Application for Incidental Harassment Authorization for the Non-Lethal Taking of Whales and Seals in Conjunction with Planned 2010 Exploration Drilling Program near Camden Bay in the Beaufort Sea, Alaska

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Prepared by:

Shell Offshore Inc.
3601 C Street, Suite 1000
Anchorage, Alaska 99503

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Executive Summary

Shell Offshore Inc. (Shell) plans to complete two exploration wells at two drill sites in the eastern Beaufort Sea on Outer Continental Shelf (OCS) leases acquired from the U.S. Minerals Management Service during the 2010 drilling season. Shell plans to use the M/V *Frontier Discoverer* (*Discoverer*) drillship (specifications listed in Attachment A), attended by a minimum of seven support vessels for the purposes of ice management, anchor handling, oil spill response (OSR), refueling, and resupply. The *Discoverer* is an industry-standard, ice-reinforced drillship similar to those routinely used in the Beaufort and Chukchi Seas since the 1980s, as well as elsewhere in the world's oceans. During drilling and associated operations, the drillship will emit near continuous non-pulse sounds that ensonify only very limited areas (approximately 0.01 km^2) of the ocean bottom and intervening water column.

Since the early 1990s, the National Marine Fisheries Service (NMFS) has issued incidental harassment authorizations (IHAs) to industry for the non-lethal taking of small numbers of marine mammals related to the non-pulse, continuous sounds generated by offshore exploration drilling. Shell requests an IHA pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5), to allow non-lethal takes of whales and seals incidental to Shell's 2010 exploration drilling program.

Shell has calculated the estimated take of marine mammals from the low-level non-pulse sound generating sources active during drilling operations and, as detailed herein, determined that any takes that might result from the proposed operations would not be of biological significance to marine mammal populations.

The only anticipated impacts to marine mammals associated with the drilling exploration program that might result in a take are propagation of sounds from the drillship. Any impacts to whales and seals would be temporary and result in only short-term displacement of seals and whales from within ensonified zones produced by such noise sources.

An impact analysis of underwater sound generated by the planned 2010 exploration drilling program (included herein) determined that the following marine mammals will be exposed to sounds ≥120 and ≥160 decibels (dB) re 1 µPa (see Tables 4-1 for marine mammal populations and Table 6-7 for total maximum number of exposures to sound). The ≥160 dB exposures are listed in parentheses:

· 1977 (14) Bowhead whales (approximately 0.12 percent of the population exposed to sounds ≥160 dB)
· 4 (0) Beluga whales (no exposures of the Beaufort and eastern Chukchi Sea stock populations to sounds ≥160 dB)
· 22 (0) Bearded seals no exposure to sounds ≥160 dB)
· 436 (0) Ringed seals (no exposure to sounds ≥160 dB)

The same impact analysis determined that a maximum of three spotted seals will be exposed to sounds ≥ 160 dB whereas no more than five narwhal, harbor porpoise, gray whale, humpback whale, Minke whale, and ribbon seal each will be exposed to any sounds ≥160 dB.

In regard to the subsistence harvest of bowhead whale in the Beaufort Sea, as a consequence of Shell's planned mitigation measures any effects on the bowhead whale as a subsistence resource also will be negligible.

The organization of this request for IHA follows the organization of Chapter 50 Code of Federal Regulations (CFR) § 216.104 (a). The remainder of this document is organized as to follow 50 CFR § 216.104 (a) (1)-(14).

Shell relied on guidance in 50 CFR 216.104, Submission of Requests, to prepare its request for this IHA:

> (a) In order for the National Marine Fisheries Service (NMFS) to consider authorizing the taking by U.S. citizens of small numbers of marine mammals incidental to a specified activity (other than commercial fishing), or to make a finding that incidental take is unlikely to occur, a written request must be submitted to the Assistant Administrator. All requests must include the following information for their activity:

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

Information required by 50 CFR § 216.104 (a):

Shell plans to conduct an exploration drilling program on U.S. Department of the Interior, Minerals Management Service (MMS) Alaska OCS leases located north of Point Thomson near Camden Bay in the Beaufort Sea during the 2010 drilling season (Camden Bay 2010 Exploration Drilling Program, hereinafter, the "drilling program"*)* (Figure 1-1).

The leases were acquired during the Beaufort Sea Oil and Gas Lease Sales 195 (March 2005) and 202 (April 2007). During the 2010 drilling program, Shell plans to complete two exploration wells at two drill sites, one well each on the Torpedo prospect (NR06-04 Flaxman Island lease block 6610, OCS-Y-1941 [Flaxman Island 6610]) and the Sivulliq prospect (NR06-04 Flaxman Island lease block 6658, OCS-Y 1805 [Flaxman Island 6658]). All drilling is planned to be vertical.

Shell plans to drill the Torpedo prospect well first, followed by the Sivulliq well, unless adverse surface conditions or other factors dictate a reversal of drilling sequence. In that case, Shell will mobilize to the Sivulliq prospect and drill there first.

The ice reinforced drillship *Discoverer* will be used to drill the wells. Rig specification for the *Discoverer* is located in Attachment A. While on location at the drill sites, the *Discoverer* will be affixed to the seafloor using eight 7-ton Stevpris anchors arranged in a radial array.

During the 2010 drilling season, the *Discoverer* will be attended by a minimum of seven vessels that will be used for ice management, anchor handling, oil spill response (OSR), refueling, resupply, and servicing of the drilling operations. Two vessels will conduct ice management, an ice management vessel and an anchor handler.

Re-supply between the drill sites and West Dock will use a coastwise qualified vessel. An ice-capable OSR barge (OSRB), with an associated tug will be located nearby during the planned drilling program. The OSRB will be supported by a berthing vessel for the OSR crew. An OSR tanker also will be nearby for its storage capability of recovered liquids.

The *Discoverer* and its associated support vessels will transit through the Bering Strait into the Chukchi Sea on July 1 or later, arriving on location near Camden Bay approximately July 10. Exploration drilling activities at the Sivulliq or Torpedo drill sites are planned to begin on or about July 10 and run through October 31, 2010, with a suspension of all operations beginning August 25 for the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts. The *Discoverer* and support vessels will leave the Camden Bay project area, will move to a location at or north of 71.25^o N latitude and at or west of 146.4^o W longitude and will return to resume activities after the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts conclude. Activities will extend through October 31, depending on ice and weather.

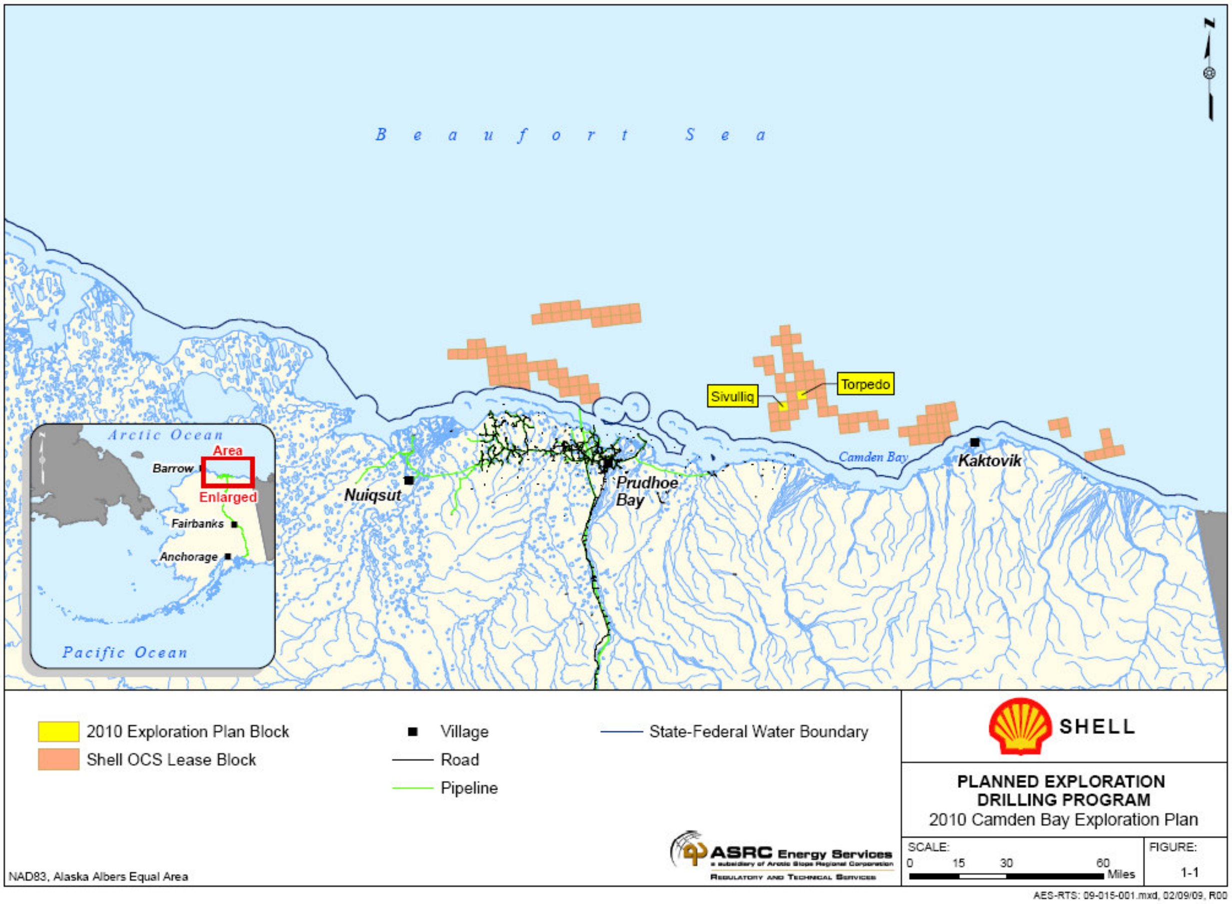
Helicopters are planned to provide support for crew change, provision re-supply, and search-and-rescue operations during the drilling season. The aircraft operations will principally be based in Deadhorse, Alaska.

At the end of the drilling season, the *Discoverer*, ice management vessels, and support vessels will transit west into and through the Chukchi Sea.

TABLE 1-1 CAMDEN BAY 2010 EXPLORATION DRILLING PROGRAM – PROPOSED VESSEL AND AIRCRAFT LIST

Vessel	Trip Frequency or Duration
Drillship and Drill Support (or similar)	
Frontier Discoverer	Stays in the prospect area throughout 2010 drilling season
Vladimir Ignatjuk – ice management	Stays in the area of the drillship throughout the 2010 drilling season
Nordica – anchor handler and ice management	Stays in the area of the drillship throughout the 2010 drilling season
Arctic Seal – resupply	Several trips between West Dock and the drill sites in Camden Bay
Nanuq - Berthing vessel	Stays in the area of the OSRB and drillship throughout the 2010 drilling season
OSRB and Support (or similar)	
Endeavor -OSRB with associated ice class tug	Stays in the area of the drillship throughout the 2010 drilling season
OSR Workboats (4)	Stays in the area of the drillship throughout the 2010 drilling season
Affinity (OSR Tanker) – recovered liquid storage	Stays in the area of the drillship throughout the 2010 drilling season
Aircraft (or similar)	
(2) Super Puma, Sikorsky 592, AB 139 or similar – crew rotation	Three trips between the shorebase and offshore vessels per day throughout the 2010 drilling season
(1) Helicopter – search-and-rescue	Trips made only in emergency; training flights

Figure 1-1 – Camden Bay 2010 Exploration Drilling Program Lease Block Locations



Planned Mitigation

The *Discoverer* and all support vessels will operate in accordance with the provisions of a Plan of Cooperation (POC). Shell prepared a POC to mitigate effects of Shell's planned exploration drilling program where activities 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 POC was prepared based upon Shell's experience (recent and past) in the Alaska OCS and in consultation with affected Beaufort and Chukchi Sea communities and marine mammal associations. During these meetings, Shell focused on lessons learned from prior years' activities and presented mitigation measures for avoiding potential conflicts, which are outlined in the 2010 POC. Shell's Chukchi Sea POC addresses primarily vessel transit activities. For the proposed Camden Bay drilling program, Shell's POC addresses the issue of vessel transit, whereas the POC with Beaufort Sea villages will address vessel transit, drilling and associated activities. The mitigation measures described in Section 12.3 are intended to minimize any adverse effects on the availability of marine mammals for subsistence uses.

2. The dates and duration of such activity and the specific geographic region where it will occur:

Anticipated Duration of this Permit

Shell anticipates that the IHA issued by NMFS for the planned Camden Bay 2010 exploration drilling program will be valid for one year from the date of issuance.

Timing of Mobilization and Demobilization of the Discoverer

Shell's base plan is for two ice management/anchor handling vessels, the M/V *Vladimir Ignatjuk* and the ice management/anchor handling vessel M/V *Nordica* or similar vessels, to accompany the *Discoverer* traveling north of Dutch Harbor through the Bering Strait, after July 1, 2010 then through the Chukchi Sea, around Pt. Barrow and east through the Alaskan Beaufort Sea, before arriving on location of the Torpedo "H" location on or about July 10^{th}, or Sivulliq "N" if adverse surface conditions or other factors dictate a reversal of drilling sequence. At the completion of the drilling season on or before October 31, 2010, one or two ice management vessels, along with various support vessels, such as the OSR fleet, will accompany the *Discoverer* as it travels west through the Beaufort Sea, then south through the Chukchi Sea and the Bering Strait. Subject to ice conditions alternate exit routes may be considered.

Exploration Drilling

Shell plans to complete exploration wells at two drill sites located near Camden Bay during the 2010 drilling season: Torpedo H (lease block 6610) and Sivulliq N (lease block 6658) (Figure 1-1 and Table 2-1). Shell will mobilize into the Beaufort Sea in early July and plans to commence drilling as soon as ice, weather, and other conditions allow for safe drilling operations. Shell's plan assumes the *Discoverer* will be on location at Torpedo "H" by July 10^{th}, or Sivulliq "N" if ice or other adverse surface conditions dictate a different drilling sequence.

TABLE 2-1 DRILL SITE LOCATIONS AND WATER DEPTHS

Drill site	Distance from shore	NR06-04 Lease Block No.	Surface Location (NAD 83)		Water Depth
			Latitude (north)	Longitude (west)	Feet
Sivulliq N	16 miles	6658	70° 23' 29.5814"	145° 58' 52.5284"	107
Torpedo H	22 miles	6610	70° 27' 01.6193"	145° 49' 32.0650"	120

Activities associated with the 2010 Beaufort Sea exploration drilling program and analyzed herein include operation of the *Discoverer*, associated support vessels, crew change support and re-supply. The *Discoverer* will remain at the location of the designated exploration drill sites except when mobilizing and demobilizing to and from Camden Bay, transiting between drill sites, and temporarily moving off location if it is determined ice conditions require such a move to ensure the safety of personnel and/or the environment in accordance to Shells Ice Management Plan. Ice management vessels, anchor tenders, and OSR vessels will remain in close proximity to the drillship during drilling operations. Crew change/re-supply vessels will transit to and from the drillship at the estimated frequency shown in Table 1. Helicopter flight support from Deadhorse will provide crew changes, and fixed-wing aircraft may depart from Deadhorse also, for an aerial survey program utilized for marine mammal monitoring.

Exploration drilling activities at the Sivulliq or Torpedo drill sites are planned to begin on or about July 10 and run through October 31, 2010, with a suspension of all operations beginning August 25 for the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts. The *Discoverer* and support vessels will leave the Camden Bay project area and will return to resume activities after the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts conclude. Activities will extend through October 31, depending on ice and weather.

Shell will cease drilling on or before October 31st, after which the *Discoverer* will exit the Alaskan Beaufort Sea. In total, it is anticipated by Shell that the exploration drilling program will require approximately 74 drilling days, excluding weather, whaling shut-down or other operational delays. Shell assumes approximately 11 additional days will be needed for drillship mobilization, drillship moves between locations, and drillship demobilization.

3. Species and Numbers of Marine Mammals in Area:

Marine mammals that occur in the area of the planned Camden Bay 2010 exploration drilling program belong to three taxonomic groups: odontocetes (toothed cetaceans, such as beluga whale and narwhal), mysticetes (baleen whales), and carnivora (pinnipeds and polar bears). Cetaceans and pinnipeds (except Pacific walrus) are the subject of this IHA application to NMFS. The Pacific walrus and polar bear are managed by the U.S. Fish & Wildlife Service (USFWS).

Eight cetacean and four seal species under the jurisdiction of NMFS are known to or may occur in the area of the planned exploration drilling program (Table 2). Two of these species, the bowhead and humpback whales, are listed as "Endangered" under the U.S. Endangered Species Act (ESA). Humpback whales normally do not occur in the Chukchi or Beaufort Seas; however, several humpback sightings were recorded during vessel-based surveys in the Chukchi Sea in 2007 (Reiser et al. 2009a), and a single humpback whale sighting was recorded in the Beaufort Sea east of Barrow in 2007 (Green et al. 2007).

To avoid redundancy, we have included the required information about the species that are known to or may be present and (insofar as it is known) numbers of these species in Section 4, below.

4. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals:

Sections 3 and 4 are integrated here to minimize repetition.

Eight cetacean and four seal species could occur in the general area of the planned exploration drilling program (Table 4-1). The marine mammal species under NMFS's jurisdiction most likely to occur in the general area of the planned Camden Bay 2010 exploration drilling program in the Beaufort Sea include two cetacean species (beluga and bowhead whales), and three seal species (ringed, bearded, and spotted seals). Most encounters are likely to occur in nearshore shelf habitats or along the ice edge. The marine mammal species that is likely to be encountered most widely (in space and time) throughout the period of the planned drilling program is the ringed seal. Encounters with bowhead and beluga whales are expected to be limited to particular regions and seasons, as discussed below.

TABLE 4-1 THE HABITAT, ABUNDANCE (IN THE BEAUFORT SEA), AND CONSERVATION STATUS OF MARINE MAMMALS INHABITING THE AREA OF THE PLANNED EXPLORATION DRILLING PROGRAM

Species	Habitat	Abundance	ESA[1]	IUCN[2]	CITES[3]
Odontocetes Beluga whale (*Delphinapterus leucas*) (Eastern Chukchi Sea Stock	Offshore, Coastal, Ice edges	3,710[4]	Not listed	VU	II
Beluga whale (Beaufort Sea Stock)	Offshore, Coastal, Ice edges	39,257[5]	Not Listed	VU	II
Narwhal (*Monodon monoceros*)	Offshore, Ice edge	Rare[6]	Not listed	DD	II
Killer whale (*Orcinus orca*)	Widely distributed	Rare	Not listed	LR-cd	II
Harbor Porpoise (*Phocoena phocoena*) (Bering Sea Stock	Coastal, inland waters, shallow offshore waters	Uncommon	Not listed	VU	II
Mysticetes Bowhead whale (*Balaena mysticetus*)	Pack ice & coastal	11,800[7]	Endangered	LR-cd	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	Uncommon	Not listed	LR-cd	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	Rare	Not listed	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Shelf, coastal	Rare	Endangered	–	–
Pinnipeds Bearded seal (*Erignathus barbatus*)	Pack ice, shallow offshore waters	300,000-450,000[8] 4863[9]	In review for listing	–	–
Spotted seal (*Phoca largha*)	Pack ice, coastal haulouts	1000[10]	Arctic pop. Segments not listed	–	–
Ringed seal (*Pusa hispida*)	Landfast & pack ice, offshore	326,500[11]	In review for listing	–	–
Ribbon seal (*Histriophoca fasciata*)	Offshore, pack ice	Rare	Not Listed	–	–

[1] U.S. Endangered Species Act.
[2] IUCN Red List of Threatened Species (2003). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004). Appendix I = endangered/threatened; Appendix II = threatened/at risk; Appendix III = some restrictions on trade of animals/animal parts.
[4] Angliss and Allen (2009)
[5] Beaufort Sea population (IWC 2000, Angliss and Allen 2009).
[6] Population in Baffin Bay and the Canadian arctic archipelago is ~60,000 (DFO 2004); very few enter the Beaufort Sea.
[7] 2004 Population estimate (Koski et al. 2009).
[8] Alaska population (USDI/MMS 1996).
[9] Eastern Chukchi Sea population (NMML, unpublished data).
[10] Alaska Beaufort Sea population (USDI/MMS 1996).
[11] Alaskan Beaufort Sea population estimate (Amstrup 1995).

Other cetacean species that have been observed in the Beaufort Sea but are uncommon or rarely identified in the project area include harbor porpoise, narwhal, killer whale, Minke whale, humpback whale, and gray whale. These species could occur in the project area, but each of these species is uncommon or rare in the area and relatively few encounters with these species are expected during the exploration drilling program. The narwhal occurs in Canadian waters and occasionally in the Beaufort Sea, but it is rare there and is not expected to be encountered.

(1) Odontocetes

(a) Beluga (*Delphinapterus leucas*)

Beluga whales are largely absent from the coast of the Alaskan Beaufort Sea during summer. A few beluga whales could be encountered there in late summer and autumn. There is a higher probability of encountering westward-migrating belugas farther offshore in the Beaufort Sea (>60 km, or water depths >200 m) during late summer and autumn than in nearshore locations.

The beluga whale is an arctic and subarctic species that includes several populations in Alaska and northern European waters. It has a circumpolar distribution in the Northern Hemisphere and occurs between 50ºN and 80ºN (Reeves et al. 2002). It is distributed in seasonally ice-covered seas and migrates to warmer coastal estuaries, bays, and rivers in summer for molting (Finley 1982).

Pod structure in beluga groups appears to be along matrilineal lines, with males forming separate aggregations. Small groups are often observed traveling or resting together. Belugas often migrate in groups of 100 to 600 animals (Braham and Krogman 1977) or more. The relationships between whales within groups are not known, although hunters have reported that belugas form family groups with whales of different ages traveling together (Huntington 2000).

In Alaska, beluga whales comprise five distinct stocks: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). For the planned exploration drilling program near Camden Bay in the Beaufort Sea, only the Beaufort Sea stock and eastern Chukchi Sea stock may be encountered. Some eastern Chukchi Sea animals enter the Beaufort Sea in late summer (Suydam et al. 2005).

The most recent estimate of the ***eastern Chukchi Sea*** population is 3710 animals (Angliss and Allen 2009). This estimate was based on surveys conducted in 1989–1991. Survey effort was concentrated on the 170-km long Kasegaluk Lagoon where belugas are known to occur during the open-water season. The calculation was considered to be a minimum population estimate for the eastern Chukchi Sea stock because the surveys on which it was based did not include offshore areas where belugas are also likely to occur. This population is considered to be stable. It is assumed that beluga whales from the eastern Chukchi stock winter in the Bering Sea (Angliss and Allen 2009).

