

**MARINE MAMMAL MONITORING
AND MITIGATION PLAN**

for

**Exploration Drilling of Selected Lease Areas
in Camden Bay in the Alaskan Beaufort Sea in 2012**



Shell Offshore Inc.

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ACRONYMS

~	approximately
°	degree
°C	degrees Celsius
°T	degrees True North
4MP	Marine Mammal Monitoring and Mitigation Plan
μPa	micropascal
ADF&G	Alaska Department of Fish and Game
AEWC	Alaska Eskimo Whaling Commission
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CDs	compact discs
cm ³	cubic centimeters
Com Center	Communications and Call Centers
COPAC	Coastal and Offshore Pacific Corporation
DASAR	Directional Autonomous Seafloor Acoustic Recorder
dB	decibel(s)
<i>Discoverer</i>	Motor Vessel <i>Noble Discoverer</i>
DSLR	digital single lens reflex (camera)
GPS	Global Positioning System
ft	feet
ft ²	square feet
hr	hour
Hz	Hertz
IHA	Incidental Harassment Authorization
in ³	cubic inches
kHz	kilohertz
km	kilometer(s)
km ²	kilometers squared
km/hr	kilometers per hour
lb	pounds
Leq	noise equivalent level
LGL	LGL Alaska Research Associates, Inc.
LOA	Letter of Authorization
m	meter(s)
m ²	square meters
μPa	micropascal
mi	mile(s)
MMPA	Marine Mammal Protection Act
PSO	Protected Species Observer
MMS	Minerals Management Service
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NSB	North Slope Borough
NVD	night-vision device
psi	pounds per square inch
rms	root mean square
Shell	Shell Offshore Inc.

Twin Otter	DeHavilland Twin Otter
USFWS	U.S. Fish and Wildlife Service
VSI	vertical seismic imager
VSP	vertical seismic profile
ZVSP	zero-offset vertical seismic profile

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INTRODUCTION

Shell Offshore Inc. (Shell) submits the following Marine Mammal Monitoring and Mitigation Program (4MP) for exploration drilling activities in Camden Bay in the Beaufort Sea during the 2012 open-water season. The 4MP developed for Shell's exploration drilling program is designed to protect the marine mammal resources in the area, fulfill reporting obligations to the Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS), and establish a means for gathering additional data on marine mammals for future operations planning.

Shell plans to conduct exploration drilling within existing lease holdings in Camden Bay of the Beaufort Sea. One drilling vessel, either the conical drilling unit *Kulluk* (*Kulluk*) owned by Shell, or the drillship Motor Vessel (*M/V*) *Noble Discoverer* (*Discoverer*) owned and operated by Noble Drilling will be used in the Beaufort Sea during the 2012 exploration drilling activities, but not both. The *Kulluk* is an ice-class drilling platform designed, engineered and constructed to safely operate in the Arctic. The *Discoverer* is an ice-class drillship also designed, engineered and constructed to safely operate in the Arctic. In addition to the drilling equipment, several support vessels will be used. The support vessels will include tugs and barges, a primary ice management vessel, an anchor handler/ice management vessel, resupply vessels, vessels to store and transport drilling muds and other materials, and oil spill response vessels.

At the completion of each well a zero-offset vertical seismic profile (ZVSP) likely will be conducted. During ZVSP surveys, an airgun array is deployed adjacent to the drillship, while geophone receivers are lowered into the wellbore. The sound source (airgun array) is fired repeatedly, and the sonic waves are recorded by receivers (geophones) located in the wellbore. The survey will last 10-14 hours as the receivers are moved through the length of the wellbore and the airguns are fired 5-7 times after each movement. The purpose of the ZVSP is to gather geophysical information at various depths, which can then be used to tie-in or ground-truth geophysical information from the previous seismic surveys with geological data collected within the wellbore.

Shell's 4MP is a combination of active monitoring of the area of operations and the implementation of mitigation measures designed to minimize project impacts to marine resources. Monitoring will provide information on the numbers of marine mammals potentially affected by the exploration operations and facilitate real time mitigation to prevent injury of marine mammals by industrial sounds or activities. These goals will be accomplished by conducting vessel-based, aerial, and acoustic monitoring programs to document the potential reactions of marine mammals in the area to the various sounds and activities and to characterize the sounds produced by the exploration drilling activities, support vessels, and ZVSP.

