INCIDENTAL HARASSMENT AUTHORIZATION REQUEST FOR THE NON-LETHAL HARASSMENT OF MARINE MAMMALS DURING THE LIBERTY GEOHAZARD SURVEY, BEAUFORT SEA, ALASKA, 2014

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Submitted by

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1 DETAILED OVERVIEW OF OPERATIONS TO BE CONDUCTED

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

BP Exploration (Alaska), Inc. (BP) plans to conduct a shallow geohazard survey in federal and state waters of Foggy Island Bay in the Beaufort Sea during the open water season of 2014. The project area lies mainly within the Liberty Unit, but also includes portions of the Duck Island Unit as well as non-unit areas (Figure 1). BP requests an Incidental Harassment Authorization (IHA) allowing non-lethal harassment of marine mammals incidental to the proposed geohazard survey. This application for an IHA is submitted pursuant to Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a)(5). This section provides operational details of the shallow geohazard survey. Information on the dates, duration, and project area are being provided in Section 2.

1.1 Purpose

BP is evaluating development of the Liberty field. The Liberty reservoir is located in federal waters in Foggy Island Bay about 8 miles (mi) east of the Endicott Satellite Drilling Island (SDI). The project's preferred alternative is to build a gravel island situated over the reservoir. In support of the preferred alternative, a Site Survey is planned with an emphasis on obtaining two-dimensional high-resolution (2DHR) shallow geohazard data using an airgun array and a towed streamer. Additional infrastructure required for the preferred alternative would include a subsea pipeline. A Sonar Survey, using multibeam echosounder, sidescan sonar, subbottom profiler, and magnetometer is proposed over the Site Survey location and subsea pipeline corridor area. The purpose of this proposed survey is to evaluate the existence and location of archaeological resources and potential geologic hazards on the seafloor and in the shallow subsurface.

1.2 Project Details

The Liberty geohazard survey will consist of two phases. During the first phase, the Site Survey, the emphasis is on obtaining shallow geohazard data using an airgun array and a towed streamer. During the second phase, the Sonar Survey, data will be acquired both in the Site Survey location and subsea pipeline corridor area (Figure 1) using the multibeam echosounder, sidescan sonar, subbottom profiler, and the magnetometer. The sections below provide more details about the project components associated with the shallow geohazard survey.

1.2.1 Vessel Mobilization

One vessel will be used for the geohazard survey. The proposed survey vessel (*R/V Thunder* or equivalent) is about 70 x 20 feet (ft) in size. This vessel will be transported to the North Slope by truck and prepared and launched at West Dock or Endicott. Vessel preparation includes the assembly of navigation, acoustic, and safety equipment. Initial fueling and stocking of recording equipment will also be part of the vessel preparations. Once assembled, the navigation and acoustic systems will be tested at West Dock or at the project site.

1.2.2 Navigation and Data Management

The vessel will be equipped with Differential Global Navigation Satellite System (GNSS) receivers capable of observing dual constellations and backup. Corrected positions will be provided via a precise point positioning (PPP) solution. A kinematic base station will be kept at the housing facilities in Deadhorse to mitigate against the inability to acquire a PPP signal.

Tidal corrections will be determined through GNSS computation, comparison with any local tide gauges, and, if available, with tide gauges operated by other projects.

A navigation software package will display known obstructions, islands, and identified areas of sensitivity. The software will also show the pre-determined source line positions within the two survey areas. The information will be updated as necessary to ensure required data coverage. The navigation software will also record all measured equipment offsets and corrections and vessel and equipment position at a frequency of no less than once per 5 seconds for the duration of the project.

1.2.3 Housing and Logistics

Approximately 20 people will be involved in the operation. Most of the crew will be accommodated at existing camps and some crew will be housed on the vessel. Support activities, such as crew transfers and vessel re-supply are primarily planned to occur at Endicott and West Dock. However, support activities may also occur at other nearby vessel accessible locations if needed (e.g. East Dock). Equipment staging and onshore support will primarily occur at West Dock, but may also take place at other existing road-accessible pads within the Prudhoe Bay Unit area as necessary. For protection from weather, the vessel may anchor near West Dock, near the barrier islands, or other near shore locations.

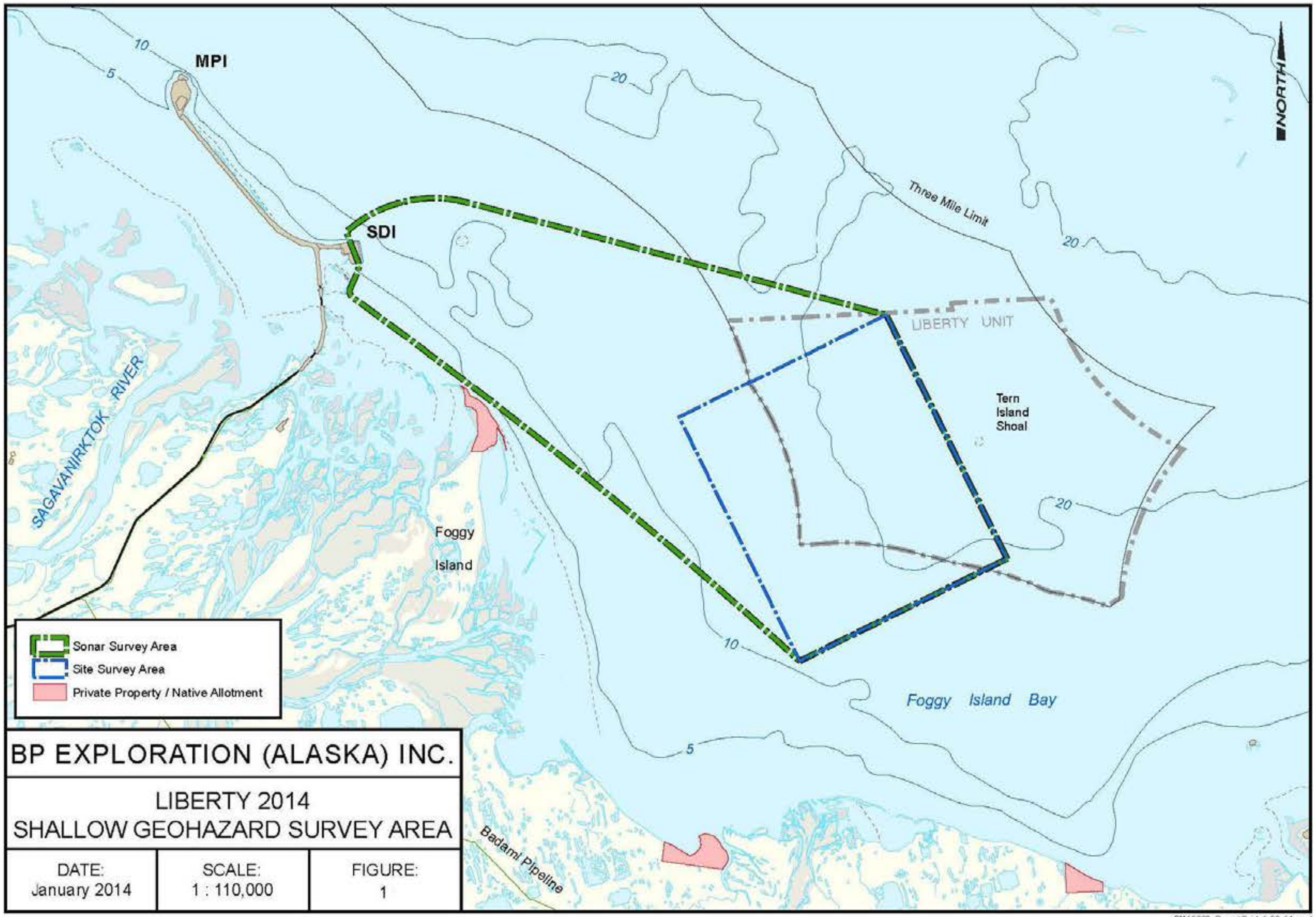

Figure 1. Proposed Liberty geohazard project area, showing the Site Survey Area (Phase 1) and Sonar Survey Area (Phase 2).

1.2.4 Data Acquisition

Equipment that will be used for the proposed shallow geohazard survey includes airgun, multibeam echosounder, sidescan sonar, subbottom profiler, and a marine magnetometer. Details related to data acquisition are summarized below. Any substitution of the equipment will be in accordance with permit requirements.

Survey design

One vessel will be used for the proposed survey. The proposed vessel (*R/V Thunder* or equivalent) is about 70 x 20 feet (ft) in size. The airgun and streamer, sidescan sonar, and magnetometer will be deployed from the vessel. The multibeam echosounder and subbottom profiler will be hull-mounted. No equipment will be placed on the sea floor as part of survey activities.

The survey will acquire data in two phases. During the first phase the emphasis is on obtaining shallow geohazard data in the Site Survey area using an airgun array and a towed streamer. During the second phase data will be acquired in both the Site Survey and Sonar Survey areas using the multibeam echosounder, sidescan sonar, subbottom profiler, and the magnetometer. Each phase has an expected duration of about 7.5 days, based on a 24-hour workday. Between the first and second phase the operations will be focused on changing equipment for about 5 days.

2DHR Seismic

High-resolution seismic data acquisition will only take place during Phase 1 in the Site Survey area. The 2DHR seismic source will consist of one of two potential arrays, each with a discharge volume of 30 in^3 and containing multiple airguns. The first array option will have three 10 in^3 airguns and the other array option will have a 20 in^3 and a 10 in^3 airgun. Table 1 summarizes airgun array specifics for each option. A 5 in^3 airgun will be utilized as the mitigation gun. The tow depth will be about 3 ft.

The receivers will be placed on a streamer that is towed behind the source vessel. The streamer will be about 984 ft (300 meters [m]) in length and will contain 48 receivers at about 20 ft (6.25 m) spacing.

Seismic data will be acquired on two grids. Grid 1 will contain lines spaced at 492 ft (150 m) with perpendicular 984 ft (300 m) spaced lines. Grid 2 will contain ~65 ft (20 m) spaced lines. The total line length of both grids will be about 342 mile (550 km).

The vessel will travel with a speed of approximately 3-4 knots. The seismic pulse interval is 20.5 ft (6.25 m), which means a shot every 3 to 4 seconds.

Table 1. Proposed 30 in^3 Airgun Array Configurations and Source Signatures as Predicted by the Gundalf Airgun Array Model for 1 m depth.

ARRAY SPECIFICS	30 IN^3 ARRAY OPTION 1	30 IN^3 ARRAY OPTION 2
Number of guns	Three 2000 psi sleeve airguns (3 x 10 in^3)	Two 2000 psi sleeve airguns (1 x 20 in^3, 1 x 10 in^3)
Zero to peak	4.89 bar-m (~234 dB re µPa @1 m)	3.62 bar-m (~231 dB re 1µPa @1 m)
Peak to peak	9.75 bar-m (~240 dB re µPa @1 m)	7.04 bar-m (~237 dB re 1µPa @1 m)
RMS pressure	0.28 bar-m (~209 dB re µPa @1 m)	0.22 bar-m (~207 dB re 1µPa @1 m)
Dominant frequencies	About 20-300 Hz	About 20-300 Hz

Multibeam Echosounder and Sidescan Sonar

A multibeam echosounder and sidescan sonar will be used to obtain high accuracy information regarding bathymetry and isonification of the seafloor. For accurate object detection, a side scan sonar survey is required to complement a multibeam echosounder survey.

The proposed multibeam echosounder operates at a rms source level of approximately 220 dB re 1 µPa @1m. The multibeam echosounder emits high frequency energy in a fan-shaped pattern of equidistant or equiangular beam spacing. The beam width of the emitted sound energy in the along track direction is 2 degrees at 200 kilohertz (kHz) and 1 degree at 400 kHz, while the across track beam width is 1 degree at 200 kHz and 0.5 degrees at 400 kHz (Table 2). The maximum ping rate of the multibeam echosounder is 60 Hz.

The proposed sidescan sonar system will operate at about 100 kHz (120 kHz to 135 kHz) and 400 kHz (400 kHz to 450 kHz). The estimated rms source level is approximately 215 dB re 1µPa @1m (Table 2). The sound energy is emitted in a narrow fan-shaped pattern, with a horizontal beam width of 1.5 degrees for 100 kHz and 0.4 degrees at 400 kHz, with a vertical beam height of 50 degrees. The maximum ping rate of the sidescan sonar is 30 Hz.

Data acquisition with the multibeam echosounder and sidescan sonar data will take place along all grids in the Sonar Survey area. Additional multibeam echosounder and sidescan sonar infill lines will be added to obtain 150% coverage over certain areas.

In addition, BP may conduct a strudel scour survey in the Kadleroshilik and Sagavanirktok River overflood areas for about 3 days, depending on results from reconnaissance flights in June. This data would be collected from a separate vessel equipped with a multibeam echosounder and sidescan sonar. These units would operate at a frequency of about 400 kHz. Because this operating frequency is outside the hearing range of marine mammals, the strudel scour survey is not part of this IHA application.

Subbottom Profiler

The purpose of the subbottom profiler is to provide an accurate digital image of the shallow sub-surface sea bottom, below the mud line. The proposed system emits energy in the frequency bands of 2 to 16 kHz (Table 2). The beam width is 15 to 24 degrees, depending on the center frequency. Typical pulse rate is between 3 and 6 Hz. Subbottom profiler data will be acquired continuously along all grids during phase 2 of the operations, i.e., after 2DHR seismic data has been obtained.

Magnetometer

A marine magnetometer will be used for the detection of magnetic deflection generated by geologic features, and buried or exposed ferrous objects, which may be related to archaeological artifacts or modern man-made debris. The magnetometer will be towed at a sufficient distance behind the vessel to avoid data pollution by the vessel's magnetic properties. Magnetometers measure changes in magnetic fields over the seabed and do not produce sounds.

Table 2. Source characteristics of the proposed geophysical survey equipment of the Liberty geohazard survey.

EQUIPMENT	OPERATING FREQUENCY	ALONG TRACK BEAM WIDTH	ACROSS TRACK BEAM WIDTH	RMS SOUND PRESSURE LEVEL
Multibeam echosounder	200 - 400 kHz	1 - 2^o	0.5 - 1^o	~220 dB re 1µPa @1m
Sidescan sonar	120 - 135 kHz	1.5 ^{o}	50 ^{o}	~215 dB re 1µPa @1m
	400 - 450 kHz	0.4^o	50^o	
Subbottom profiler	2 - 16 kHz	15-24^o	15-24^o	~216 dB re 1µPa @1m

2 DATES, DURATION AND REGION OF ACTIVITY

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

BP seeks incidental harassment authorization for the period of July 1 to September 30, 2014. The survey will commence with mobilization of equipment to Deadhorse by truck. The survey is expected to take approximately 20 days to complete, not including weather downtime, and is planned between July 1 and August 25. To limit potential impacts to the bowhead whale migration and the subsistence hunting, airgun operations dates will be in accordance with the dates agreed in the Conflict Avoidance Agreement (CAA), historically ending August 25. Demobilization of equipment is planned to be complete before the end of September.

The project area of the proposed Liberty shallow geohazard survey lies within Foggy Island Bay as shown in Figure 1. The Phase 1 Site Survey, focused on obtaining shallow geohazard data using an airgun array and a towed streamer, will occur within approximately 12 square miles (mi^2). The Phase 2 Sonar Survey will occur over the Site Survey area and over approximately 5mi^2 within the 29-mi^2 area identified in Figure 1. The Sonar Survey is focused on acquiring shallow geohazard data using the multibeam echosounder, sidescan sonar, subbottom profiler, and the magnetometer. Activity outside the area delineated on Figure 1 may include vessel turning while using airguns, vessel transit, and other vessel movements for project support and logistics. The approximate boundaries of the two survey areas are between 70°14’10”N and 70°20’20”N and between 147°29’05”W and 147°52’30”W

3 SPECIES AND NUMBERS OF MARINE MAMMALS IN THE PROJECT AREA

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

Whale and seal species as listed in Table 3 are the subjects of this IHA request to the National Marine Fisheries Service (NMFS). In the U.S., the walrus and polar bear are managed by the U.S. Fish & Wildlife Service (USFWS). A request for a letter of authorization (LOA) to allow incidental non-lethal harassment of Pacific walrus and polar bear during the proposed Liberty geohazard project activities in Foggy Island Bay has already been issued by the USFWS.

The marine mammal species under NMFS jurisdiction that are known to, or may, occur in the Beaufort Sea include eight whale species and four species of seals (Table 3). Two whale species, the bowhead and humpback whales, are listed as endangered under the Endangered Species Act (ESA). The bowhead whale is the most common species in the Beaufort Sea, whereas humpback whales are considered extralimital and encounters in Foggy Island Bay are therefore not expected. Of the six non-ESA listed whales, the gray whale and beluga whale are the most commonly occurring species in the Beaufort Sea. The narwhal, killer whale, harbor porpoise, and minke whale are rare or extralimital to the Beaufort Sea and therefore unlikely to be encountered in Foggy Island Bay. Abundance estimates of these four extralimital species are not provided in Table 3 and their status and distribution are only briefly discussed in Section 4.3. The ringed, bearded, and spotted seals are the most commonly occurring seal species in the Beaufort Sea. Ribbon seals occur mainly in the Chukchi Sea and western part of the Beaufort Sea and encounters in Foggy Island Bay are not expected. NMFS issued the final rule for listing the Bering Sea distinct population segment (DPS) of bearded seals and Arctic stock of ringed seals as threatened under the ESA in December 2012. This rule became effective as of February 26, 2013 for both species (NMFS 2012a, 2012b). NMFS determined not to list the Bering Sea stock of spotted seals and the ribbon seals under the ESA, because they are currently not in danger of extinction or likely to become endangered in the foreseeable future (NMFS 2009, 2013a).

Table 3. Abundance estimates, habitat, and conservation status of marine mammals under NMFS jurisdiction that could or are likely to occur in the Beaufort Sea during the open-water season. Abundance estimates are not provided for species that are rare or extralimital to the Beaufort Sea.