Although beluga whales are known to congregate in Kasegaluk Lagoon during summer, evidence from a small number of satellite-tagged animals suggests that some of these whales may subsequently range into the Arctic Ocean north of the Beaufort Sea. Suydam et al. (2005) put satellite tags on 23 beluga whales captured in Kasegaluk Lagoon in late June and early July 1998–2002. Five of these whales moved far into the Arctic Ocean and into the pack ice to 79–80°N. These and other whales moved to areas as far as 1,100 km offshore between Barrow and the Mackenzie River Delta spending time in water with 90% ice coverage.

The ***Beaufort Sea population*** was estimated to contain 39,258 individuals as of 1992 (DeMaster 1995; Angliss and Allen 2009). This estimate was based on the application of a sightability correction factor of 2× to the 1992 uncorrected census of 19,629 individuals made by Harwood et al. (1996). This estimate was obtained from a partial survey of the known range of the Beaufort Sea population and may be an underestimate of the true population size. This population is not considered by NMFS to be a strategic stock and is believed to be stable or increasing (Angliss and Allen 2009).

Beluga whales of the Beaufort stock winter in the Bering Sea, summer in the eastern Beaufort Sea, and migrate through offshore waters of western and northern Alaska (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 (Braham et al. 1984; Ljungblad et al. 1984; Richardson et al. 1995a).

Much of the Beaufort Sea seasonal population enters the Mackenzie River estuary for a short period during July–August to molt their epidermis, but they spend most of the summer in offshore waters of the eastern Beaufort Sea, Amundsen Gulf and more northerly areas (Davis and Evans 1982; Harwood et al. 1996; Richard et al. 2001). Belugas are rarely seen in the central Alaskan Beaufort Sea during the early summer, but a number were reported there during early July from aerial surveys in 2008 (Christie et al. 2009). 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. 1999). During fall aerial surveys in the Alaskan Beaufort Sea, Lyons et al. (2009) reported the highest beluga sighting rates during the first two weeks of September and in the northern part of their survey area.

Moore (2000) and Moore et al. (2000) suggested that beluga whales select deeper water at or beyond the shelf break independent of ice cover. However, during the westward migration in late summer and autumn, small numbers of belugas are sometimes seen near the north coast of Alaska (e.g., Johnson 1979). Christie et al. (2009) reported higher beluga sighting rates at locations >60 km offshore than at locations nearer shore during aerial surveys in the Alaskan Beaufort Sea in 2006-2008. The main fall migration corridor of beluga whales is ~100+ km north of the coast. Satellite-linked telemetry data show that some belugas of this population migrate west considerably farther offshore, as far north as 76º to 78ºN latitude (Richard et al. 1997, 2001).

In summary, beluga whales are largely absent from the coast of the Alaskan Beaufort Sea during summer, but a few beluga whales could be encountered there in late summer and autumn. There is a higher probability of encountering westward-migrating belugas farther offshore in the Beaufort Sea during late summer and autumn than in nearshore locations. Belugas of the eastern Chukchi population could also be encountered in the Beaufort Sea.

(b) Narwhal (*Monodon monoceros*)

Narwhals have a discontinuous arctic distribution (Hay and Mansfield 1989; Reeves et al. 2002). A large population inhabits Baffin Bay, West Greenland, and the eastern part of the Canadian Arctic archipelago, and much smaller numbers inhabit the Northeast Atlantic/East Greenland area. Population estimates for the narwhal are scarce, and the IUCN-World Conservation Union lists the species as Data Deficient (IUCN Red List of Threatened Species 2003). Innes et al. (2002) estimated a population size of 45,358 narwhals in the Canadian Arctic, although only part of the area was surveyed. There are scattered records of narwhal in Alaskan waters, including reports by subsistence hunters, where the species is considered extralimital (Reeves et al. 2002). Thus, it is possible, but very unlikely, that individuals could be encountered in the area of the planned drilling program.

(c) Harbor Porpoise (*Phocoena phocoena*)

Small numbers of harbor porpoises could occur in the general area of the planned Beaufort Sea drilling program.

The harbor porpoise is a small odontocete that inhabits shallow, coastal waters—temperate, subarctic, and arctic—in the Northern Hemisphere (Read 1999). Harbor porpoises occur mainly in shelf areas where they can dive to depths of at least 220 m and stay submerged for more than 5 min (Harwood and Wilson 2001) feeding on small schooling fish (Read 1999). Harbor porpoises typically occur in small groups of only a few individuals and tend to avoid vessels (Richardson et al. 1995a).

The subspecies *P. p. vomerina* ranges from the Chukchi Sea, Pribilof Islands, Unimak Island, and the southeastern shore of Bristol Bay south to San Luis Obispo, California. Point Barrow, Alaska, is the approximate northeastern extent of their regular range (Suydam and George 1992), though there are extralimital records east to the mouth of the Mackenzie River in the Northwest Territories, Canada and recent sightings in the Beaufort Sea in the vicinity of Prudhoe Bay during surveys in 2007 and 2008 (Christie et al. 2009). MMOs onboard industry vessels reported one harbor porpoise sighting in the Beaufort Sea in 2006 and no sightings were recorded in 2007 or 2008 (Savarese et al. 2009). Monnett and Treacy (2005) did not report any harbor porpoise sightings during aerial surveys in the Beaufort Sea from 2002 through 2004.

(2) Mysticetes

(a) Bowhead Whale (*Balaena mysticetus*)

Few bowhead whales are expected in the project area at the commencement of the drilling program in July. Shell anticipates more bowheads to be present in the area in the fall during the whales' westward migration. Mitigation measures built into Shell's operational plans will mitigate any potential impacts on local subsistence bowhead whale hunting and will minimize impacts on the species during drilling activities before and after the subsistence hunt.

Bowhead whales only occur at high latitudes in the northern hemisphere and have a disjunctive circumpolar distribution (Reeves 1980). The bowhead is one of only three whale species that spend their entire lives in the Arctic. Bowhead whales are found in the western Arctic (Bering, Chukchi, and Beaufort Seas), the Canadian Arctic and West Greenland (Baffin Bay, Davis Strait, and Hudson Bay), the Okhotsk Sea (eastern Russia), and the Northeast Atlantic from Spitzbergen westward to eastern Greenland. Four stocks are recognized for management purposes. The largest is the Western Arctic or Bering–Chukchi–Beaufort (BCB) stock, which includes whales that winter in the Bering Sea and migrate through the Bering Strait, Chukchi Sea and Alaskan Beaufort Sea to the Canadian Beaufort Sea, where they feed during the summer. These whales migrate west through the Alaskan Beaufort Sea in the fall as they return to wintering areas in the Bering Sea. Satellite tracking data reported by the Alaska Department of Fish and Game (ADF&G) indicate that some bowhead whales continue migrating west past Barrow and through the Chukchi Sea to Russian waters where they may spend days to weeks apparently feeding before turning south toward the Bering Sea (ADFG 2009, Quakenbush et al. 2009). Other researchers have also reported a westward movement of bowhead whales through the northern Chukchi Sea during fall migration (Moore et al. 1995; Mate et al. 2000).

The pre-exploitation population of bowhead whales in the Bering, Chukchi, and Beaufort Seas is estimated to have been 10,400-23,000 whales. Commercial whaling activities may have reduced this population to perhaps 3000 animals (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) despite annual subsistence harvests of 14–74 bowheads from 1973 to 1997 (Suydam et al. 1995). A census in 2001 yielded an estimated annual population growth rate of 3.4% (95% CI 1.7–5%) from 1978 to 2001 and a population size (in 2001) of ~10,470 animals (George et al. 2004, recently revised to 10,545 by Zeh and Punt [2005]). A population estimate from photo identification data collected in 2004 was 11,800 (Koski et al. 2009) which further supports the estimated 3.4 percent population growth rate. Assuming a continuing annual population growth of 3.4%, the 2010 bowhead population may number around 14,247 animals. 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). Although apparently recovering well, the BCB bowhead population is currently listed as "***Endangered***" under the ESA and is classified as a ***strategic stock*** by NMFS and ***depleted*** under the MMPA (Angliss and Allen 2009).

The BCB stock of bowhead whales winters in the central and western Bering Sea and many of them summer in the Canadian Beaufort Sea and Amudsen Gulf (Moore and Reeves 1993). Spring migration through the Chukchi and the western Beaufort Seas occurs through offshore ice leads, generally from mid-April to early June but with small numbers passing during March to mid-April and early- through mid-June (Braham et al. 1984; Moore and Reeves 1993; Koski et al. 2005).

Some bowheads arrive in coastal areas of the eastern Canadian Beaufort Sea and Amundsen Gulf in late May and June, but most may remain among the offshore pack ice of the Beaufort Sea until mid-summer. After feeding primarily in the Canadian Beaufort Sea and Amundsen Gulf, bowheads migrate westward from late August through mid- or late October. Fall migration into the Alaskan Beaufort Sea is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999; Blackwell et al. 2004, 2009; Greene et al. 2007). Satellite tracking of bowheads has also shown that some whales move to the Chukchi Sea prior to September (ADFG 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.

The Minerals Management Service (MMS) has conducted or funded late-summer/autumn aerial surveys for 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; Monnett and Treacy 2005; Treacy et al. 2006). Bowheads tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice (Moore 2000; Treacy et al. 2006). In addition, the sighting rate tends to be lower in heavy ice years (Treacy 1997:67). During fall migration, most bowheads migrate west in water ranging from 15 to 200 m deep (Miller et al. 2002). Some individuals enter shallower water, particularly in light ice years, but very few whales are ever seen shoreward of the barrier islands in the Alaskan Beaufort Sea. Survey coverage far offshore in deep water is usually limited, and offshore movements may have been underestimated. However, the main migration corridor is over the continental shelf.

In autumn, westward-migrating bowhead whales typically reach the Kaktovik and Cross Island areas in early September when the subsistence hunts for bowheads typically begin in those areas (Kaleak 1996; Long 1996; Galginaitis and Koski 2002; Galginaitis and Funk 2004, 2005; Koski et al. 2005). In recent years the hunts at those two locations have usually ended by mid- to late September.

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

Most spring-migrating bowhead whales will pass through the Beaufort Sea prior to the start of drilling operations in early July. However, a few whales that may remain in the Barrow area or other parts of the Alaskan Beaufort Sea during the summer could be encountered during project activities or by transiting vessels. More encounters with bowhead whales would occur during the westward fall migration in September and October. Shell, however, will suspend drilling operations beginning on August 25, before the beginning of the Kaktovik and Nuiqsut (Cross Island) fall hunts, and will not resume drilling operations until the Kaktovik and Nuiqsut (Cross Island) hunts are concluded.

(b) Gray Whale (*Eschrichtius robustus*)

Few if any gray whales are expected to be found in the eastern Beaufort Sea in the vicinity of the project area. Any gray whales present would likely be found in nearshore areas at some distance from Shell's offshore drilling locations.

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. There are two populations in the North Pacific. A relic population which survives in the western Pacific summers near Sakhalin Island far from the planned area of the exploration drilling program. The larger eastern Pacific or California gray whale population recovered significantly from commercial whaling during its protection under the ESA until 1994 and numbered about 29,758 ±3122 in 1997 (Rugh et al. 2005). However, abundance estimates since 1997 indicate a consistent decline followed by stabilization or gradual recovery. Rugh et al. (2005) estimated the population to be 18,178 ±1780 in winter 2001-2 and Rugh et al. (2008) estimated the population in winter 2006-7 to have been 20,110 ±1766. The eastern Pacific stock is not considered by NMFS to be endangered or to be a strategic stock.

Eastern Pacific gray whales 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 calving season, most of these gray whales migrate about 8000 km, generally along the west coast of North America, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957; Rice and Wolman 1971; Braham 1984; Nerini 1984; Moore et al. 2003; Bluhm et al. 2007). Most gray whales begin a southward migration in November with breeding and conception occurring in early December (Rice and Wolman 1971).

Most summering 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. More recently, Moore et al. (2003) suggested that gray whale use of Chirikov Basin has decreased, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower quality food. Coyle et al (2007) noted that ampeliscid amphipod production in the Chirikov Basin had declined by 50% from the 1980s to 2002-3 and that as little as 3-6% of the current gray whale population could consume 10-20% of the ampelischid amphipod annual production. These data support the hypotheses that changes in gray whale distribution may be caused by changes in food production and that gray whales may be approaching, or have surpassed, the carrying capacity of their summer feeding areas. Bluhm et al. (2007) noted high gray whale densities along ocean fronts and suggested that ocean fronts may play an important role in influencing prey densities in eastern North Pacific gray whale foraging areas. The northeastern-most of the recurring feeding areas is in the northeastern Chukchi Sea southwest of Barrow (Clarke et al. 1989).

Gray whales occur regularly near Point Barrow, but historically only a small number of gray whales have been sighted in the Beaufort Sea east of Point Barrow. Hunters at Cross Island (near Prudhoe Bay) took a single gray whale in 1933 (Maher 1960). Only one gray whale was sighted in the central Alaskan Beaufort Sea during the extensive aerial survey programs funded by MMS and industry from 1979 to 1997. However, during September 1998, small numbers of gray whales were sighted on several occasions in the central Alaskan Beaufort (Miller et al. 1999; Treacy 2000). More recently, a single sighting of a gray whale was made on 1 August 2001 near the Northstar production island (Williams and Coltrane 2002). Several gray whale sightings were reported during both vessel-based and aerial surveys in the Beaufort Sea in 2006-2008 (Christie et al. 2009; Saverese et al. 2009). Several single gray whales have been seen farther east in the Canadian Beaufort Sea (Rugh and Fraker 1981), indicating that small numbers must travel through the Alaskan Beaufort during some summers. In recent years, ice conditions have become reduced near Barrow, and gray whales may have become more common there and perhaps in the Beaufort Sea. In the springs of 2003 and 2004, a few tens of gray whales were seen near Barrow by early to mid-June (LGL Ltd and NSB-DWM, unpubl. data). However, no gray whales were sighted during cruises north of Barrow in 2002 or 2005 (Harwood et al. 2005; Haley and Ireland 2006).

Given the infrequent occurrence and nearshore distribution of gray whales in the Beaufort Sea in summer, no more than a few gray whales are expected to be near the planned exploration drilling program in the Beaufort Sea. Beaufort Sea gray whales would be expected to remain close to shore and thus at some distance from much of the planned drilling activity.

(c) Minke Whale (*Balaenoptera acutorostrata*)

It is not likely that Minke whales will be observed in the project area.

Minke whales have a cosmopolitan distribution at ice-free latitudes (Stewart and Leatherwood 1985), and also occur in some marginal ice areas. Angliss and Allen (2009) recognize two minke whale stocks in U.S. waters including (1) the Alaska stock, and (2) the California/Oregon/Washington stock. There is no abundance estimate for the Alaska stock. Provisional estimates of Minke whale abundance based on surveys in 1999 and 2000 are 810 and 1003 whales in the central-eastern and southeastern Bering Sea, respectively. These estimates have not been corrected for animals that may have been submerged or otherwise missed during the surveys, and only a portion of the range of the Alaskan stock was surveyed. Minke whales range into the Chukchi Sea but are not likely to occur in the Beaufort Sea. Savarese et al. (2009) reported one Minke whale sighting in the Beaufort Sea in 2007 and 2008. Minke whales would be unlikely to be observed in the Beaufort Sea near the planned exploration drilling program.

(d) Humpback Whale (*Megapter novaeangliae*)

It is not likely that humpback whales will occur in the project area during the drilling season.

Humpback whales are distributed in major oceans worldwide but have apparently been absent from Arctic waters of the North Pacific (Angliss and Allen 2009). In general, humpback whales spend the winter in tropical and sub-tropical waters where breeding and calving occur, and migrate to higher latitudes for feeding during the summer.

Humpback whales were hunted extensively during the 20th century and worldwide populations may have been reduced to ~10% of their original numbers. The International Whaling Commission banned commercial hunting of humpback whales in the Pacific Ocean in 1965 and humpbacks were listed as **Endangered** under the ESA and depleted under the MMPA in 1973. Most humpback whale populations appear to be recovering well.

Humpbacks feed on euphausiids, copepods, and small schooling fish, notably herring, capelin, and sandlance (Reeves et al. 2002). As with other baleen whales, the food is trapped and filtered when large amounts of water are taken into the mouth and forced out through the baleen plates. Humpbacks have large, robust bodies and long pectoral flippers which may reach 1/3 of their body length. They are frequently observed breaching or engaged in other surface activities. Adult male and female humpback whales average 14 and 15 m (46 and 49 ft) in length, respectively (Wynne 1997). Most individual humpback whales can be identified by distinctive patterns on the tail flukes. The dorsal fin is variable in shape and located well back toward the posterior 1/3 of the body on a hump which is particularly noticeable when the back is arched during a dive (Reeves et al. 2002).

During the summer months humpback whales are common in Prince William Sound, and along the south side of the Alaska Peninsula to Unimak Pass. Humpback whales are less common in the Bering Sea and rare in the Chukchi Sea. Greene et al. (2007) reported and photographed a humpback whale cow/calf pair east of Barrow near Smith Bay in 2007, which is the first known occurrence of humpback whale in the Beaufort Sea. Humpback whales would be unlikely to occur near the planned exploration drilling program in the Beaufort Sea.

(3) Seals

(a) Bearded Seal (*Erignathus barbatus*)

Bearded seals are associated with sea ice and have a circumpolar distribution (Burns 1981a). During the open-water period, bearded seals occur mainly in relatively shallow areas, because they are predominantly benthic feeders (Burns 1981a). They prefer areas of water no deeper than 200 m (e.g., Harwood et al. 2005). No reliable estimate of bearded seal abundance is available for the Chukchi and Beaufort Seas (Angliss and Allen 2009). The Alaska stock of bearded seals is not classified by NMFS as endangered or a strategic stock. However, a decision to list the species under the ESA, due to the potential impact to seal habitats resulting from current warming trends, is still under consideration by NMFS.

In Alaskan waters, bearded seals occur over the continental shelves of the Bering, Chukchi, and Beaufort Seas (Burns 1981a). The Alaska stock of bearded seals may consist of about 300,000–450,000 individuals (USDI/MMS 1996).

The bearded seal is the largest of the northern phocids. Bearded seals have occasionally been reported to maintain breathing holes in sea ice; however, in winter they are found primarily in areas with persistent leads or cracks and in broken areas within the pack ice, particularly if the water depth is <200 m. 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 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, they usually move shoreward into open water areas when the pack ice retreats to areas with water depths greater than 200 m (Cameron et al. 2009). In the Beaufort Sea, suitable habitat is limited to areas where the continental shelf is narrow because the pack ice edge frequently occurs seaward of the shelf and over water too deep for benthic 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 although a recent tagging study showed occasional movements of adult bearded seals seaward of the continental shelf (Cameron et al. 2009). WesternGeco conducted marine mammal monitoring during its open-water seismic program in the Alaskan Beaufort Sea from 1996 to 2001. Operations were conducted in nearshore waters, and of a total 454 seals that were identified to species while no airguns were operating, 4.4% were bearded seals, 94.1% were ringed seals and 1.5% were spotted seals (Moulton and Lawson 2002). Savarese et al. (2009) reported bearded seal densities in the Beaufort Sea ranging from 0.035 to 0.003 seals/km^2, during vessel-based surveys in 2006-2008.

(b) Spotted Seal (*Phoca largha*)

Spotted seals, also known as largha seals, occur in the Beaufort, Chukchi, Bering and Okhotsk seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). They migrate south from the Chukchi Sea and through the Bering Sea in October (Lowry et al. 1998). Spotted seals overwinter in the Bering Sea and inhabit the southern margin of the ice during spring (Shaughnessy and Fay 1977).

An early estimate of the size of the world population of spotted seals was 370,000–420,000, and the size of the Bering Sea population, including animals in Russian waters, was estimated to be 200,000–250,000 animals (Bigg 1981). The current total number of spotted seals in Alaskan waters is not known (Angliss and Allen 2009), but the estimate is most likely between several thousand and several tens of thousands (Rugh et al. 1997). During the summer spotted seals are found in Alaska from Bristol Bay through western Alaska to the Chukchi and Beaufort Seas. The ADF&G placed satellite transmitters on 4 spotted seals and estimated that the proportion of seals hauled out was 6.8%. Based on an actual minimum count of 4145 hauled out seals, Angliss and Allen (2009) estimated the Alaskan population at 59,214 animals. The Alaska stock of spotted seals is not classified as endangered, threatened, or as a strategic stock by NMFS (Angliss and Allen 2009), although the southern distinct population segment (DPS) of spotted seals was recently listed as a threatened species, it occurs entirely outside of US waters.

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) from July until September. At this time of year, spotted seals haul out on land part of the time, but they also spend extended periods at sea. Spotted seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 69–72ºN. In summer, they are rarely seen on the pack ice, except when the ice is very near 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).

Relatively low numbers of spotted seals are present in the Beaufort Sea. A small number of spotted seal haulouts 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 recent times <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. A total of 12 spotted seals were positively identified near the source vessel during open-water seismic programs in the central Alaskan Beaufort Sea during the 6 years from 1996 to 2001 (Moulton and Lawson 2002, p. 317). Numbers seen per year ranged from zero (in 1998 and 2000) to four (in 1999). More recently Greene et al. (2007) reported 46 spotted seal sightings during barge operations between West Dock and Cape Simpson. Most sightings occurred from western Harrison Bay to Cape Simpson with only one sighting offshore of the Colville River delta. Some of these could have been repeat sightings of the same individuals as the barges traversed the same area on numerous occasions. Small numbers of spotted seals could occur in the vicinity of the planned exploration drilling program.

(c) Ringed Seal (*Phoca hispida*)

Ringed seals have a circumpolar distribution and occur in all seas of the Arctic Ocean (King 1983). They are closely associated with ice, and in the summer they often occur along the receding ice edges or farther north in the pack ice. In the North Pacific, they occur in the southern Bering Sea and range south to the seas of Okhotsk and Japan. They are found throughout the Beaufort, Chukchi, and Bering seas (Angliss and Allen 2009).

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 shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi 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). Ringed seals maintain breathing holes in the ice and occupy lairs in accumulated snow (Smith and Stirling 1975). They 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).

Ringed seals are year-round residents in the Beaufort Sea and the ringed seal is the most frequently encountered seal species in the area. 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. More recent estimates based on extrapolation from aerial surveys and on predation estimates for polar bears (Amstrup 1995) suggest an Alaskan Beaufort Sea population at ~326,500 animals. The Alaska stock of ringed seals is not endangered, and is not classified as a strategic stock by NMFS. However, a decision to list the species under the ESA, due to the potential impact to seal habitats resulting from current warming trends, is still under consideration by NMFS.

Moulton et al. (2002) reported ringed seal densities (uncorrected) ranging from 0.43 to 0.63 seal/km^2 in nearshore areas (>3 m deep) during aerial surveys during late spring in the central Alaskan Beaufort Sea. Ringed seal will likely be the most abundant marine mammal species encountered in the areas area of the planned drilling program in the Beaufort Sea.

