from Purdue Univ., Fort Wayne, IN, for Amoco Production Co., Anchorage, AK. 228 p.

White, M.J., Jr., J. Norris, D. Ljungblad, K. Baron and G. di Sciara. 1978. Auditory thresholds of two beluga whales (*Delphinapterus leucas*). HSWRI Tech. Rep. 78-109. Rep. from Hubbs/Sea World Res. Inst., San Diego, CA, for Naval Ocean Systems Center, San Diego, CA. 35 p.

Williams, T.M., G.A. Antonelis and J. Balke. 1994. Health evaluation, rehabilitation and release of oiled harbor seal pups. p 227-241 In: T.R. Loughlin (ed.), Marine Mammals and the Exxon Valdez. Academic Press, San Diego.

Williams, M.T. and J.A. Coltrane. (eds.). 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. 643. Rep. from LGL Alaska Res. Assoc. Inc. for BP Explor. (Alaska) Inc., ExxonMobil Production, a division of Exxon Mobil Corp., Phillips Alaska Inc. Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 103 p.

Williams, M.T., T.G. Smith and C.J. Perham. 2002. Ringed seal structures in sea ice near Northstar, winter and spring of 2000-2001. p. 4-1 to 4-33 In: W.J. Richardson and M.T. Williams (eds., 2001, q.v). LGL Rep. P485-2.

Williams, M.T., R. Rodrigues, V.D. Moulton, and S.B. Blackwell. 2006a. Summary of ringed seal responses during the break-up and open water period. P. 6-1 to 6-9 *In:* W.J. Richardson (ed., 2008, q.v.). LGL Rep. P1004.

Williams, M.T., V.D. Moulton, W.J. Richardson, and S.B. Blackwell. 2006b. Summary of results of overwintering ringed seals in relation to Northstar sounds P. 3-1 to 3-37 *In:* W.J. Richardson (ed., 2008, q.v.). LGL Rep. P1004.

Williams, M.T., C.S. Nations, T.G. Smith, V.D. Moulton and C. Perham. 2006c. Ringed seal (*Phoca hispida*) use of subnivean structures in the Alaskan Beaufort Sea during development of an oil production facility. **Aquatic Mammals** 32 (3): 311-324.

Woodby, D.A. and D.B. Botkin. 1993. Stock sizes prior to commercial whaling. p. 387-407 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mamm., Lawrence, KS. 787 p.

Woodward Clyde Consultants. 1995. Northstar Unit Beaufort Sea, Alaska: Literature Review.

Würsig, B. and C. Clark. 1993. Behavior. p. 157-199 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mamm., Lawrence, KS. 787 p.

Würsig, B., E.M. Dorsey, W.J. Richardson and R.S. Wells. 1989. Feeding, aerial and play behavior of the bowhead whale, *Balaena mysticetus*, summering in the Beaufort Sea. Aquat. Mamm. 15(1):27-37.

Würsig, B., E.M. Dorsey, M.A. Fraker, R.S. Payne, W.J. Richardson and R.S. Wells. 1984. Behavior of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea: surfacing, respiration, and dive characteristics. Can. J. Zool. 62(10):1910-1921.

Zeh, J.E., C.W. Clark, J.C. George, D. Withrow, G.M. Carroll and W.R. Koski. 1993. Current population size and dynamics. p. 409-489 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds.), The bowhead whale. Spec. Publ. 2. Soc. Mar. Mammal., Lawrence, KS. 787 p.

Zeh, J.E., A.E. Raftery, and A.A. Schaffner. 1996. Revised estimates of bowhead population size and rate of increase. Rep. Int. Whal. Comm. 46:670.