SPECIES	ABUNDANCE[1]	HABITAT	ESA[2]	IUCN[3]
		WHALES		
Bowhead whale (Bering-Chukchi-Beaufort Stock)	16,892[4]	Pack ice, open water coastal and offshore	Endangered	LC
Gray whale (eastern Pacific population)	19,126[5]	Coastal, lagoons	Not listed	LC
Beluga whale (Beaufort Sea Stock)	39,258	Offshore, ice edge, coastal, lagoons.	Not listed	NT
Minke whale	Rare/Extralimital	Shelf, coastal	Not listed	LC
Humpback whale	Rare/Extralimital	Shelf, coastal	Endangered	LC
Narwhal	Rare/Extralimital	Offshore, ice edge	Not listed	NT
Killer whale	Rare/Extralimital	Variable habitats	Not listed	DD
Harbor Porpoise	Rare/Extralimital	Variable habitats	Not listed	--
		SEALS		
Ringed seal (Beaufort Sea Stock)	1,000,000[6]	Landfast and pack ice, open water	Threatened	LC
Bearded seal (Beringia DPS)	125,000[7]	Pack ice, open water	Threatened	LC
Spotted seal (eastern and central Bering Sea)	141,479[8]	Pack ice, open water, coastal haulouts	Not listed	DD
Ribbon seal (eastern Bering Sea)	49,000[9]	Pack ice, open water	Not listed	DD

[1] Abundance estimates are derived from the most recent Alaska Marine Mammal Stock Assessment Reports (Allen & Angliss 2013), unless otherwise noted.

[2] U.S. Endangered Species Act of 1973

[3] IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <www.iucnredlist.org>. Codes for IUCN classifications version 3.1: EN = Endangered; NT = Near Threatened; LC = Least Concern; DD = Data Deficient, and -- = not yet assessed. http://www.iucnredlist.org/apps/redlist/static/categories_criteria_3_1#categories.

[4] Estimate based on the 2011 bowhead census (Givens et al. 2013).

[5] Estimate based on 2006/2007 data (Allen & Angliss 2012).

[6] Reliable abundance estimates are currently not available (Allen & Angliss 2013). However, based on historical information an abundance estimate of 1 million was considered reasonable (Kelly et al. 2010a).

[7] Reliable abundance estimates are currently not available (Allen & Angliss 2013). Based on available data, current total Bering Sea bearded seal population is considered to be twice the estimate reported by Ver Hoef et al. (2010): this is approximately 125,000 individuals (cited in Cameron et al. 2010).

[8] Based on Verhoef et al. (in review) as cited in Angliss & Allen (2013).

[9] Interim estimate until aerial survey data from 2003, 2007, and 2008 has been analyzed (Allen & Angliss 2013).

4 STATUS AND (SEASONAL) DISTRIBUTION OF AFFECTED SPECIES OR STOCKS OF MARINE MAMMALS

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

This section contains information on the population status and seasonal distribution of the marine mammal species listed in Table 3, based on the most recent data available.

4.1 Whales

4.1.1 Beluga Whale (Delphinapterus leucas)

There are five stocks of beluga whales in Alaska: the Cook Inlet, Bristol Bay, eastern Bering Sea, eastern Chukchi Sea, and Beaufort Sea stocks (Allen & Angliss 2013). Animals of the Beaufort Sea stock and eastern Chukchi Sea stock could potentially occur in the project area. The most recent population estimate for the Beaufort Sea stock is 39,258 individuals and the eastern Chukchi Sea stock is estimated at 3,710 animals (Allen & Angliss 2013). The population estimate of the Beaufort Sea stock is based on 1992 data and the size estimate of the eastern Chukchi Sea stock arises from survey efforts in 1989-1991. The population trends of both stocks are currently unknown; however, based on available data, there is no evidence that the eastern Chukchi Sea stock is declining (Allen & Angliss 2013).

In spring, the Beaufort and Chukchi Sea stocks of beluga whales use open leads in the sea ice to migrate from their wintering grounds in the Bering Sea to their respective summer grounds in the Beaufort and Chukchi seas. Most animals of the Beaufort Sea stock migrate to the Mackenzie River estuary in the Canadian Beaufort Sea where they arrive in April or May, with some animals arriving as early as March or as late as July (Braham et al. 1977). They typically stay there during July and August to molt, feed, and calve. Later in the summer they spread out, foraging in offshore waters of the eastern Beaufort Sea, Amundsen Gulf, and other northern waters (Davis & Evans 1982, Harwood et al. 1996, Richard et al. 2001). Belugas from the Chukchi Sea stock stay in coastal areas or shallow lagoons early in the summer, such as the Kasegaluk Lagoon. Later in the summer (after mid-July) they move offshore to forage in the ice-packed deeper waters along and beyond the continental shelf (Finley 1982, Suydam et al. 2005). Five of 23 beluga whales fitted with satellite tags in Kasegaluk Lagoon (captured in late June and early July 1998-2002) were tracked north into the Arctic Ocean venturing into 90% pack ice at 79-80°N (Suydam et al. 2005), suggesting that a significant proportion of the population may be at these high latitudes during the mid- to late summer period. In the fall, the Chukchi and Beaufort Sea stocks both return to their wintering grounds in the Bering Sea following a deepwater route along the continental shelf break or routes farther offshore.

Beluga whales are often seen migrating in large groups (Braham et al. 1977), probably consisting of smaller permanent social units, such as nursing groups or family units (Brodie 1989). Beluga whales feed on a variety of fish and invertebrates, their diet varying by season and location

(Burns & Seaman 1985, Hazard 1988). In summer, beluga whales feed on a variety of schooling and anadromous fish, particularly Arctic cod. Most feeding is done over the continental shelf and in nearshore estuaries and river mouths.

In the central and eastern Beaufort Sea most beluga whales migrate in deep offshore waters along the ice edge more than 60 mi north of the Alaskan coast, both during the spring and fall migration (Clarke et al. 2012, 2013). Relatively few beluga sightings have been recorded in the nearshore area of Foggy Island Bay. Opportunistic sightings have been recorded from Northstar Island, the STP facility, and Endicott. During the 2008 OBC seismic survey in Foggy Island Bay, three sightings of eight individuals were observed at about 3 mi east of Endicott SDI (Aerts et al. 2008). In 2013, two adult belugas were reported at MPI (Endicott) on August 10 for about two days. Two weeks later, a large group of belugas (no estimate provided) were seen in the same area. Observers of the ASAMM aerial survey also recorded more nearshore beluga sightings than historically seen (2013 daily flight summaries – NOAA website). Based on available information, we can expect to encounter beluga whales in or close to the survey area. However, the chance of such encounters during the summer period is small.

4.1.2 Bowhead Whale (Balaena mysticetus)

Four stocks of bowhead whales are recognized worldwide by the International Whaling Commission (IWC) for management purposes (Allen & Angliss 2013). The largest of these four stocks, the Western Arctic or Bering-Chukchi-Beaufort (BCB) stock, inhabits Alaskan waters. Commercial whaling decreased the bowhead population to approximately 3,000 whales (Woodby and Botkin 1993). Abundance estimates of whales from the BCB stock, before they were overharvested by commercial whaling, were between 10,400−23,000 whales. Since the ban on commercial whaling the bowhead population has increased steadily. This is evidenced by data collected during 1977-2011 from ice-based counts, acoustic locations, and aerial transect data (Figure 9 in Givens et al. 2013). In 2011 the NSB successfully completed a new ice-based count of bowhead whales and estimated the population at ~16,892 animals with an annual growth rate of 3.7% (George et al. 2013; Givens et al. 2013). Although the bowhead whale is recovering well following its decline, it is currently still listed as endangered under the ESA, depleted by the MMPA (Allen & Angliss 2013), and an Alaska Species of Concern with the Alaska Department of Fish and Game (ADF&G). The Alaska Eskimo Whaling Commission (AEWC) has co-managed this stock with the U.S. government since the 1980s.

Whales of the BCB stock winter in the Bering Sea and migrate through the Bering Strait, Chukchi Sea, and Alaskan Beaufort Sea to their summer feeding grounds in the Mackenzie River Delta, Canadian Beaufort Sea. Most bowheads arrive in the coastal areas of the eastern Canadian Beaufort Sea and Amundsen Gulf in late May and June, but some remain in the offshore pack ice of the Beaufort Sea until about mid-July. Starting about mid-August through late October, bowheads migrate westwards through the Alaskan Beaufort Sea to their wintering grounds in the central and western Bering Sea (Moore and Reeves 1993; Quakenbush et al. 2010). Late summer and fall aerial surveys have been conducted in the Alaskan Beaufort Sea since 1979 and have provided useful information on long-term bowhead whale migration and distribution patterns (see Ljungblad et al. 1986, 1987; Moore et al. 1989; Monnett and Treacy 2005; Treacy et al. 2006; Clarke et al. 2012, 2013). The main migration corridor is located over the continental shelf, typically within 34 mi of shore during years with light to moderate ice conditions (Treacy et al. 2006). Data demonstrate that bowhead whales tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice. Sighting rates are also lower in heavy ice years. During the fall migration, most bowheads migrate west in water ranging from 50 to 656 ft deep (Miller et al. 2002; Clarke et al. 2012) and few whales have been seen shoreward of the barrier islands in the Alaskan Beaufort Sea. In 2013, however, nearshore sightings were more common than historically (NOAA daily flight summaries at http://www.asfc.noaa.gov/nmml/cetacean/bwasp/2013).

Although most bowhead feeding activity occurs in the Canadian Beaufort Sea, feeding activity has also regularly been documented at Point Barrow and, less frequently, in other areas of the Alaskan Beaufort Sea (Richardson & Thomson 2002; Koski et al. 2008b; BOWFEST and ASAMM annual reports). Satellite tagging data showed that some whales were moving back and forth during the summer feeding season between the Alaskan and Canadian Beaufort Sea (Quakenbush et al. 2010). Satellite data from one tagged whale that remained in the central Beaufort Sea for several weeks in July appeared to be associated with at least 14 whales (Clarke et al. 2012).

Bowhead whales may be encountered during the Liberty shallow hazard survey during the summer season, but likely in low numbers. Historically, only few bowhead whales have been recorded during the summer season close to shore (e.g., ASAMM 1979-2011 database), although this might have coincided with limited survey effort during this period. Aerial surveys conducted as part of industrial operations in Harrison and Prudhoe Bay from early July through early October 2008 and 2010 also recorded few bowheads before mid-August. None of these whales were close to shore (Christie et al. 2010; Brandon et al. 2011). Vessel-based observers recorded one multiple species sighting of six animals, consisting of a few bowheads, on August 16 near Narwhal Island during the OBC Liberty seismic survey (Aerts et al. 2008). During the 2012 and 2013 ASAMM aerial survey, a larger number of bowhead whales were seen in nearshore waters than would be expected based on historical data (Clarke et al. 2013; daily flight summaries 2013 season, available online at NOAA website).

4.1.3 Gray Whale (Eschrichtius robustus)

Gray whales originally inhabited both the North Atlantic and North Pacific oceans. The Atlantic population is believed to have become extinct by the early 1700s, likely from overharvesting. There are currently two populations of gray whales in the North Pacific Ocean: the eastern North Pacific population, which lives along the west coast of North-America, and the western North Pacific population, which is believed to occur mainly along the coast of eastern Asia (Rice et al. 1984; Swartz et al. 2006) and summers near Sakhalin Island, Russia. Recent satellite tagging and photo-identification data suggests that there is overlap between the eastern and western populations.

Though populations have fluctuated greatly, the eastern Pacific gray whale population has recovered significantly from commercial whaling, and was delisted from the ESA in 1994. In 1997, Rugh et al. (2005) estimated the population at 29,758 ±3,122, and in winter 2001-2002 the estimate was 18,178 ±1,780. The population estimate increased during winter 2006–2007 to 20,110 ±1,766 (Rugh et al. 2008). NMFS does not consider the eastern Pacific stock of gray whales to be endangered or to be a strategic stock.

The eastern North Pacific population annually migrates from warm wintering ground lagoons in coastal Baja California and Mexico to summer foraging areas in the Bering and Chukchi seas off northern Alaska and Russia (Jones et al. 1984; Swartz et al. 2006; Lagerquist et al. 2011), primarily between Cape Lisburne and Point Barrow, most often in shallow coastal habitat (Moore et al. 2000). Not all eastern gray whales follow this migration pattern. A small subset of the eastern population feeds in coastal water off of British Columbia, Washington, and Oregon (Calambokidis et. al. 2002, 2010). In addition, gray whale calls have been recorded throughout the winter in the Beaufort Sea near Barrow, Alaska, suggesting that some gray whales remain in arctic waters during this season (Stafford et al. 2007).

Few gray whales have historically been recorded in the Beaufort Sea east of Point Barrow. Hunters at Cross Island took a single gray whale in 1933 (Maher 1960). A total of five gray whales (3 sightings) were sighted during 30 years of BWASP/ASAMM aerial surveys (database available on the NOAA website). Two of these whales were seen in the Prudhoe Bay area. A single gray whale was also seen 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 and 2007 (Jankowski et al. 2008; Lyons et al. 2009). In 2008, a multiple species sighting of six animals consisting of bowhead and gray whales were observed during the Liberty seismic survey in Foggy Island Bay close to Narwhal Island (Aerts et al. 2008). A few gray whales have also been observed in the Canadian Beaufort Sea (Rugh and Fraker 1981) indicating that small numbers have been passing through the Alaskan Beaufort in some years. Given the infrequent occurrence of gray whales in the Beaufort Sea, the probability of encountering gray whales during the Liberty geohazard project is low.

4.2 Seals

4.2.1 Bearded Seal (Erignathus barbatus)

Bearded seals have a circumpolar distribution. In Alaska, they occur over the continental shelf waters of the Bering, Chukchi, and Beaufort seas (Burns 1981). There is no reliable estimate of bearded seal abundance in Alaskan waters (Allen and Angliss 2013; Cameron et al. 2010). The abundance in the Bering Sea, based on aerial survey data collected in the central Bering Sea pack ice in 2007, is estimated at ~125,000 (Cameron et al. 2010). In the Chukchi Sea, the number of animals is estimated at ~27,000, based on data from 1999-2000 spring aerial surveys flown along the coast from Shishmaref to Barrow (Cameron et al. 2010). Aerial surveys of the eastern Beaufort Sea conducted in June during 1974–1979, resulted in an average estimate of 2,100 individuals (Stirling et al. 1982), uncorrected for animals in the water. Since the survey area covered roughly half of the ice-covered continental shelf of the western Beaufort Sea, the estimated number of bearded seals in the Beaufort Sea is thought to be 1.5 times 2,100 or ~3,150 (Cameron et al. 2010). Based on these numbers the Alaskan stock of bearded seals is considered to be greater than ~155,000 (NMFS 2012a) and may be as large as 250,000–300,000 (Popov 1976, Burns 1981, MMS 1996). NMFS listed the Alaska stock of bearded seals, part of the Beringia DPS, as threatened under the ESA, effective February 26, 2013 (NMFS 2012a).

Bearded seals are closely associated with sea ice, specifically when they breed, give birth, raise young, molt, and rest. Bearded seals migrate seasonally with the advance and retreat of sea-ice (Kelly 1988). As the ice recedes in the spring, bearded seals migrate from their winter grounds in the Bering Sea north through the Bering Strait (mid-April to June) to areas along the margin of the multi-year ice in the Chukchi Sea or to nearshore areas of the central and western Beaufort Sea. Pupping takes place on top of the ice from late-March through May, primarily in the Bering and Chukchi seas. Some pupping occurs on moving pack ice in the Beaufort Sea. Bearded seals do not form herds, although loose aggregations of animals may occur. Spring surveys along the Alaskan coast indicate that bearded seals prefer areas of 70% to 90% sea ice coverage (Allen and Angliss 2011). They generally inhabit areas of shallow water (less than 656 ft) that are seasonally ice-covered (Cameron et al. 2009; Allen and Angliss 2011). As the ice forms again in the fall and winter, most seals move south with the advancing ice edge through the Bering Strait into the Bering Sea where they spend the winter (Cameron et al. 2010). This southward migration is less noticeable and predictable than the northward movements in late spring and early summer (Burns 1981; Kelly 1988). Some bearded seals may overwinter in the Chukchi and Beaufort seas, but conditions are likely not as favorable.

Bearded seals have been commonly observed in the central Alaskan Beaufort Sea. Surveys associated with seismic programs in 2006, 2007, 2008, and 2010 reported tens of bearded seal sightings during vessel-based and aerial surveys (Funk et al. 2008, Hauser et al. 2008, Savarese et al. 2010, Brandon et al. 2011, Reiser et al. 2011). Similar numbers were recorded during barge-based vessel surveys conducted from 2005 to 2007 (Green et al. 2005, 2006, 2007). Bearded seals were commonly sighted during aerials surveys conducted in the Beaufort Sea (Moulton et al. 2003, Clarke et al. 2011, 2012). During BP's OBC seismic survey in Foggy Island Bay, observers recorded a limited number of seal sightings (18) of which at least one was a confirmed bearded seal (Aerts et al. 2008). Based on available data bearded seals are expected to occur in the survey area, but the number of sightings is expected to be small.

4.2.2 Spotted Seal (Phoca largha)

The spotted seal is found from the Beaufort Sea to the Sea of Japan. They are most numerous in the Bering and Chukchi seas (Quakenbush 1988), although small numbers do range into the Beaufort Sea during summer (Rugh et al. 1997; Lowry et al. 1998). There is no reliable estimate of the size of the Alaskan stock of spotted seals. The most current estimate of for the eastern and central Bering Sea is 141,479 animals (95% CI 92,769–321,882). This number is derived from aerial surveys conducted by NMML in 2007 from U.S. Coast Guard icebreakers that provided greater access to the central and eastern Bering Sea pack ice (Ver Hoef et al. in review, as cited in Allen and Angliss 2012). NMFS conducted a status review of the spotted seal to determine if listing under the ESA was warranted, because of concerns about changing ice conditions and associated potential habitat loss (Boveng et al. 2009). Based on this status review NMFS did not list spotted seals under the ESA, because they are currently not in danger of extinction or likely to become endangered in the foreseeable future (NMFS 2009).