Monitoring during exploration drilling activity and periods when exploration drilling activity is not occurring will provide information on the numbers of marine mammals

potentially affected by the exploration operations and facilitate real time mitigation to prevent impacts to marine mammals by industrial sounds or activities. Vessel-based marine mammal observers (Protected Species Observers or PSOs) onboard the *Kulluk* or *Discoverer* and all support vessels will record the numbers and species of marine mammals observed in the exploration area and any observable reaction of marine mammals to the exploration activities. Aerial monitoring, designed primarily for detecting cetaceans, will be used to identify any large scale distributional changes of cetaceans relative to the activities and add to the existing database on the abundance and distribution of observed species. An addition to the aerial monitoring in 2012 is the capture of digital still and video imagery at the same time as the aerial surveys. This imagery will be collected with sensors that will be deployed in unmanned aerial systems (UAS) in the future and the data will be used to validate and compare observations made by people with those obtainable in the imagery. The acoustic program will characterize the sounds produced by the exploration drilling activities and support vessels, and document the potential reactions of marine mammals in the area, particularly bowhead whales, to those sounds and activities.

VESSEL-BASED MARINE MAMMAL MONITORING PROGRAM

Introduction

The vessel-based operations of Shell's 4MP are designed to meet the requirements of the Incidental Harassment Authorization (IHA) and Letter of Authorization (LOA) requested from NMFS and USFWS, respectively, for this project, and to meet any other stipulated agreements between Shell and other agencies or groups. The objectives of the program will be:

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

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

The vessel-based portion of Shell's 4MP will be required to support the exploration drilling activities in the eastern Alaskan Beaufort Sea. The dates and operating areas will depend upon ice and weather conditions, along with Shell's arrangements with agencies and stakeholders. Exploration drilling activities are expected to begin July 10 and continue through October 31, 2012 with a break from 25 August to mid-to-late September to prevent interference with subsistence whaling activities. The exact date

when drilling operations will recommence in September is not known at this time, but they will restart once Nuiqsut and Kaktovik have called an end to fall whaling. Vessel-based monitoring for marine mammals will begin 5–7 days before exploration drilling begins (i.e. anchors are deployed); will continue throughout the period of exploration drilling operations, and will cease 5-7 days after exploration drilling stops (i.e. anchors are pulled) to comply with anticipated provisions in the IHA and LOA that Shell expects to receive from NMFS and USFWS.

The vessel-based work will provide:

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

The 4MP will be operated and administered consistent with monitoring programs conducted during seismic and shallow hazards surveys in 2006–2010 or such alternative requirements as may be specified in the IHA and LOA received from NMFS and USFWS, respectively for this project. Any other stipulated agreements between Shell and agencies or groups such as BOEM, BSEE, the North Slope Borough (NSB), the local whaling captains associations, and the Alaska Eskimo Whaling Commission (AEWC) will also be fully incorporated. All PSOs will be provided training through a program approved by NMFS, USFWS (if so stipulated) and Shell, as described later. At least one observer on each vessel will be an Inupiat who will have the additional responsibility of communicating with coastal communities and directly with Inupiat whalers during the whaling season. Details of the vessel-based marine mammal monitoring program are described below.

Mitigation Measures During Exploration Drilling Activities and Zero-Offset Vertical Seismic Profile Surveys

Shell’s planned offshore exploration drilling program incorporates both design features and operational procedures for minimizing potential impacts on marine mammals and on subsistence hunts. The design features and operational procedures of the mitigation measures have been described in the IHA (Section 12 of the IHA application to which this 4MP is appended) and LOA applications submitted to NMFS and USFWS respectively, and are not repeated in entirety here. Survey design features include:

- timing and locating some exploration drilling and support activities to avoid interference with the annual fall bowhead whale hunts from Kaktovik, Nuiqsut (Cross Island), and Barrow;
- identifying transit routes and timing to avoid other subsistence use areas and communicate with coastal communities before operating in or passing through these areas;
- conducting pre-season sound propagation modeling to establish the appropriate safety and behavioral radii;
- vessel-based monitoring to implement appropriate mitigation, if necessary, and to determine the effects of project activities on marine mammals;
- modifications to the *Kulluk* to reduce sound propagation into the water;
- acoustic monitoring of the *Kulluk* and vessel sounds and marine mammal vocalizations;
- aerial surveys with photographic equipment and PSOs over operations to help determine the effects of project activities on marine mammals, and
- seismic activity mitigation measures during performance of ZVSP surveys.