(d) Ribbon Seal (*Histriophoca fasciata*)

Ribbon seals are found along the pack-ice margin in the southern Bering Sea during late winter and early spring and they move north as the pack ice recedes during late spring to early summer (Burns 1970; Burns et al. 1981b). Little is known about their summer and fall distribution, but Kelly (1988) suggested that they move into the southern Chukchi Sea based on a review of sightings during the summer. However, ribbon seals appeared to be relatively rare in the northern Chukchi Sea during recent vessel-based surveys in summer and fall of 2006 and 2007 with only two sightings among 1371 seal sightings identified to species (Reiser et al. 2009a).

Ribbon seals do not normally occur in the Beaufort Sea; however, two ribbon seal sightings were reported during vessel-based activities near Prudhoe Bay in 2008 (Savarese et al. 2009). Regardless, ribbon seals are unlikely to occur in the vicinity of the planned drilling program in the Beaufort Sea in 2009.

5. 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:

The only type of incidental taking sought in this application is that of takes by noise harassment. The only source of project–created noise for the exploration drilling program for which Shell requests authorization of non-lethal "takes" of whales and seals is that produced by the drillship *Discoverer.* Although the bulk of the activity will be centered in the area of exploration drilling, potential exposures or impacts to marine mammals also will occur as the drillship and associated vessels mobilize to and from Camden Bay for the exploration drilling program.

Noise propagation measurements from *Discoverer* are not presently available. However, measurements of a similar drill vessel, *Northern Explorer II*, were performed at two different times and locations in the Beaufort Sea (Miles et al. 1987, Greene 1987a). In both cases a support vessel was present in the vicinity of the drillship, thus providing an aggregate source level for modeling the combined drilling activities. These measurement results were used by JASCO Research Ltd. to model the likely sound propagation from the *Discoverer* and its support vessels at the planned drill site locations (JASCO 2007). These modeled sound radii have been used for calculation of estimated "takes by harassment" by the drillship in this document. Source levels for the *Discoverer* were estimated based on its similarity to the drillship *Northern Explorer II*, thus the *Northern Explorer II* was used as a proxy source for the *Discoverer*. A comparison of the key specifications for the two vessels is given in Table 5-1.

TABLE 5-1
COMPARISON OF THE SPECIFICATIONS FOR THE *NORTHERN EXPLORER II* AND *FRONTIER DISCOVERER* (WORLD OIL, 2003)

Parameter	*Northern Explorer II*	*Frontier Discoverer*
Hull	115 x 30.5 x 8.7 m	155 x 21 x 11 m
Derrick	Pyramid 185'; 1,000,000 lb.	Pyramid, 170'; 1,333,000 lb.
Drawworks	Ideco E 2100	EMSCO E-2100
Pumps	2 x Nat'l 12P-160 triplex	2 x EMSCO FB-1600
Prime movers	4 x GE 752R, 3,000 bhp	6 x Cat. D-399 diesels, 1,325 hp
Top drive	Varco TDS-3	Varco TDS-3
Rotary table	Ideco LR-375	National C-495

The acoustic propagation model used in this study is JASCO Research's Marine Operations NoiseModel (MONM). MONM computes received sound levels in rms units when source levels are specified also in those units.

MONM treats sound propagation in range-varying acoustic environments through a wide-angled parabolic equation solution to the acoustic wave equation. The specific parabolic equation code in MONM is based on the Naval Research Laboratory's Range-dependent Acoustic Model. This code has been extensively benchmarked for accuracy and is widely employed in the underwater acoustics community [Collins, 1993].

Sound propagation measurements will be performed on the *Discoverer* and support vessels in 2010, once these are on location near Camden Bay in the Beaufort Sea. The results of those measurements will be used during the season to implement mitigation measures as required by the permit.

6. Numbers of marine mammals that may potentially be taken:

Shell seeks authorization for potential "taking" of small numbers of marine mammals under the jurisdiction of NMFS in the planned area of activity. Species for which authorization is sought are bowhead, gray, and beluga whales, and ringed, spotted, and bearded seals. Exposure estimates and requests for takes of ribbon seal, humpback whale, minke whale, harbor porpoise and narwhal are also included, but are very minimal as sightings of these species in the Beaufort Sea are very rare.

The only anticipated impacts to marine mammals are associated with noise propagation from the exploration drilling program and associated support vessels. Impacts would consist of temporary and short-term displacement of seals and whales from within ensonified zones produced by such noise sources.

The exploration drilling program in the Beaufort Sea planned by Shell is not expected to "take" more than small numbers of marine mammals, or have more than a negligible, biologically insignificant effect on their populations. Discussions of estimated "takes by harassment" are presented below.

6.1 Exposure Estimates for Exploration Drilling

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied, as described herein (see section 12.3), will minimize the possibility of injurious takes. However, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures. In the sections below, we describe methods to estimate "take by harassment" and present estimates of the numbers of marine mammals that might be affected during the planned exploration drilling program in the Beaufort Sea. The estimates are based on data obtained during marine mammal surveys in and near the planned exploration drilling sites and on estimates of the sizes of the areas where effects could potentially occur. Adjustments to reported population or density estimates were made to account for seasonal distributions and population increases or declines insofar as possible.

The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection. There is some uncertainty about the representativeness of those data and the assumptions used below to estimate the potential "take by harassment". However, the approach used here is the best available at this time.

Basis for Estimating "Take by Harassment"

"Take by Harassment" is calculated in this section by multiplying the expected densities of marine mammals that may occur near the exploratory drilling operations by the area of water likely to be exposed to continuous sound levels of ≥120 dB and ≥160 dB. The single exception to this method is for the estimation of exposures of bowhead whales during the fall migration where more detailed data were available allowing an alternate approach, described below, to be used. This section describes the estimated densities of marine mammals that may occur in the project area. The area of water that may be ensonified to the above sound levels is described further below in the section *Potential Number of "Takes by Harassment."* There is no evidence that avoidance at received sound levels of ≥120 dB or ≥160 dB would have significant effects on individual animals or that the subtle changes in behavior or movements would "rise to the level of taking" according to guidance by NMFS (NMFS 2001). Any changes in behavior caused by sounds at or near the 120 dB level would likely fall within the normal variation in such activities that would occur in the absence of the drilling program.

Marine mammal densities near the operation are likely to vary by season and habitat. However, sufficient published data allowing the estimation of separate densities during summer (July and August) and fall (September and October) are only available for beluga and bowhead whales. As noted above, exposures of bowhead whales during the fall are not calculated using densities (see below). So summer and fall densities have been estimated for beluga whales and a summer density has been estimated for bowhead whales. Densities of all other species have been estimated to represent the duration of both seasons.

Marine mammal densities are also likely to vary by habitat type. In the Alaskan Beaufort Sea, where the continental shelf break is relatively close to shore, marine mammal habitat is often defined by water depth. Bowhead and beluga occurrence within nearshore (0-40 m), outer continental shelf (40-200 m), slope (200-2000 m), basin (>2000 m), or similarly defined habitats have been described previously (Moore et al. 2000, Richardson and Thomson 2002). The presence of most other species have generally only been described relative to the entire continental shelf zone (0-200 m) or beyond. Sounds produced by the drilling vessel are expected to drop below 120 dB and 160 dB within the nearshore zone (0-40 m water depth). Sounds ≥120 dB or ≥160 dB are not expected to occur in waters >200 m.

In addition to water depth, densities of marine mammals are likely to vary with the presence or absence of sea ice (see below for descriptions by species). At times during either summer or fall, pack-ice may be present in some of the area around the drilling operation. However, the retreat of sea ice in the Alaskan Beaufort Sea has been substantial in recent years so we have assumed that only 33% of the area exposed to sounds ≥120 dB or ≥160 dB by the drilling vessel will be in ice margin habitat. Therefore ice-margin densities of marine mammals in both seasons have been multiplied by 33% of the area exposed to sounds by the drilling vessel, while open-water (nearshore) densities have been multiplied by the remaining 70% of the area.

To provide some allowance for the uncertainties, "maximum estimates" as well as "average estimates" of the numbers of marine mammals potentially affected have been derived. For a few marine mammal species, several density estimates were available, and in those cases the mean and maximum estimates were determined from the survey data. In other cases, no applicable estimate (or perhaps a single estimate) was available, so correction factors were used to arrive at "average" and "maximum" estimates. These are described in detail in the following sections.

Detectability bias, quantified in part by $f(0)$, is associated with diminishing sightability with increasing lateral distance from the trackline. Availability bias [$g(0)$] refers to the fact that there is <100% probability of sighting an animal that is present along the survey trackline. Some sources of densities used below included these correction factors in their reported densities. In other cases the best available correction factors were applied to reported results when they had not been included in the reported data (e.g. Moore et al. 2000).

Cetaceans

As noted above, the densities of beluga and bowhead whales present in the Beaufort Sea are expected to vary by season and location. During the early and mid-summer, most belugas and bowheads are found in the Canadian Beaufort Sea and Amundsen Gulf or adjacent areas. Low numbers are found in the eastern Alaskan Beaufort Sea. Belugas begin to move across the Alaskan Beaufort Sea in August, and bowheads do so toward the end of August.

Beluga density estimates were derived from data in Moore et al. (2000). During the summer, beluga whales are most likely to be encountered in offshore waters of the eastern Alaskan Beaufort Sea or areas with pack ice. The summer beluga whale nearshore density (Table 6-1) was based on 11,985 km of on-transect effort and 9 associated sightings that occurred in water ≤50 m in Moore et al. (2000; Table 2). A mean group size of 1.63, a f(0) value of 2.841, and a g(0) value of 0.58 from Harwood et al. (1996) were also used in the calculation. Moore et al. (2000) found that belugas were equally likely to occur in heavy ice conditions as open water or very light ice conditions in summer in the Beaufort Sea, so the same density was used for both nearshore and ice-margin estimates (Table 6-1). The fall beluga whale nearshore density was based on 72,711 km of on-transect effort and 28 associated sightings that occurred in water ≤50 m reported in Moore et al (2000). A mean group size of 2.9 (CV=1.9), calculated from all Beaufort Sea fall beluga sightings in ≤50 m of water present in the BWASP database, along with the same f(0) and g(0) values from Harwood et al. (1996) were also used in the calculation. Moore et al. (2000) found that during the fall in the Beaufort Sea belugas occurred in moderate to heavy ice at higher rates than in light ice, so ice-margin densities were estimated to be twice the nearshore densities. Based on the CV of group size maximum estimates in both season and habitats were estimated as four times the average estimates. "Takes by harassment" of beluga whales during the fall in the Beaufort Sea were not calculated in the same manner as described for bowhead whales (below) because of the relatively lower expected densities of beluga whales in nearshore habitat near the exploration drilling program and the lack of detailed data on the likely timing and rate of migration through the area.

TABLE 6-1
EXPECTED SUMMER (JUL - AUG) DENSITIES OF BELUGA AND BOWHEAD WHALES IN THE EASTERN ALASKAN BEAUFORT SEA. DENSITIES ARE CORRECTED FOR F(0) AND G(0) BIASES. SPECIES LISTED UNDER THE U.S. ESA AS ENDANGERED ARE SHOWN IN ITALICS.

	Nearshore		Ice Margin	
Species	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**
Beluga	0.0030	0.0120	0.0030	0.0120
Bowhead whale	0.0186	0.0717	0.0186	0.0717

TABLE 6-2
EXPECTED FALL (SEP - NOV) DENSITIES OF BELUGA AND BOWHEAD WHALES IN THE EASTERN ALASKAN BEAUFORT SEA. DENSITIES ARE CORRECTED FOR F(0) AND G(0) BIASES. SPECIES LISTED UNDER THE U.S. ESA AS ENDANGERED ARE SHOWN IN ITALICS.

	Nearshore		Ice Margin	
Species	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**
Beluga	0.0027	0.0108	0.0054	0.0216
Bowhead whale [a]	*N/A*	*N/A*	*N/A*	*N/A*

[a] See text for description of how bowhead whales estimates were made.

Industry aerial surveys of the continental shelf near Camden by in 2008 recorded eastward migrating ***bowhead whales*** until 12 July (Lyons and Christie 2009). No bowhead sightings were recorded again, despite continued flights, until 19 August. Aerial surveys by industry operators did not begin until late August of 2006 and 2007, but in both years bowheads were also recorded in the region before the end of August (Christie et al. 2009). The late August sightings were likely of bowheads beginning their fall migration so the densities calculated from those surveys were not used to estimate summer densities in this region. The three surveys in July of 2008 resulted in density estimates of 0.0099, 0.0717, and 0.0186 whales/km^2 respectively. The estimate of 0.0186 whales/km^2 was used as the average nearshore density and the estimate of 0.0717 whales/km^2 was used as the maximum. Sea ice was not present during these surveys. Moore et al. (2000) reported that bowhead whales in the Alaskan Beaufort Sea were distributed uniformly relative to sea ice, so the same nearshore densities were used for ice-margin habitat.

During the fall most bowhead whales will be migrating west past the exploration drilling program, so it is less accurate to assume that the number of individuals present in the area from one day to the next will be static. However, feeding, resting, and milling behaviors are not entirely uncommon at this time and location either. In order to incorporate the movement of whales past the planned operations, and because the necessary data are available, we have developed an alternate method of calculating the number of individuals exposed to sounds produced by the exploration drilling program. The method is founded on estimates of the proportion of the population that would pass within the >120 dB and ≥160 dB zones on a given day in the fall during exploration drilling program.

Exploration drilling will be suspended on August 25 prior to the start of the bowhead subsistence hunts at Kaktovik and Nuiqsut (Cross Island) and will be resumed when the hunts are concluded. After the completion of the subsistence hunts, ~40 days of activity will be required to complete the planned drilling operations. If the bowhead population has continued to grow at an annual rate of 3.4%, the current population size would be ~14,247 individuals based on a 2001 population of 10,545 (Zeh and Punt 2005). Based on data in Richardson and Thomson (2002, Appendix 9.1), the number of whales expected to pass each day after conclusion of the bowhead subsistence hunts (assumed to be 15 September) was estimated as a proportion of the population. Minimum and maximum estimates of the number of whales passing each day were not available, so a single estimate based on the 10-day moving average presented by Richardson and Thomson 2002) was used. Richardson and Thomson (2002) also calculated the proportion of animals within water depth bins (<20m, 20-40m, 40-200m, >200m). Using this information we multiplied the total number of whales expected to pass the drilling program each day by the proportion of whales that would be in each depth category to estimate how many individuals would be within each depth bin on a given day. The proportion of each depth bin falling within the ≥120 dB zone was then multiplied by the number of whales within the respective bins to estimate the total number of individuals that would be exposed on each day. This was repeated for a total of 40 days (15 September to 24 October) and the results were summed to estimate the total number of bowhead whales that might be exposed to ≥120 dB during the migration period in the Beaufort Sea.

For ***other cetacean species*** that may be encountered in the Beaufort Sea, densities are likely to vary somewhat by season, but differences are not expected to be great enough to require estimation of separate densities for the two seasons. Harbor porpoises and gray whales are not expected to be present in large numbers in the Beaufort Sea during the fall but small numbers may be encountered during the summer. They are most likely to be present in nearshore waters (Table 6-3). Narwhals are not expected to be encountered within the drilling program area. However, there is a chance that a few individuals may be present if ice is nearby. The first record of humpback whales in the Beaufort Sea was documented in 2007 so their presence cannot be ruled out. Since these species occur so infrequently in the Beaufort Sea, little to no data are available for the calculation of densities. Minimal densities have therefore been assigned for calculation purpose and to allow for chance encounters (Table 6-3).

Seals

Extensive surveys of ringed and bearded seals have been conducted in the Beaufort Sea, but most surveys have been conducted over the landfast ice, and few seal surveys have occurred in open water or in the pack ice. Kingsley (1986) conducted ***ringed seal*** surveys of the offshore pack ice in the central and eastern Beaufort Sea during late spring (late June). These surveys provide the most relevant information on densities of ringed seals in the ice margin zone of the Beaufort Sea. The density estimate in Kingsley (1986) was used as the average density of ringed seals that may be encountered in the ice margin (Table 6-3). The average ringed seal density in the nearshore zone of the Alaskan Beaufort Sea was estimated from results of ship–based surveys at times without seismic operations reported by Moulton and Lawson (2002; Table 6-3).

Densities of ***bearded seals*** were estimated by multiplying the ringed seal densities by 0.051 based on the proportion of bearded seals to ringed seals reported in Stirling et al. (1982; Table 6-3). ***Spotted seal*** densities in the nearshore zone were estimated by summing the ringed seal and bearded seal densities and multiplying the result by 0.015 based on the proportion of spotted seals to ringed plus bearded seals reported in Moulton and Lawson (2002; Table 6-3). Minimal values were assigned as densities in the ice–margin zones (Table 6-3). Minimal values were used to estimate ***ribbon seal*** densities as their presence in the Beaufort Sea is very uncommon.

TABLE 6-3
EXPECTED DENSITIES OF CETACEANS (EXCLUDING BELUGA AND BOWHEAD WHALE) AND SEALS IN THE ALASKAN BEAUFORT SEA

Species	Nearshore		Ice Margin	
	Average Density (# / km^2)	Maximum Density (# / km^2)	Average Density (# / km^2)	Maximum Density (# / km^2)
Odontocetes				
Monodontidae				
Narwhal	0.0000	0.0000	0.0000	0.0001
Phocoenidae				
Harbor porpoise	0.0001	0.0004	0.0000	0.0000
Mysticetes				
Gray whale	0.0001	0.0004	0.0000	0.0000
Pinnipeds				
Bearded seal	0.0181	0.0724	0.0128	0.0512
Ribbon seal	0.0001	0.0004	0.0001	0.0004
Ringed seal	0.3547	1.4188	0.2510	1.0040
Spotted seal	0.0037	0.0149	0.0001	0.0004

Potential Number of "Takes by Harassment"

Best and Maximum Estimates of the Number of Individuals that may be Exposed to ≥160 and ≥120 dB

Numbers of marine mammals that might be present and potentially disturbed are estimated below based on available data about mammal distribution and densities at different locations and times of the year as described above. Exposure estimates are based on a single drillship (*Discoverer*) operating in Camden Bay beginning in July. Shell will not operate the *Discoverer* and associated vessels in Camden Bay during the 2010 Kaktovik and Nuiqsut (Cross Island) fall bowhead whale subsistence harvests. Shell will suspend exploration activities on August 25, prior to the beginning of the hunts, and will resume activities in Camden Bay after conclusion of the subsistence harvests, and be completed by on or about October 31, 2010. Actual drilling may occur on ~74 days while the *Discoverer* is in Camden Bay, approximately half of which would occur before and after the fall bowhead subsistence hunts.

The number of different individuals of each species potentially exposed to received levels ≥160 dB and ≥120 dB re 1 µPa within each season and habitat zone was estimated by multiplying:

- the anticipated area to be ensonified to the specified level in the time period and habitat zone to which a density applies, by
- the expected species density.

The numbers of exposures were then summed for each species across the seasons and habitat zones.

Estimated Area Exposed to Sounds ≥160 dB

The ≥160 dB radius for the *Discoverer* was modeled by JASCO to be ~35 m. A radius of 52.5 m (35 × 1.5) was used to estimate the area ensonified to ≥160 dB around the drillship (~0.01 km^2). The 50% inflation of the modeled radius is recommended by some acousticians as a conservative approach when modeling a new sound source in a new location. Waters are ≤40 m deep in areas that may be exposed to sounds ≥160 dB by the *Discoverer*. The area exposed to sounds from drilling occurs in water ≤40 m deep so 67% was multiplied by the nearshore zone densities and the remaining 33% by the ice-margin densities.

For analysis of potential effects on migrating bowhead whales we calculated the total distance perpendicular to the migration path ensonified to ≥160 dB (52.5 m radius x 2 = 105 m) by the *Discoverer*. This represents 0.3% of the 36 km between the barrier islands and the 40 m bathymetry line so it was assumed that 0.3% of the bowheads migrating within the nearshore zone (water depth 0-40 m) may be exposed to sounds ≥160 dB if they showed no avoidance of the drilling operations.

Estimates Area Exposed to Sounds ≥120 dB

The total area of a 7.4 km radius circle (172 km^2; representing 1.5 × the ≥120 dB radius of 4.93 km modeled by JASCO for the *Discoverer*) was used to calculate the area ensonified to ≥120 dB around the *Discoverer* operating at either of the planned drill sites (Sivulliq N and Torpedo H). This area falls within water less than 40 m deep at both planned locations. The area exposed to sounds by drilling occurs in waters ≤40 m deep so 67% was multiplied by the nearshore zone densities and the remaining 33% by the ice-margin densities.

For analysis of potential effects on migrating bowhead whales we calculated the total distance perpendicular to the migration path ensonified to ≥120 dB (7.4 km radius x 2 = 14.8 km) by the *Discoverer*. This represents 41% of the 36 km between the barrier islands and the 40 m bathymetry line so it was assumed that 41% of the bowheads migrating within the nearshore zone (water depth 0-40 m) may be exposed to sounds ≥120 dB if they showed no avoidance of the drilling operations.

Cetaceans

Cetacean species potentially exposed to drilling program sounds with received levels ≥120 dB would involve mysticetes (bowhead, gray, humpback, and minke whales), monodontids (beluga and narwhal), and porpoise (harbor porpoise; Tables 6-4 and 6-5). Species with an estimated average number of individuals exposed are included here for completeness, but are not likely to be encountered. Average and maximum estimates of the number of individual cetaceans exposed, in descending order, are bowhead whale (1968 and 1977) beluga (1 and 4), gray whale (0 and 5), humpback whale (0 and 5), minke whale (0 and 5), harbor porpoise (0 and 5), and narwhal (0 and 5; Table 6-7). Few animals are expected to be exposed to sounds ≥160 dB due to the small size of this zone, but minimal estimates have been used to account for chance encounters.

The estimates show that one endangered cetacean species (the bowhead whale) is expected to be exposed to sounds ≥120 dB and ≥160 dB unless bowheads avoid the area around the exploration drill sites (Tables 6-4 and 6-5). Migrating bowheads are likely to do so to some extent, though many of the bowheads engaged in other activities, particularly feeding and socializing, probably will not.

TABLE 6-4
ESTIMATES OF THE NUMBERS OF BELUGA AND BOWHEAD WHALES IN AREAS WHERE MAXIMUM RECEIVED SOUND LEVELS IN THE WATER WOULD BE ≥120 DB AND (≥160 DB) DURING SHELL'S PLANNED EXPLORATION DRILLING PROGRAM NEAR CAMDEN BAY IN THE BEAUFORT SEA, ALASKA, JULY – AUG 2010. NOT ALL MARINE MAMMALS WILL CHANGE THEIR BEHAVIOR WHEN EXPOSED TO THESE SOUND LEVELS.