Like other ice seals, spotted seals overwinter in the Bering Sea. From late fall through spring, spotted seal habitat-use is closely associated with the distribution and characteristics of seasonal sea ice. The ice provides a dry platform away from land predators during the whelping, nursing, breeding, and molting periods. Pupping occurs in the Bering Sea wintering areas in early spring (March and April), followed by mating and molting in May and June (Quakenbush 1988). The herds break up when the usable sea ice disappears in early summer and spotted seals move toward ice-free coastal waters from Bristol Bay through western Alaska to the Chukchi and Beaufort seas. Unlike other ice seals, spotted seals use coastal haulouts for at least part of the summer. Spotted seals are commonly seen in bays, lagoons, and estuaries, but also range offshore as far north as 69-72°N. When sea ice begins to form in the fall, spotted seals occupy the ice habitat, moving southwards to the Bering Sea overwintering areas (Lowry et al. 1998).

Spotted seals have been observed frequently in the central Alaskan Beaufort Sea in recent years, although in low numbers. Haulout sites in the Beaufort Sea include Oarlock Island, Pisasuk River, the Colville River Delta, and Sagavanirktok River, of which the latter is near Foggy Island Bay. Historically, the Colville River Delta and nearby Sagavanirktok River supported as many as 400-600 spotted seals, but in recent times fewer than 20 seals have been seen at any one site (Johnson et al. 1999).

From 2005-2007, Green et al. (2005, 2006, 2007) monitored marine mammals from barges travelling between Prudhoe Bay and Cape Simpson. Overall, they observed between 23 and 54 spotted seals annually. Savarese et al. (2010) reported between 59 and 125 spotted seals annually during surveys in the central Beaufort Sea between 2006−2008. In 2010, Reiser et al. (2011) reported most spotted seals in July and August while other seal species were more commonly observed in September and October. During BP's OBC seismic survey in Foggy Island Bay, just southeast of the proposed project area, observers recorded a limited number of seal sightings (18) of which one confirmed spotted seal (Aerts et al. 2008). During the geohazard survey in Foggy Island Bay we expect to see some spotted seals, but in low numbers.

4.2.3 Ringed Seal (Phoca hispida)

Ringed seals have a circumpolar distribution (King 1983) and are year round residents in the Beaufort, Bering and Chukchi seas (King 1983, Allen and Angliss 2011). There is currently no complete population estimate available for the entire Alaskan stock (Allen and Angliss 2012).

Historic 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 (1999) estimated 80,000 ringed seals in the Beaufort Sea during summer and 40,000 during winter, indicating that half of the population moves into the Chukchi and Bering seas in winter. There is increasing concern about the future of the ringed seal due to receding ice conditions and potential habitat loss. NMFS listed the Arctic stock of ringed seals as threatened under the ESA, effective February 26, 2013 (NMFS 2012b).

Like other ice seals, ringed seals are closely associated with sea ice during breeding, pupping, and molting. During the open-water season, ringed seals are widely dispersed as single animals or in small groups and they are known to move into coastal areas (Smith 1987; Harwood and Stirling 1992; Moulton and Lawson 2002; Green et al. 2007). Satellite-tagging data revealed that ringed seals cover large distances between foraging areas and haulout sites during the open-water season (Lowry et al. 1998, 2000; Kelly et al. 2010b; Herreman et al. 2012). The time spent on haulout sites is much shorter than the time spent foraging in open water. For example, in July ringed seals spent 70% of the time in open water, increasing to ≥90% in August (Kelly et al. 2010b).

Ringed seals have routinely been observed during previous seismic surveys in this region and time period (e.g., Aerts et al. 2008; Funk et al. 2008; Savarese et al. 2010; Brandon et al. 2011; Reiser et al. 2011), during monitoring from Northstar Island (e.g., Aerts and Richardson 2009, 2010) and during aerial surveys flown for bowhead whales (Clarke et al. 2011). They are typically the most abundant seal species seen in the Beaufort Sea. Based on the data available, ringed seals are likely to be the most abundant marine mammal species encountered in the area of the proposed activities. Despite being the most abundant seal species, the number of seals that we expect to encounter during the proposed geohazard survey is relatively low, due to the limited size of the project area, the short survey duration, and the limited number of seals seen in Foggy Island Bay during a shallow water seismic survey (Aerts et al. 2008).

4.3 Uncommon or Extralimital Species

Minke whales, humpback whales, killer whales, narwhal, harbor porpoises, and ribbon seals could occur in the Beaufort Sea but are either uncommon or extralimital (Table 3). We do not expect to encounter any of these species during the proposed Liberty geohazard survey.

Minke whales are relatively common in the Bering and southern Chukchi seas and have recently also been sighted in the northeastern Chukchi Sea (Aerts et al. 2013; Clarke et al. 2013). Minke whales are rare in the Beaufort Sea. They have not been reported in the Beaufort Sea during the BWASP/ASAMM surveys (Clarke et al. 2011, 2012, 2013; Monnet and Treacy 2005) and there was only one observation in 2007 during vessel-based surveys in the region (Funk et al. 2010).

Humpback whales have not generally been found in the Arctic Ocean. However, subsistence hunters have spotted humpback whales in low numbers around Barrow and there have been several confirmed sightings of humpback whales in the northeastern Chukchi Sea in recent years

(Aerts et al. 2013; Clarke et al. 2013). The first confirmed sighting of a humpback whale in the Beaufort Sea was recorded in August 2007 (Hashagen et al. 2009) when a cow and calf were observed 54 mi east of Point Barrow. No additional sightings have been documented in the Beaufort Sea.

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from southeast Alaska through the Aleutian Islands to the Bering and Chukchi seas (Allen and Angliss 2013). Killer whales have been seen infrequently in the Beaufort Sea (Leatherwood et al. 1986; Allen and Angliss 2013). George et al. (1994) reported that killer whales are seen at Point Barrow in low numbers each year. No killer whales have been reported in the Beaufort Sea during the BWASP/ASAMM aerial surveys conducted from 2006–2012 (Clarke et al. 2011, 2012, 2013). Oil industry staff based at Northstar Island and the Endicott Main Production Island reported occasional unconfirmed killer whale sightings.

Narwhal are common in the waters of northern Canada, west Greenland, and in the European Arctic, but rarely occur in the Beaufort Sea (COSEWIC 2004). Only a handful of sightings have occurred in Alaskan waters (Allen and Angliss 2013). George and Suydam (unpublished data) summarized eight observations of 11-12 individuals by Alaska Native hunters in the Chukchi and Beaufort seas between 1989 and 2008. No narwhal have been reported during the BWASP surveys conducted in the Beaufort Sea or during seismic survey program monitoring.

Harbor porpoise occur from Point Barrow along the western Alaskan coast, along the Aleutians and throughout southeast Alaska (Allen and Angliss 2013) but are considered extralimital in the Beaufort Sea. However, a small number of porpoises were seen in recent years (Hauser et al. 2008; Lyons et al. 2009).

Ribbon seals are found in the North Pacific Ocean and parts of the Arctic Ocean, most often along the pack ice (Allen and Angliss 2013). Ribbon seals have been sighted in very low numbers in the northeastern Chukchi Sea (Aerts et al. 2013; Haley et al. 2010). No ribbon seals have been reported as part of the BWASP surveys conducted in the Beaufort Sea or during seismic survey program monitoring, although three animals were reported during a vessel-based marine mammal monitoring program near Prudhoe Bay in 2008 (Savarese et al. 2010).

5 TYPE OF INCIDENTAL HARASSMENT AUTHORIZATION REQUESTED

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

BP seeks authorization for non-lethal incidental "level B harassment" of marine mammals pursuant to Section 101(a)(5)(D) of the MMPA during its proposed Liberty geohazard survey in Foggy Island Bay, Beaufort Sea, for the period July 1 through September 30, 2013. "Level B harassment" is defined under the MMPA as "*any act of pursuit, torment or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing* *disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding or sheltering.*"

Harassment of whales and seals from the proposed geohazard activities described in Section 1 of this application, if it occurs at all, is mainly expected to occur due to exposure to pulsed sounds from airguns and other acoustic equipment used for data acquisition.

The response of whales and seals to pulsed sounds depends on many factors as described in Section 7 of this application. Disturbance reactions, such as avoidance, may occur among some whales and seals in proximity to the vessel during survey operations. No injury to whales and seals is expected from exposure to airgun sounds or other geophysical equipment given the nature of the activity in combination with the planned mitigation measures (see Section 11).

In summary, BP seeks authorization of incidental non-lethal harassment of whales and seals from pulsed sounds generated during the permitted project activities.

6 NUMBER OF MARINE MAMMALS THAT MAY BE HARASSED

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

This section describes the methods used to estimate the numbers of marine mammals that might be affected during the proposed shallow geohazard survey activities in Foggy Island Bay. Section 7 provides a summary of potential impacts from airgun sounds and other geophysical equipment on marine mammals. In theory, exposure to airgun sounds could lead to a temporary reduction in hearing sensitivity or permanent hearing damage in marine mammals in close proximity to the source (defined as level A harassment under the MMPA). Sounds generated by airguns and some sonar equipment could also elicit behavioral responses in marine mammals (defined as level B harassment under the MMPA). The current thresholds for the onset of potential "level A harassment" from pulsed sounds are 190 dB re 1 µPa (rms) for seals and 180 dB (rms) for whales. The threshold for potential "Level B harassment" from pulsed sounds is 160 dB re 1 µPa (rms) for all marine mammals (NMFS 2005). More information regarding marine mammal responses to pulsed sounds has become available since these criteria were established (e.g., Southall et al. 2007) and updated acoustic criteria are therefore being developed (NMFS 2013b; NOAA 2013). The new acoustic thresholds for level A harassment will reflect species-specific differences in hearing sensitivity and duration of sound exposure. The new level B harassment criteria will likely be based on dose-response curves specific to different marine mammal groups, acknowledging that marine mammals do not all react similarly to sound exposure and that not all individuals will respond when exposed to sounds.

Actual observations of impacts from sound exposure unequivocally meeting the definition of "harassment" or "take" are rare, in part due to the difficulties associated with making and interpreting observations at sea. With that in mind sound exposures are being used as surrogates for potential "takes." The number of whales and seals potentially "taken" by airgun sounds requested in this IHA application are thus based on estimated number of exposures, realizing that exposures do not equal "take" and that the actual number of events that would unequivocally meet the definition of "take" will probably be much lower than the estimated number of potential "takes."

Number of possible exposures are based on estimated animal densities in the estimated area ensonified with pulsed sound levels of 160 dB re 1µPa (rms) or more during the course of the season based on best available data. Species most likely to be encountered in the survey area in relatively high numbers are ringed seals, followed by bearded and spotted seals (see Section 4). Most bowhead whales occur farther offshore during July or August, although some animals have been observed in nearshore areas in the past few years (Clarke et al. 2013; 2013 ASAMM daily flight summaries). We do not expect to encounter bowhead whales within the project area during the survey period. Gray and beluga whales could also occur in the project area, however the chance of encounters is low. Although whale species that are rare or extralimital to the Beaufort Sea are not expected to be present in the project area, BP requested harassment authorization for a few animals to cover incidental occurrences.

Section 6.1 describes the approach used to estimate marine mammal densities representative for the area and season of operation. Section 6.2 summarizes the anticipated distances to received sound levels from the proposed airgun arrays, derived from existing measurements. The estimated numbers of marine mammals potentially exposed and the requested authorization are summarized in Section 6.3.

6.1 Marine Mammal Abundance Estimates

The shallow geohazard survey will take place in two phases and has an estimated duration of approximately 20 days, including 5 days between the two phases where operations will be focused on changing equipment. Data acquisition will also be halted at the start of the Cross Island fall bowhead whale hunt, as agreed upon in the CAA.

During phase 1 of the project, 2DHR seismic data will be acquired in about 12 mi^2 of the Site Survey area. The duration is estimated at about 7.5 days, based on a continuous 24-hr operation and not including downtime.

During phase 2, data will be acquired in the Site Survey area (11 mi^2) and over approximately 5 mi^2 of the 29 mi^2 Sonar Survey area using the multibeam echosounder, sidescan sonar, subbottom profiler, and magnetometer. The total duration of phase 2 is also expected to be 7.5 days, based on a continuous 24-hr operation and not including downtime.

Most whale species are migratory and therefore show a seasonal distribution, with different densities for the summer period (covering July and August) and the fall period (covering September and October). Seal species in the Beaufort Sea do not show a distinct seasonal distribution during the open water period between July and October. Data acquisition of the proposed shallow geohazard survey will take place during summer (before start of Nuiqsut whaling), so for this IHA application only summer densities were estimated. Whale and seal densities in the Beaufort Sea will further depend on the presence of sea ice. However, if ice cover within or close to the project area is more than approximately 10%, survey activities may not start or will be halted. Densities related to ice conditions are therefore not included in this IHA application.

Spatial differentiation is an important factor for marine mammal densities, both in latitudinal and longitudinal gradient. Taking into account the location and limited size of the survey area (including the associated area of influence), data from the nearshore zone of the Beaufort Sea have been used for the calculation of densities, if available.

Density estimates are based on best available data. Because available data did not always cover the area of interest, is subject to large temporal and spatial variation, and correction factors for perception and availability bias were not always known, there is some uncertainty in the data and assumptions used in the estimated number of exposures. To provide allowance for these uncertainties, maximum density estimates have been provided in addition to average density estimates.

6.1.1 Beaufort Sea Whale Densities

Beluga Whale

The 1979–2011 BWASP aerial survey database, available from the NOAA website (http://www.afsc.noaa.gov/ NMML/software/bwasp-comida.php), contains a total of 62 belugas (31 sightings) in block 1, which covers the nearshore and offshore Foggy Island Bay area. Except for one solitary animal in 1992, all these belugas were seen in September or October; the months with most aerial survey effort. None of the sightings occurred south of 70°N, which is to be expected because beluga whales generally travel much farther north (Moore and Clarke 1992, Suydam et al. 2011). The summer effort in the 1979–2011 database is limited. BP thus considered the 2012–2013 data to be the best available data for calculating beluga summer densities (Clarke et al. 2013; http://www.asfc.noaa.gov/nmml/cetacean/bwasp/2013), even though the 2013 daily flight summaries posted on NOAA's website have not undergone post-season QAQC.

To estimate the density of beluga whales in the Foggy Island Bay area, the 2012 on-transect beluga sighting and effort data from the ASAMM surveys flown in July and August in the Beaufort Sea were used. The area most applicable to the proposed geohazard survey was the area from 140W-154W and water depths of 0-20 m (Table 13 in Clarke et al. 2013). In addition, beluga sighting and effort data of the 2013 survey were used, as reported in the daily flight summaries on the NOAA website. Although sightings from block 1 were the most representative, many aerial surveys flown in block 1 also covered blocks 2 and 10, which were much farther from shore. Because it was difficult to determine the survey effort specific to block 1 from the available information, sighting and effort data from block 2 and 10 were included in our calculations. The number of individuals counted on transect, together with the transect kilometers flown, were used to calculate density estimates (Table 4). The number of individuals per line transect (ind/km) were converted to a density per area (ind/km^2) using the effective strip width (ESW) of 0.614 km for belugas, calculated from 2008-2012 aerial survey data flown with the Commander aircraft (Ferguson, personal communication 30 Oct 2013).

Table 4. Summary of beluga sighting and effort data from the 2012 and 2013 ASAMM aerial surveys flown in July and August in the Beaufort Sea. See text for more details on how the number of individuals per kilometer (ind/km) and densities (ind/km^2) were derived.

YEAR	EFFORT (IN KM)	NR. IND	IND/KM	IND/KM^2
2012	1431	5	0.0035	0.0028
2013	7572	99	0.0131	0.0182
			Average	*0.0105*
			Maximum	*0.0182*
			Minimum	*0.0028*

Bowhead Whale

Estimated summer bowhead whale densities were derived from the 2012 and 2013 ASAMM aerial surveys flown in the Beaufort Sea (Clarke et al. 2013; www.asfc.noaa.gov/nmml/). The 1979–2011 ASAMM database contains only one on-transect bowhead whale sighting during July and August (in 2011), likely due to the limited summer survey effort. In contrast, the 2012 and 2013 surveys include substantial effort during the summer season and are thus considered to be the best available data, even though the 2013 daily flight summaries posted on NOAA's website have not undergone post-season QAQC.

The estimated density of bowhead whales in Foggy Island Bay was derived from the 2012 on-transect bowhead sighting and effort data from surveys flown in July and August in block 1 (Table 4 in Clarke et al. 2013) and from the 2013 survey, as reported in the daily flight summaries on the NOAA website. Although sightings from block 1 were the most representative, many aerial surveys flown in block 1 also covered blocks 2 and 10, which were much farther from shore. Because it was difficult to determine the survey effort specific to block 1 from the available information, sighting and effort data from block 2 and 10 were included in our calculations (Table 5). The number of individuals per line transect (ind/km) were converted to a density per area (ind/km^2) using the effective strip width (ESW) of 1.15 km for bowheads, calculated from 2008-2012 aerial survey data flown with the Commander aircraft (Ferguson, personal communication 30 Oct 2013).

Table 5. Summary of bowhead sighting and effort data from the 2012 and 2013 ASAMM aerial surveys flown in July and August in the Beaufort Sea. See text for more details on how the number of individuals per kilometer (ind/km) and densities (ind/km^2) were derived.

YEAR	EFFORT (IN KM)	NR. IND	IND/KM	IND/KM^2
2012	1493	5	0.0033	0.0015
2013	3973	88	0.0221	0.0096
			Average	*0.0055*
			Maximum	*0.0096*
			Minimum	*0.0015*

Other whale species

No densities have been estimated for gray whales and for whale species that are rare or extralimital to the Beaufort Sea (humpback whale, minke whale, killer whale, harbor porpoise, narwhal; see Table 3), because sightings of this animals have been very infrequent. Gray whales may be encountered in small numbers throughout the summer and fall, especially in the nearshore areas. Small numbers of harbor porpoises may be encountered as well. During an aerial survey offshore of Oliktok Point in 2008, approximately 40 mi (65 km) west of the proposed survey area, two harbor porpoises were sighted offshore of the barrier islands, one on 25 August and the other on 10 September (Hauser et al. 2008). The first confirmed sighting of a humpback whale with calf was documented on 1 August 2007, about 54 mile (87 km) east of Point Barrow (Hashagen et al. 2009), so an occasional sighting could occur but is very unlikely. For the purpose of this IHA request, small numbers have been included in the requested "take" authorization to cover incidental occurrences of any of these species during the proposed survey (see Section 6.3), although no actual "take" of these species is expected to occur.