The potential disturbance of marine mammals during operations will be minimized further through the implementation of several vessel-based mitigation measures (see Section 12 of the IHA application to which this 4MP is appended) if mitigation becomes necessary.

Safety and Disturbance Zones

Under current NMFS guidelines (e.g., NMFS 2000), “safety radii” for marine mammals around industrial sound sources are customarily defined as the distances within which received sound levels are ≥ 180 decibels (dB) re 1 micropascal (μPa) root mean square (rms) for cetaceans and ≥ 190 dB re 1 μPa rms for pinnipeds. These safety criteria are based on an assumption that sound energy received at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels might have some such effects. Disturbance or behavioral effects to marine mammals from underwater sound may occur after exposure to sound at distances greater than the safety radii (Richardson et al. 1995). NMFS assumes that marine mammals exposed to underwater impulsive sounds at received levels ≥ 160 dB rms have the potential to exhibit behavioral reactions great enough to meet the definition of “harassment” in the Marine Mammal Protection Act (MMPA). For continuous sounds NMFS has established a similar disturbance threshold at ≥ 120 dB rms.

Exploration Drilling Activities

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

Sounds from the *Kulluk* have previously been measured in the Beaufort Sea (Greene 1987, Miles et al. 1987). The broadband back-propagated source level estimated by Greene (1987) from these measurements was 185 dB re 1 μ Pa at 1 meter (m). These measurements were used as a proxy for modeling the sounds likely to be produced by exploration drilling activities from the *Kulluk* (Zykov and Hannay 2007). Based on the models, broadband sound levels from exploration drilling are expected to fall below 180 dB re 1 μ Pa rms approximately 43 ft (13 m) from the *Kulluk*. The 160 dB re 1 μ Pa rms radius would extend ~180 ft (55 m) from the *Kulluk* and the 120 dB re 1 μ Pa rms radius would be expected to be ~8 mi (~13 kilometer [km]) from the *Kulluk*. To be precautionary, the modeled radius for levels exceeding 120 dB re 1 μ Pa, of 13.3 km, was multiplied by 1.5 to provide the ~12 mi (20 km) radius considered for estimating numbers of possible marine mammal exposures to sounds that might lead to harassment. As noted above, modifications have been made to the *Kulluk* to reduce sound propagation into the water from the *Kulluk*; thus the above radii are likely to be less than those estimated above.

Sounds from the *Discoverer* have not previously been measured in the Arctic. However, measurements of sounds produced by the *Discoverer* were made in the South China Sea in 2009 (Austin and Warner 2010). The results of those measurements were used to model the sound propagation from the *Discoverer* (including a nearby support vessel) at planned drilling locations in the Chukchi and Beaufort seas (Warner and Hannay 2011). Broadband source levels of sounds produced by the *Discoverer* varied by activity and direction from the ship, but were generally between 177 and 185 dB re 1 μ Pa at 1 m rms (Austin and Warner 2010). Propagation modeling at the Sivulliq and Torpedo prospects yielded somewhat different results, with sounds expected to propagate shorter distances at the Sivulliq site (Warner and Hannay 2011). As a precautionary approach, the larger distance to which sounds ≥ 120 dB (2.06 mi [3.32 km]) are expected to propagate at the Torpedo site have been used to estimate the area of water potentially exposed at both locations. The estimated 2.06 mi (3.32 km) distance was multiplied by 1.5 (= 3.09 mi [4.98 km]) as a further precautionary measure before calculating the total area that may be exposed to continuous sounds ≥ 120 dB re 1 μ Pa rms by the *Discoverer* at each drill site. Assuming one well will be drilled in each season (summer and fall), the total area of water ensonified to ≥ 120 dB rms in each season would be 30 mi² (78 square kilometers [km²]).