	Number of Exposure to Sound Levels ≥120 dB and (≥160 dB)					
	Nearshore		Ice Margin		Total	
Species	Avg.	Max.	Avg.	Max.	Avg.	Max.
Beluga	0 (0)	1 (0)	0 (0)	1 (0)	1 (0)	2 (0)
Bowhead whale	2 (0)	8 (0)	1 (0)	4 (0)	3 (0)	12 (0)

TABLE 6-5
ESTIMATES OF THE NUMBERS OF BELUGA AND BOWHEAD WHALES IN AREAS WHERE MAXIMUM RECEIVED SOUND LEVELS IN THE WATER WOULD BE ≥120 DB AND (≥160 DB) DURING SHELL'S PLANNED EXPLORATION DRILLING PROGRAM NEAR CAMDEN BAY IN THE BEAUFORT SEA, ALASKA, SEP – OCTOBER 31, 2010. MAXIMUM VALUES FOR BOWHEAD WHALES WERE NOT CALCULATED DUE TO THE ALTERNATIVE METHOD USED TO ESTIMATE BOWHEAD WHALE EXPOSURES AS DESCRIBED IN THE TEXT. NOT ALL MARINE MAMMALS WILL CHANGE THEIR BEHAVIOR WHEN EXPOSED TO THESE SOUND LEVELS.

	Number of Exposure to Sound Levels ≥120 dB and (≥160 dB)					
	Nearshore		Ice Margin		Total	
	Avg.	Max.	Avg.	Max.	Avg.	Max.
Beluga	0 (0)	1 (0)	0 (0)	1 (0)	1 (0)	2 (0)
Bowhead whale [a]	1965 (14)	*N/A*	*N/A*	*N/A*	1965 (14)	*N/A*

[a] See text for description of bowhead whale estimates for the Fall in the Beaufort Sea.

TABLE 6-6
ESTIMATES OF THE NUMBERS OF MARINE MAMMALS (EXCLUDING BELUGA AND BOWHEAD WHALES, WHICH ARE SHOWN IN TABLES 6-4 AND 6-5, IN EACH OFFSHORE AREA WHERE MAXIMUM RECEIVED SOUND LEVELS IN THE WATER WOULD BE ≥120 DB AND (≥160 DB) DURING SHELL'S PLANNED EXPLORATION DRILLING PROGRAM NEAR CAMDEN BAY IN THE BEAUFORT SEA, ALASKA, JULY – OCTOBER 31, 2010. NOT ALL MARINE MAMMALS WILL CHANGE THEIR BEHAVIOR WHEN EXPOSED TO THESE SOUND LEVELS.

	Number of Exposure to Sound Levels ≥120 dB and (≥160 dB)					
	Nearshore		Ice Margin		Total	
Species	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**
Odontocetes						
Monodontidae						
Narwhal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Phocoenidae						
Harbor porpoise	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Mysticetes						
Gray whale	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pinnipeds						
Bearded seal	4 (0)	16 (0)	1 (0)	6 (0)	6 (0)	22 (0)
Ribbon seal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Ringed seal	81 (0)	322 (0)	28 (0)	114 (0)	109 (0)	436 (0)
Spotted seal	1 (0)	3 (0)	0 (0)	0 (0)	1 (0)	3 (0)
Total Pinnipeds	86 (0)	342 (0)	30 (0)	120 (0)	115 (0)	462 (0)

TABLE 6-7
SUMMARY OF THE NUMBER OF POTENTIAL EXPOSURES OF MARINE MAMMALS TO RECEIVED SOUND LEVELS IN THE WATER OF ≥120 DB AND (≥160 DB) DURING SHELL'S PLANNED EXPLORATION DRILLING PROGRAM NEAR CAMDEN BAY IN THE BEAUFORT SEA, ALASKA, JULY – OCTOBER 31, 2010. ARBITRARY MINIMUM ESTIMATES HAVE BEEN REQUESTED AT THE ≥160 DB LEVEL TO ACCOUNT FOR ANY CHANCE ENCOUNTERS. NOT ALL MARINE MAMMALS WILL CHANGE THEIR BEHAVIOR WHEN EXPOSED TO THESE SOUND LEVELS.

Species	Total Number of Exposure to Sound Levels >120 dB and (≥160 dB)	
	Avg.	Max.
Odontocetes		
Monodontidae		
Beluga	1 (0)	4 (0)
Narwhal	0 (0)	5 (5)
Phocoenidae		
Harbor porpoise	0 (0)	5 (5)
Mysticetes		
Bowhead whale [a]	1968 (14)	1977 (14)
Gray whale	0 (0)	5 (5)
Humpback Whale	0 (0)	5 (5)
Minke Whale	0 (0)	5 (5)
Total Cetaceans	1968 (14)	1992 (29)
Pinnipeds		
Bearded seal	6 (0)	22 (0)
Ringed seal	109 (0)	436 (0)
Ribbon Seal	0 (0)	5 (5)
Spotted seal	1 (0)	3 (5)
Total Pinnipeds	115 (0)	467 (10)

Seals

Many of the animals exposed to sound levels near 120 dB would not react to those sound levels, particularly seals, and exposure to this sound level should not be considered "takes". Even for species that may change their behavior or alter their migration route, those changes are likely to be within the normal range of activities for the animals and may not rise to the level of "taking" based on guidance in NMFS (2001). Animals that divert around the activity at the lower sound levels would not approach close enough that they would alter their behavior to the degree that they would be "taken by harassment". Thus, actual number of animals that will be "taken" lies somewhere between the number exposed to ≥120 and ≥160 dB.

Ringed Seals

The ringed seal is the most widespread and abundant pinniped in ice-covered arctic waters, and there appears to be a great deal of year-to-year variation in abundance and distribution of these marine mammals. Ringed seals account for a large number of marine mammals expected to be encountered during the exploration drilling program, and hence exposed to sounds with received levels ≥120 dB. The average (and maximum) estimate is that 109 (436) ringed seals might be exposed to sounds with received levels ≥120 dB from the exploration drilling program, and no exposures to ≥160 dB.

Other Seal Species

Two additional seal species are expected to be encountered. Average and maximum estimates for bearded seal exposures to sound levels ≥120 dB were 6 and 22, respectively. For spotted seal these exposure estimates were 1 and 3, respectively. The ribbon seal is unlikely to be encountered, but their presence cannot be ruled out. No bearded or spotted seals are expected to be exposed to ≥160 dB.

Conclusions

The planned exploration drilling program in the Beaufort Sea will involve one drillship that will introduce continuous sounds into the ocean while it is active. Other routine vessel operations are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

Cetaceans

Effects on cetaceans are generally expected to be restricted to avoidance of an area around the drilling operations and short-term changes in behavior, falling within the MMPA definition of "Level B harassment".

Using the 120 dB criterion, the best (average) estimates of the numbers of individual cetaceans exposed to sounds ≥120 dB represent varying proportions of the populations of each species in the Beaufort Sea and adjacent waters. For species listed as "Endangered" under the ESA, our estimates include ~1977 bowheads. This number is ~14% of the Bering-Chukchi-Beaufort population of >14,247 assuming 3.4% annual population growth from the 2001 estimate of >10,545 animals (Zeh and Punt 2005). Only 14 individuals are estimated to be exposed to sounds ≥160 dB if they do not avoid the area very near drilling operations, equaling <1% of the population. The small numbers of other mysticetes whales that may occur in the Beaufort Sea are unlikely to be present around the planned operations. The few that might occur would represent a very small proportion of their respective populations.

Some monodontids may be exposed to sounds produced by the drilling program, and the numbers potentially affected are small relative to the population sizes (Table 6-7). Narwhals are extremely rare in the U.S. Beaufort Sea and few, if any, are expected to be encountered during the survey. The best estimate of the number of belugas that might be exposed to ≥120 dB (4) represents <1% of their population. No animals are expected to be exposed to levels ≥160 dB although minimal numbers have been requested to allow for chance encounters.

Seals

A few seal species are likely to be encountered in the study area, but ringed seal is by far the most abundant in this area. The maximum estimates of the numbers of individuals exposed to sounds at received levels ≥120 dB during the exploration drilling program are as follows: ringed seals (436), bearded seals (22), and spotted seals (3), (representing <1% of their respective Beaufort Sea populations). Seals are unlikely to react to continuous sounds until they are much stronger than 120 dB, so it is probable that only a small percentage of these animals would actually be disturbed. Few seals are estimated to be exposed to sounds ≥160 dB although minimal estimates have been included to allow for chance encounters.

7. The anticipated impact of the activity on the species or stock:

The likely or possible impacts of the planned offshore exploratory drilling program on marine mammals will be related primarily to acoustic effects. Petroleum development and associated activities in marine waters introduce sound into the environment. The acoustic sense of marine mammals probably constitutes their most important distance receptor system, and underwater sounds could (at least in theory) have several types of effects on marine mammals. Potential acoustic effects relate to sound produced by drilling activity, vessels and aircraft.

Noise Characteristics and Effects

The effects of sound on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995a):

(1) The sound 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 sound 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,b).

(3) The sound 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. The latter is 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 man made sound 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, and environmental sounds such as ice or surf noise.

(6) Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity. Effects of non-explosive sounds on hearing thresholds of some marine mammals have been studied. However, some data are now available for two species of odontocetes exposed to a single strong noise pulse lasting 1 second (Ridgway et al. 1997 and pers. comm.) and for three species of pinnipeds exposed to moderately strong sound for 20-22 minutes (Kastak et al. 1999). 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 (probably at least 10 dB above the TTS threshold).

Drilling Sounds

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

Most drilling sounds generated from vessel-based operations occur at relatively low frequencies below 600 Hz although tones up to 1850 Hz were recorded by Greene (1987a) during drilling operations in the Beaufort Sea. At a range of 0.17 km the 20-1000 Hz band level was 122-125 dB for the drillship *Explorer I*. Underwater sound levels were slightly higher (134 dB) during drilling activity from the Explorer II at a range of 0.20 km although tones were only recorded below 600 Hz. Underwater sound measurements from the Kulluk at 0.98 km were higher (143 dB) than from the other two vessels.

Aircraft Noise

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

Dominant tones in noise spectra from helicopters are generally below 500 Hz (Greene and Moore 1995). 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.

Because of Doppler shift effects, the frequencies of tones received at a stationary site diminish when an aircraft passes overhead. The apparent frequency is increased while the aircraft approaches and is reduced while it moves away.

Aircraft flyovers are not heard underwater for very long, especially when compared to how long they are heard in air as the aircraft approaches an observer. Helicopters flying to and from the drillship will generally maintain straight-line routes at altitudes of 1,000 ft ASL, thereby limiting the received levels at and below the surface.

Vessel Noise

In addition to the drillship, various types of vessels will be used in support of the operations including ice management vessels, anchor handlers, and oil-spill response vessels. Sounds from boats and vessels have been reported extensively (Greene and Moore 1995; Blackwell and Greene 2002, 2005, 2006). Numerous measurements of underwater vessel sound have been performed in support of recent industry activity in the Chukchi and Beaufort Seas. Results of these measurements were reported in various 90-day and comprehensive reports since 2007. For example, Garner and Hannay (2009) estimated sound pressure levels of 100 dB at distances ranging from ~2.4 to 3.7 km from various types of barges. MacDonald et al. (2008) estimated higher underwater sound pressure levels from the seismic vessel *Gilavar* of 120 dB at ~21 km from the source, although the sound level was only 150 dB at 26 m from the vessel. Like other industry-generated sound, underwater sound from vessels is generally at relatively low frequencies.

The primary sources of sounds from all vessel classes are propeller cavitation, propeller singing, and propulsion or other machinery. Propeller cavitation is usually the dominant noise source for vessels (Ross 1976). Propeller cavitation and singing are produced outside the hull, whereas propulsion or other machinery noise originates inside the hull. There are additional sounds produced by vessel activity, such as pumps, generators, flow noise from water passing over the hull, and bubbles breaking in the wake. Icebreakers contribute greater sound levels during ice-breaking activities than ships of similar size during normal operation in open water (Richardson et al. 1995a). This higher sound production results from the greater amount of power and propeller cavitation required when operating in thick ice.

Summary of Potential Effects of Exposure to Underwater Sounds

The potential effects of sounds from the proposed exploratory drilling activities might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical effects (Richardson et al. 1995a). It is unlikely that there would be any cases of temporary or especially permanent hearing impairment, or non-auditory physical effects.

Tolerance

Numerous studies have shown that underwater sounds from industry activities are often readily detectable in the water at distances of many kilometers. Numerous studies have also shown that marine mammals at distances more than a few kilometers away often show no apparent response to industry activities of various types. This is often true even in cases when the sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to underwater sound such as airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds, small odontocetes, and sea otters seem to be more tolerant of exposure to some types of underwater sound than are baleen whales.

Masking

Masking effects of underwater sounds on marine mammal calls and other natural sounds are expected to be limited. Some whales however, are known to continue calling in the presence of pulsed sound. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a more recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). That has also been shown during recent work in the Gulf of Mexico (Tyack et al. 2003). Bowhead whale calls are frequently detected in the presence of seismic pulses, although the numbers of calls detected may sometimes be reduced (Richardson et al. 1986; Greene et al. 1999; Blackwell et al. 2009). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete, given the intermittent nature of seismic pulses. Also, the sounds important to small odontocetes for communication are predominantly at much higher frequencies than are airgun sounds.

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Based on NMFS (2001, p. 9293), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, it is meant "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. In predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This practice, however, likely overestimates the numbers of marine mammals that are affected in some biologically-important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by industrial sounds are based on behavioral observations during studies of several species. Detailed studies have been done on humpback, gray, and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, small toothed whales, and sea otters.

Baleen Whales—Baleen whale responses to pulsed sound have been studied more thoroughly than responses to continuous sound. Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much greater distances. However, baleen whales exposed to strong noise pulses often react by deviating from their normal migration route. In the case of migrating gray and bowhead whales, observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors. Baleen whale responses to pulsed sound however, may depend on the type of activity in which the whales are engaged. Some evidence suggests that feeding bowhead whales may be more tolerant of underwater sound than migrating bowheads (Miller et al. 2005; Lyons et al. 2009; Christie et al. 2009).

Richardson et al. (1995b) reported changes in surfacing and respiration behavior, and the occurrence of turns during surfacing in bowhead whales exposed to playback of underwater sound from drilling activities. These subtle behavioral effects were temporary and localized, and occurred at distances up to 2-4 km. Safety radii for the proposed drilling activities are expected to be small and are not expected to result in significant disturbance to baleen whales.

Some bowheads appeared to divert from their migratory path after exposure to projected icebreaker sounds. Other bowheads however, tolerated projected icebreaker sound at levels 20 dB and more above ambient sound levels. The source level of the projected sound however, was much less than that of an actual icebreaker, and reaction distances to actual ice breaking may be much greater than those reported here for projected sounds.

Brewer et al. (1993) and Hall et al. (1994) reported numerous sightings of marine mammals including bowhead whales in the vicinity of offshore drilling operations in the Beaufort Sea. One bowhead whale sighting was reported within ~400 m of a drilling vessel although other sightings were at much greater distances. Few bowheads were recorded near industrial activities by aerial observers, but observations by surface observers suggested that bowheads may have been closer to industrial activities than was suggested by results of aerial observations.

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

Patenaude et al. (2002) reported fewer behavioral responses to aircraft overflights by bowhead compared to beluga whales. Behaviors classified as reactions consisted of short surfacings, immediate dives or turns, changes in behavior state, vigorous swimming, and breaching. Most bowhead reaction resulted from exposure to helicopter activity and little response to fixed-wing aircraft was observed. Most reactions occurred when the helicopter was at altitudes ≤150 m and lateral distances ≤250 m. Restriction on aircraft altitude will be part of the mitigation measures during the proposed drilling activities and likely to have little or no disturbance effects on baleen whales. Any disturbance that did occur would likely be temporary and localized.

Southall et al. (2007 Appendix C) reviewed a number of papers describing the responses of marine mammals to non-pulsed sound. In general, little or no response was observed in animals exposed at received levels from 90-120 dB. Probability of avoidance and other behavioral effects increased when received levels were 120-160 dB. Some of the relevant reviews of Southall et al. (2007) are summarized below.

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

Malme et al. (1983, 1984) used playback of sound from helicopter overflight and drilling rigs and platforms to study behavioral effects on migrating gray whales. Received levels exceeding 120 dB induced avoidance reactions. Malme et al. (1984) calculated 10%, 50%, and 90% probabilities of gray whale avoidance reactions at received levels of 110, 120, and 130 dB, respectively.

Malme et al. (1986) observed the behavior of feeding gray whales during four experimental playbacks of drilling sounds (50 to 315 Hz; 21- min overall duration and 10% duty cycle; source levels 156 to 162 dB). In two cases for received levels of 100 to 110 dB, no behavioral reaction was observed. Avoidance behavior was observed in two cases where received levels were 110 to 120 dB.

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

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

Palka & Hammond (2001) analyzed line transect census data in which the orientation and distance off transect line were reported for large numbers of Minke whales. Minor changes in locomotion speed, direction, and/or diving profile were reported at ranges from 563 to 717 m at RLs of 110 to 120 dB.

Biassoni et al. (2000) and Miller et al. (2000) reported behavioral observations for humpback whales exposed to a low-frequency sonar stimulus (160- to 330-Hz frequency band; 42-s tonal signal repeated every 6 min; source levels 170 to 200 dB) during playback experiments. Exposure to measured received levels ranging from 120 to 150 dB resulted in variability in humpback singing behavior.

Croll et al. (2001) investigated responses of foraging fin and blue whales to the same low frequency active sonar stimulus off southern California. Playbacks and control intervals with no transmission were used to investigate behavior and distribution on time scales of several weeks and spatial scales of tens of kilometers. The general conclusion was that whales remained feeding within a region for which 12 to 30% of exposures exceeded 140 dB.

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

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

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

At least six of 17 groups of beluga whales appeared to alter their migration path in response to underwater playbacks of icebreaker sound (Richardson et al. 1995b). Received levels from the icebreaker playback were estimated at 78-84 dB in the 1/3-octave band centered at 5000 Hz, or 8-14 dB above ambient. If beluga whales reacted to an actual icebreaker at received levels of 80 dB, reactions would be expected to occur at distances on the order of 10 km. Finley et al. (1990) also reported beluga avoidance of icebreaker activities in the Canadian High Arctic at distances of 35 to 50 km. In addition to avoidance, changes in dive behavior and pod integrity were also noted. Beluga whales have also been report to avoid active seismic vessels at distances of 10-20 km (Miller et al. 2005). It is likely that at least some beluga whales may avoid the vicinity of the proposed activities thus reducing the potential for exposure to high levels of underwater sound.

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

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

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

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

Observations during 1983 (LGL & Greeneridge 1986) involved two ice-breaking ships with aerial survey and ice-based observations during seven sampling periods. Narwhals and belugas generally reacted at received levels ranging from 101 to 121 dB in the 20- to 1,000-Hz band and at a distance of up to 65 km. Large numbers (100s) of beluga whales moved out of the area at higher received levels. As noise levels from icebreaking operations diminished, a total of 45 narwhals returned to the area and engaged in diving and foraging behavior. During the final sampling period, following an 8-h quiet interval, no reactions were seen from 28 narwhals and 17 belugas (at received levels ranging up to 115 dB).

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

Gordon et al. (1992) conducted opportunistic visual and acoustic monitoring of sperm whales in New Zealand exposed to nearby whale-watching boats (within 450 m). Sperm whales respired significantly less frequently, had shorter surface intervals, and took longer to start clicking at the start of a dive descent when boats were nearby than when they were absent. Noise spectrum levels of whale watching boats ranged from 109 to 129 dB/Hz. Over a bandwidth of 100 to 6,000 Hz, equivalent broadband source levels were ~157 dB; received levels at a range of 450 m were ~104 dB.

Buckstaff (2004) reported elevated dolphin whistle rates with RLs from oncoming vessels in the 110 to < 120 dB. These hearing thresholds were apparently lower than those reported by a researcher listening with towed hydrophones.

Morisaka et al. (2005) compared whistles from three populations of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). One population was exposed to vessel noise with spectrum levels of ~85 dB/Hz in the 1- to 22-kHz band (broadband received levels ~128 dB) as opposed to ~65 dB/Hz in the same band (broadband RL ~108 dB) for the other two sites. Dolphin whistles in the noisier environment had lower fundamental frequencies and less frequency modulation, suggesting a shift in sound parameters as a result of increased ambient noise.

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

Monteiro-Neto et al. (2004) studied avoidance responses of tucuxi (*Sotalia fluviatilis*) to Dukane® Netmark acoustic deterrent devices. In a total of 30 exposure trials, ~5 groups each demonstrated significant avoidance compared to 20 pinger off and 55 no-pinger control trials over two quadrats of about 0.5 km^2. Estimated exposure received levels were ~115 dB.

Awbrey & Stewart (1983) played back semi-submersible drillship sounds (source level: 163 dB) to belugas in Alaska. They reported avoidance reactions at 300 and 1,500 m and approach by groups at a distance of 3,500 m (received levels ~110 to 145 dB over these ranges assuming a 15 log R transmission loss). Similarly, Richardson et al. (1990) played back drilling platform sounds (source level: 163 dB) to belugas in Alaska. They conducted aerial observations of eight individuals among ~100 spread over an area several hundred meters to several kilometers from the sound source and found no obvious reactions. Moderate changes in movement were noted for three groups swimming within 200 m of the sound projector.

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

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

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

Blackwell et al. (2004) reported little or no reaction of ringed seals in response to pile-driving activities during construction of a man-made island in the Beaufort Sea. Ringed seals were observed swimming as close as 46 m from the island and may have been habituated to the sounds which were likely audible at distances <3000 m underwater and 0.5 km in air. Moulton et al. (2003) reported that ringed seal densities on ice in the vicinity of a man-made island in the Beaufort Sea did not change significantly before and after construction and drilling activities.

Southall et al. (2007) reviewed literature describing responses of pinnipeds to non-pulsed sound and reported that the limited data suggest exposures between ~90 and 140 dB generally do not appear to induce strong behavioral responses in pinnipeds exposed to nonpulse sounds in water; no data exist regarding exposures at higher levels. It is important to note that among these studies of pinnipeds responding to nonpulse exposures in water, there are some apparent differences in responses between field and laboratory conditions. In contrast to the mid-frequency odontocetes, captive pinnipeds responded more strongly at lower levels than did animals in the field. Again, contextual issues are the likely cause of this difference.

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

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

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

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and ≥190 dB, respectively (NMFS 2000). Those criteria have been used in defining the safety (shut down) radii during seismic survey activities in the Arctic in recent years. However, those criteria were established before there were any data on the minimum received levels of sounds necessary to cause temporary auditory impairment in marine mammals. In summary,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary threshold shift (TTS), let alone permanent auditory injury, at least for belugas and delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

NMFS is presently developing new noise exposure criteria for marine mammals that account for the now-available scientific data on TTS and other relevant factors in marine and terrestrial mammals (NMFS 2005; D. Wieting *in*
http://mmc.gov/sound/plenary2/pdf/plenary2summaryfinal.pdf).