6.1.2 Beaufort Sea Seal Densities

Ice seals of the Beaufort Sea are mostly associated with sea ice and most census methods count seals when they are hauled out on the ice. To account for the proportion of animals present but not hauled out (availability bias) or seals present on the ice but missed (detection bias), a correction factor should be applied to the "raw" counts. This correction factor is dependent on the behavior of each species. To estimate what proportion of ringed seals were generally visible resting on the sea ice, radio tags were placed on seals during spring 1999-2003 (Kelly et al. 2006). The probability that seals were visible, derived from the satellite data, was applied to seal abundance data from past aerial surveys and indicated that the proportion of seals visible varied from less than 0.40 to more than 0.75 between survey years. The environmental factors that are important in explaining the availability of seals to be counted were found to be time of day, date, wind speed, air temperature, and days from snow melt (Kelly et al. 2006). Besides the uncertainty in the correction factor, using counts of basking seals from spring surveys to predict seal abundance in the open-water period is further complicated by the fact that seal movements differ substantially between these two seasons. Data from nine ringed seals that were tracked from one subnivean period (early winter through mid-May or early June) to the next showed that ringed seals covered large distances during the open water foraging period (Kelly et al. 2010b). Ringed seals tagged in 2011 close to Barrow also traveled long distances during the open water season (Herreman et al. 2012).

Data collected during four shallow water OBC seismic surveys in the Beaufort Sea (Harris et al. 2001, Aerts et al. 2008, Hauser et al. 2008, HDR 2012) was used to estimate densities for ringed, bearded, and spotted seals. Habitat and survey specifics are very similar to the proposed survey, therefore these data were considered to be more representative than basking seal densities from spring aerial survey data (e.g., Moulton et al. 2002; Frost et al. 2002, 2004).

Because survey effort in kilometers was only reported for one of the surveys, the sighting rate (ind/h) was used for calculating potential seal exposures. No distinction was made in seal density between summer and autumn season. Also, no correction factors were applied to the reported seal sighting rates.

Seal species ratios

During the 1996 OBC survey, 92% of all seal species identified were ringed seals, 7% bearded seals and 1% spotted seals (Harris et al. 2001). This 1996 survey occurred in two habitats, one about 19 mile east of Prudhoe Bay near the McClure Islands, mainly inshore of the barrier islands in water depths of 10 to 26 ft, and the other 6 to 30 mi northwest of Prudhoe Bay, about 0 to 8 mile offshore of the barrier islands in water depths of 10 to 56 ft (Harris et al. 2001). In 2008, two OBC seismic surveys occurred in the Beaufort Sea, one in Foggy Island Bay, about 15 mi SE of Prudhoe Bay (Aerts et al. 2008), and the other at Oliktok Point, > 30 mi west of Prudhoe Bay (Hauser et al. 2008). In 2012, an OBC seismic was done in Simpson Lagoon, bordering the area surveyed in 2008 at Oliktok Point (HDR 2012). Based on the number of identified individuals there were 75% ringed seals, 8% bearded seals, and 17% spotted seals in Foggy Island Bay (Aerts et al. 2008). At Oliktok Point, there were 22% ringed seals, 39% bearded seals, and 39% spotted seals (Hauser et al. 2008). At Simpson Lagoon, there were 62% ringed seals, 15% bearded seals, and 23% spotted seals (HDR 2012). Because it is often difficult to identify seals to species, a large proportion of seal sightings were unidentified in all four OBC surveys described here. The total seal sighting rate was therefore used to calculate densities for each species, using the average ratio over all four surveys for ringed, bearded, and spotted seals, i.e., 63% ringed, 17% bearded, and 20% spotted seals.

Seal sighting rates

During the 1996 OBC survey (Harris et al. 2001) the sighting rate for all seals during periods when airguns were not operating was 0.630 ind/h. The sighting rate during non-seismic periods was 0.046 ind/h for the survey in Foggy Island Bay, just east of Prudhoe Bay (Aerts et al. 2008). The OBC survey that took place at Oliktok Point recorded 0.0674 ind/h when airguns were not operating (Hauser et al. 2008), and the maximum sighting rate during the Simpson Lagoon OBC seismic survey was 0.030 ind/h (HDR 2012).

The average seal sighting rate, based on these four surveys, was 0.193 ind/h. The maximum was 0.63 ind/h and the minimum 0.030 ind/h. The average and maximum sighting rates (ind/h) for each of the three seal species was estimated using the proportion of ringed, bearded, and spotted seals as mentioned above (Table 6).

6.1.3 Whale and Seal Density Summary

For the purpose of calculating the potential number of beluga and bowhead whale exposures to received sound levels of ≥160 dB re 1µPa, the minimum density from Tables 4 and 5 was used as the average density. To derive a maximum estimated number of exposures the average densities from Tables 4 and 5 were used. This approach was considered reasonable for two reasons:

1. The 2012 data were based on block 1, which is the most representative block for the proposed geohazard survey.
2. The 2013 beluga and bowhead whale sighting data included areas outside the zone of influence of the proposed project, where most animals were seen. For example, only 3 of the 89 beluga sightings were seen in block 1 in 2013. Bowheads were also less common in block 1.

Table 6 summarizes the densities that were used in the calculation of potential number of exposures for whales and seals.

Table 6. Estimated summer densities of whales and sighting rates of seals (average and maximum) for the proposed geohazard survey. Densities are provided in number of individuals per km^2 (ind/km^2), while sighting rates are provided in number of individuals per hour (ind/h). No densities or sighting rates were estimated for extralimital species.

SPECIES	SUMMER DENSITIES (IND/KM^2)	
	AVERAGE	MAXIMUM
Bowhead whale	0.0015	0.0055
Beluga whale	0.0028	0.0105
	SUMMER SIGHTING RATES (IND/H)	
	AVERAGE	MAXIMUM
Ringed seal	0.122	0.397
Bearded seal	0.033	0.107
Spotted seal	0.039	0.126

6.2 Safety and Disturbance Zone Distances

Due to the natural variability in the marine environment, application of precautionary correction factors, and data interpretation in the generation of circular isopleths, there is poor agreement between modeled and measured distances to received sound pressure levels (Aerts & Streever, 2013; see Appendix A). For the proposed 2014 geohazard survey, existing SSV measurements were therefore used to establish distances to received sound pressure levels of 190, 180, 160, and 120 dB re 1µPa (rms).

Airgun arrays consist of a cluster of independent sources, giving some degree of directionality to their sounds, especially at higher frequencies. Because of this, as well as differential propagation characteristics in different directions and other factors, sounds generated by arrays do not spread evenly in all directions. Both broadside and endfire measurements of the array were included in calculating distances to the various received sound levels. Because mitigation guns are single airguns rather than arrays, their sounds are not inherently directional. Although propagation of the sounds from mitigation guns can be directional due to differential propagation characteristics in different directions and other factors, broadside and endfire measurements are not typically reported for mitigation gun measurements.

Seven SSV measurements exist of 20-40 in^3 airgun arrays in the shallow water environment of the Beaufort Sea that were considered to be representative of the proposed 30 in^3 airgun arrays (Table 7A). These measurements were from 2008 (n=4), 2011 (n=1) and 2012 (n=2), all in water depths less than about 50 ft. For the 5 in^3 mitigation gun, measured distances of a 10 in^3 mitigation gun from four shallow hazard SSV surveys in the Beaufort Sea were used: one in 2007, two in 2008, and one in 2011. Table 7A shows average, maximum, and minimum measured distances to each of the four received SPL rms levels for 20-40 in^3 arrays and 10 in^3 single gun. The mitigation radii of the proposed 30 in^3 airgun arrays and 5 in^3 gun were derived from the average distance of the 20-40 in^3 and the 10 in^3 SSV measurements, respectively (Table 8). Distances to sound pressure levels of 190, 180, and 160 dB re 1µPa, generated by the proposed geophysical equipment is much lower than for airguns (Table 7B). The operating frequency of the sidescan sonar is within hearing range of toothed whales (beluga) only, with a distance of 50 m to 180 dB re 1 µPa (rms) and 230 m to 160 dB re 1 µPa (rms) (Warner & McCrodan 2011). Sounds generated by the subbottom profiler are within the hearing range of all marine mammal species occurring in the area, but do not produce sounds strong enough to reach sound pressure levels of 190 or 180 dB re 1 µPa (rms). The distance to 160 dB re 1 µPa (rms) is estimated at 30 m (Warner & McCrodan 2011).

Table 7A. Average distances (in meters) to four received rms SPLs (in dB re 1 µPa) calculated from existing SSV measurements of airgun arrays with discharge volumes of 20-40 and 10 in^3.

AIRGUN DISCHARGE VOLUME (IN^3)		DISTANCE (IN METERS)			
		190 dB	180 dB	160 dB	120 dB
20-40 IN^3	Avg	58	160	944	6,423
(n=7)	Max	138	293	1,602	12,000
	Min	6	67	640	2,300
10 IN^3	Avg	16	45	451	10,783
(n=4)	Max	53	120	600	16,000
	Min	3	20	280	5,000

Table 7B. Distances (in meters) to four received rms SPLs (in dB re 1 μPa) from existing measurements of geophysical equipment, similar to those proposed for this survey. Measurements were conducted in water depths of about 100 ft (~35 m). Source: Warner & McCrodan 2011.

EQUIPMENT	DISTANCE (IN METERS)				COMMENT
	190 dB	180 dB	160 dB	120 dB	
Multibeam echosounder	-	-	-	330	Outside hearing range of any marine mammal species
Sidescan sonar	22	47	230	5,100	Within hearing range of toothed whales only
Subbottom profiler	-	-	30	450	Within hearing range of all marine mammal species

Table 8. Distances (in meters) to be used for mitigation purposes for the proposed airgun arrays of the 2014 Liberty geohazard survey.

AIRGUN DISCHARGE VOLUME (IN^3)	DISTANCE (IN METERS)	
	190 dB RE 1 μPA	180 dB RE 1 μPA
30 in^3	70	200
5 in^3	20	50

6.3 Number of marine mammals potentially affected

The current threshold for the onset of potential "level B harassment" from pulsed sounds for marine mammals is 160 dB re 1 μPa (rms) (NMFS 2005). The radii associated with received sound levels of 160 dB re 1 μPa (rms) or higher were therefore used to calculate the number of potential marine mammal exposures to airgun sounds for this IHA application. The distances to received levels of 180 dB and 190 dB re 1 μPa (rms) are mainly relevant as safety radii to avoid level A harassment of marine mammals through implementation of shutdown and power down measures (see Section 11 for a summary of the mitigation measures).

The potential number of marine mammals that might be exposed to the 160 dB re 1 μPa (rms) sound pressure level was calculated differently for whales and seals as described in the sections below. Table 9 summarizes the number of potential marine mammal exposures to airgun sound levels of ≥160 dB re 1 μPa (rms) during the proposed geohazard survey and specifies the number for which authorization is requested. The sounds generated by the multibeam echosounder, sidescan sonar, and subbottom profiler are either outside the hearing range of marine mammals, or not strong enough to propagate at distances far enough to expect marine mammals to be present and to respond in manner that would constitute a "take" under the MMPA. The numbers of marine mammals estimated to be exposed to sound pressure levels of 160 dB re 1 μPa (rms) or more as calculated for airgun sounds therefore will cover any incidental sound exposures to the sonar systems to be used.

6.3.1 Number of Whales Potentially Exposed to ≥160 dB

The potential number of bowhead and beluga whales that might be exposed to the 160 dB re 1 µPa (rms) sound pressure level was calculated by multiplying:

- the expected bowhead and beluga density as summarized in Tables 4 and 5;
- the anticipated area around the vessel that is ensonified by the 160 dB re 1 µPa (rms) sound pressure level from airguns; and
- the estimated number of 24-hr days that the airguns are operating.

The area expected to be ensonified was determined based on the maximum distance to the 160 dB re 1 µPa (rms) sound pressure level of the seven 20-40 in^3 array measurements (Table 7A), which is 1.6 km. Based on a radius of 1.6 km, the 160 dB isopleth for the proposed arrays is 8 km^2.

The estimated number of 24-hr days of airgun operations is 7.5 days (180 hours), not including downtime. Downtime is related to weather, equipment maintenance, mitigation implementation, and other circumstances.

Average and maximum estimates of the number of bowhead and beluga whales potentially exposed to sound pressure levels of 160 dB re 1µPa (rms) or more are summarized in Table 9. Species such as gray whale, narwhal, killer whale and harbor porpoise are not expected to be encountered but might be present in very low numbers. The maximum expected number of exposures for these species, as provided in Table 9, is based on the likelihood of incidental occurrences.

The average and maximum number of bowhead whales potentially exposed to airgun sound levels of 160 dB re 1µPa (rms) or more is estimated at 0 and ~1, respectively. The limited number of exposures is due to the low estimated density of bowheads in Foggy Island Bay during July and August, the short duration of the survey, and the small acoustic footprint. For the requested authorization, the maximum number was multiplied by three to account for unexpected bowhead occurrences. The average and maximum number of potential beluga exposures to 160 dB is similar to that of bowhead whales. Belugas are known to show aggregate behavior and can occur in large numbers in nearshore zones, as evidenced by the sighting from Endicott in August 2013. For the unlikely event that a group of belugas appears within the 160 dB isopleth during the geohazard survey, a number of 75 was added to the requested authorization. Chance encounters with small numbers of other whale species are possible, but exposures to 160 dB or more are very unlikely for these species.

These estimated exposures do not take into account the mitigation measures that will be implemented, such as: marine mammal observers watching for animals, shutdowns or power downs of the airguns when marine mammals are seen within defined ranges, and ramp up of airguns. These measures will further reduce the number of exposures and expected short-term reactions, and minimize any effects on hearing sensitivity.

6.3.2 Number of Seals Potentially Exposed

The estimated number of seals that might be exposed to pulsed sounds of 160 dB re 1 µPa (rms) is calculated by multiplying:

- the expected species specific sighting rate as provided in Table 6; and
- the total number of hours that airguns will be operating during the data acquisition period.

The estimated number of hours that airguns will be operating is 180 hours (7.5 days of 24 hour operations). The resulting average and maximum number of ringed, bearded, and spotted seal exposures based on 180 hours of airgun operations are summarized in Table 9. The assumption was that all seal sightings would occur within the 160 dB isopleth.

The maximum number of ringed seals potentially exposed is <0.001% of the estimated population size of the Beaufort Sea stock (Table 3). The maximum number of bearded seals and spotted seals potentially exposed to sound levels of 160 dB or more represent <0.02% of their estimated population sizes. BP's requested authorization for harassment of seals covers the maximum number of animals potentially exposed, based on sighting numbers from three recent OBC seismic surveys. Generally, seals are not likely to react to seismic sounds at the distance associated with the 160 dB re 1 µPa (rms) received sound level (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). If they do show a behavioral response it is expected to be short-term without any negative consequences for the individuals or their populations (see Section 7 for more detailed information).

Table 9. Average and maximum estimated number of whales and seals potentially exposed to sound levels of 160 dB re 1µPa (rms) or more during the Liberty geohazard survey. The number of animals for which authorization is requested is specified in a separate column.

SPECIES	NR OF IND POTENTIALLY EXPOSED TO ≥160 DB		REQUESTED AUTHORIZATION
	AVG	MAX	
Bowhead whale	0	1	3
Beluga whale	0	1	3 (75)*
Gray whale	0	1	1
Killer whale	0	1	1
Harbor porpoise	0	1	1
Humpback whale	0	1	1
Minke whale	0	1	1
Ringed seal	22	71	71
Bearded seal	6	19	19
Spotted seal	7	23	23
Ribbon seal	0	1	1

* *A number of 75 is added to the requested authorization for the unlikely event that a group of belugas appears within the 160 dB isopleth during airgun operations.*

7 ANTICIPATED IMPACT ON SPECIES OR STOCKS

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

This section summarizes the potential impacts on marine mammals from the proposed airgun operations and the other geophysical equipment (i.e., multibeam echosounder, sidescan sonar, and subbottom profiler). A number of factors should be considered when determining the potential impact from sound exposures, including the species exposed, duration of exposures, frequencies of exposures, sound pressures and energy levels of exposures, hearing ability of species exposed, physiological and behavioral sensitivity to sound of species exposed, and context in which exposures occur (Ellison et al. 2011). Based on available literature we summarized what is known about marine mammal responses to airgun sound and sonar systems such as those used in this survey.

7.1 Potential effects of airgun sounds

Based on the species and circumstances, airgun sounds can have different effects on marine mammal species, such as temporary or permanent hearing impairment, non-auditory injury, masking of natural sounds important to marine mammals, or behavioral disturbance (Richardson et al. 1995).

7.1.1 Hearing Impairment and Non-Auditory Injury

Permanent or temporary hearing impairment or threshold shifts could occur when marine mammals are exposed to very strong sounds or to less strong sounds for a prolonged period. Close proximity to airgun pulses has the potential for permanent or temporary threshold shifts (PTS or TTS). Current policy regarding exposure of marine mammals to high-level sounds is that whales and seals should not be exposed to impulsive sounds ≥180 and ≥190 dB re 1 µPa (rms), respectively (NMFS 2000). Those criteria have been used in defining the safety (shutdown) radii planned for the proposed geohazard survey, but were established without actual data on the minimum received levels of sounds necessary to cause temporary auditory impairment in marine mammals. Based on an extensive review and syntheses of newly available data on possible TTS and PTS onset in marine mammals from pulsed sounds (Southall et al. 2007), it was suggested that threshold criteria for TTS and PTS should be based on peak sound pressure levels or cumulative sound exposure levels. Efforts are currently underway to revise the existing criteria taking into account the most recent scientific data on TTS (NMFS 2013b; NOAA 2013).