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

ZVSP Surveys

The sound source to be used by Shell for the ZVSP survey in 2012 is the ITAGA eight-airgun array, which consists of four 150 cubic inches (in³) (2,458 cubic meters [cm³]) airguns and four 40 in³ (655 cm³) airguns. These airguns can be activated in any combination and Shell would utilize the minimum airgun volume required to obtain an acceptable signal. A similar airgun source was used in the region in 2008 during the BP Liberty seismic survey. Preseason estimates of the propagation of airgun sounds from the ITAGA vertical seismic profiler (VSP) sound source have been estimated based on the measurements of the seismic source reported in BP's 90-day report (Aerts et al. 2008). The BP Liberty source was also an eight-airgun array, but had a slightly larger total volume of 880 in³ (14,421 cm³). Because the number of airguns is the same, and the difference in total volume only results in an estimated 0.4 dB decrease in the source level of the ZVSP source, the 100th percentile propagation model from the measurements of the BP Liberty source is almost directly applicable. However, the BP Liberty source was towed at a depth of 5.9 ft (1.8 m), while the ZVSP source will be lowered to a target depth of 13 ft (4 m) (from 10-23 ft [3-7 m]). The lower depth of the ZVSP source has the potential to increase the source strength by as much as 6 dB. Thus, the constant term in the propagation equation from the BP Liberty source has been increased from 235.4 to 241.4 while the remainder of the equation ($-18*\text{Log}R - 0.0047*R$) has been left unchanged. This equation results in the following estimated distances to maximum received levels: 190 dB = 1,719 ft (524 m); 180 dB = 4,068 ft (1,240 m); 160 dB = 12,041 ft (3,670 m); 120 dB = 34,449 ft (10,500 m).

PSOs on the *Kulluk* or *Discoverer* will initially use these estimated safety radii for monitoring and mitigation purposes. Two experienced acoustic contractors, JASCO Applied Sciences and Greeneridge Sciences, will perform direct measurements of the received levels of underwater sound versus distance and direction from the ZVSP array using calibrated hydrophones. The acoustic data will be analyzed as quickly as reasonably practicable (within 5 days) in the field and used to verify (and if necessary adjust) the safety distances during later ZVSP surveys. The mitigation measures to be implemented will include pre-ramp up watches, ramp ups, power downs and shut downs as described below.

Ramp Ups

A ramp up of an airgun array provides a gradual increase in sound levels, and involves a step-wise increase in the number and total volume of airguns firing until the full volume is achieved. The purpose of a ramp up (or "soft start") is to "warn" cetaceans and pinnipeds in the vicinity of the airguns and to provide the time for them to leave the area and thus avoid any potential injury or impairment of their hearing abilities.

During the proposed ZVSP surveys, the operator will ramp up the airgun arrays slowly. Full ramp ups (i.e., from a cold start when no airguns have been firing) will begin by firing a single airgun in the array. A full ramp up will not begin until there has been a minimum of 30 minutes of observation of the safety zone by PSOs to assure that no marine mammals are present. The entire safety zone must be visible during the 30-minute lead-in to a full ramp up. If the entire safety zone is not visible, then ramp up

from a cold start cannot begin. If a marine mammal(s) is sighted within the safety zone during the 30-minute watch prior to ramp up, ramp up will be delayed until the marine mammal(s) is sighted outside of the safety zone or the animal(s) is not sighted for at least 15-30 minutes: 15 minutes for small odontocetes and pinnipeds, or 30 minutes for baleen whales and large odontocetes.

Power Downs and Shut Downs

A power down is the immediate reduction in the number of operating energy sources from all firing to some smaller number. A shut down is the immediate cessation of firing of all energy sources. The arrays will be immediately powered down whenever a marine mammal is sighted approaching close to or within the applicable safety zone of the full arrays, but is outside the applicable safety zone of the single source. If a marine mammal is sighted within the applicable safety zone of the single energy source, the entire array will be shut down (i.e., no sources firing).

Protected Species Observers

Vessel-based monitoring for marine mammals will be done by trained PSOs throughout the period of exploration drilling operations to comply with expected provisions in the IHA and LOA that Shell receives. The observers will monitor the occurrence and behavior of marine mammals near the *Kulluk* or *Discoverer* during all daylight periods during operation, and during most daylight periods when exploration drilling operations are not occurring. PSO duties will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the exploration drilling operations; and documenting exposures of animals to sound levels that may constitute harassment as defined by NMFS.

Number of Observers

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

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

PSO teams will consist of Inupiat observers and experienced field biologists. An experienced field crew leader and an Inupiat observer will be members of every PSO team onboard the *Kulluk* or *Discoverer* and each support vessel during the exploration drilling program. The total number of PSOs may decrease later in the season as the duration of daylight decreases assuming NMFS does not require continuous nighttime monitoring. Inupiat PSOs will also function as Native language communicators with hunters and whaling crews and with the Communications and Call Centers (Com Centers) in Native villages along the Beaufort Sea coast.