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the drilling activities to avoid exposing them to underwater sound levels that might, at least in theory, cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the proposed activities. In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects might also occur in marine mammals exposed to strong underwater sound. Possible types of non-auditory physiological effects or injuries that theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to industrial sound sources and beaked whales do not occur in the proposed study area. It is unlikely that any effects of these types would occur during the proposed project given the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. At least in terrestrial mammals, TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity in both terrestrial and marine mammals recovers rapidly after exposure to the noise ends.

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002, 2005). Given the available data, the received level of a single seismic pulse might need to be ~210 dB re 1 μPa rms (~221–226 dB pk–pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received energy. Source levels associated with drilling activities are much lower than those produced during seismic airgun activity.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. However, no cases of TTS are expected given the moderate size of the source, and the likelihood that baleen whales (especially migrating bowheads) would avoid the drilling and vessel activities before being exposed to levels high enough for there to be any possibility of TTS.

Initial evidence from prolonged exposures to sound suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999, 2005; Ketten et al. 2001; cf. Au et al. 2000). For harbor seal, which is closely related to the ringed seal, TTS onset apparently occurs at somewhat lower received energy levels than for odontocetes.

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 µPa (rms). NMFS is in the process of developing an EIS to establish new sound exposure criteria for marine mammals (NMFS 2005). New criteria are likely to include a time component in addition to sound pressure level which has been the only metric used previously when developing mitigation measures for industrial sound exposure for marine mammals. Due to the relatively small sound radii expected to result from the proposed drilling and support activities, marine mammals would be unlikely to incur TTS without remaining very near the activities for some unknown time period. Given the proposed mitigation and the likelihood that many marine mammals are likely to avoid the proposed activities, exposure sufficient to produce TTS is unlikely to occur.

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

There is no specific evidence that exposure to underwater industrial sound associated with oil exploration can cause PTS in any marine mammal. However, given the possibility that mammals might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to such activities might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level at least several decibels above that inducing mild TTS.

It is highly unlikely that marine mammals could receive sounds strong enough (and over a sufficient duration) to cause permanent hearing impairment during the proposed exploratory drilling program. Marine mammals are unlikely to be exposed to received levels strong enough to cause even slight TTS. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels immediately adjacent to the drillship may not be sufficient to induce PTS, even if the animals remain in the immediate vicinity of the activity. The planned monitoring and mitigation measures, including measurement of sound radii and visual monitoring when mammals are seen within "safety radii", will minimize the already-minimal probability of exposure of marine mammals to sounds strong enough to induce PTS.

***Non-auditory Physiological Effects*.—** Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, and other types of organ or tissue damage. If any such effects do occur, they probably would be limited to unusual situations when animals might be exposed at close range for unusually long periods. It is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolism. This possibility was first explored at a workshop (Gentry [ed.] 2002) held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to bubble formation in tissues caused by exposure to noise from naval sonar. However, the opinions were inconclusive. Jepson et al. (2003) first suggested a possible link between mid-frequency sonar activity and acute and chronic tissue damage that results from the formation *in vivo* of gas bubbles, based on the beaked whale stranding in the Canary Islands in 2002 during naval exercises. Fernández et al. (2005a) showed those beaked whales did indeed have gas bubble-associated lesions as well as fat embolisms. Fernández et al. (2005b) also found evidence of fat embolism in three beaked whales that stranded 100 km north of the Canaries in 2004 during naval exercises. Examinations of several other stranded species have also revealed evidence of gas and fat embolisms (e.g., Arbelo et al. 2005; Jepson et al. 2005a; Méndez et al. 2005). Most of the afflicted species were deep divers. There is speculation that gas and fat embolisms may occur if cetaceans ascend unusually quickly when exposed to aversive sounds, or if sound in the environment causes the destabilization of existing bubble nuclei (Potter 2004; Arbelo et al. 2005; Fernández et al. 2005a; Jepson et al. 2005b). Even if gas and fat embolisms can occur during exposure to mid-frequency sonar, there is no evidence that that type of effect occurs in response to the types of sound produced during the proposed exploratory activities. Also, most evidence for such effects have been in beaked whales, which do not occur in the proposed survey area.

Available data on the potential for underwater sounds from industrial activities to cause auditory impairment or other physical effects in marine mammals suggest that such effects, if they occur at all, would be temporary and limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of the proposed activities, including most baleen whales, some odontocetes (including belugas), and some pinnipeds, are especially unlikely to incur auditory impairment or other physical effects.

Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Underwater sound from drilling and support activities are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey, has raised the possibility that beaked whales exposed to strong pulsed sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding. The potential for stranding to result from exposure to strong pulsed sound suggests that caution be used when exposing marine mammals to pulsed or other underwater sound. Most of the stranding events associated with exposure of marine mammals to pulsed sound however, have involved beaked whales which do not occur in the proposed area. Additionally, the sound produced from the proposed activities will be at much lower levels than those reported during stranding events.

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

Subsistence hunting continues to be an essential aspect of Inupiat Native life, especially in rural coastal villages. The Inupiat participate in subsistence hunting activities in and around the Beaufort Sea. The animals taken for subsistence provide a significant portion of the food that will last the community through the year. Marine mammals represent on the order of 60-80% of the total subsistence harvest. Along with the nourishment necessary for survival, the subsistence activities strengthen bonds within the culture, provide a means for educating the young, provide supplies for artistic expression, and allow for important celebratory events. In this IHA application Shell specifically discusses the potential impact from the drilling program to subsistence use of the bowhead whale, beluga, and seals, which are the primary marine mammals harvested for subsistence that are also covered under this authorization of incidental take by NMFS.

Bowhead Whale. Activities associated with Shell's planned exploration drilling program would have no or negligible effects on bowhead whales. Noise and general activity associated with drilling and operation of vessels and aircraft have the potential to impact bowhead whales. However, as noted above in Section 7, though temporary diversions of the swim path of migrating whales have been documented, the whales have generally been observed to resume their initial migratory route within a distance of 6-20 mi or 10-30 km (Davis 1987; Brewer et al. 1993; Hall et al. 1994). Drilling noise has not been shown to block or impede migration even in narrow ice leads (Davis 1987; Richardson et al. 1991). Any effects on the bowhead whale, as a subsistence resource, would be negligible.

Exploration drilling operations could in some circumstances affect subsistence hunts by placing the animals further offshore or otherwise at a greater distance from villages thereby increasing the difficulty of the hunt or retrieval of the harvest, or creating a safety risk to the whalers. Residents of Kaktovik and Nuiqsut hunt bowheads during the fall migration. In 2010, Shell's operations will commence in July before the fall hunt begins, cease during these bowhead subsistence hunts, and resume after they are completed so the exploration program would have no direct impact on these subsistence activities. Any effects on bowhead behavior or movements would therefore have no impact on the Kaktovik or Nuiqsut (Cross Island) fall whaling as Shell's drilling program will cease on August 25th, prior to the start of the hunts, and will not resume until the hunts have concluded.

Helicopters (2-3 trips/day) servicing the offshore operations could traverse areas utilized by Kaktovik or Nuiqsut (Cross Island) whalers for fall whaling from a Deadhorse shorebase location. Helicopters traffic often evokes no response from bowheads, but the whales sometimes engage in hasty dives or abrupt turns (Richardson et al. 1985, 1995a). Bowhead whales tend to be more sensitive in shallow water (Richardson et al 1985). Any such behavioral responses would be momentary and have negligible effect on the subsistence resource and no effect on the subsistence activity. Aircraft shall not operate below 1500 ft (457 m) unless the aircraft is engaged in marine mammal monitoring, approaching, landing or taking off, or unless engaged in providing assistance to a whaler or in poor weather (low ceilings) or any other emergency situations. Aircraft engaged in marine mammal monitoring shall not operate below 1500 ft (457 m) in areas of active whaling; such areas to be identified through communications with the Com-Centers. Except for airplanes engaged in marine mammal monitoring, aircraft shall use a flight path that keeps the aircraft at least 5 mi (8 km) inland until the aircraft is directly south of its offshore destination, then at that point it shall fly directly north to its destination. In addition, aircraft will not get closer than 1500 ft (457 m) of groups of whales.

No routine vessel traffic will traverse this subsistence area. Vessels within 900 ft (274 m) of marine mammals will reduce speed, avoid separating members from a group and will avoid multiple changes in direction. Vessel speeds will be reduced during inclement weather to avoid collisions with marine mammals.

The planned period of the drilling program begins in July 2010, ceases on August 25th for the bowhead whale subsistence harvests by Kaktovik and Nuiqsut (Cross Island) hunters, and then restarts after the harvest has concluded. During this period most marine mammals are expected to be dispersed throughout the area, except during the peak of the bowhead whale migration in the Beaufort Sea, which occurs from late August into October. Bowhead whales are expected to be in the Canadian Beaufort Sea during much of the time prior to the subsistence whaling shutdown that occurs on August 25th and, therefore, are not expected to be affected by the drilling program prior to that date. After the conclusion of the bowhead whale subsistence harvest, bowheads may travel in proximity to the drilling program area and hear sounds from drilling and associated vessel and aircraft traffic, and may be displaced by these activities. The potential impacts of drilling to the fall bowhead whale migration during the subsistence harvests is eliminated by Shell's commitment to shutdown the drilling program during the Kaktovik and Nuiqsut (Cross Island) harvests.

Beluga. Beluga are not a prevailing subsistence resource in the communities of Kaktovik and Nuiqsut, the nearest communities to Shell's planned 2010 drilling program. Therefore, any such behavioral responses of avoidance of activity areas by beluga in the Beaufort Sea would have a no effect on the subsistence resource.

Seals. Seals are an important subsistence resource and ringed seals make up the bulk of the seal harvest. Most ringed and bearded seals are harvested in the winter or in the spring before Shell's exploration drilling program would commence, but some harvest continues into the drilling season period and could possibly be affected by Shell's planned activities. Spotted seals are also harvested during the summer. Shell lease blocks where exploration activities would occur are located more than 16 mi (26 km) offshore, so activities within the prospects would have no impact on subsistence hunting for seals. Helicopter traffic between the shorebase and the offshore drilling operations could potentially disturb seals and, therefore, subsistence hunts for seals, but any such effects would be minor due to the small number of flights and the altitude at which they typically fly, and the fact that most seal hunting is done during the winter and spring.

Any effects on subsistence hunts for seals would be negligible and temporary lasting only minutes after the flight has passed.

9. Anticipated impact on habitat:

Shell’s planned 2010 drilling program will not result in any permanent impact on habitats used by marine mammals, or to their prey sources. With regard to migrating cetaceans and seals, any effects would be temporary and of short duration at any one place. The primary potential impacts to all marine mammals are associated with elevated sound levels from exploration drilling operations, its support vessels, and aircraft. The effects to habitat of marine mammals by sounds from the planned drilling program are expected to be negligible.

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

The level of sound at which a fish will react or alter its behavior is usually well above the detection level. Fish have been found to react to sounds when the sound level increased to about 20 dB above the detection level of 120 dB (Ona 1988); however the response threshold can depend on the time of year and the fish's physiological condition (Engas et al. 1993). In general, fish react more strongly to pulses of sound rather than a continuous signal (Blaxter et al. 1981), and a quicker alarm response is elicited when the sound signal intensity rises rapidly compared to sound rising more slowly to the same level.

Investigations of fish behavior in relation to vessel noise (Olsen et al. 1983; Ona 1988; Ona and Godo 1990) have shown that fish react when the sound from the engines and propeller exceeds a certain level. Avoidance reactions have been observed in fish such as cod and herring when vessels approached close enough that received sound levels are 110 dB to 130 dB (Nakken 1992; Olsen 1979; Ona and Godo 1990; Ona and Toresen 1988). However, other researchers have found that fish such as polar cod, herring, and capeline are often attracted to vessels (apparently by the noise) and swim toward the vessel (Rostad et al. 2006). Typical sound source levels of vessel noise in the audible range for fish are 150 dB to 170 dB (Richardson et al. 1995a). In calm weather, ambient noise levels in audible parts of the spectrum lie between 60 dB to 100 dB.

Ice management would be expected to produce the most intense sounds associated with exploration drilling. Reported source levels for vessels during ice management have ranged from 175 dB to 185 dB (Brewer et al. 1993, Hall et al. 1994). Sound pressures generated while drilling have been measured during past exploration in the Beaufort and Chukchi seas. Sounds generated by drilling and ice management are generally low frequency, and within the frequency range detectable by most fish.

Fish have been found to react to sounds when the sound level increased to about 20 dB above the detection level of 120 dB re 1 μPa (Ona 1988); Based on a sound level of approximately 140dB, there may be some avoidance by fish of the area near the drillship while drilling, around ice management vessels in transit and during ice management, and around other support and supply vessels when underway. Any reactions by fish to these sounds will last only minutes (Mitson and Knudsen 2003; Ona et al. 2007) longer than the vessel is operating at that location or the drillship is drilling. Any potential reactions by fish would be limited to a relatively small area within about 0.21 mi (0.34 km) of the drillship during drilling (JASCO 2007). Avoidance by some fish or fish species could occur within portions of this area. No important spawning habitats are known to occur at or near the drilling locations. Effects of sound generation on fish will therefore be negligible, localized, and short term. Likewise, the impact to fish as a prey species for odontocetes or seals will therefore be negligible.

10. Anticipated impact of habitat loss or modification:

The effects of the planned exploration drilling program are expected to be negligible. It is estimated that only a small portion of the animals utilizing the areas of the planned program would be temporarily displaced. During the period of the exploration drilling program (July 10-August 25, and the again from the end of Kaktovik and Nuiqsut (Cross Island) bowhead whale subsistence harvests to on or about October 31st), most marine mammals would be dispersed throughout the area. The peak of the bowhead whale migration through the Beaufort Sea typically occurs in late August and October. Again, some bowheads might be temporarily displaced seaward during this time. The numbers of cetaceans and seals subject to displacement are small in relation to abundance estimates for the mammals addressed under this IHA application.

In addition, feeding does not appear to be an important activity by bowheads migrating through the eastern and 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 is not expected to have any significant or long-term consequences for individual bowheads or their population. Bowheads, gray, or beluga whales are not predicted to be excluded from any habitat.

The planned drilling program is not expected to have any habitat-related effects that would produce long-term affects to marine mammals or their habitat due to the limited extent of the acquisition areas and timing of the program.

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

Details of the planned mitigations are discussed in the Marine Mammal Monitoring and Mitigation Plan (4MP) (Attachment B).

12. 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 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:

12.1 A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation.

Shell has prepared and will implement a Plan of Cooperation (POC or Plan) pursuant to MMS Lease Sale Stipulation No. 5, which requires that all exploration operations be conducted in a manner that prevents unreasonable conflicts between oil and gas activities and the subsistence activities and resources of residents of the North Slope. This stipulation also requires adherence to, and USFWS and NMFS regulations, which require an operator to implement a POC to mitigate the potential for conflicts between the proposed activity and traditional subsistence activities (50 CFR § 18.124(c)(4) and 50 CFR § 216.104(a)(12)).

The POC identifies the measures that Shell has developed in consultation with North Slope subsistence communities and will implement during its planned 2010 Beaufort Sea and Chukchi Sea exploration drilling programs to minimize any adverse effects on the availability of marine mammals for subsistence uses. In addition, the POC details Shell's communications and consultations with local subsistence communities concerning its planned 2010 exploration drilling program, potential conflicts with subsistence activities, and means of resolving any such conflicts (50 CFR § 18.128(d) and 50 CFR § 216.104(a) (12) (i), (ii), (iv)). Shell has documented its contacts with the North Slope subsistence communities, as well as the substance of its communications with subsistence stakeholder groups.

Shell's 2010 Beaufort Sea exploration drilling program, which is planned for the Sivulliq and/or Torpedo prospects in Camden Bay (Figure 1-1), is set-out in detail in the Camden Bay Exploration Plan (EP) and the impacts of the project, as well as the measures Shell will implement to mitigate those impacts, are analyzed in the Camden Bay EIA. Shell will implement this POC, and the mitigation measures set-forth herein, for both its Beaufort and Chukchi exploration programs.

The affected subsistence communities that were consulted regarding Shell's 2010 activities include: Barrow, Kaktovik, Wainwright, Kotzebue, Kivalina, Point Lay and Point Hope. Several one-on-one meetings were also held throughout the villages.

Beginning in early January 2009, Shell held one-on-one meetings with representatives from NSB and Northwest Arctic Borough (NWAB), subsistence-user group leadership, and Village Whaling Captain Association representatives. These meetings took place at the convenience of the community leaders and in various venues. Meetings were held starting on the 12th of January 2009 and continuing through April of 2009. Shell's primary purpose in holding individual meetings was to inform and prepare key leaders, prior to the public meetings, so that they would be prepared to give appropriate feedback on planned activities.

Attempts were made to meet individually with Whaling Captains and hold a community meeting in Nuiqsut; however, after receipt of a request by the Mayor, the scheduled meeting was cancelled. Shell subsequently sent correspondence to all post office box holders in Nuiqsut on February 26, indicating its willingness to visit and have dialogue on the proposed plans. Table 4.2-1 provides a list of public meetings attended by Shell while developing this POC (Attachment C). Attachment C, updated to May 7 2009 presents sign-in sheets and presentation materials used at the POC meetings. Also, comment analysis tables summarizing feedback on Shell activities, with responses and mitigation measures were constructed using information received during the numerous meetings; these are included in Attachment C.

Shell presented the proposed project to the NWAB Assembly on January 27, to the NSB Assembly on February 2 and to the NSB and NWAB Planning Commissions in a joint meeting on March 25. Meetings were also scheduled with representatives from the AEWC, and presentations on proposed activities were given to ICAS, and the Native Village of Barrow. Shell made several attempts to be included on the agenda for the Native Village of Point Hope to consult on the 2010 program beginning in February 2009; however, Shell was not successful in scheduling a formal meeting before submission of this application to NMFS (Shell did host a public meeting in Point Hope on March 24). Since this IHA application submission, Shell has successfully completed POC meeting with several communities. The meetings include:

- June 1, 2009: NSB Assembly meeting
- June 2, 2009: Point Lay – meeting with village leadership
- June 3, 2009: Kaktovik – meeting with village leadership
- June 17, 2009: Point Hope – meeting with village leadership
- August 5, 2009: NWAB Assembly meeting
- August 27, 2009: NSB Planning Commission meeting

All engagements were directed towards discussing Shell's planned 2010 drilling activities in Camden Bay and the Chukchi Sea.

Shell attended the 2009 Conflict Avoidance Agreement (CAA) negotiation meetings in support of their 2009 Shallow Hazards surveys taking place in the Chukchi Sea. Shell is committed to a CAA process and will demonstrate this by making a good-faith effort to negotiate an agreement every year it has planned activities. On December 8, 2009 Shell held consultation meeting with representative from the various marine mammal commissions. Prior to drilling in 2010, Shell will also hold additional consultation meetings with the affected communities and subsistence user groups, NSB, and NWAB to discuss the mitigation measures included in the EP and POC.

12.2 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.

Beginning in early January 2009, Shell held one-on-one meetings with representatives from NSB and NWAB, subsistence-user group leadership, and Village Whaling Captain Association representatives. These meetings took place at the convenience of the community leaders and in various venues. Meetings were held starting on the 12th of January 2009 and continuing through April of 2009. Shell's primary purpose in holding individual meetings was to inform key leaders, prior to the public meetings, so that they would be prepared to give appropriate feedback on planned activities.

Shell conducted POC community meetings in the Chukchi Sea villages of Wainwright, Point Hope, and Point Lay, and Kotzebue regarding its Beaufort Sea 2010 exploration drilling program. During these meetings, Shell focused on lessons learned from prior years' activities and presented mitigation measures for avoiding potential conflicts, which are outlined in the 2010 POC. For this Camden Bay drilling program, Shell's POC with Chukchi Sea villages primarily addresses the issue of transit of vessels, whereas the POC with Beaufort Sea villages addresses vessel transit, drilling and associated activities. Shell will also facilitate meetings with the above-mentioned marine mammal commissions that are focused on ice seals, walrus, polar bears, and beluga.

12.3 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;

The following mitigation measures, plans and programs, are integral to this POC and were developed during consultation with potentially affected subsistence groups and communities. These measures, plans, and programs will be implemented by Shell during its 2010 exploration drilling operations in both the Beaufort and Chukchi Seas to monitor and mitigate potential impacts to subsistence users and resources. The mitigation measures Shell has adopted and will implement during its 2010 Camden Bay and Chukchi Sea exploration drilling operations are listed and discussed below. These mitigation measures reflect Shell's experience conducting exploration activities in Alaska over the last three years and its ongoing efforts to engage with local subsistence communities to better understand their concerns and develop appropriate and effective mitigation measures to address those concerns. This most recent version of Shell's planned mitigation measures was presented to community leaders and subsistence user groups starting in January of 2009 and has evolved since in response to information learned during the consultation process.

Subsistence Mitigation Measures

To minimize any cultural or resource impacts to subsistence whaling activities from its exploration operations, Shell will suspend drilling activities on August 25, 2010 prior to the start of the Kaktovik and Cross Island bowhead whale hunting season. The drillship and associated vessels will remain outside of the Camden Bay area during the hunt. Shell will resume drilling operations after the conclusion of the hunt and, depending on ice and weather conditions, continue its exploration activities through October 31, 2010. In addition to the adoption of this project timing restriction, Shell will implement the following additional measures to ensure coordination of its activities with local subsistence users to minimize further the risk of impacting marine mammals and interfering with the subsistence hunt:

- To minimize impacts on marine mammals and subsistence hunting activities, the drillship and support vessels will transit through the Chukchi Sea along a route that lies offshore of the polynya zone. In the event the transit outside of the polynya zone results in Shell having to break ice (as opposed to managing ice by pushing it out of the way), the drillship and support vessels will enter into the polynya zone far enough so that ice breaking is not necessary. If it is necessary to move into the polynya zone, Shell will notify the local communities of the change in the transit route through the Com Centers.
- Shell has developed a Communication Plan and will implement the plan before initiating exploration drilling operations to coordinate activities with local subsistence users as well as Village Whaling Associations in order to minimize the risk of interfering with subsistence hunting activities, and keep current as to the timing and status of the bowhead whale migration, as well as the timing and status of other subsistence hunts. The Communication Plan includes procedures for coordination with Communication and Call Centers to be located in coastal villages along the Chukchi and Beaufort Seas during Shell's proposed activities in 2010.
- Shell will employ local Subsistence Advisors from the Beaufort and Chukchi Sea villages to provide consultation and guidance regarding the whale migration and subsistence hunt. There will be a total of nine subsistence advisor-liaison positions (one per village), to work approximately 8-hours per day and 40-hour weeks through Shell's 2010 exploration project. The subsistence advisor will use local knowledge (Traditional Knowledge) to gather data on subsistence lifestyle within the community and advise as to ways to minimize and mitigate potential impacts to subsistence resources during the drilling season. Responsibilities include reporting any subsistence concerns or conflicts; coordinating with subsistence users; reporting subsistence-related comments, concerns, and information; and advising how to avoid subsistence conflicts. A subsistence advisor handbook will be developed prior to the operational season to specify position work tasks in more detail.
- Shell will recycle drilling muds (e.g., use those muds on multiple wells), to the extent practicable based on operational considerations (e.g., whether mud properties have deteriorated to the point where they cannot be used further), to reduce discharges from its operations. At the end of the season excess water base fluid, approximately 1500 bbl, will be pre-diluted to a 30:1 ratio with seawater and then discharged.
- Shell will also implement flight restrictions prohibiting aircraft from flying within 1,000 ft (300 m) of marine mammals or below 1,500 ft (457 m) altitude (except during takeoffs and landings or in emergency situations) while over land or sea.