In theory, hearing impairment and non-auditory physical effects (e.g., stress, neurological effects, bubble formation, and other types of organ or tissue damage) might occur in marine mammals exposed to strong, pulsed underwater sounds. However, the limited data available from captive marine mammals do not provide definitive evidence that any of these effects occur even for marine mammals in close proximity to large airgun arrays. Most baleen whales, some toothed whales (including belugas), and some seals show behavioral avoidance of source vessels operating airguns. In addition, the planned monitoring and mitigation measures include shutdowns of airguns should animals enter designated "safety radii." Given the brief duration of exposure of any marine mammal in combination with the proposed monitoring and mitigation measures, auditory impairment or other non-auditory physical effects are unlikely to occur during the present project. The following subsections provide more detail about current knowledge of TTS, PTS, and non-auditory physical effects from pulsed sounds.

Permanent and Temporary Threshold Shift (PTS, TTS)

Noise induced hearing loss occurs when sensitive structures in the inner ear are damaged, which can happen following exposure to harmful noise, i.e., very loud impulsive sounds or very loud continuous sounds over a long duration. These sensitive structures, called cochlear hair cells, are small sensory cells that convert sound energy into electrical signals that travel to the brain. Once damaged, hair cells cannot grow back. PTS occurs when exposure to impulsive or continuous noise results in damage of hair cells and thus in permanent hearing loss. TTS or temporary hearing loss occurs following sound exposures less severe than those that cause PTS.

No direct information is available about what sound characteristics have the potential to elicit onset of PTS in marine mammals. Instead, the potential for PTS has been derived from studies measuring the onset of TTS. Most of these studies were conducted with captive toothed whales, such as bottlenose dolphins and beluga whales (see review in Southall et al. 2007). Both species are mid-frequency cetaceans. Only limited information on TTS exists for high-frequency cetaceans (e.g., Lucke et al. 2008; Popov et al. 2011) and none for low-frequency cetaceans (baleen whales). To derive criteria for auditory injury, Southall et al. (2007) used the TTS data available for mid-frequency cetaceans as a surrogate for the low- and high-frequency cetaceans, assuming that all groups have similar auditory mechanisms. Animals do not perceive equally well at all frequencies within their functional hearing range. Sound sources that have their primary spectral components at frequencies that animals can only perceive at high received sound levels, if at all, are less likely to affect the animal. Test sounds used in TTS experiments consist of frequencies that fall well within the functional hearing range of the animals, though not necessarily always within their best hearing sensitivity. Most TTS experiments in which toothed whales, porpoises, and seals were exposed to sound signals used non-pulse tones of frequencies from about 2-115 kHz. Toothed whales exposed to such tones of various duration, showed brief, mild TTS at received sound pressure levels (SPL) of 190–204 dB re 1µPa (Schlundt et al. 2000; Finneran et al. 2005, Finneran & Schlundt 2007). Harbor porpoises seemed to be more susceptible to TTS than harbor seals when exposed to octave-band white noise centered around 4 kHz for 60 minutes (Kastelein et al. 2012). TTS studies with baleen whales do not exist, thus levels or properties of sound that are required to induce TTS in baleen whales are unknown.

In the proposed project, marine mammals are unlikely to be exposed to received levels of seismic pulses strong enough to cause more than slight TTS and given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels reasonably close to the airgun array may not be sufficient to induce PTS, especially because a mammal would not be exposed to more than one strong pulse unless it swam reasonably close to the airgun array for a period longer than the inter-pulse interval. Bowhead and beluga whales generally avoid the immediate area around operating seismic vessels. The planned monitoring and mitigation measures, including visual monitoring, power downs, and shutdowns of the airguns when mammals are seen within the designated safety radii, will minimize the limited probability of exposure of marine mammals to sounds strong enough to induce severe TTS or 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. However, studies examining such effects are very limited. If any such effects do occur, they would probably be limited to unusual situations such as animals exposed at close range for unusually long periods. It is doubtful that any single marine mammal would be exposed to strong seismic sounds for a sufficiently long time period that significant physiological stress would develop. That is especially the case during the proposed project where the airgun array is small and operates in a limited area for a short duration.

7.1.2 Masking

Anthropogenic underwater sound has the potential to interfere with the communication of marine mammal species or can affect their ability to detect environmental sounds. This phenomenon, also called masking, can occur when the frequency of the introduced sound is close to that used by the animal and is present for a significant fraction of the time (Richardson et al. 1995). However, masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data available. Some whales are known to continue calling in the presence of seismic pulses: their calls could be detected between seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Studies from northern Norway and the Gulf of Mexico demonstrated continued sperm whale calling in the presence of seismic pulses (Madsen et al. 2002; Tyack et al. 2003). There has, however, also been evidence that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994). Bowhead whale calls are frequently detected in the presence of seismic pulses, although the number of calls detected may sometimes be reduced (Richardson et al. 1986; Greene et al. 1999), possibly because animals moved away from the sound source or ceased calling (Blackwell et al. 2013). In contrast to studies showing reduced calling, Di Lorio and Clarke (2010) found evidence of increased calling by blue whales during activities that used a sparker (a lower-energy seismic source).

Masking effects of seismic pulses are expected to be negligible during the planned project given the low number of whales expected to be exposed, the intermittent nature of seismic pulses, and the fact that ringed seals (most likely to be present in the area) are not vocal during this period. However, reverberation and multi-path arrival could, at least in theory, lead to some masking.

7.1.3 Behavioral Disturbance

Behavioral responses to sound exposure can be variable, ranging from subtle changes in behavioral parameters (e.g., breathing rate, travel speed, dive time) to more conspicuous changes in activities (e.g., disruption to feeding or migration) and displacement. Short-term subtle behavioral responses that are within the animal's normal range and do not have any biological significance are not considered to require a small take authorization (NMFS 2001, p. 9293). Biologically significant in this case means, "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations," as defined by the National Resource Council (NRC 2005).

Behavioral reactions to sound are context-specific and depend on the species exposed, the state of maturity of the animal, its experience, current activity, reproductive state, and many other factors including environmental influences that affect sound propagation (Richardson et al. 1995; Gordon et al. 2004; Ellison et al. 2011). If a marine mammal reacts to an underwater sound by briefly 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, or even the population, could occur. The sound criteria used to estimate how many marine mammals might be disturbed to some biologically important degree by a seismic program are based on studies of several species that reported behavioral observations. Baleen whale behavioral studies exist mainly for bowhead, humpback, and gray whales. Less detailed data are available for other baleen whale species and for toothed whales.

Baleen whales

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range appear to cause obvious avoidance behavior in some individuals. For the much smaller airgun array of this survey, measured distances to received levels of 160 dB re 1 μPa rms ranged from about 0.4 to 1 mi (about 0.6 to 1.6 km) depending on various factors (see Table 7A). Baleen whales within those distances of operating source vessels may show avoidance or other disturbance reactions, but few baleen whales are expected to occur in the Foggy Island Bay area during the survey period.

Subtle behavioral changes sometimes become evident at lower received levels. Studies have shown that some species of baleen whales, particularly bowhead and humpback whales, can show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms. Weir (2008) found that encounter rates and mean distance with humpback whales did not differ significantly according to airgun operational status during a 10-month seismic survey offshore Angola. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn are unusually responsive, with avoidance occurring out to distances of 12 to 18 mi (20 to 30 km) from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999) where received levels were measured to be ~120-130 dB re 1 µPa rms. The call detection rate of bowhead whales migrating through areas with airgun activity was found to be dropping significantly at sound exposure levels of more than 120 dB re 1µPa·s^{-2} as summed over 15 minutes (Blackwell et al. 2013). Other research on bowhead whales (Miller et al. 2005; Koski et al. 2008b) corroborates earlier evidence that, during the summer feeding season, bowheads are not as sensitive to seismic sources. In summer, bowheads typically begin to show avoidance reactions at a received level of about 160–170 dB re 1 µPa rms (Richardson et al. 1986; Ljungblad et al. 1988; Miller et al. 1999). Koski et al. (2008) reported that feeding bowheads tolerated received levels of seismic sounds that approached ~160 dB re 1 µPa rms and that some tolerated even higher levels; one group of three whales tolerated received levels of ~180 dB re 1 µPa rms. Analyses of aerial survey data also showed the importance of context-specific parameters (such as activity, season, reproductive state) in behavioral responses of bowhead whales to airgun sounds (Robertson et al. 2013).

Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. Based on small sample sizes they estimated that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 µPa (rms) and that at received levels of 163 dB, 10% of feeding whales interrupted feeding. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast, and on observations of the distribution of feeding Western Pacific gray whales off Sakhalin Island, Russia during a seismic survey (Yazvenko et al. 2007).

The Liberty geohazard survey takes place in shallow waters in the summer, with limited bowhead whale presence (if at all). As part of the planned mitigation measures, BP will end data acquisition (i.e., the use of airguns) in late August at a date agreed upon in the CAA. Impacts to bowhead whales from the proposed activities are therefore expected to be minimal, if they occur at all.

Toothed whales

Based on the limited information about the potential impacts from airgun sounds on toothed whales (compared to the more extensive studies conducted on baleen whales), it can be concluded that reactions of toothed whales to large airgun arrays are variable and generally seem to be confined to a smaller radius than has been observed for baleen whales. There are a few studies that report responses of various toothed whales to airgun sounds, such as the sperm whale study in the Gulf of Mexico (Tyack et al. 2003; Jochens et al. 2006; Miller et al. 2009) and the increasing amount of information based on monitoring studies conducted during seismic surveys (e.g., Stone 2003; Smultea et al. 2004; Moulton and Miller 2005). Miller et al. (2009) conducted at-sea experiments where reactions of sperm whales were monitored through the use of controlled sound exposure experiments from large airgun arrays consisting of 20-guns and 31-guns. Of 8 sperm whales observed, none changed their behavior when exposed to either a ramp-up at 4-8 mi (7-13 km) or full array exposures at 0.6-8 mi (1-13 km). As noted above with humpback whales, Weir (2008) found that encounter rates and mean distance with sperm whales did not differ significantly according to airgun operational status during a 10-month seismic survey offshore Angola. Weir (2008) also reported that Atlantic spotted dolphins did occur at significantly greater distances from the active array compared to periods when the guns were off, although there was no evidence of prolonged or large-scale displacement.

Most delphinids show some limited avoidance of seismic vessels operating large airgun systems, though seismic operators and marine mammal observers sometimes see dolphins and other small toothed whales relatively close to vessels that are operating airguns. Some dolphins seem to be attracted to seismic vessels and floats and some have been observed to bow-ride with the waves of the vessels even when large arrays of airguns were operating. Nonetheless, there have been indications that small toothed whales sometimes move away, or maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Goold 1996a, b, c; Calambokidis & Osmek 1998; Stone 2003). An example are the lower sighting rates of beluga whales within 6.2-12 mi (10-20 km) of an active seismic vessel recorded during aerial surveys and vessel-based observations conducted as part of seismic operations in the southeastern Beaufort Sea. These results suggest that some belugas might be avoiding seismic operations at distances of up to 12 mi (20 km) (Miller et al. 2005).

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

The distance to received sound levels that could potentially cause a behavioral change in toothed whales is small for the Liberty geohazard survey (about 1 km). In addition, few beluga whales are expected to be present in August in Foggy Island Bay.

Seals

Seals are generally even less responsive to airgun sounds than whales and are not likely to show a strong avoidance reaction to the airgun sources that will be used during the proposed geohazard survey. Visual monitoring from seismic vessels has shown only slight avoidance or other changes in behavior in seals, if any responses occurred at all. Ringed seals do not frequently avoid the area within a few hundred meters of operating airgun arrays (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). However, telemetry work suggests that avoidance and other behavioral reactions by harbor and grey seals to small airgun sources may at times be stronger than evident to date from visual studies of seal reactions to airguns (Thompson et al. 1998). Even if reactions of the seal species occurring in the proposed study area are similar to those in the telemetry study, they will be confined to small distances and durations, with no long-term effects on seal individuals or populations.

7.1.4 Stranding and Mortality

Marine mammals can be killed or severely injured when they happen to be in close proximity to underwater detonations of high explosives. Airgun pulses are much less energetic and have slower rise times. Some marine mammal species appear to be highly susceptible to strong, pulsed sounds (e.g., beaked whales), however, there is no evidence that airgun sounds can result in mortality or stranding. Any effects of this type are highly unlikely for the proposed survey because of the small airgun array, the brief duration of exposure of any marine mammal, and the implementation of shutdown procedures.

7.2 Potential effects of sonar systems

The proposed geohazard survey will use acoustic equipment such as a multibeam echosounder, sidescan sonar, and subbottom profiler to obtain accurate information regarding bathymetry and objects on the seafloor. Sounds produced by these instruments have the potential to cause hearing impairment, masking, and behavioral responses in marine mammals. The extent to which marine mammals may be impacted depends on several factors. There are two main questions that should be considered to assess the impact on marine mammals from these sound sources:

1. Is the sound generated by these instruments within the hearing range of the marine mammal species occurring in the area?
2. If the sound is within the hearing range, what are the propagation characteristics, and at what distances does the generated sound reach levels at which hearing impairment or behavioral responses could occur?

As discussed in previous sections of this application, marine mammal species belonging to three "hearing classes" (from Southall et al. 2007) could occur in the project area:

1. Low frequency cetaceans, believed to hear at frequencies between about 7 Hz and 22 kHz, although based on new information the upper hearing limit is now considered to be about 30 kHz (NOAA 2013). Bowhead and gray whales belong to this hearing class. Bowhead whales generally occur well offshore from the project area and do not occur in the Beaufort Sea in large numbers until mid August or later. Gray whales are not commonly sighted in the Beaufort Sea.
2. Mid-frequency cetaceans, believed to hear at frequencies between about 150 Hz to 160 kHz. Most toothed whale species belong to this hearing class, such as the beluga whale. Although the beluga whale generally travels far offshore, they occasionally occur in coastal waters and therefore could be present in the project area.
3. Pinnipeds, believed to hear at frequencies between about 75 Hz and 75 kHz under water. All three ice seal species that could occur in the project area belong to this hearing class.

Taking into account the auditory bandwidth of the marine mammal species listed above, the multibeam echosounder does not produce frequencies within the hearing range of marine mammals that could occur in the project area. Exposure to sounds generated by this instrument therefore does not present a risk of potential physiological damage, hearing impairment, and behavioral responses.

The sidescan sonar does not produce frequencies within the hearing range of bowhead whales and seals, but when operating at 110-130 kHz could be audible by beluga whales depending on the strength of the signal. The signal from side scan sonars is narrow, typically in the form of a conical beam projected directly below the vessel. Based on previous measurements of a sidescan sonar working at similar frequencies in deeper water, distances to sound levels of 190 and 180 dB re 1µPa (rms) were 22 and 47 m, respectively (Warner and McCrodan 2011). It is unlikely that an animal would be exposed for an extended time to a signal strong enough for TTS or PTS to occur, unless the animal is present within the beam under the vessel and swimming with the same speed and direction. The distance at which beluga whales could react behaviorally to the sidescan sonar signal is about 200 m (Warner and McCrodan 2011). However, the response, if it occurs at all, is expected to be short term and without any biological consequences to the individual animal or population. Masking is unlikely to occur due to the nature of the signal and because beluga whales generally vocalize at frequencies lower than 100 kHz.

Subbottom profilers will be audible to all three hearing classes of marine mammals that occur in the project area. Based on previous measurements of various subbottom profilers, the rms sound pressure level does not reach 180 dB re 1µPa (Funk et al. 2008; Ireland et al. 2009; Warner and McCrodan 2011). Distances to sound levels that could result in mild behavioral responses, such as avoidance, ranged from 1 to 30 m. These mild, short-term behavioral responses would not be significant enough to constitute a “take” under the Marine Mammal Protection Act (NMFS 2001).

7.2.1 Masking

It is unlikely that sounds produced by the geophysical equipment described here will meaningfully mask marine mammal communications given its low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. In the case of bowhead whales, the frequencies of the sonar signals will not overlap with the predominant low frequencies in their calls, further reducing masking potential for bowheads.

7.2.2 Stranding and Mortality

Some stranding events of mid-frequency cetaceans were attributed to the presence of sonar surveys in the area (e.g., Southall et al. 2006). Recently, an independent scientific review panel concluded that the mass stranding of approximately 100 melon-headed whales in northwest Madagascar in 2008 was primarily triggered by a multibeam echosounder system (Southall et al. 2013), acknowledging that it was difficult to find evidence showing a direct cause-effect relationships. The multibeam echosounder proposed in this survey will operate at much higher frequencies, outside the hearing range of any marine mammal. The sidescan sonar and subbottom profiler are much less powerful. Considering the acoustic specifics of these instruments, the shallow water environment, the unlikely presence of toothed whales in the area, and planned mitigation measures, no marine mammal stranding or mortality are expected.

8 ANTICIPATED IMPACT ON SUBSISTENCE

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

Subsistence hunting and fishing are essential for Alaska residents to maintain social organization and household economics, particularly in rural coastal villages (Wolfe and Walker 1987). Resources obtained through subsistence hunting and fishing are highly valued commodities fundamental to the customs and traditions of the Inupiat culture, including artistic expression, religion and family life. Subsistence harvesting provides important sources of nutrition in almost all Arctic rural communities and is a vital part of their livelihood.

BP does not expect that the proposed project activities will adversely affect subsistence hunting. Mitigation measures will be implemented to minimize or completely avoid any adverse effects on the availability of subsistence resources. Additionally, avoidance guidelines and mitigation measures are developed in a formal agreement with the Alaska Eskimo Whaling Commission (AEWC), individual community Whaling Captain's Associations, BP and other industry participants in the form of the CAA.

8.1 Subsistence Resources

Marine mammals are legally hunted in Alaskan waters by coastal Alaska Natives and represent between 60% and 80% of their total subsistence harvest. The species regularly harvested by subsistence hunters in and around the Beaufort Sea are bowhead and beluga whales, ringed, spotted, and bearded seals, and polar bears. The latter is not discussed in this section, as polar bears do not fall under the jurisdiction of NMFS. The importance of each of the subsistence species varies among the communities and is mainly based on availability and season.

The communities closest to the project area are, from west to east, the villages of Barrow, Nuiqsut, and Kaktovik. Barrow is located >200 mi northwest from the survey area. It is the largest community on the Alaska's Beaufort Sea coast with an estimated population of 4,212 in 2010 (U.S. Census Bureau). Important marine subsistence resources for Barrow include bowhead and beluga whales, ice seals, polar bears, and walrus. Nuiqsut is located near the mouth of the Colville River, about 73 mi west of the project area and had a projected population of 402 in 2010 (U.S. Census Bureau). The most important marine subsistence resource for Nuiqsut is the bowhead whale, and to a lesser extent beluga whales, polar bears, and seals. Nuiqsut hunters use Cross Island as a base to hunt for bowhead whales during the fall migration and have historically hunted bowhead whales as far east as Flaxman Island. Kaktovik is located on Barter Island, about 91 mi east of the project area. Major marine subsistence resources include bowhead and beluga whales, seals, and polar bears. Approximately 50% of Kaktovik households participate in fall whaling (Fuller and George 1999).

8.1.1 Bowhead Whale

The bowhead whale is a critical subsistence and cultural resource for the North Slope communities of Barrow, Nuiqsut, and Kaktovik (Table 10). The level of allowable harvest is determined under a quota system in compliance with the International Whaling Commission (IWC 1980; Gambell 1982). The quota is based on the nutritional and cultural needs of Alaskan Natives as well as on estimates of the size and growth of the Bering-Chukchi-Beaufort seas stock of bowhead whales (Donovan 1982; Braund 1992). The AEWC allots the number of bowhead whales that each community is permitted to harvest. Contemporary whaling in Kaktovik dates from 1964 and in Nuiqsut from 1973 (EDAW/AECOM 2007; Galginaitis and Koski 2002). The number of boats used or owned in 2011 by the subsistence whaling crew of the villages of Kaktovik, Nuiqsut, and Barrow was 8, 12, and 40, respectively. These numbers presumably change from year to year.

Bowhead harvesting in Barrow occurs both during the spring (April-May) and fall (September-October) when the whales migrate relatively close to shore (ADNR 2009). During spring, bowheads migrate through open ice leads close to shore. The hunt takes place from the ice using umiaks (bearded seal skin boats). During the fall, whaling is shore-based and boats may travel up to 30 mi a day (EDAW/AECOM 2007). In Barrow, most whales were historically taken during spring whaling. More recently, however, the efficiency of the spring harvest appeared to be lower than the fall harvest due to ice and weather conditions as well as struck whales escaping under the ice (Suydam et al. 2010). In the past few years the bowhead fall hunt has become increasingly important.

Nuiqsut and Kaktovik hunters harvest bowhead whales only during the fall. The bowhead spring migration in the Beaufort Sea occurs too far from shore for hunting because ice leads do not open up nearshore (ADNR 2009). In Nuiqsut, whaling takes place from early September through mid-to-late September as the whales migrate west (EDAW/AECOM 2007). Nuiqsut whalers harvest an average of 2 bowheads each year (Table 10). Whaling from Kaktovik also occurs in the fall, primarily from late August through late September or early October (EDAW/AECOM 2007). Kaktovik whalers hunt from the Okpilak and Hulahula rivers east to Tapkaurak Point (ADNR 2009). Whaling activities are staged from the community rather than remote camps; most whaling takes place within 12 mi of the community (ADNR 2009). Kaktovik whalers harvest an average of 2–3 bowhead whales each year (Table 10).

Table 10. Average number (standard deviation) of bowhead whales landed in each village between 1974-1977 and 1978-2011 (the quota was instituted in 1978). Source: Suydam and George 2011

VILLAGE	1974-1977 AVERAGE/YEAR	1978-2011 AVERAGE/YEAR
Barrow	15.5 (7.05)	15.5 (8.23)
Nuiqsut	0	2.0 (1.22)
Kaktovik	1.5 (1.0)	2.5 (1.0)

8.1.2 Beluga Whale

The harvest of beluga whales is managed cooperatively through an agreement between NMFS and the Alaska Beluga Whale Committee (ABWC). From 2005-2009, 5-48 beluga whales were harvested annually from the Beaufort Sea stock (Allen & Angliss 2013), with a mean annual take of 25.8 animals. Both Nuiqsut and Kaktovik harvest few beluga whales, mostly opportunistically during the fall bowhead hunt.

8.1.3 Seals

Seals represent an important subsistence resource for the North Slope communities. Harvest of bearded seals usually takes place during the spring and summer open water season from Barrow (EDAW/AECOM 2007) with only a few animals taken by hunters from Kaktovik or Nuiqsut. Seals are also taken during the ice-covered season, with peak hunting occurring in February (ADNR 2009). In 2003, Barrow-based hunters harvested 776 bearded seals, 413 ringed seals and 12 spotted seals (ADNR 2009). Nuiqsut hunters harvest seals in an area from Cape Halkett to Foggy Island Bay. For the period 2000-2001, Nuiqsut hunters harvested one bearded seal and 25 ringed seals (ADNR 2009). Kaktovik hunters also hunt seals year-round. In 2002-2003, hunters harvested 8 bearded seals and 17 ringed seals.

8.2 Anticipated Impact

The proposed geohazard survey will take place between 1 July and 30 September, with data acquisition occurring during about 15 days in July and August. The project area is located >200 mi southeast from Barrow, ~73 mi east from Nuiqsut, and ~91 mi west from Kaktovik. Due to the timing of the project and the distance from the surrounding communities, there will be no effects on spring harvesting and little or no effects on the occasional summer harvest of beluga whale and subsistence seal hunts (ringed and spotted seals are primarily harvested in winter, while bearded seals are hunted during July-September in the Beaufort Sea). The community of Nuiqsut may begin fall whaling activities in late August to early September from Cross Island (just north of the survey area). As part of the planned mitigation measures, BP will complete all airgun operations at a date agreed upon by the Nuiqsut whaling captains as captured in the CAA. No or little impact on the fall bowhead hunt from the proposed activities is therefore expected to occur.

As in previous years, BP will communicate with the villages to identify what measures have been or will be taken to minimize adverse impacts of the planned activities on subsistence harvesting (see Section 12 for more details). BP will meet with the AEWC and the communities' Whaling Captains Associations as part of the CAA development, to establish avoidance guidelines, and other mitigation measures to be followed where the proposed activities may have an impact on subsistence.

9 ANTICIPATED IMPACT ON HABITAT

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

The proposed geohazard survey is not expected to result in any permanent impact on habitats used by marine mammals or to the food sources they use. The proposed survey will be of limited spatial and temporal extent and any effects are expected to be localized and short-term.

The primary potential impact associated with the proposed activity will be elevated sound levels and their associated direct effects on marine mammals rather than any specific impact to habitat (see Section 6 and 7). As described in Section 7, avoidance reactions by whales and seals, if they occur, will be of short duration and limited to a relatively small area around the vessel.

With respect to the prey species of seals and some whales, the airguns used in the proposed surveys are small. The characteristics of airgun sounds are such that the zone of potential injury to fish and invertebrates is limited to within a few meters of the source (Buchanan et al. 2004). Adult fish near seismic operations are likely to avoid the immediate vicinity of the sound source and thus avoid injury. The only designated Essential Fish Habitat (EFH) species that may occur in the vicinity of the planned project activities are adult salmon, and their presence in the Beaufort Sea is limited, although possibly increasing (George et al. 2007, Bacon et al. 2009, Fechhelm et al. 2009). While there is limited data on the impacts of airguns and other sound sources on the food sources of whales and seals, there is no information to suggest that any potential impacts will affect marine mammal populations. During the proposed survey BP proposes to conduct a monitoring study that might increase our knowledge about impacts on fish from airgun sounds in a field setting (see Section 13).

10 ANTICIPATED IMPACT OF LOSS OR MODIFICATION OF HABITAT ON MARINE MAMMALS

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

None of the project activities have the ability to damage or otherwise destruct marine mammal habitat that would result in habitat loss or modification.

11 MITIGATION MEASURES

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

The introduction of pulsed airgun sounds into the marine environment is the main source of potential impacts on marine mammal species and is the focus of this request. As discussed in Section 7, exposure to airgun sounds in close proximity to the source may result in different effects to marine mammals, such as behavioral changes, TTS or PTS. The mitigation measures described in this section, implemented to reduce any potential impact on marine mammals, are based on a combination of requirements set forth by NMFS. The mitigation measures can be divided into two main groups:

1. General mitigation measures that apply throughout the survey (Section 11.1); and
2. Specific mitigation measures that apply to airgun operations (Section 11.2).

The primary purpose of the specific measures is to detect marine mammals within, or about to enter designated safety zones and to initiate immediate shutdown or power down of the airgun(s). PSOs are an important component in implementing these mitigation measures. Section 11.3 provides information on the PSO observation protocol, communication procedures, and data recording.

11.1 General mitigation measures

The general mitigation measures apply at all times to the vessel involved in the Liberty geohazard survey. This vessel will operate under an additional set of specific mitigation measures during airgun operations as summarized in Section 11.2.

- To minimize collision risk with marine mammals, the vessel shall not be operated at speeds that would make collisions with whales likely. When weather conditions require, such as when visibility drops, the vessel shall adjust speed accordingly to avoid the likelihood of collisions.

- Vessel operators shall check the waters immediately adjacent to the vessel to ensure that no marine mammals will be injured when the vessel's propellers (or screws) are engaged.
- Vessel operators shall avoid concentrations or groups of whales and the vessel shall not be operated in a way that separates members of a group. In proximity of feeding whales or aggregations, vessel speed shall be less than 10 knots.
- When within 900 ft (300 m) of whales vessel operators shall take every effort and precaution to avoid harassment of these animals by:
    - reducing speed and steering around (groups of) whales if circumstances allow, but never cutting off a whale's travel path; and
    - avoiding multiple changes in direction and speed.
- Sightings of dead marine mammals will be reported immediately to the BP HSSE Representative. The BP HSSE Representative is responsible for ensuring reporting of the sightings according to the guidelines provided by NMFS.
- In the event that any aircraft (such as helicopters) are used offshore to support the planned survey, the mitigation measures below will apply:
    - Under no circumstances, other than an emergency, shall aircraft be operated at an altitude lower than 1,000 ft above sea level (ASL) when within 0.3 mile (0.5 km) of groups of whales.
    - Helicopters shall not hover or circle above or within 0.3 mile (0.5 km) of groups of whales.

11.2 Seismic Survey Mitigation Measures

Specific mitigation measures will be adopted during airgun operations according to NMFS guidelines, provided that doing so will not compromise operational safety requirements. The mitigation measures outlined below have been established by NMFS to prevent marine mammals from exposures to received sound pressure levels of 190 dB dB re 1µPa (rms) for seals and 180 dB re 1µPa (rms) for whales.

PSOs on board the vessel play a key role in monitoring the 190 and 180 dB safety zones and implementation of the mitigation measures. Their primary role is to monitor marine mammals near the vessel during all daylight airgun operations and during any nighttime start-up of the airguns. Pre-season distances to received sound levels of 190 and 180 dB of the proposed airgun arrays were determined based on existing SSV measurements (Table 7A). PSOs will use these distances to monitor the safety zones during the entire project. When marine mammals are observed within, or about to enter, these designated safety zones, PSOs have the authority and the responsibility to call for immediate power down (or shutdown) of airgun operations as required by the situation. A summary of the procedures associated with each mitigation measure is provided below. The criteria are consistent with guidance by NMFS.

11.2.1 Ramp Up Procedure

Ramp up procedures of an airgun array involves a step-wise increase in the number of operating airguns until the required discharge volume is achieved. The purpose of a ramp up (sometimes also referred to as soft start) is to provide marine mammals in the vicinity of the activity the opportunity to leave the area and thus avoid any potential injury or impairment of their hearing abilities.

During ramp up, BP intends to implement the common procedure of doubling the number of operating airguns at 5-minute intervals, starting with the smallest gun in the array. Ramp up of the 30 in^3 array from a shutdown will therefore take 10 minutes for the three-airgun option and 5 minutes for the two-airgun option. First the smallest gun in the array will be activated (10 in^3) and after 5 minutes the second airgun (10 in^3 or 20 in^3). For the three-airgun array an additional 5 minutes are then required to activate the third 10 in^3 airgun.

Ramp up is not required if the duration of the shutdown is less than 10 minutes. Ramp up procedures following a shutdown exceeding 10 minutes in duration will be applied as follows.

1. Ramp up can be started if the safety zone has been free of marine mammals for a consecutive 30-minute period. The entire safety zone must have been visible and under observation by PSOs during the 30-minute period. If the entire safety zone is not visible through the entire 30-minute period, ramp up from a shutdown cannot begin.
2. The 30-minute period will be extended if a marine mammal is sighted within the safety zone. If a marine mammal is seen in the safety zone but is then observed to leave the safety zone, the 30-minute period will resume uninterrupted. Otherwise, the 30-minute observation period has to be restarted from the time of the last sighting of the marine mammal inside the safety zone.
3. If the shutdown was required because of the presence of a marine mammal in the safety zone during sound source operations, ramp up can be started if the marine mammal(s) for which the shutdown occurred has been observed to leave the safety zone or has not been sighted for at least 15 minutes (pinnipeds) or 30 minutes (cetaceans). This assumes that there was a continuous observation effort by PSOs prior to the shutdown and that the entire safety zone was visible.
4. The airgun operator and PSOs will maintain records of the times when ramp-ups start and when the airgun arrays reach full power.

11.2.2 Power Down Procedures

A power down is the immediate reduction in the number of operating airguns such that the radii of the 190 dB and 180 dB (rms) zones are decreased to the extent that an observed marine mammal is not in the applicable safety zone of the full array. For this geohazard survey, the operation of one airgun continues during a power down. The continued operation of one airgun is intended to (a) alert marine mammals to the presence of airgun activity, and (b) retain the option of initiating a ramp up to full operations under poor visibility conditions.

1. The array will be immediately powered down whenever a marine mammal is sighted approaching close to or within the applicable safety zone of the full array, but is outside the applicable safety zone of the single airgun.
2. Likewise, if a mammal is already within the safety zone of the full array when first detected, the airgun array will be powered down to one operating gun immediately.
3. If a marine mammal is sighted within or about to enter the applicable safety zone of the single airgun, it too will be shutdown.
4. Following a power down, ramp up to the full airgun array will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it has been visually observed leaving the safety zone of the full array, or has not been seen within the zone for 15 minutes (seals) or 30 minutes (whales).

11.2.3 Shutdown Procedures

The operating airgun(s) will be shutdown completely if a marine mammal approaches or enters the 190 or 180 dB (rms) safety radius of the smallest airgun for which safety radii are available.

Airgun activity will not resume until the marine mammal has cleared the safety radius of the full array. The animal will be considered to have cleared the safety radius as described above under ramp up procedures.

11.2.4 Poor visibility conditions

BP plans to conduct 24-hr operations. PSOs will not be on duty during ongoing operations during darkness, given the very limited effectiveness of visual observation at night (there will be no periods of darkness in the survey area until mid-August). The proposed provisions associated with operations at night or in periods of poor visibility include the following:

- If during foggy conditions, heavy snow or rain, or darkness (which may be encountered starting after mid-August), the full 180 dB safety zone is not visible, the airguns cannot commence a ramp-up procedure from a full shut-down.
- If one or more airguns have been operational before nightfall or before the onset of poor visibility conditions, they can remain operational throughout the night or poor visibility conditions. In this case ramp-up procedures can be initiated, even though the

safety zone of the full array may not be visible, on the assumption that marine mammals have been alerted by the sounds from the single airgun and have moved away.

BP is aware that available techniques to effectively detect marine mammals during limited visibility conditions (darkness, fog, snow, and rain) are in need of development and has in recent years supported research and field trials intended to improve methods of detecting marine mammals under these conditions.

11.3 Protected Species Observers

Two marine mammal observers (referred to as PSOs) will be present on the vessel during each 12-hour shift. Of these two PSOs, one will be on watch at all times to monitor the 190 and 180 dB safety zones for the presence of marine mammals. The main objectives of the vessel-based marine mammal monitoring are as follows:

1. To implement mitigation measures during airgun operations (e.g., airgun power-down, shut-down and ramp-up); and
2. To record all marine mammal data needed to estimate the number of marine mammals potentially affected, which must be reported to NMFS within 90 days after the survey.

11.3.1 Protected Species Observer Protocol

BP intends to work with experienced PSOs. At least one Alaska Native resident, who is knowledgeable about Arctic marine mammals and the subsistence hunt, is expected to be included as one of the team members aboard the vessel. Before the start of the survey the vessel crew will be briefed on the function of the PSOs, their monitoring protocol, and mitigation measures to be implemented.

At least one observer will monitor for marine mammals at any time during daylight hours (there will be no periods of total darkness until mid-August). PSOs will be on duty in shifts of a maximum of 4 hours at a time, although the exact shift schedule will be established by the lead PSO in consultation with the other PSOs.

The vessel will offer a suitable platform for marine mammal observations. Observations will be made from locations where PSOs have the best view around the vessel. During daytime, the PSO(s) will scan the area around the vessel systematically with reticle binoculars and with the naked eye. Because the main purpose of the PSO on board the vessel is detecting marine mammals for the implementation of mitigation measures according to specific guidelines, BP prefers to keep the information to be recorded as concise as possible. This will allow the observer to focus on detecting marine mammals. The following information will be collected:

- Environmental conditions – consisting of sea state (in Beaufort Windforce scale according to NOAA), visibility (in km, with 10 km indicating the horizon on a clear day), and sun glare (position and severity). These will be recorded at the start of each shift, whenever there is an obvious change in one or more of the environmental variables, and whenever the observer changes shifts;

- Project activity – consisting of airgun operations (on or off), number of active guns, and where possible line number. This will be recorded at the start of each shift, whenever there is an obvious change in project activity, and whenever the observer changes shifts; and
- Sighting information – consisting of the species (if determinable), group size, position and heading relative to the vessel, behavior, movement, and distance relative to the vessel (initial and closest approach). These will be recorded upon sighting a marine mammal or group of animals.