13. 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 the population 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 planned marine mammal monitoring program for the exploration drilling program for 2010 is included as Attachment B to this document addresses the issues in item 13.

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

Various agencies and programs may undertake marine mammal studies in the Beaufort Sea during the course of the 2010 drilling season. It is unclear if these studies might be relevant to Shell's planned exploration drilling program. Shell is prepared to share information obtained during implementation of our marine mammal monitoring program with a variety of groups who may find the data useful in their research. A suggested list of recipients includes:

- The NSB Department of Wildlife Management (T. Hepa)
- The USFWS Office of Marine Mammal Management (C. Perham and J. Garlic-Miller)
- The MMS's Bowhead Whale Aerial Survey Program (C. Monnett)
- National Oceanic and Atmospheric Association, National Marine Mammal Laboratory (Robyn Angliss)
- The Kuukpik Subsistence Oversight Panel (KSOP)
- Alaska Eskimo Whaling Commission (H. Brower -Barrow)
- Beluga Whale Committee (W. Goodwin -Kotzebue)
- Inupiat Community of the Arctic Slope (Martha Ipalook Faulk -Barrow)
- North Slope Science Initiative (J. Payne)
- MMS Field Supervisor (Jeff Walker)
- Alaska Department of Natural Resources (D. Perrin)
- Alaska Department of Fish and Game

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Attachment A

Frontier Discoverer Specifications

FRONTIER DISCOVERER SPECIFICATIONS

TYPE-DESIGN	Drillship - Sonat Offshore Drilling Discoverer Class
SHAPE	Monohull with sponsons added for ice resistance
SHIP BUILDERS & YEAR	Namura Zonshno Shipyard, Osaka, Japan - hull number 355
YEAR OF HULL CONSTRUCTION	1965
YEAR OF CONVERSION	1976
DATE OF LAST DRY-DOCKING	2007

FRONTIER DISCOVERER DIMENSIONS

LENGTH	514 ft	156.7 meters (m)
LBP	486 ft	148.2 m
MAX HEIGHT (ABOVE KEEL)	274 ft	83.7 m
HEIGHT OF DERRICK ABOVE RIG FLOOR	175 ft	53.3 m

FRONTIER DISCOVERER MOORING EQUIPMENT

Anchor pattern symmetric 8 points system. The unit is fitted with Sonat Offshore Drilling patented roller turret mooring system giving the unit the ability to maintain favorable heading without an interruption of the drilling operations

ANCHORS	Stevpris New Generation 7,000 kilograms (kg) ea; 15,400 pounds (lb) ea
ANCHOR LINES	Chain Wire Combination
SIZE/GRADE	2-3/4" wire 3" ORQ Chain
LENGTH	2,450 ft (747 m) wire, 1,150 ft (351 m) chain (useable) per anchor

FRONTIER DISCOVERER OPERATING WATER DEPTH

MAX WATER DEPTH	1,000 ft with present equipment (can be outfitted to 2,500 ft)
MAX DRILLING DEPTH	20,000 ft

FRONTIER DISCOVERER DRILLING PACKAGE

DRAW WORKS	Ideco E-2,100, 1,600 hp
ROTARY	National C-495 with 49-1/2" opening
MUD PUMPS	2 x Continental Emsco Model FB-1600 Triple Mud Pumps
DERRICK	Pyramid 170 ft. with 1,300,000 lbs nominal capacity
PIPE RACKING	BJ 3 arm system
DRILL STING COMPENSATOR	Shaffer 400 K x 18 ft stroke
RISER TENSIONS	8 x 80k Shaffer 50 ft stroke tensioners
CROWN BLOCK	Pyramid with 9 each 60" diameter sheaves rated at 1,330,000 lbs
TRAVELING BLOCK	Continental - Emsco RA60-6
BOP	Cameron 18-3/4" x 10,000 psi
RISER	Cameron RCK type
TOP DRIVE	Varco TDS-3S, with GE-752 motor, 500 ton
BOP HANDLING	Hydraulic skid based system, drill floor

FRONTIER DISCOVERER DISPLACEMENT

FULL LOAD	20,253 Metric Tons (mt)
DRILLING	18,780 mt (Drilling, max load, deep hole, deep water)

FRONTIER DISCOVERER DRAUGHT

DRAFT AT LOAD LINE	27 ft	8.20 m
TRANSIT	(fully loaded, operating , departure)	8.02 m
DRILLING		7.67 m

FRONTIER DISCOVERER HELIDECK

MAXIMUM HELICOPTER SIZE	Sikorsky 61N & 92N
FUEL STORAGE	2 ea 720 gallon tanks

FRONTIER DISCOVERER ACCOMODATIONS

NUMBER OF BEDS	124
SEWAGE TREATMENT UNIT	Hamworthy ST-10

FRONTIER DISCOVERER PROPULSION EQUIPMENT

PROPELLER	1 ea 15' 7" diameter, fixed blade
PROPULSION DRIVE UNIT	Marine Diesel, 6 cylinder, 2 cycle, Crosshead type
HORSEPOWER	7,200 hp @ 135 RPM

GENERAL STORAGE CAPACITIES

SACK STORAGE AREA	934 cubic meters (m^3)
BULK STORAGE BENTONITE/BARITE	180 m^3 - 4 tanks
BULK CEMENT	180 m^3 - 4 tanks
LIQUID MUD	
Active	1,200 Barrels (bbls)
Reserve	1,200 bbls
Total	2,400 bbls
POTABLE WATER	1,670 bbls / 265.5 m^3 (aft peak can be used as add. pot water tank)
DRILL WATER	5,798 bbls / 921.7 m^3
FUEL OIL	6,497 bbls / 1,033 m^3 (2S, 2P, 3S, 3P, 4S and 4P upper wings can be used as additional fuel storage or well test crude tankage)

TRANSIT SPEED	8 knots

MARINE MAMMAL MONITORING AND MITIGATION PLAN

for

Exploration Drilling of Selected Lease Areas in the Alaskan Beaufort Sea in 2010

Shell Offshore Inc.

Original Submission May 2009
Revised Submission December 2009
Second Revised Submission March 2010

Marine Mammal Monitoring and Mitigation Plan

For

Exploration Drilling of Selected Lease Areas in the Alaskan Beaufort Sea

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ACRONYMS

4MP	Marine Mammal Monitoring and Mitigation Plan
ADF&G	Alaska Department of Fish and Game
AEWC	Alaska Eskimo Whaling Commission
DASAR	Directional Autonomous Seafloor Acoustic Recorder
dB	decibel
CD	Compact Disc
Discoverer	Frontier Discoverer
GPS	Global Positioning System
ft	feet
Hz	Hertz
IHA	Incidental Harassment Authorization
kHz	kilohertz
km	kilometer
LGL	LGL Alaska Research Associates, Inc.
LOA	Letter of Authorization
m	meters
Mi	miles
MMO	Marine Mammal Observer
MMS	Minerals Management Service
NMFS	National Marine Fisheries Service
NSB	North Slope Borough
NVD	Night-vision Device
rms	Root Mean Square
Scripps	Scripps Institute of Oceanography
Shell	Shell Offshore Inc.
SPL	Sound Pressure Level
USFWS	U.S. Fish and Wildlife Service

INTRODUCTION

Shell Offshore Inc. submits the following Marine Mammal Monitoring and Mitigation Program (4MP) for exploration drilling activities in the Beaufort Sea during the 2010 open-water season. The 4MP developed for Shell's 2010 exploration drilling program is designed to protect the marine mammal resources in the area, fulfill reporting obligations to the Minerals Management Service (MMS), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS), and establish a means for gathering additional data on marine mammals for future operations planning.

Shell plans to conduct exploration drilling within existing lease holdings in the Beaufort Sea. One drillship, the *Discoverer* owned by Frontier Drilling, will be used in the Beaufort Sea during the 2010 exploration drilling activities. The drillship is an ice-class drilling vessel designed, engineered and constructed to safely operate in the Arctic. In addition to the drillship, several support vessels will be required. The support vessels will include tugs and barges, an icebreaker, anchor handler/ice management vessel, and oil spill response vessels.

Shell's 4MP is a combination of active monitoring of the area of operations and the implementation of mitigation measures designed to minimize project impacts to marine resources. If marine mammals are observed within or about to enter specific safety radii around the proposed drilling operation mitigation will be initiated by vessel-based marine mammal observers (MMOs). The size of the 180 and 190 dB re 1 μPa (rms) safety radii were modeled and are described below in the section *Mitigation Measures during Drilling Activities.* These radii will be used to initiate mitigation during initial drilling activities at which time an acoustics contractor will measure underwater sound propagation from the drilling activities to empirically determine the size of safety radii. These measured radii will be used for mitigation purposes as soon as they become available. An initial sound source analysis will be supplied to NMFS and the drilling operators within 120 hours of completion of the measurements. A more detailed report describing the sounds produced by the drillship and support vessels will be issued to NMFS as part of the 90-day report following the end of the drilling season. Potential mitigation involving shut down of the operation is thought be unlikely due to the relatively low sound level produced during drilling operations (Greene 1987; Miles et al. 1987).

Monitoring during drilling activity and periods when drilling activity is not occurring will provide information on the numbers of marine mammals potentially affected by the exploration operations and facilitate real time mitigation to prevent impacts to marine mammals by industrial sounds or activities. These goals will be accomplished by conducting vessel-based, aerial, and acoustic monitoring programs which are described below. Vessel-based MMOs onboard the drillship and all support vessels will record the numbers and species of marine mammals observed in the exploration area and any observable reaction of marine mammals to the exploratory activities. Aerial monitoring, designed primarily for detecting cetaceans, will be used to identify any large scale distributional changes of cetaceans relative to the activities and add to the existing database on the abundance and distribution of observed species. The acoustic program will characterize the sounds produced by the drilling activities and support vessels, and document the potential reactions of marine mammals in the area, particularly bowhead whales, to those sounds and activities.

VESSEL-BASED MARINE MAMMAL MONITORING PROGRAM

Introduction

The vessel-based operations of Shell's 4MP are designed to meet the requirements of the IHA and LOA which will be issued by NMFS and USFWS, respectively, for this project, and to meet any other stipulation agreements between Shell and other agencies or groups. The objectives of the program will be:

- to ensure that disturbance to marine mammals and subsistence hunts is minimized and all permit stipulations are followed,
- to document the effects of the proposed exploratory activities on marine mammals, and
- to collect baseline data on the occurrence and distribution of marine mammals in the study area.

The 4MP will be implemented by a team of experienced MMOs, including both biologists and Inupiat personnel. MMOs will be stationed aboard the drillship and associated support vessels throughout the drilling period. Reporting of the results of the vessel-based monitoring program will include the estimation of the number of "takes" as stipulated in the IHA and LOA.

The vessel-based portion of Shell's 4MP will be required to support the drilling activities in the central and eastern Alaskan Beaufort Sea. The dates and operating areas will depend upon ice and weather conditions, along with Shell's arrangements with agencies and stakeholders. Drilling activities are expected to occur during July through October 2010. Vessel-based monitoring for marine mammals will begin5–7 days before drilling begins; will continue throughout the period of drilling operations, and will cease 5-7 days after drilling stops to comply with anticipated provisions in the IHA and LOA that Shell expects to receive from NMFS and USFWS.

The vessel-based work will provide:

- the basis for real-time mitigation, if necessary, as required by the various permits that Shell receives,
- information needed to estimate the number of "takes" of marine mammals by harassment, which must be reported to NMFS and USFWS,
- data on the occurrence, distribution, and activities of marine mammals in the areas where the drilling program is conducted,
- information to compare the distances, distributions, behavior, and movements of marine mammals relative to the drillship at times with and without drilling activity,
- a communication channel to coastal communities including Inupiat whalers, and
- employment and capacity building for local residents, with one objective being to develop a larger pool of experienced Inupiat MMOs.

The 4MP will be operated and administered consistent with monitoring programs conducted during seismic and shallow hazards surveys in 2006–2008 or such alternative requirements as may be specified in the IHA issued by NMFS for this project. Any other stipulation agreements between Shell and agencies or groups such as MMS, USFWS, NSB, and AEWC will also be fully incorporated. All MMOs will be provided training through a program approved by NMFS and Shell, as described later. At least one observer on each vessel will be an Inupiat who will have the additional responsibility of communicating with coastal communities and directly with Inupiat whalers during the whaling season. Details of the vessel-based marine mammal monitoring program are described below.

Mitigation Measures during Drilling Activities

Shell's planned offshore drilling program incorporates both design features and operational procedures for minimizing potential impacts on marine mammals and on subsistence hunts. The design features and operational procedures have been described in the IHA and LOA applications submitted to NMFS and USFWS, respectively and are summarized below. Survey design features include:

- timing and locating some drilling and support activities to avoid interference with the annual fall bowhead whale hunts from Kaktovik, Nuiqsut (Cross Island), and Barrow;
- identifying transit routes and timing to avoid other subsistence use areas and communicate with coastal communities before operating in or passing through these areas, and;
- conducting pre-season sound propagation modeling to establish the appropriate safety and behavioral radii.

The potential disturbance of marine mammals during drilling operations will be minimized further through the implementation of several ship-based mitigation measures if mitigation becomes necessary.

Safety and Disturbance Zones

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around industrial sound sources are customarily defined as the distances within which received sound levels are ≥180 dB re 1 µPa (rms) for cetaceans and ≥190 dB re 1 µPa (rms) for pinnipeds. These safety criteria are based on an assumption that sound energy received at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels might have some such effects. Disturbance or behavioral effects to marine mammals from underwater sound may occur after exposure to sound at distances greater than the safety radii (Richardson et al. 1995). NMFS assumes that marine mammals exposed to underwater continuous sound levels ≥120 dB rms have the potential to be disturbed behaviorally.

Initial safety and behavioral radii for the sound levels produced by the drilling activities have been modeled. These radii will be used for mitigation purposes should they be necessary until direct measurements are available early during the exploration activities.

Sounds from the *Discoverer* have not previously been measured in the Arctic or elsewhere, but sounds from a similar drillship, *Explorer II*, were measured in the Beaufort Sea (Greene 1987, Miles et al. 1987). The underwater received sound pressure level in the 20 to 1000 Hz band for drilling activity by the *Explorer II*, including a nearby support vessel, was 134 dB re 1 µPa at 0.2 km (Greene 1987). The back-propagated source levels (175 dB re 1 µPa at 1 m) from these measurements were used as a proxy for modeling the sounds likely to be produced by drilling activities from the *Discoverer*. Based on the models, source levels from drilling are not expected to reach the 180 dB rms level and are expected to fall below 160 dB rms 35 m from the drillship. The 120 dB rms radius is expected to be 4.9 km from the drillship.

Sounds produced by the *Robert Lameur* were measured by Greene (1987) while actively managing ice in the Beaufort Sea and were estimated to fall below 160 dB rms <100 m from the vessel and below 120 dB rms within 8 km. Estimated source levels form these measurements were generally below the 180 dB rms (and 190 dB rms) criteria for potential injury to marine mammals although estimated source levels were slightly above 180 dB rms in some cases (Greene 1987; Miles et al. 1987). These estimated source measurements were used to model the expected sounds produced at the exploratory well sites by the *Discoverer* and associated support vessels.

The source levels noted above for exploration drilling and support vessel activities are not high enough to cause a temporary reduction in hearing sensitivity or permanent hearing damage to marine mammals. Consequently, mitigation as described for seismic activities including ramp ups, power downs, and shut downs should not be necessary for drilling activities. However, Shell plans to use MMOs onboard the drillship and the various support vessels to monitor marine mammals and their responses to industry activities and to initiate mitigation measures should in-field measurements of the operations indicate conditions represent a threat to the health and well-being of marine mammals.

Marine Mammal Observers

Vessel-based monitoring for marine mammals will be done by trained MMOs throughout the period of drilling operations to comply with expected provisions in the IHA and LOA that Shell receives. The observers will monitor the occurrence and behavior of marine mammals near the drillship during all daylight periods during operation, and during most daylight periods when drilling operations are not occurring. MMO duties will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the drilling operations; and documenting "take by harassment" as defined by NMFS.

Number of Observers

A sufficient number of MMOs will be required onboard each vessel to meet the following criteria

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

MMO teams will consist of Inupiat observers and experienced field biologists. An experienced field crew leader and an Inupiat observer will be members of every MMO team onboard the drillship and each support vessel during the drilling program. The total number of MMOs may decrease later in the season as the duration of daylight decreases assuming NMFS does not require continuous nighttime monitoring.

Crew Rotation

Shell anticipates that there will be provision for crew rotation at least every six weeks to avoid observer fatigue. During crew rotations detailed hand-over notes will be provided to in incoming crew leader by the outgoing leader. Other communications such as email, fax, and/or phone communication between the current and oncoming crew leaders during each rotation will also occur when possible. In the event of an unexpected crew change Shell will facilitate such communications to insure monitoring consistency among shifts.

Observer Qualifications and Training

Crew leaders and most other biologists serving as observers in 2010 will be individuals with experience as observers during one or more of the 1996-2009 seismic or shallow hazards monitoring projects in Alaska, the Canadian Beaufort, or other offshore areas in recent years.

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

Most observers, including Inupiat observers, will also complete a two-day training and refresher session on marine mammal monitoring, to be conducted shortly before the anticipated start of the 2010 drilling season. Any exceptions will have or receive equivalent experience or training. The training session(s) will be conducted by qualified marine mammalogists with extensive crew-leader experience during previous vessel-based seismic monitoring programs.

Primary objectives of the training include:

- review of the marine mammal monitoring plan for this project, including any amendments specified by NMFS or USFWS in the IHA or LOA, by MMS, or by other agreements in which Shell may elect to participate;
- review of marine mammal sighting, identification, and distance estimation methods;
- review of operation of specialized equipment (reticle binoculars, night vision devices, and GPS system);
- review of, and classroom practice with, data recording and data entry systems, including procedures for recording data on mammal sightings, monitoring operations, environmental conditions, and entry error control. These procedures will be implemented through use of a customized computer database and laptop computers;
- review of the specific tasks of the Inupiat Communicator.

MMO Handbook

A Marine Mammal Observers' Handbook will be prepared for Shells' monitoring program. Handbooks contain maps, illustrations, and photographs, as well as text, and is intended to provide guidance and reference information to trained individuals who will participate as MMOs. The following topics will be covered in the MMO Handbook for the Shell project:

- summary overview descriptions of the project, marine mammals and underwater noise, the marine mammal monitoring program (vessel-based, aerial, acoustic measurements, special studies), the NMFS IHA and USFWS

LOA and other regulations/permits/agencies, the Marine Mammal Protection Act;
- monitoring and mitigation objectives and procedures, initial safety radii;
- responsibilities of staff and crew regarding the marine mammal monitoring plan;
- instructions for ship crew regarding the marine mammal monitoring plan;
- data recording procedures: codes and coding instructions, common coding mistakes, electronic database; navigational, marine physical, field data sheet;
- use of specialized field equipment (reticle binoculars, NVDs, laser rangefinders);
- reticle binocular distance scale;
- table of wind speed, Beaufort wind force, and sea state codes;
- data storage and backup procedures;
- list of species that might be encountered: identification, natural history;
- safety precautions while onboard;
- crew and/or personnel discord; conflict resolution among MMOs and crew;
- drug and alcohol policy and testing;
- scheduling of cruises and watches;
- communications;
- list of field gear that will be provided;
- suggested list of personal items to pack;
- suggested literature, or literature cited; and
- copies of the NMFS IHA and USFWS LOA when available.

Monitoring Methodology

The observer(s) will watch for marine mammals from the best available vantage point on the drillship and support vessels. The observer(s) will scan systematically with the unaided eye and 7×50 reticle binoculars, supplemented with 20 x 60 image-stabilized Zeiss Binoculars or Fujinon 25 x 150 "Big-eye" binoculars and night-vision equipment when needed (see below). Personnel on the bridge will assist the marine mammal observer(s) in watching for marine mammals.

Information to be recorded by marine mammal observers will include the same types of information that were recorded during recent monitoring programs associated with Industry activity in the Arctic (e.g. Ireland et al. 2009). When a mammal sighting is made, the following information about the sighting will be recorded:

- Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from observer, apparent reaction to activities (e.g., none, avoidance, approach, paralleling, etc.), closest point of approach, and behavioral pace.
- Time, location, speed, and activity of the vessel, sea state, ice cover, visibility, and sun glare.
- The positions of other vessel(s) in the vicinity of the observer location.

The ship's position, speed of support vessels, and water temperature, water depth, sea state, ice cover, visibility, and sun glare will also be recorded at the start and end of each observation watch, every 30 minutes during a watch, and whenever there is a change in any of those variables.

Distances to nearby marine mammals will be estimated with binoculars (Fujinon 7×50 binoculars) containing a reticle to measure the vertical angle of the line of sight to the animal relative to the horizon.

Observers may use a laser rangefinder to test and improve their abilities for visually estimating distances to objects in the water. However, previous experience showed that a Class 1 eye-safe device was not able to measure distances to seals more than about 70 m (230 ft) away. The device was very useful in improving the distance estimation abilities of the observers at distances up to about 600 m (1968 ft)—the maximum range at which the device could measure distances to highly reflective objects such as other vessels. Humans observing objects of more-or-less known size via a standard observation protocol, in this case from a standard height above water, quickly become able to estimate distances within about ±20% when given immediate feedback about actual distances during training.

Monitoring At Night and In Poor Visibility

Night-vision equipment ("Generation 3" binocular image intensifiers, or equivalent units) will be available for use when/if needed. Past experience with night-vision devices (NVDs) in the Beaufort Sea and elsewhere has indicated that NVDs are not nearly as effective as visual observation during daylight hours (e.g., Harris et al. 1997, 1998; Moulton and Lawson 2002).

Specialized Field Equipment

Shell will provide or arrange for the following specialized field equipment for use by the onboard MMOs: reticle binoculars, Big-eye binoculars, GPS unit, laptop computers, night vision binoculars, and possibly digital still and digital video cameras.