11.3.2 Communication Procedures

When marine mammals in the water are detected within or about to enter the designated safety zones for the airgun array, power-down or shutdown procedures will be implemented immediately. To assure prompt implementation of power-downs and shutdowns, effective channels of communication between the PSOs and the airgun technicians will be established. During the power-down and shutdown, the PSO(s) will continue to maintain watch to determine when the animal(s) are outside the safety radius. Airgun operations can be resumed with a ramp up procedure if the observers have visually confirmed that the animal(s) moved outside the safety zone, or if the animal(s) were not observed within the safety zone for 15 minutes (seals) or for 30 minutes (whales). Direct communication with the airgun operator will be maintained throughout these procedures.

11.3.3 Data Recording

All marine mammal observations and any airgun power-down, shutdown, and ramp up will be recorded in a standardized format. Data will be entered into or transferred to a custom database. The accuracy of the data entry will be verified daily through QAQC procedures. Recording procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to other programs for further processing and archiving.

12 PLAN OF COOPERATION

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

As in previous years, BP considers participation in the CAA, with the Alaska Eskimo Whaling Commission (AEWC) and North Slope communities' Whaling Captains' Associations, as the written Plan of Cooperation with the nearby communities with respect to subsistence bowhead whale hunting. This stakeholder-driven approach to multi-use management has proven to be very effective in reducing conflicts (Lefevre 2013).

With regard to a plan of cooperation for other marine mammal species, BP will communicate with subsistence users in the area to ensure that our activities do not prevent access to the resources should hunting of animals other than the bowhead whale take place during the proposed survey.

12.1 Stakeholder Engagement

BP has begun discussions with the AEWC to develop a CAA intended to minimize potential interference with bowhead subsistence hunting. Initial CAA coordination meetings began in September 2013. BP also attended and participated in meetings with the AEWC on December 13, 2013 and will attend future meetings to be scheduled in 2014. The CAA, when executed, will describe measures to minimize any adverse effects on the availability of bowhead whales for subsistence uses.

The North Slope Borough Department of Wildlife Management (NSB-DWM) will be consulted and BP plans to present the project to the NSB Planning Commission in 2014. BP will hold meetings in the community of Nuiqsut to present the proposed project, address questions and concerns from community members, and provide them with contact information of project management to which they can direct concerns during the survey.

During the NMFS Open-Water Meeting in Anchorage in 2013, BP presented their proposed projects to various stakeholders that were present during this meeting. BP will provide updates to the projects and their monitoring and mitigation measures during the open water meeting of 2014.

BP will continue to engage with the affected subsistence communities regarding its Beaufort Sea activities, as done throughout the history of BP's Alaska North Slope operations. As in previous years, BP will meet formally and/or informally with several stakeholder entities: the North Slope Borough (NSB) Planning Department, NSB-DWM, NMFS, AEWC, Inupiat Community of the Arctic Slope (ICAS), Inupiat History Language and Culture Center (IHLC), USFWS, Nanuq and Walrus Commissions, and ADF&G.

Project information was provided to and input on subsistence obtained from the AEWC and Nanuq Commission at the following meetings:

- AEWC, October 17, 2013
- Nanuq Commission, October 17, 2013

Additional meetings with relevant stakeholders will be scheduled and a record of attendance and topics discussed will be maintained and submitted to NMFS.

12.2 Measures to Reduce Impact

The measures to reduce impacts and ensure communication with the community listed below were developed from the 2013 CAA and previous NSB Development Permits (with specific stipulations addressing subsistence users under NSBMC 19.70.050).

BP will comply with the CAA terms and NSB permit stipulations to address plans to meet with the affected community to resolve conflicts and notify the communities of any changes in the operation. More detailed information about the mitigation measures that will be implemented to reduce impacts to marine mammals are outlined in Section 11 of the IHA request.

- PSOs on board vessels are tasked with looking out for whales and other marine mammals in the vicinity of the vessel to assist the vessel captain in avoiding harm to whales and other marine mammals.;
- Vessels and aircraft will avoid areas where species that are sensitive to noise or vessel movements are concentrated;
- Communications and conflict resolution are detailed in the CAA. BP will participate in the Communications Center that is operated annually during the bowhead subsistence hunt;
- Communications with the village of Nuiqsut to discuss community questions or concerns including all subsistence hunting activities;
    - Pre-project meeting(s) with Nuiqsut representatives will be held at agreed times with groups in the community of Nuiqsut. If additional meetings are requested, they will be set up in a similar manner;
- Contact information for BP will be provided to community members and distributed in a manner agreed at the community meeting;
- BP has contracted with a liaison from Nuiqsut who will help coordinate meetings and serve as an additional contact for local residents during planning and operations;
- Inupiat Communicators will be employed and work on the vessel. They will also serve as PSOs; and
- BP and contractors will follow a Polar Bear and Pacific Walrus Awareness and Interaction Plan addressing food and waste management, personnel training, reporting guidance on sightings, and safety and communication regarding polar bears.

12.3 Future Plan of Cooperation Consultations

BP continues to engage with the relevant subsistence communities regarding its Beaufort Sea activities, as done throughout the history of BP's Alaska North Slope operations. With regard to the proposed Liberty geohazard survey, BP will present the data on marine mammal sightings and the results of the marine mammal monitoring and mitigation as part of our 90-day report to the regulatory authorities. BP will also present the results at the 2015 NMFS Open-Water Meeting in Anchorage, which is attended by many representatives of interested stakeholder groups, including the NSB DWM and AEWC.

13 MONITORING AND REPORTING PLAN

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

In keeping with guidance provided by the NMFS in Section 5.3 of the 2013 Supplemental Draft Environmental Impact Statement (SDEIS), BP considered a number of monitoring and reporting opportunities that could contribute to the collective knowledge of marine mammals, marine mammal prey, and marine mammal habitat. The potential to conduct meaningful research on impacts of airgun sounds on marine mammals during the shallow water Liberty geohazard survey is limited due to the small number of animals in the region and other factors. However, the potential to conduct research on fish species in relation to airgun operations–including prey species important to ice seals–may yield valuable information relevant to Section 5.3.1(e) of the SDEIS, which calls for "an increase in our understanding of how the activity affects marine mammal habitat, such as through effects on prey sources or acoustic habitat." The effect of airgun sounds on large-scale fish behavior is an issue of concern not only for marine mammal conservation but also for the Inupiat traditional Arctic cisco fishery in Nuiqsut, Alaska.

13.1 Fish and Sound Monitoring

Combined with the North Prudhoe OBS seismic survey, the proposed geohazard survey offers a unique opportunity to assess the impacts of sounds on fish, specifically on changes in fish abundance in fyke nets that have been sampled in the area for more than thirty years. During the first two months of the open water season from 1981 through 2013, biologists contracted by BP checked fyke nets daily, with the exception of 1999 and 2000. Figures 2 and 3 show fyke net sampling and a fyke net design and Figure 2 shows the fyke net locations relative to the planned geohazard survey. Primary species caught are Arctic cisco (*Coregonus autumnalis*), least cisco (*Coregonus sardinella*), northern Dolly Varden (*Salvalinus malma*), broad whitefish

(*Coregonus nasus*), humpback whitefish (*Coregonus pidschian*), Arctic flounder (*Liopsetta glacialis*), fourhorn sculpin (*Myoxocephalus quadricornis*) and rainbow smelt (*Osmerus mordax*). In a typical year, more than 50,000 fish representing 18 species are caught in the fyke nets. In 2012, more than 30,000 fish were caught of which about 40% consisted of Arctic cisco and broad whitefish (Fechhelm & Raborn 2013).

Figure 2. Fyke net sampling in Prudhoe Bay.

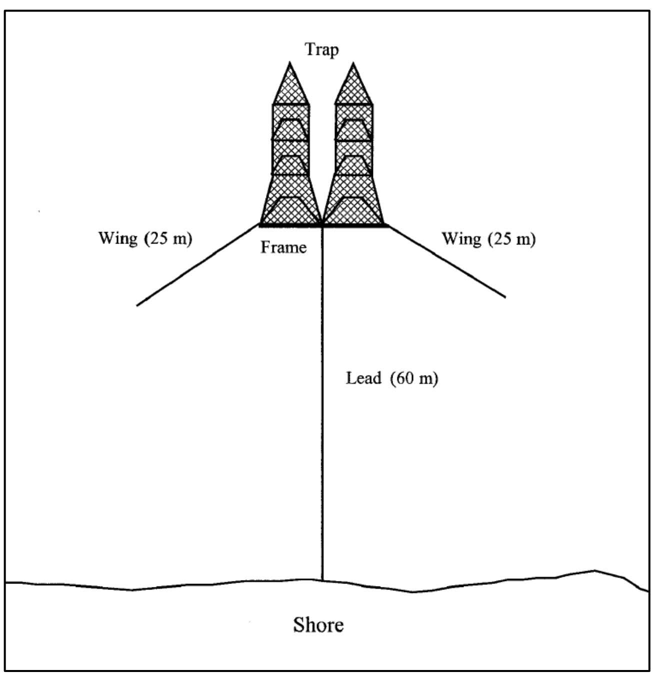

Figure 3. Fyke net design and layout.

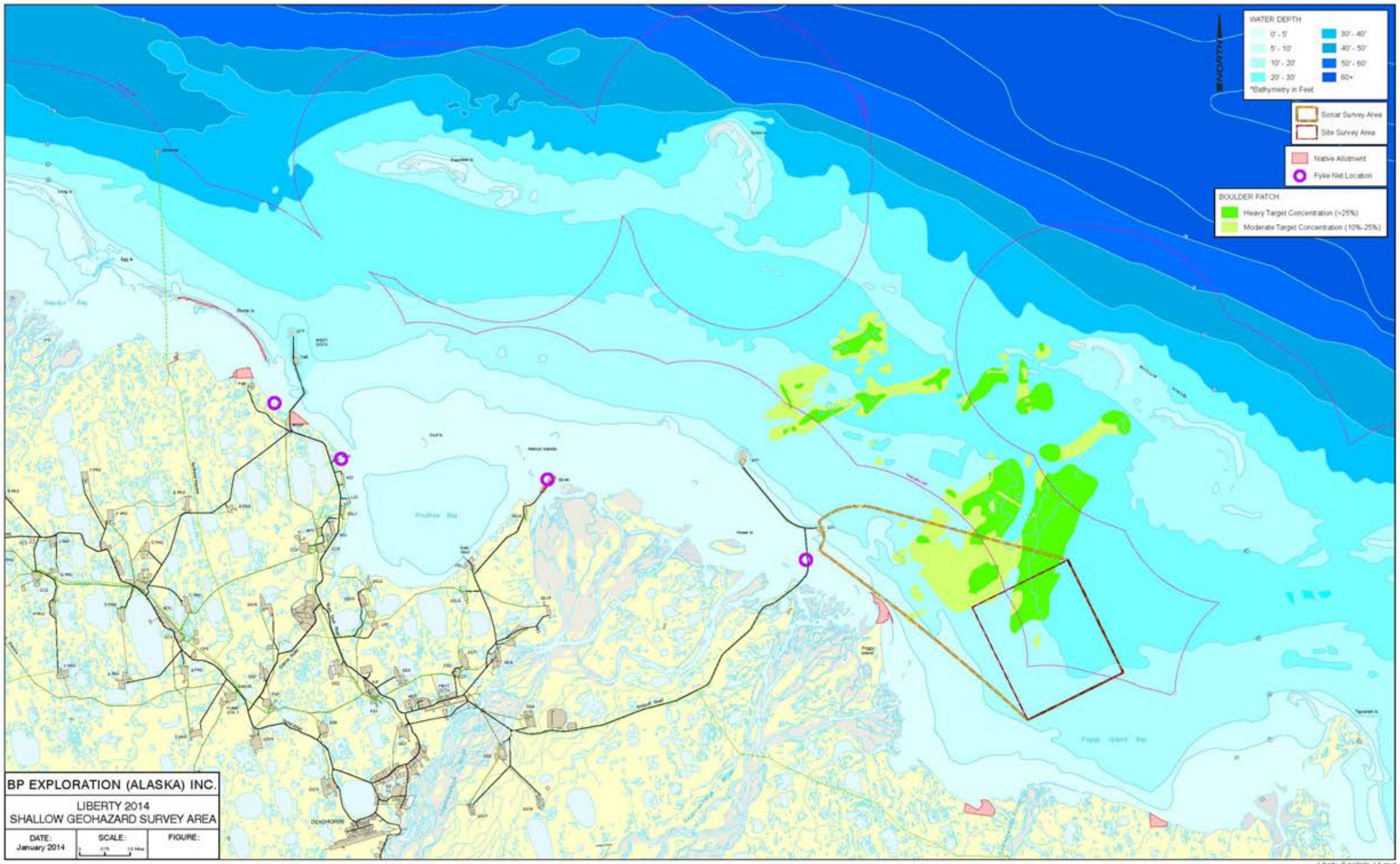

Figure 2. Liberty geohazard survey are in relation to locations of long-term fyke net stations. Water depth at fyke net stations is 1-1.5 m.

During the two-month study period, fish are counted and sized every day, unless sampling is prevented by weather, the presence of bears, or other events. Fish mortality is also noted. The fish-sampling period coincides with the Liberty geohazard survey (as well as the North Prudhoe Bay Seismic Survey, described in a separate application), resulting in a situation where fish captured in each of the four fyke nets will have been exposed to varying daily exposures to sounds from various sources, including airguns and other sources described in this application.

To document relationships between fish catch in each fyke net and received sound levels, BP will attempt to instrument each fyke net location with a recording hydrophone. Recording hydrophones, to the extent possible, will have a dynamic range that extends low enough to record near ambient sounds and high enough to capture sound levels during relatively close approaches by sources associated with BP's activities (i.e., likely levels as high as about 200 dB re 1 uPa for airgun arrays associated with the North Prudhoe Bay Seismic Survey, and substantially lower for sources associated with the Liberty geohazard survey). Bandwidth will extend from about 10 Hz to at least 500 Hz.

In addition, because some fish (especially salmonids) are likely to be sensitive to particle velocity instead of or in addition to sound pressure level, BP will attempt to instrument each fyke net location with a recording particle velocity meter.

Acoustic and environmental data will be used in statistical models to assess relationships between acoustic and fish variables. Table 11 lists possible variables that could be included in the analyses.

Additional analyses may compare catch rates immediately before and after the beginning of airgun operations and immediately before and after cessation of airgun operations. Other analyses could assess changes in multi-year catch patterns that could be attributed to BP operations.

Table 11. Possible acoustic, fish, and environmental variables that could be considered for multi-variate analyses to determine the impact from airgun sounds on fish.

Fish variables	Acoustic variables	Environmental variables
Daily fish abundance per net (probably in Log of Catch per Unit Effort)	Daily maximum rms and peak sound pressure levels	Julian day
Daily number of fish mortalities for each species in each net	Daily maximum per pulse sound exposure levels	Daily wind conditions
	Daily cumulative sound exposure levels	Daily water temperatures
	Daily average such as Leq (equivalent continuous noise level)	Tide conditions
	Daily average and maximum particle velocity values	

Details of the study, including a detailed analytical plan, will be determined after the study has been approved as part of the Incidental Harassment Authorization. These details will be developed in consultation with an expert panel. Professor Art Popper and Dr. Tony Hawkins, both world-renowned for their work with fish responses to underwater sound, have agreed to serve on the panel. Other panelists invited to serve on the panel will include a fisheries biometrician, a North Slope Borough biologist, a NOAA representative, and a subsistence hunting representative from Nuiqsut.

13.2 Reporting

90-day report

BP will submit a report to NMFS within 90 days after the end of the shallow geohazard survey summarizing relevant project information and results from the PSO program. Summaries of the project activities and results of the marine mammal monitoring and mitigation data will include the following information:

- Summary of project start and end dates, airgun activity, number of guns, and the number and circumstances of implementing ramp up, power down, shutdown, and other mitigation actions;
- Marine mammal observation effort in total number of hours and total number of line kilometers. This will include a summary of environmental conditions that can affect marine mammal detection, such as visibility and sea state;
- A summary of marine mammal sighting information, such as species observed, group sizes, behavior, distribution, and the date and time of each sighting;
- A summary of sighting information related to airgun activity, including (a) marine mammal sighting rates; (b) sighting distances (initial and closest point of approach); and (c) observed behaviors and movements; and
- An estimate of seal and whale exposures to sound levels of 160 dB re 1µPa (rms) and a comparison to the estimated exposures in the IHA application. BP cannot provide estimates of “takes” since it is impossible to determine which exposures would have resulted in a behavioral response that would be considered a “take” as defined by the MMPA.

Fish and Airgun Sound Report

- BP will present the results of the fish and airgun sound study to NMFS in a detailed report that will also be submitted to a peer reviewed journal for publication, presented at a scientific conference, and presented in Barrow and Nuiqsut.

14 COORDINATING RESEARCH TO REDUCE AND EVALUATE INCIDENTAL HARASSEMENT

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

Provided that an acceptable methodology and business relationship can be worked out in advance, BP will work with any number of external entities, including other energy companies, agencies, universities, and NGOs, in its efforts to manage, understand, and fully communicate information about environmental effects related to activities that produce anthropogenic sound.

BP remains committed to an improved understanding of the cumulative effects of multiple sound sources. BP has sponsored an expert working group through the University of California tasked with development of a method (or methods) for better understanding cumulative effects on marine mammals associated with underwater sound. Experts from the NSB, the NMFS, the Marine Mammal Commission (MMC), and a number of other organizations have participated in this working group. The NSB also contributed funding and logistical support. The method developed by the working group, as it stands in late 2013, includes three key steps:

1. Model the acoustic footprint in a region of interest over a period of interest (e.g., the Beaufort Sea during a fall migration);
2. Let simulated whales (animats) swim through the modeled footprint, and
3. Collect sound exposure data from each of the animats swimming through the modeled footprint and analyze this data.

In 2012, BP, with the support of the working group, presented the method to the Society of Petroleum Engineers in Perth, Australia, and published a summary paper in the proceedings from the conference (Streever et al. 2012). In late 2013, the working group submitted a paper fully describing the method to a technical journal for publication. The working group continues to pursue a qualitative method for assessing cumulative effects. BP has been contacted by various individuals associated with the National Research Council about interest in the issue and the approach adopted by the expert working group. BP hopes to see this effort continued and expanded in the coming year.