Field Data-Recording, Verification, Handling, and Security

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

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

In addition to routine MMO duties, Inupiat observers will be encouraged to record comments about their observations into the "comment" field in the database. Copies of these records will be available to the Inupiat observers for reference if they wish to prepare a statement about their observations. If prepared, this statement would be included in the 90-day and final reports documenting the monitoring work.

Field Reports

Throughout the drilling program, the observers will prepare a report each day or at such other interval as the IHA, LOA, or Shell may require summarizing the recent results of the monitoring program. The reports will summarize the species and numbers of marine mammals sighted. These reports will be provided to NMFS and to the drilling operators.

Reporting

The results of the 2010 vessel-based monitoring, including estimates of "take by harassment", will be presented in the 90-day and final technical report(s). Reporting will address the requirements established by NMFS in the IHA.

The technical report(s) will include:

- summaries of monitoring effort: total hours, total distances, and distribution of marine mammals through the study period accounting for sea state and other factors affecting visibility and detectability of marine mammals;
- analyses of the effects of various factors influencing detectability of marine mammals including sea state, number of observers, and fog/glare;
- species composition, occurrence, and distribution of marine mammal sightings including date, water depth, numbers, age/size/gender categories, group sizes, and ice cover;
- analyses of the effects of drilling operations:
  - sighting rates of marine mammals during periods with and without drilling activities (and other variables that could affect detectability);
  - initial sighting distances versus drilling state;
  - closest point of approach versus drilling state;
  - observed behaviors and types of movements versus drilling state;
  - numbers of sightings/individuals seen versus drilling state;
  - distribution around the drillship and support vessels versus drilling state;
  - estimates of "take by harassment".

AERIAL SURVEY PROGRAM

Objectives

An aerial survey program will be conducted in support of the drilling program in the Beaufort Sea during the summer and fall of 2010. The drilling program may start in the Beaufort Sea as early as 10 July 2010. The objectives of the aerial survey will be:

- to advise operating vessels as to the presence of marine mammals (primarily cetaceans) in the general area of operation;
- to collect and report data on the distribution, numbers, movement and behavior of marine mammals near the drilling operations with special emphasis on migrating bowhead whales;
- to support regulatory reporting related to the estimation of impacts of drilling operations on marine mammals;

- to investigate potential deflection of bowhead whales during migration by documenting how far east of drilling operations a deflection may occur, and where whales return to normal migration patterns west of the operations, and
- to monitor the accessibility of bowhead whales to Inupiat hunters.

Safety

Safety will be of primary importance in all decisions regarding the planning and conduct of the aerial surveys. Safety-related considerations during planning have included choice of aircraft, aircraft operator, and pilots; outfitting of the aircraft; lengths and locations of survey grids; and safety training. Safety during aerial survey operations will include careful and judicious consideration of weather and avoidance of flight in questionable conditions. Although the pilots will have ultimate authority, the aerial survey crew will also be required to make their own judgments and to avoid flying in questionable circumstances. To this end, the aerial survey teams will have a crew leader with experience conducting this type of survey in arctic conditions, and will have the authority to cancel or (in agreement with the pilots) amend flight operations as necessary for safety.

Selection of Aircraft

Specially-outfitted Twin Otter aircraft are expected to be the survey aircraft and have an excellent safety record. These aircraft will be specially modified for survey work and have been used extensively by NMFS, ADF&G, COPAC, NSB, and LGL during many marine mammal projects in Alaska, including Industry funded projects as recent as the 2006–2008 seasons. The aircraft will be provided with a comprehensive set of survival equipment appropriate to offshore surveys in the Arctic. For safety reasons, the aircraft will be operated with two pilots.

Survey Procedures

Flight and Observation Procedures

Aerial survey flights will begin 5 to7 days before operations at the exploration well sites get underway. Surveys will be flown daily throughout drilling operations, weather and flight conditions permitting, and continued for 5 to 7 days after all activities at the site have ended.

The aerial survey procedures will be generally consistent with those used during earlier industry studies (Davis et al. 1985; Johnson et al. 1986; Evans et al. 1987; Miller et al. 1997, 1998, 1999, 2002; Patterson 2007). This will facilitate comparison and pooling of data where appropriate. However, the specific survey grids will be tailored to Shell's operations. During the 2010 drilling season Shell will coordinate and cooperate with the aerial surveys conducted by MMS/NMFS and any other groups conducting surveys in the same region.

It is understood that the timing, duration, and location (between two identified well sites) of Shell's drilling operations are subject to change as a result of unpredictable weather and ice conditions, as well as regulatory and stakeholder concerns. The aerial survey design is flexible and able to adapt at short notice to changes in the operations.

For marine mammal monitoring flights, aircraft will be flown at ~120 knots ground speed and usually at an altitude of 1000 ft. Flying at a survey speed of 120 knots greatly increases the amount of area that can be surveyed, given aircraft limitations, with minimal effect on the ability to detect bowhead whales. Surveys in the Beaufort Sea are directed at bowhead whales and an altitude of 900-1000 ft is the lowest survey altitude that can normally be flown without concern about potential aircraft disturbance; it is also the altitude recommended by NMFS for IHA monitoring efforts for bowhead whales. Aerial surveys at an altitude of 1000 ft do not provide much information about seals but are suitable for both bowhead and beluga whales. The need for a 900-1000+ ft cloud ceiling will limit the dates and times when surveys can be flown. Selection of a higher minimum altitude for surveys (e.g. 1500 ft) would result in a significant reduction in the number of days where surveys would be possible, impairing the ability of the aerial program to meet its objectives. All other aircraft during the 2010 drilling program shall not operate below 1500 ft (457 m) unless the aircraft is engaged in marine mammal monitoring, approaching, landing, taking off, under poor weather (low ceilings) conditions, engaged in providing assistance to a whaling vessel in distress, or any other emergency situations.

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

Transect information, sighting data and environmental data will be entered into a GPS-linked computer by the third observer, and simultaneously recorded on digital voice recorders for backup and validation. At the start of each transect, the observer recording data will record the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction (°T) and outside air temperature (°C). In addition, each observer will record the time, visibility (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, moderate, severe) at the start and end of each transect, and at 2-min intervals along the transect. This will provide data in units suitable for statistical summaries and analyses of effects of these variables (and position relative to the drillship) on the probability of detecting animals (see Davis et al. 1982; Miller et al. 1999; Thomas et al. 2002). The data logger will automatically record time and aircraft position (latitude and longitude) for sightings and transect waypoints, and at pre-selected intervals along the transects.

Supplementary Data

Ice observations during aerial surveys will be recorded and satellite imagery may be used, where available, during post-season analysis to determine ice conditions adjacent to the survey area. These are standard practices for surveys of this type, and are necessary in order to interpret factors responsible for variations in sighting rates.

Shell will, as a high priority, assemble the information needed to relate marine mammal observations to the locations of the drillship, and to the estimated received levels of industrial sounds at mammal locations. During the aerial surveys, Shell will record relevant information on other industry vessels, whaling vessels, low-flying aircraft, or any other human activities that are seen in the survey area.

Coordination with MMS/NMFS Aerial Surveys

The MMS is planning to continue its wide-ranging aerial surveys of bowhead whales and other marine mammals in the Beaufort Sea during the autumn of 2010. In 2010, the surveys will be contracted to the National Marine Mammal Laboratory in Seattle. These surveys include the area where drilling activities will occur. Shell will co-ordinate with MMS/NMML to share data, both during the drilling season and for use in analyses and reports.

Shell will also consult with MMS/NMML regarding coordination during the drilling season and real-time sharing of data. The aims will be

- to ensure aircraft separation when both crews conduct surveys in the same general region;
- to coordinate the 2010 aerial survey projects in order to maximize consistency and minimize duplication;
- to use data from MMS's broad-scale surveys to supplement the results of the more site-specific Shell surveys for purposes of assessing the effects of drilling activities on whales and estimating "take by harassment";
- to maximize consistency with previous years' efforts insofar as feasible.

It is expected that raw bowhead sighting and flightline data will be exchanged between MMS and Shell on a daily basis during the drilling season, and that each team will also submit its sighting information to NMFS in Anchorage each day. After the Shell and MMS data files have been reviewed and finalized, they will be exchanged in digital form.

Shell is not aware of any other related aerial survey programs presently scheduled to occur in the Alaskan Beaufort Sea in areas where Shell is anticipated to be conducting drilling operations during July–October 2010. However, one or more other programs are possible in support of other industry and research operations. If another aerial survey project were planned, Shell would seek to coordinate with that project to ensure aircraft separation, maximize consistency, minimize duplication, and share data.

Survey Design

During the late summer and fall, bowhead whale is the primary species of concern, but belugas and gray whales are also present. Bowheads and belugas migrate through the Alaskan Beaufort Sea from summering areas in the central and eastern Beaufort Sea and Amundsen Gulf to their wintering areas in the Bering Sea (Clarke et al. 1993; Moore et al. 1993; Miller et al. 2002). Small numbers of bowheads are sighted in the eastern Alaskan Beaufort Sea starting mid-August and near Barrow starting late August but the main migration does not start until early September. Recent surveys (COMIDA 2009) and GPS tagging (ADFG 2009) have also recorded some bowheads in the western Alaskan Beaufort Sea in July and August. The bowhead migration tends to be through nearshore and shelf waters, although in some years small numbers of whales are seen near the coast and/or far offshore. Bowheads frequently interrupt their migration to feed (Ljungblad et al. 1986a; Lowry 1993; Landino et al. 1994; Würsig et al. 2002; Lowry et al. 2004) and their stop-overs vary in duration from a few hours to a few weeks (Koski et al. 2002). A commonly used feeding area is in and near Smith Bay, east of Barrow. Less consistently used feeding areas are in coastal and shelf waters near and east of Kaktovik. In 2007 and 2008 bowhead whales also used areas near Camden Bay to feed during the migration (Ireland et al. 2008; Funk et al. 2009).

To address concerns regarding deflection of bowheads at greater distances the survey pattern around drilling operations has been designed to document whale distribution from about

40 km east of the drilling operations to about 60 km west of operations (Fig. 1). Aerial surveys will be conducted daily starting 5 to 7 days before drilling operations begin.

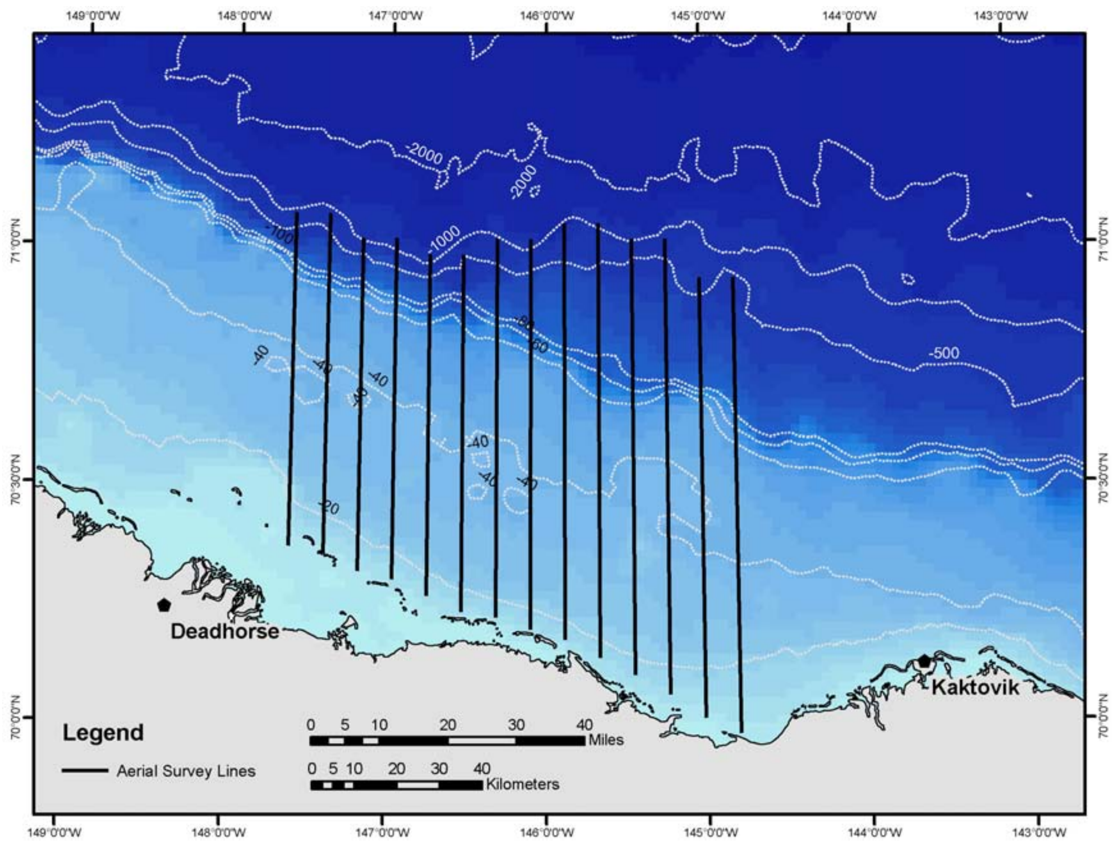

FIGURE 1. Central Alaskan Beaufort Sea showing a representative aerial survey pattern that will be flown daily during late summer and fall. The survey grid will be moved east or west depending on the precise location of the drillship and lines will be shifted slightly within the grid for each survey in order to randomize their location and meet sampling design objectives.

Bowhead whale movements during the late summer/autumn are generally from east to west, and transects should be designed to intercept rather than parallel whale movements. The transect lines in the grid will be oriented north-south, equally spaced at 8 km, and randomly shifted in the east-west direction for each survey by no more than the transect spacing. The survey grid will total about 1300 km in length, requiring ~6 h to survey at a speed of 220 km/h (120 knots), plus ferry time. Exact lengths and durations will vary somewhat depending on the position of the drilling operation and thus of the grid, the sequence in which lines are flown (often affected by weather), and the number of refueling/rest stops.

Weather permitting, transects making up the grid in the Beaufort Sea will be flown in sequence from west to east. This decreases difficulties associated with double counting of whales that are (predominantly) migrating westward. The survey sequence around the drilling operation is designed to monitor the distribution of whales around the drilling operation.

Analysis of Aerial Survey Data

During the field program, preliminary maps and summaries of the daily surveys will be provided to NMFS as normally required by the terms of the IHA. While in the field data will be checked for entry errors and files will be backed up to CDs or portable memory drives. Two levels of analyses will be conducted at the end of the season. The first level will consist of basic summaries that are required for the 90-day report specified by the IHA. These include summaries of numbers of marine mammals seen, survey effort by date, maps summarizing sightings, and estimates of numbers of marine mammals that are "taken" according to NMFS criteria. The second level of analyses will be presented in the subsequent comprehensive report. The comprehensive report will provide more detailed analyses of the data to quantify the effect of the drilling program on the distribution and movements of marine mammals.

Estimation of Numbers "Taken"

Shell has used this methodology, which was developed using past studies in the Beaufort and Chukchi sea regions (Miller et al. 1999; Haley and Ireland 2006) and other areas of the world (Lawson et al. 1998; Holst et al. 2005; Ireland et al. 2005), for estimating the numbers of marine mammals that are "taken" (as defined by NMFS). These estimates require estimating the numbers of animals present near or passing the drilling program during periods without drilling activity and assuming that similar numbers would have passed during those activities if the activities were not conducted. The planned approach has been accepted by NMFS as satisfying the requirements for "take" estimates for previous monitoring programs.

The criteria to be used in tabulating and estimating numbers of cetaceans potentially exposed to various sound levels will be consistent with those used during previous related projects in 1996-2008, unless otherwise directed by NMFS. Only cetaceans will be addressed using the aerial survey data because the altitude of the surveys is too high to reliably detect and identify pinnipeds. As in previous studies, Shell anticipates that there will be four components:

1. *Numbers of cetaceans observed within the area ensonified strongly by the drilling operations.* For cetaceans, Shell will estimate the numbers of animals exposed to received rms levels of sounds exceeding 120, 160 dB and 180 dB re 1 µPa, as required by NMFS.

2. *Numbers of cetaceans observed showing apparent reactions to drilling operations, e.g., heading in an "atypical" direction.* Animals exhibiting apparent responses to the activities will be counted as affected by the programs if they were exposed to sounds from those activities.

3. *Numbers of cetaceans estimated to have been subjected to sound levels ≥120, ≥160 and ≥180 dB re 1µ Pa (rms) when no monitoring observations were possible*. This will involve using the observations from the survey aircraft (Shell and MMS), supplemented by relevant vessel-based observations, to estimate how many cetaceans were exposed over the full course of Shell's 2010 drilling program to situations where received sound levels were ≥120, ≥160 and ≥180 dB rms. In the case of the bowhead whale, Shell will estimate the proportions of the observed whales that were close enough to shore to have passed through the area where exposure might occur, and could have passed while drilling operations were underway. Shell's aerial survey design, together with the complementary aerial surveys to be conducted by MMS, will provide the needed data.

4. *The number of bowheads whose migration routes came within 20 km of the drilling activity, or would have done so if they had not been displaced farther offshore, will be estimate*d. If the 2010 data indicate that the avoidance distance exceeds 20 km, the larger avoidance distance will also be used for estimating the numbers of whales potentially responding to the drilling activity. These estimates will be obtained by determining the displacement distance based on the aerial survey results, and then estimating how many bowheads were likely to approach the avoided area during times while the drillship and support vessels were present.

Effects of Drilling Program on Bowhead Migration

The location of the bowhead migration corridor in 2010 will be determined by examining data from periods with drilling activities and data from east of those operations. The MMS aerial survey data will be a useful supplement for areas well east of the drilling program. Shell will contrast the numbers of bowhead sightings and individuals vs. distance from shore:

- during periods with vs. without drilling operations, and
- near vs. east vs. west of the exploration areas.

The distance categories will be linked to received sound levels based on the results from the acoustic measurement task. Analyses will be done on a sightings-per-unit effort basis to allow meaningful interpretation even though aerial survey effort is inevitably inconsistent at different distances offshore.

To determine how far east, north and west displacement effects (if any) extend, additional analyses will be conducted on bowhead sightings and survey effort in relation to distance and bearing from the drilling operations during times with and without operations. Shell anticipates applying a logistic or Poisson regression approach to assess the effects of distance and direction from the drilling operations on sighting probability of bowhead whales, allowing for the confounding influence of sightability (sea state, ice conditions, etc) and other covariates. Such an approach has been used extensively in analyses of whale and seal distribution in the Beaufort Sea (Manly et al. 2004; Moulton et al. 2005). Other analyses that may be useful to describe the effects of the drilling operation on the bowhead migration path, including summaries of headings, behavior and swimming speeds, will be included in the technical report.

The data from the current survey may not provide enough sightings to be able to quantify the effects of Shell's 2010 activities on the bowhead whale migration path. That could occur if Shell's operations in the Beaufort Sea during the bowhead whale migration season were limited due to ice or other factors, or if 2010 is a year when weather conditions are poorer than average, which would limit the periods when surveys could be conducted.

The aerial survey data pertaining to other species of marine mammals will also be mapped and analyzed insofar as this is useful. However, the main migration corridor of belugas is far offshore, and generally north of the survey area proposed here. Few gray whales and walruses are likely to be seen because of their rarity in the Beaufort Sea area (although gray whales were seen in the area in 1998 (Miller et al. 1999) and small numbers have been seen during several recent surveys by MMS (Treacy 1998, 2000, 2002) and LGL (Patterson et al. 2007). Therefore, the proposed aerial surveys are expected to document the infrequent use of continental shelf waters of the Beaufort Sea by beluga whales, gray whales and walruses, but detailed analyses for these species probably will not be warranted. Seals cannot be surveyed quantitatively by aerial surveys at altitudes 900 to 1500 ft over open water. The aerial surveys will provide only incidental data on the occurrence of bearded and especially ringed seals in the area.

ACOUSTIC MONITORING PLAN

Drilling Sound Measurements

Objectives

Drilling sounds are expected to vary significantly with time due to variations in the level of operations and the different types of equipment used at different times onboard the drillship. The objectives of these measurements are:

- to quantify the absolute sound levels produced by drilling, and to monitor their variations with time, distance and direction from the drillship, and
- to measure the sound levels produced by vessels operating in support of drilling operations. These vessels will include crew change vessels, tugs, ice-management vessels and spill response vessels.

Equipment

The drilling and support vessel sound measurements will be performed using one of two methods, both of which involve real-time monitoring. The first method would involve use of bottom-founded hydrophones cabled back to the drillship (Fig. 2). These hydrophones weigh approximately 88 lbs (40 kilograms) with a footprint of approximately 2.7 square feet (0.5 square meters) and would be positioned between 500 m and 1000 m from the drillship, depending on the final positions of the anchors used to hold the drillship in place. Hydrophone cables would be fed to real-time digitization systems on board. In addition to the cabled system, a separate set of bottom-founded hydrophones (Fig. 3) may be deployed at various distances from the drilling operation for storage of acoustic data to be retrieved and processed at a later date.

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

Sound level monitoring with either method will occur on a continuous basis throughout all drilling activities. Both types of systems will be set to record digital acoustic data at sample rate 32 kHz, providing useful acoustic bandwidth to at least 15 kHz. Both the hydrophone systems use Reson TC4032 hydrophones with sensitivity -170 dB re V/µPa. These systems are capable of measuring absolute broadband sound levels between 90 and 180 dB re µPa. The long duration recordings will capture many different operations performed at the drillship. Retrieval of these systems will occur following completion of the drilling activities.

The deployment of drilling sound monitoring equipment will occur as soon as possible once the drillship is on site. Activity logs of drilling operations and nearby vessel activities will be maintained to correlate with these acoustic measurements.

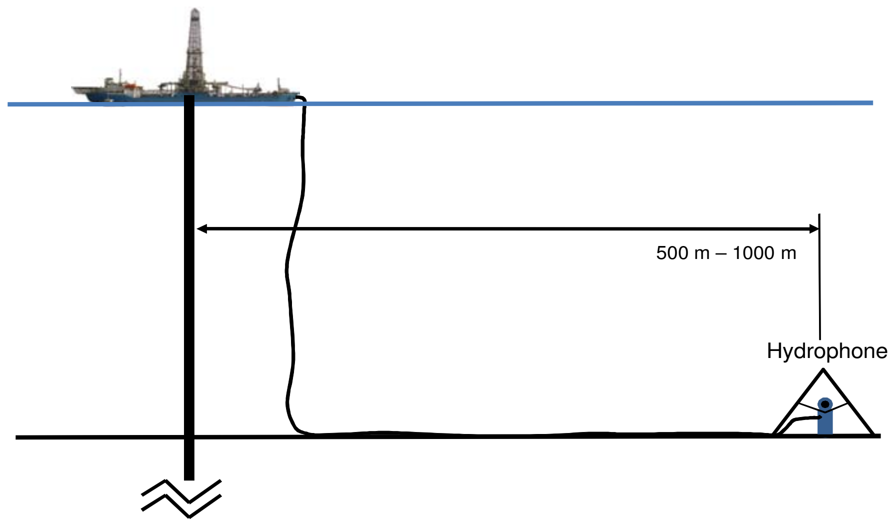

Figure 2: Cabled hydrophone method for real time monitoring of drilling noise.