In 2013, BP, with ConocoPhillips and LAMA Ecological, hosted a workshop on modeling and measurement of underwater sounds as they apply to development of mitigation radii at the Alaska Marine Science Symposium in Anchorage. The workshop led to further work presented at the 2013 Third International Conference on the Effects of Underwater Sound on Aquatic Life. This work will be published in the conference proceedings.

BP continues to support conferences and workshops related to underwater sound, including, for example, the 2013 Third International Conference on the Effects of Underwater Sound on Aquatic Life. Support includes both funding and organizational assistance.

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APPENDIX A

Comparison of Modeled and Measured Underwater Sound Isopleths and Implications for Marine Mammal Mitigation in Alaska

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Modeled and Measured Underwater Sound Isopleths and Implications for Marine Mammal Mitigation in Alaska

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Airgun, seismic, "take" estimate, MMPA

Abstract

Prior to operating airguns in Alaska, industry is usually required to model underwater sound isopleths, some of which have implications for mitigation and monitoring of potential marine mammal impacts. Field measurements are often required to confirm or revise model predictions. We compared modeled and measured airgun sound isopleths from 2006–2012 and found poor agreement. Natural variability in the marine environment, application of precautionary correction factors, and data interpretation in the generation of circular isopleths all contributed to the observed poor agreement. A broader understanding of the realities of modeled and measured underwater sound isopleths will contribute to improved mitigation practices.

1. Introduction

In seismic operations, the oil and gas industry tows airguns behind vessels to generate sound impulses. These vessels are generally referred to as “source vessels.” Images of the stratigraphy underlying the seabed are generated from reflected sound impulses. These images are used to guide exploration and production drilling, manage existing reservoirs, and identify hazards buried in the seabed. As such seismic operations are essential to the offshore oil and gas industry.

The sound impulses generated by airguns could, under certain circumstances, “take” marine mammals. The United States Marine Mammal Protection Act (MMPA) requires efforts to prevent “take”, a term that means actual injury as well as disruption of behavioral patterns (including migration, breathing, nursing, breeding, feeding, or sheltering). In addition, the MMPA requires efforts to document the number of “takes” that can occur despite preventative measures. Actual observations of impacts meeting the definition of “take” are rare, in part due to the difficulties associated with making and interpreting observations at sea. With that in mind, sound exposures are often used as a surrogate for “takes.”

During airgun operations in the Alaskan Arctic, marine mammal mitigation and monitoring required by the government in its administration of the MMPA requires knowledge of the extent of the 190, 180, 160, and 120 dB re 1 μPa (rms) isopleths. Airguns cannot be operated if seals are present within the 190 dB re 1 μPa (rms) isopleth or if cetaceans are present within the 180 dB re 1 μPA (rms) isopleth. The 160 and 120 dB re 1 μPa (rms) isopleths can trigger additional mitigation requirements. Also, animals exposed to impulsive sounds of 160 dB re 1 μPa (rms) or more (such as those associated with airguns) or continuous sounds of 120 dB re 1 μPa (rms) or more (such as those associated with vessel operations) are assumed to be potentially "taken" regardless of whether harm or meaningful behavioral responses are observed.

"Take" estimates for airgun sounds are generally derived by multiplying the extent of the modeled or measured sound isopleths of 160 dB re 1 μPa (rms) with expected species densities from scientific surveys or field observations made during previous seismic operations in the area of interest. Both sound isopleths and species densities are associated with high levels of uncertainty. In this paper we focus on the uncertainties associated with sound isopleths.

Information on the extent of sound isopleths comes from acoustic models and from acoustic measurements. Acoustic models combine information about source levels with information about factors known to affect sound propagation (including water depth, water temperature, salinity, and seabed characteristics) to yield three dimensional (distance and depth) estimated distances at which various sound levels are received. Acoustic measurements typically rely on hydrophones recording at numerous distances from a source. Both endfire and broadside measurements are sometimes reported. Endfire measurements, or measurements from the bow and stern aspects of a source vessel, are usually collected using several bottom founded hydrophones that record airgun sounds while the source vessel approaches and moves away. Broadside measurements, from the port or starboard aspects of a source vessel, are usually collected by three or more recording hydrophones placed in a line perpendicular to the source vessel's direction of travel. In contrast to acoustic models, acoustic measurements typically yield two-dimensional (distance but not depth) estimated distances at which various sound levels are received. In both cases, to facilitate mitigation and monitoring requirements in the field, isopleths are generally plotted as circles even if models or measurements indicate that actual isopleths have an irregular shape.

Over the past six years in the Alaskan Arctic, airgun operators have used both acoustic models (to predict the extent of sound isopleths) and acoustic measurements (to verify the modeled predictions). In this paper, we compare sound isopleths derived from models to those derived from measurements. In addition, we discuss the causes and ramifications of the differences in estimates derived from models and measurements, and we assess the degree to which agreement has improved over time.

2. Data Compilation of Modeled and Measured Sound Isopleths

Modeled sound isopleths from airgun operations in the Alaskan Arctic are generally reported in Requests for an Incidental Harassment Authorization (IHA) of Marine Mammals submitted to the National Marine Fisheries Service (NMFS), the government agency responsible for administering the MMPA as it applies to seals and whales. Detailed results of acoustic measurements conducted during airgun operations of the oil and gas industry are documented in monitoring reports which, according to the IHA stipulations, have to be submitted to the NMFS within 90 days of survey completion.

We obtained IHA Requests and 90-day monitoring reports of seismic surveys in the Alaskan Arctic during the period 2006–2012 from the website of the NMFS Office of Protected Resources (http://www.nmfs.noaa.gov/pr/permits/incidental.htm) (Ireland et al., 2007; Aerts et al., 2008; Funk et al., 2008; Hauser et al., 2008; Hannay & Warner 2009; O'Neill et al., 2010; Chorney et al., 2011; Warner & Hipsey, 2011; Warner & MCCrodan, 2011; McPherson & Warner, 2012) . We only compiled isopleth information for sound pressure levels that are assumed to have the potential to harm marine mammals (190 and 180 dB re 1μPa rms, for pinnipeds and cetaceans, respectively), that are used for calculating behavioral "takes" of airgun sounds (160 dB re 1μPa rms), or that might trigger mitigation requirements under some circumstances (120 dB re 1μPa rms). When available, we included both endfire and broadside measurements of the airgun sounds.

Modeled and measured isopleths from various airgun operations, involving different airgun discharge volumes and taking place in different areas, were compiled in a single database. We included the following information if available: year of survey, total airgun discharge volume (cubic inches [in^3]), smallest airgun in array (in^3), water depth in survey area (meters [m]), modeled distances to the four received sound pressure levels (m), and measured distances to the four sound pressure levels for both endfire and broadside aspects.

3. Results of Sound Isopleth Comparisons

We compiled 133 records of modeled and measured sound isopleth data from airgun operations in the Chukchi and Beaufort Seas from 2006 through 2012. Airgun operations included offshore marine streamer seismic surveys, ocean bottom cable (OBC) seismic surveys, and shallow hazard surveys. Offshore marine streamer seismic surveys used airgun discharge volumes ranging from 3,000–3,390 in^3 (up to 24 airguns) and occurred in water depths of 15–50 m. OBC seismic surveys took place in shallower water (1–20 m) and used airgun discharge volumes ranging from 320–880 in^3 (with up to 16 guns). The shallow hazard surveys for which we compiled sound isopleth data were done in water depths of 15–50 m, using 1–4 airguns of 10 in^3 each. Modeling and measurements were also done for the mitigation gun, i.e., the smallest gun in the array. Discharge volumes of mitigation guns ranged from 10–70 in^3.

Although modeling and measurement occasionally yielded sound isopleths that were in close agreement with one another, differences could be substantial (Fig. 1). For example, differences in distances to modeled and measured sound isopleths were as high as 920 m, 2,900 m, 13,405 m, and 130,000 m for the 190, 180, 160, and 120 dB re 1 μPa (rms) isopleths, respectively. Even for the smallest sources—those with airgun volumes of 10–70 in^3—differences between modeled and measured sound isopleths were as high as 150 m, 360 m, 1,120 m, and 11,392 m for the 190, 180, 160, and 120 dB re 1 μPa (rms) isopleths, respectively. Percentage differences in measured and modeled sound isopleths from the smaller airgun arrays and higher sound pressure levels were more substantial than for the larger arrays and lower sound pressure levels (Fig.1). In many cases, differences between modeled and measured estimates for a single source along a single transect were positive for some isopleths and negative for others. There was no pattern apparent between modeled and measured distances that would suggest a clear path to a correction factor. Also, there was no evidence of improved agreement over time, as might be expected if methods were improving as experience accumulated (Fig. 2). In fact, the only clear pattern was one of generally increasing differences with distance from the source, as would be expected at the larger distance scales associated with isopleths for lower sound pressure levels (Fig. 2).

Figures 1 and 2 somewhere here

4. Discussion

Distance discrepancies between modeled and measured sound pressure level isopleths can be attributed to a number of causes, ranging from inadequate input data for models to decisions about how to interpret modeled and measured data and how to convert output to circular mitigation and monitoring zones. Model predictions of underwater sound isopleths require knowledge of the source and of sound propagation. Underwater sound propagation is complex and dependent on numerous factors, such as, but not limited to, water depth, bottom type and relief, surface reflection, absorption and sound speed profile (influenced by temperature and salinity, among other), source depth, and source characteristics (e.g., frequency composition, directivity). Many of these factors are subject to temporal and spatial variability and it is unlikely that data used in models routinely reflect actual conditions during measurements.

Because uncertainty is inherent to modeling, cautionary adjustments are sometimes made to input data. For example, source levels are sometimes elevated by 3 dB re 1µPa (rms). Likewise, conservative interpretations are introduced in the measured sound isopleths that are used for mitigation purposes. In most cases, regression lines drawn through measured data points are adjusted upward to assure that 90% or in some cases 100% of data points are below the regression line used to define mitigation isopleths.

Modeling typically results in isopleths with an irregular shape, reflecting differences to modeled sound pressure levels at different depths and at different directions that are related to source directivity and sound propagation. However, the practical needs of mitigation and monitoring require conversion of these irregular shapes to circles. Typically, these circles are drawn to capture the greatest modeled distance to each isopleth, regardless of depth or bearing from the source. Measurements, on the other hand, are typically undertaken along one or a few bearings (forward, aft, and abeam of the source vessel) and at a single depth, typically close to the seabed. Measurements taken abeam of the source vessel are usually based on a small number of data points. Measurements are sometimes extrapolated to capture isopleths beyond the range of the measurements, which has the capacity to introduce substantial errors, especially at the 160 and 120 dB re 1μPa (rms). When measurements are collected at more than one bearing, the bearing with the longest distance to each isopleth is often used to define the circle used for mitigation and monitoring. The conversion of irregularly shaped polygons to circles may account for most of the modeling versus measured discrepancies described in this paper.

The challenges associated with modeling isopleths, the practice of limiting measurements to a single depth and a small number of bearings from a source vessel, and the practical need to convert irregularly shaped isopleths to circles for the purpose of mitigation and monitoring explain the poor agreement between modeled and measured isopleths. There is little reason to believe that agreement between modeled and measured isopleths will improve unless substantial changes are made to methods, including standardization of all aspects of the process. However, the real issue may not be one of improving agreement of modeled and measured isopleths, but rather one of applying mitigation distance requirements that adequately protect marine mammals without unnecessarily disrupting seismic operations. This requires not only improved methods of defining sound isopleths, but also an improved understanding of the levels and kinds of sounds likely to harm marine mammals and improved methods of detecting and ranging marine mammals under field conditions.

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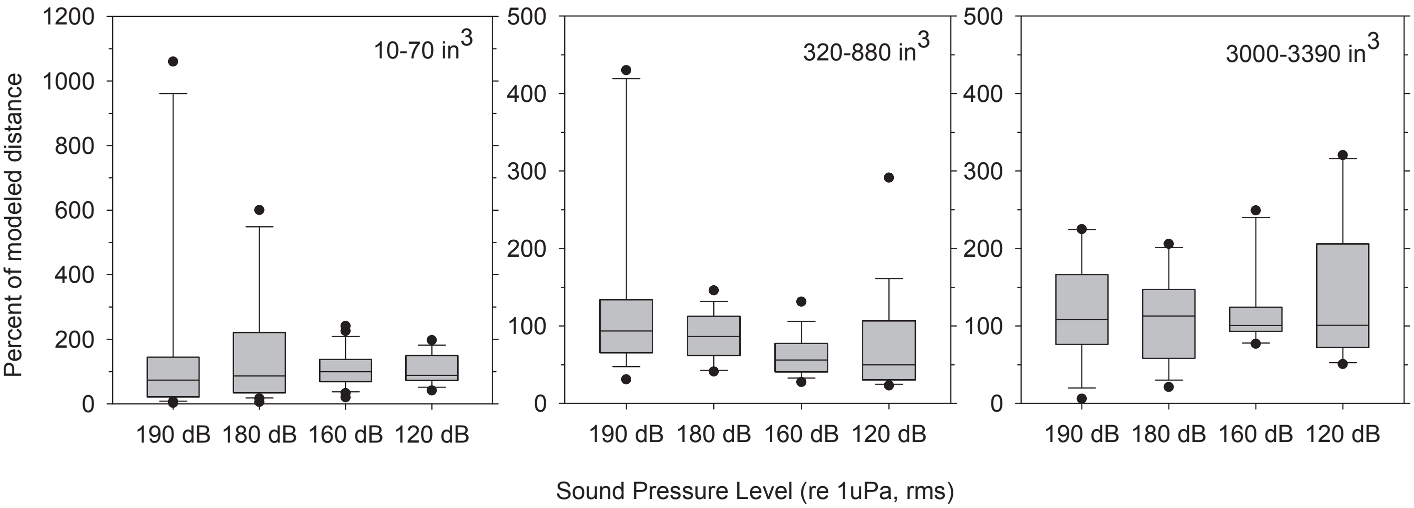
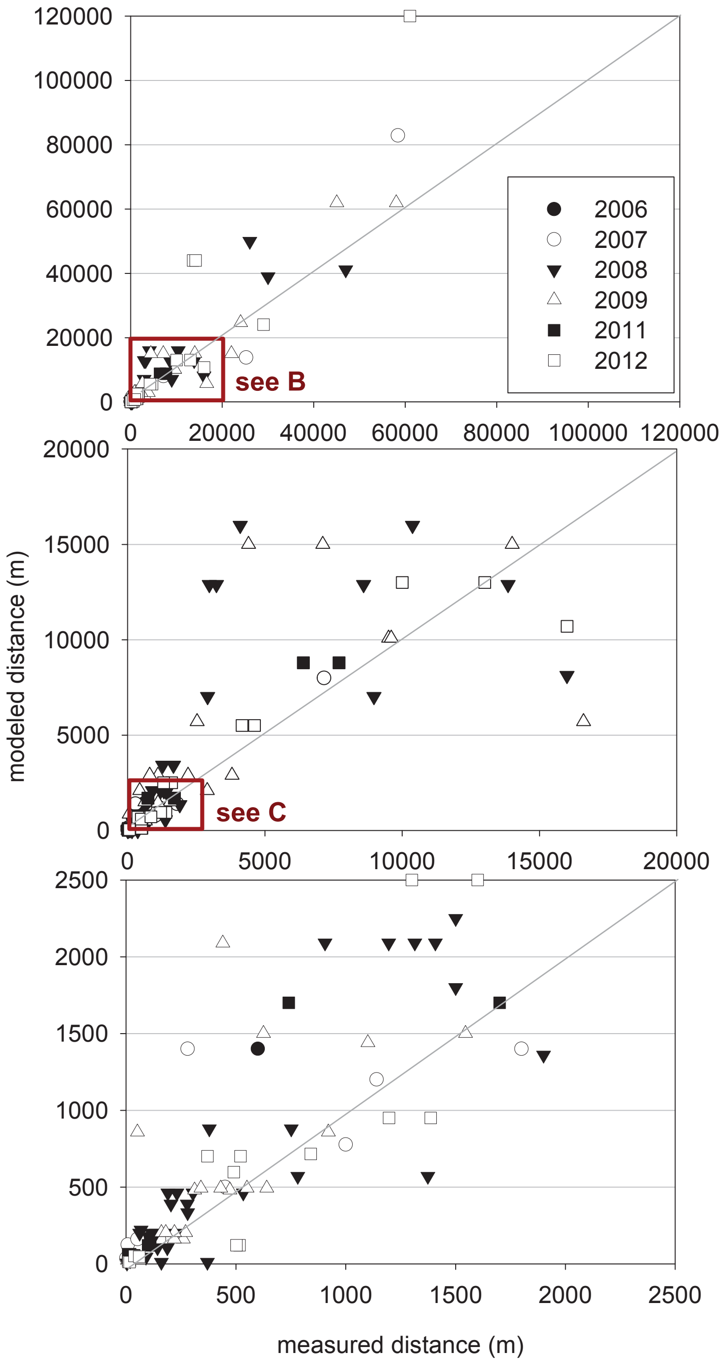
Figure legends

Figure 1. Differences between measured and modeled sound isopleths for four different sound pressure levels and three airgun volume categories. The difference is expressed in percentage of modeled distances. Boxplots show the 5, 25, 50, 75, and 95% percentage values. Note the different scale used for the 10-70 in^3 airgun graph, in which two outliers (1600% and 3600% for the 190 dB and 180 dB re 1µPa sound levels, respectively) are not displayed.

Figure 2. Modeled versus measured distances from several airgun sources to various received sound pressure levels for surveys conducted in the Alaskan arctic from 2006–2012. Points on the diagonal line represent 100% agreement between modeled and measured distances. Graphs are shown in three different scales as represented by the red squares.



Percent of modeled distance
0
200
400
600
800
1000
1200
10-70 in3
190 dB
180 dB
160 dB
120 dB
0
100
200
300
400
500
320-880 in3
190 dB
180 dB
160 dB
120 dB
0
100
200
300
400
500
3000-3390 in3
190 dB
180 dB
160 dB
120 dB
Sound Pressure Level (re 1uPa, rms)



2006
2007
2008
2009
2011
2012
see B
see C
modeled distance (m)
measured distance (m)