Figure 3. Hydrophone recording system being deployed at sea. The hydrophone system is an autonomous recorder with very high recording resolution. Acoustic data is stored internally on a hard-drive.

Vessel Sounds Monitoring

Sound produced by the vessels supporting drilling operations will be recorded by the drilling-sounds monitoring equipment. Logs of vessel position and activity will be used to determine the time varying contribution of each vessel to the overall sound level measurements. Additional dedicated measurements of vessel source levels will be obtained by having the vessels sail past the monitoring locations. These dedicated measurements will provide sound level versus distance from the respective vessels and will also be processed to compute source levels in 1/3-octave bands referenced to 1 m range.

Acoustic Data Analyses

An important purpose of the measurements of sound level variation with time is to provide information that can be correlated with observations of bowhead whale deflections around the drilling operations, should they occur. The calls of bowhead whales will be detected and located by the arrays of directional acoustic recorders (DASARS). The goal of that work will be to determine if changes in migration patterns can be correlated with changes in sound level output from the drilling operations.

Drilling sound data will be analyzed to extract a record of the frequency-dependent sound levels as a function of time. Figure 4 shows the results of this type of analysis for a previous deployment of a bottom-founded recorder. These results are useful also for correlating measured noise events with specific drilling operations and also for capturing marine mammal vocalizations. The analysis also provides absolute sound levels in finite frequency bands that can be tailored to match the highest-sensitivity hearing ranges for the various species of interest. For example, bowhead hearing is thought to be most acute in the 100 Hz - 1000 Hz frequency range which corresponds with the blue dotted line in the upper plot of Figure 4.

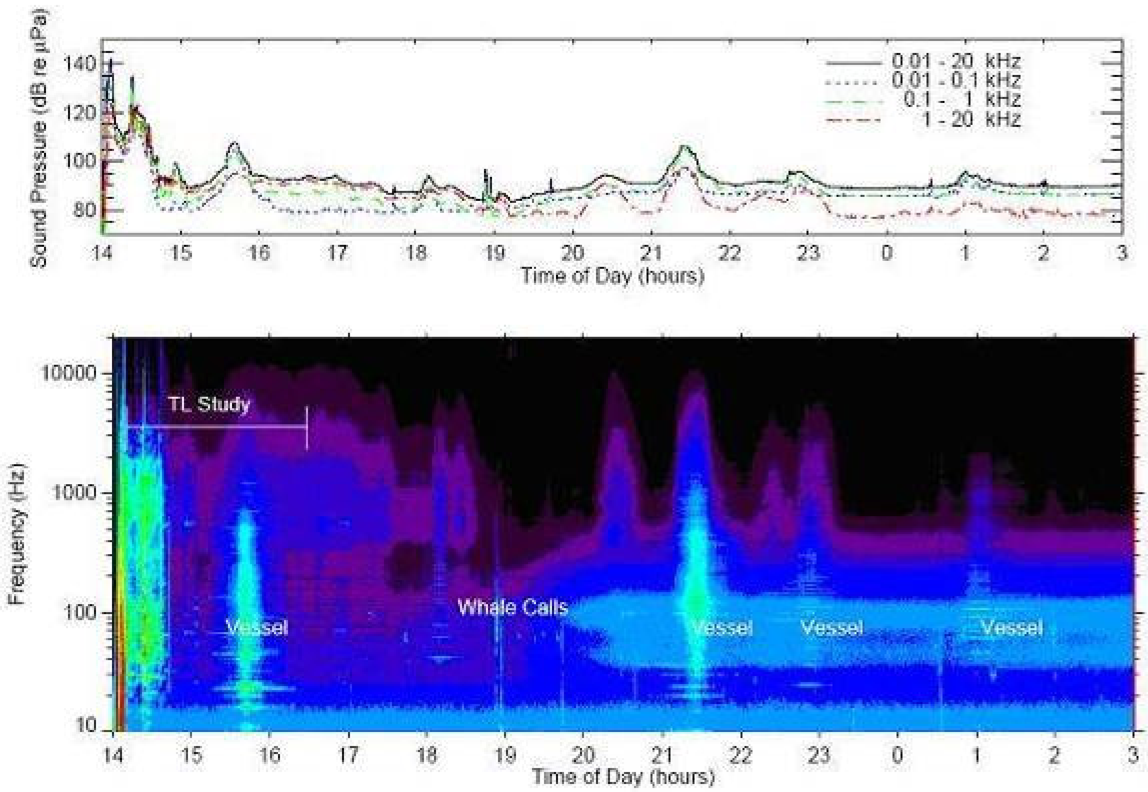

Figure 4. Lower: spectrogram of sound level measurements obtained from a hydrophone recording system. Upper: broadband and selected band level variation with time.

The analyses will also consider sound level integrated through 1-hour durations (referred to as noise equivalent level Leq(1-hour)). Figure 5 (upper) shows an example of a Leq analysis of hydrophone data. Similar graphs for long time periods will be generated as part of the data analysis performed for indicating drilling sound variation with time in selected frequency bands. These levels will be of particular importance for correlation with bowhead location data obtained from directional acoustic recording arrays deployed for Shell's 2010 bowhead migration study.

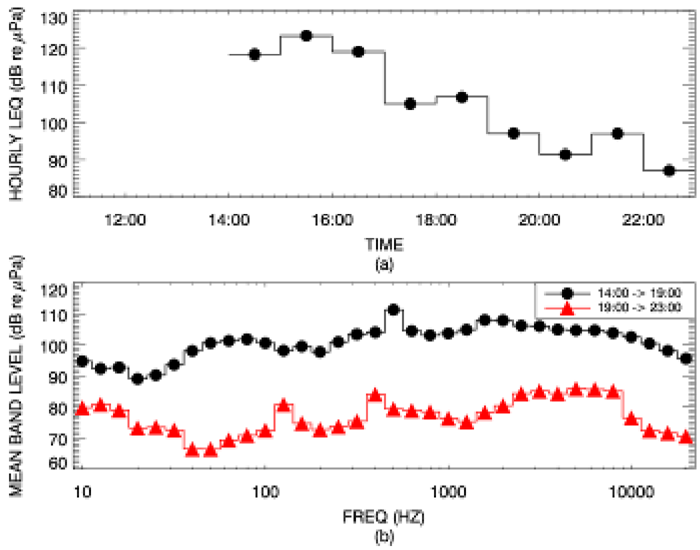

Figure 5. Upper: 1-hour Leq levels that will be calculated from acoustic measurements for use in correlating with bowhead whale deflection data.

Reporting of Results

Sound level results will be reported in the 90-day and comprehensive reports for this program. The results reported will include:

- Sound Source Levels for the drillship and all drilling support vessels.
- Spectrogram and band level versus time plots computed from the continuous recordings obtained from the hydrophone systems.
- Hourly Leq levels at the hydrophone locations. These values will be used to estimate actual sound levels at locations of deflected whales identified in Shell's Beaufort Sea Whale Migration study.
- Correlation of drilling source levels with the type of drilling operation being performed. These results will be obtained by observing differences in drilling sound associated with differences in the drillship activity as indicated in detailed drillship logs.

Acoustic Study of Bowhead Deflections

Shell plans to deploy arrays of acoustic recorders in the Beaufort Sea in 2010, similar to that which was done in 2007 and 2008 using DASARs supplied by Greeneridge. These directional acoustic systems permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document sound characteristics and propagation resulting from vessel-based drilling operations that may have the potential to cause deflections of bowhead whales from their migratory pathway. Of particular interest will be the east-west extent of deflection, if any (i.e., how far east of a sound source do bowheads begin to deflect and how far to the west beyond the sound source does deflection persist). Of additional interest will be the extent of offshore (or towards shore) deflection that might occur.

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

Objective

The objective of this study is to provide information on bowhead migration paths along the Alaskan coast, particularly with respect to industrial operations, and whether and to what extent there is deflection due to industrial sound levels. Using passive acoustics with directional autonomous recorders, the locations of calling whales will be observed for a six- to ten-week continuous monitoring period at five coastal sites (subject to favorable ice and weather conditions). Essential to achieving this objective is the continuous measurement of sound levels near the drillship. An example of the whale call locations measured from a similar array of DASARs in 2008 is presented in Figure 6 (Blackwell et al. 2009).

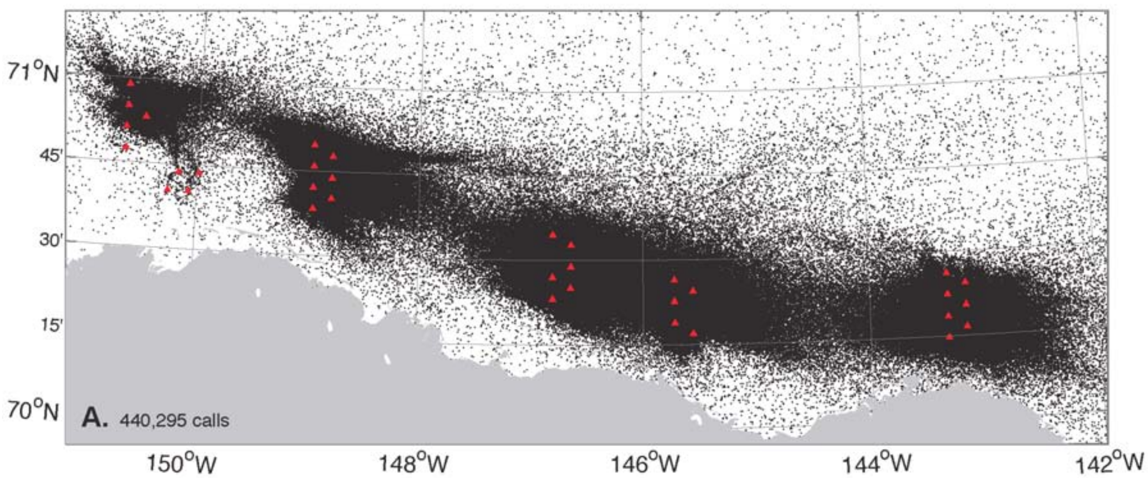

Figure 6. Bowhead whale call locations determined from the received bearings at five arrays of DASARs in the Beaufort Sea in 2008.

Monitoring Plan

Shell plans to conduct the whale migration monitoring using the passive acoustics techniques developed and used successfully since 2001 for monitoring the migration past Northstar production island northwest of Prudhoe Bay and from Kaktovik to Harrison Bay during the 2007 and 2008 migrations. Those techniques involve using DASARs to measure the arrival angles of bowhead calls at known locations, then triangulating to locate the calling whale. Hundreds of thousands, of whale calls were successfully located in 2007 and 2008.

In attempting to assess the responses of bowhead whales to the planned industrial operations, it will be essential to monitor whale locations at sites both near and far from industry activities. Shell plans to monitor at five sites along the Alaskan Beaufort coast as shown in Figure 7. The eastern-most site (#5 in Fig.7) will be just east of Kaktovik (~100 km (62 mi) west of the Sivulliq drilling area) and the western-most site (#1) will be in the vicinity of Harrison Bay (~175 km (47 mi) west of Sivulliq). Site 2 will be located west of Prudhoe Bay (~110 km (68 mi) west of Sivulliq). Site 4 will be ~10 km (6.2 mi) east of the Sivulliq drilling area and site 3 will be ~25 km (15.5 mi) west of Sivulliq. These five sites will provide information on possible migration deflection well in advance of whales encountering an industry operation and on "recovery" after passing such operations should a deflection occur.

The proposed geometry of DASARs at each site is comprised of seven DASARs oriented in a north-south pattern so that five equilateral triangles with 7-km element spacing is achieved. This geometry is illustrated in Figure 7. Five kilometer spacing has been used successfully in the migration studies at Northstar, but whale calls are received reliably at greater spacing and the 7 km spacing will result in greater coverage of whales along the north-south dimension, important in studying possible deflection.

DASARs will be installed at planned locations using a GPS. However, each DASAR's orientation once it settles on the bottom is unknown and must be determined to know how to reference the call angles measured to the whales. That is, where is true north relative to the DASAR orientation? Also, the internal clocks used to sample the acoustic data typically drift slightly, but linearly, by an amount up to a few seconds after six weeks of autonomous operation. Knowing the time differences within a second or two between DASARs is essential for identifying identical whale calls received on two or more DASARs. Solving these two problems is accomplished by transmitting known sounds at known times from known locations (by GPS) at six points around each DASAR at the beginning and at the end of the operational period. (Shell also will use a mid-season calibration.) Because of the equilateral triangular geometry, it requires 25 transmission stations for each site. Each set of transmissions requires less than half a minute. For the 5-km spacing, experience has been that it requires an hour to do 4 calibration transmissions, including transit. For our planned 7-km spacing, we estimate three calibration transmissions per hour. With 25 to do at each site, calibration of a site will require ~8 hours.

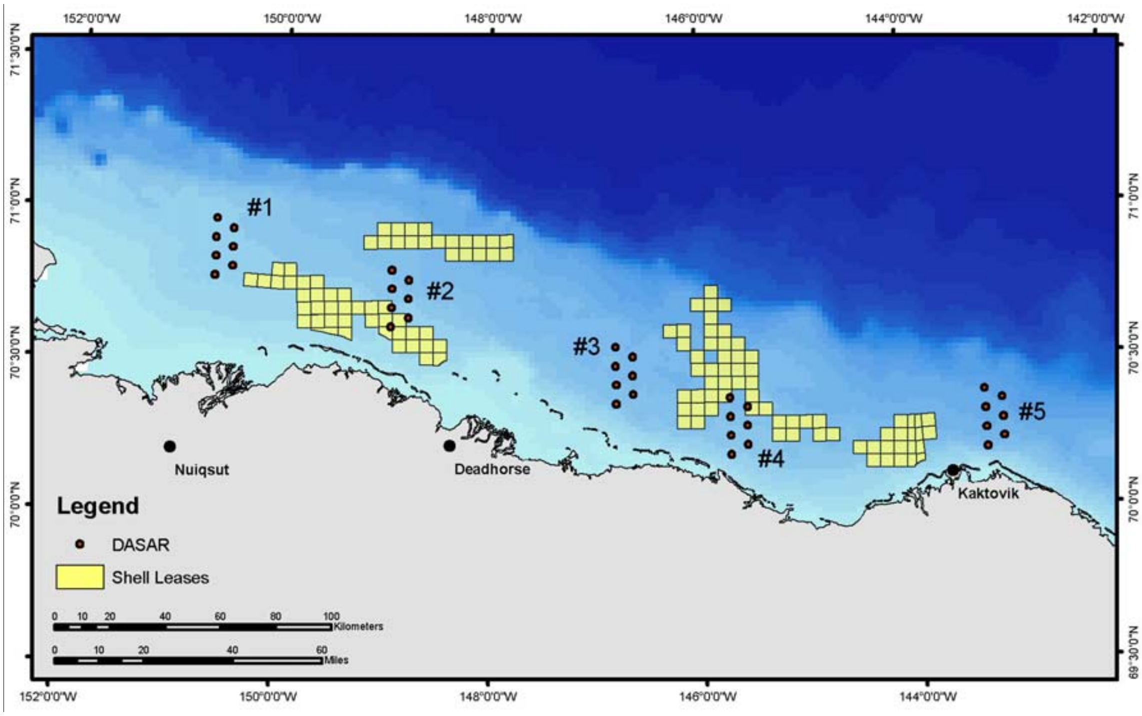

Figure 7. The Alaskan Beaufort Sea coast showing DASAR site locations for whale call location studies. The DASAR array locations at the five sites are shown to scale, with seven DASARs forming five equilateral triangles with a unit spacing of 7 km and a north-south extent of 21 km to aid being able to observe possible offshore deflection.

The calibration transmissions are made using a small projector easily deployed and retrieved over the side of a vessel by a single person. Maximum source level is only 150 dB re 1µPa at 1 m. The received level at a distance of 100 m will be ~110 dB, a level less than any known to cause disturbance to marine life.

Bowhead migration begins in late August with the whales moving westward from their feeding sites in the Canadian Beaufort Sea. It continues through September and well into October. However, because of the drilling schedule, we will attempt to install the 21 DASARs at three sites (3, 4 and 5 in Figure 7) in early August. The remaining 14 DASARs will be installed at sites 1 and 2 in late August. Thus, we propose to be monitoring for whale calls from before 15 August until sometime before the 15th of October.

At the end of the season the 4th DASAR in each array will be refurbished, recalibrated, and redeployed to collect data through the winter. The other DASARs in the arrays will be recovered. The redeployed DASARs will be programmed to record 35 minutes every three hours with a disk capacity of 10 months at that recording rate. This should be ample space to allow over-wintering from ~mid-October 2010 through mid-July 2011.

Whale call analysis for the Northstar DASARs has been a manual process in which analysts observe acoustic spectrograms in one-minute periods, looking for patterns caused by a whale call. Listening to the sound, the analyst verifies that a sound is or is not a whale call, and when it is, the bearing is calculated and stored for localization if the same call is present at one or more other DASARs in an array. In the proposed 2010 project, machine-aided call detection software will be used to simplify and accelerate the call analysis. Such software was developed with Shell's sponsorship in 2006 and is described in Greene et al. (2007). The software has been tested during data collection efforts in 2008 and is currently undergoing additional tests to understand ability to accurately determine whale call locations.

When the call locations have been assessed for accuracy, the locations will be analyzed for evidence of migration deflection. However, one must assess where the migration path would have been in the absence of industrial activities. The migration path is known to vary from year to year as a consequence of various factors. To control for this inter-annual variation, array pairs east and west of industrial activities will be used to compare offshore distances prior to and after whales pass through areas exposed to varying levels of anthropogenic sound. All DASAR arrays, and potentially those deployed for other studies (i.e., those supporting BP's studies of migration past its Northstar development), could be used to quantify density contours of the bowhead whale migration corridor. This estimation of the migration corridor would amount to an unprecedented quantification in terms of the extent of the coastline covered and the amount of data included.

Many interesting analyses will be available from the data collected by the five array sites. Only two analyses are discussed here.

One analysis will estimate the location of the migration corridor across the extent of our study area. The migration corridor will be estimated by contours for the distribution of whale locations along the coast from array #1 to array #5. Density contours will be estimated using kernel density estimation (Silverman 1998). To be included in this analysis, call precision must be high, or alternatively, calls will be inversely weighted according to the size of their error ellipse. Because Shell anticipates that calls occurring between arrays will have very low precision, the variance of density estimates in these areas will be high. If the migration corridor is generally close to shore at arrays #5 and #4, but far offshore at the locations of array #3, #2, and #1, an offshore displacement of the corridor near the planned drilling activity might be inferred. Shell plans to use block bootstrapping (Lahiri 2003) of raw data to assess variation in contours when appropriate. Block bootstrapping accounts for potential autocorrelation among locations collected during short time intervals. This analysis does not depend on quantification of underwater industrial sounds emanating from drilling operations.

A second analysis to assess deflection will relate changes in offshore distribution to changes in industrial sound levels. These analyses are predicated on the assumption that industrial sound levels will vary from below background to substantially above background throughout the season, and that reliable measurements of industrial sound at the source are available. Assuming source levels vary substantially throughout the season, this analysis will use periods of low industrial sound as "reference" periods, and relate shifts in the offshore distribution to increased levels of sound using regression or quantile regression analysis (Koenker and Park 1996; Koenker and Geling 2001; Koenker and Xiao 2002).

To illustrate the second analysis, consider DASAR sites #4 and #3 in Figure 7. Over a standard reporting period, for example 6 hours, calls located by these two arrays will be collected, as well as other environmental covariates such as water depth, ambient sound levels, time of day, etc. From these data, summary statistics for offshore distribution, and all covariates of interest will be calculated. For example, the 25th percentile of offshore distance may be calculated, as well as the average water depth of all call locations in the 6-hour reporting period. Differences in offshore summary statistics among arrays will then be calculated and used in a regression or quantile regression analysis. Using the example above, the difference in 25th percentile of offshore distance between array #4 and array #3 could be related to the average industrial sound level output by the source. Assuming displacement occurs somewhere between arrays #4 and #3, a constant difference in the 25th percentile of offshore distance when sound levels are low, and larger differences in offshore distance when industrial sound levels increase would be expected. A significant slope of the regression relating offshore distance difference to sound levels will indicate a statistically significant displacement between the arrays in question. This type of analysis can be run using any pair of DASAR arrays (e.g., between #5 and #3 or between #4 and #1, etc.).

Analysis assumptions:

- That changes in the offshore distribution of call locations reflect either changes in whale locations or changes in calling behavior.
- That industrial sound levels will vary substantially throughout the season. "Substantial" means by a level that is both detectable and important to bowhead whales. In other words, extended periods of both low and high sound production need to be present.
- Industrial sound levels surrounding the drilling sources need to be accurately quantified at varying distances in such a way that industrial sound levels and whale locations can be matched. An accurate propagation model for industrial sounds hopefully can be constructed from the collected data.
- A large number of whales will swim through the areas where arrays can reliably locate their calls.

Post-90-day Report Analysis

Analysis of all acoustic data will be prioritized to address the primary questions. The primary data analysis questions are to (a) determine when, where, and what species of animals are acoustically detected on each DASAR, (b) analyze data as a whole to determine offshore bowhead distributions as a function of time, (c) quantify spatial and temporal variability in the ambient noise, and (d) measure received levels of drillship activities. The bowhead detection data will be used to develop spatial and temporal animal distributions. Statistical analyses will be used to test for changes in animal detections and distributions as a function of different variables (e.g., time of day, time of season, environmental conditions, ambient noise, vessel type, operation conditions).

COMPREHENSIVE REPORT ON INDUSTRY ACTIVITIES AND MARINE MAMMAL MONITORING EFFORTS IN THE BEAUFORT AND CHUKCHI SEAS

Following the 2010 drilling season a comprehensive report describing the vessel-based, aerial, and acoustic monitoring programs will be prepared. The comprehensive report will describe the methods, results, conclusions and limitations of each of the individual data sets in detail. The report will also integrate (to the extent possible) the studies into a broad based assessment of industry activities, and other activities that occur in the Beaufort and/or Chukchi seas, and their impacts on marine mammals during 2010. The report will help to establish long-term data sets that can assist with the evaluation of changes in the Chukchi and Beaufort Sea ecosystems. The report will attempt to provide a regional synthesis of available data on industry activity in offshore areas of northern Alaska that may influence marine mammal density, distribution and behavior.

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