Crew Rotation

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

Observer Qualifications and Training

Crew leaders and most other biologists serving as observers in 2012 will be individuals with experience as observers during one or more of the 1996-2010 seismic or shallow hazards monitoring projects in Alaska, the Canadian Beaufort, or other offshore areas in recent years.

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

Most observers, including Inupiat observers, will also complete a two-day training and refresher session on marine mammal monitoring, to be conducted shortly before the anticipated start of the 2012 drilling season. Any exceptions will have or receive equivalent experience or training. The training session(s) will be conducted by qualified marine mammalogists with extensive crew-leader experience during previous vessel-based seismic monitoring programs.

Primary objectives of the training include:

- review of the 4MP for this project, including any amendments specified by NMFS or USFWS in the IHA or LOA, by BOEM, by BSEE, or by other agreements in which Shell may elect to participate;
- review of marine mammal sighting, identification (photographs and videos), and distance estimation methods including any amendments specified by NMFS or USFWS in the 2012 IHA or LOA;
- review of operation of specialized equipment (reticle binoculars, night vision devices, and GPS system);
- review of, and classroom practice with, data recording and data entry systems, including procedures for recording data on mammal sightings, monitoring operations, environmental conditions, and entry error control. These procedures

will be implemented through use of a customized computer database and laptop computers; and

- review of the specific tasks of the Inupiat Communicator.

PSO Handbook

A PSO Handbook will be prepared for Shell's monitoring program. The handbook will contain maps, illustrations, and photographs, as well as copies of important documents, and descriptive text intended to provide guidance and reference information to trained PSOs. The following topics will be covered in the PSO Handbook for the Shell project:

- summary overview description of the project, marine mammals and underwater noise, the 4MP (vessel-based, aerial, acoustic measurements, special studies), the NMFS IHA and USFWS LOA and other regulations/permits/agencies, the MMPA;
- monitoring and mitigation objectives and procedures, initial safety radii;
- responsibilities of staff and crew regarding the 4MP;
- instructions for ship crew regarding the 4MP;
- data recording procedures: codes and coding instructions, common coding mistakes, electronic database; navigational, marine physical, field data sheet;
- use of specialized field equipment (reticle binoculars, night-vision devices (NVDs), laser rangefinders);
- reticle binocular distance scale;
- table of wind speed, Beaufort wind force, and sea condition codes;
- data storage and backup procedures;
- list of species that might be encountered: identification, natural history;
- safety precautions while onboard;
- crew and/or personnel discord; conflict resolution among PSOs and crew;
- drug and alcohol policy and testing;
- scheduling of cruises and watches;
- communications;
- list of field gear that will be provided;
- suggested list of personal items to pack;
- suggested literature, or literature cited;
- field reporting requirements and procedures; and
- copies of the NMFS IHA and USFWS LOA when available
- Coordinates delineating areas where ships cannot operate such as the Ledyard Bay critical habitat area.

Monitoring Methodology

The observer(s) will watch for marine mammals from the best available vantage point on the *Kulluk* or *Discoverer* and support vessels. Ideally this vantage point is an elevated stable platform from which the PSO has an unobstructed 360 degree (°) view of the water. The observer(s) will scan systematically with the unaided eye and 7 × 50 reticle binoculars, supplemented with 20 × 60 image-stabilized Zeiss Binoculars or Fujinon 25 × 150 “Big-eye” binoculars and night-vision equipment when needed (see below). Personnel on the bridge will assist the PSOs in watching for marine mammals. New or inexperienced PSOs will be paired with an experienced PSO or experienced field biologist so that the quality of marine mammal observations and data recording is kept consistent.

Information to be recorded by PSOs will include the same types of information that were recorded during recent monitoring programs associated with Industry activity in the Arctic (e.g. Ireland et al. 2009, Reiser et al. 2010). When a mammal sighting is made, the following information about the sighting will be carefully and accurately recorded:

- Species, group size, age/size/sex categories (if determinable);
- Physical description of features that were observed or determined not to be present in the case of unknown or unidentified animals;
- Behavior when first sighted and after initial sighting, heading (if consistent);
- Bearing and distance from observer, apparent reaction to activities (e.g., none, avoidance, approach, paralleling, etc.), closest point of approach, and behavioral pace;
- Time, location, speed, and activity of the vessel, sea state, ice cover, visibility, and sun glare; and
- Positions of other vessel(s) in the vicinity of the observer location.

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

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

Observers may use a laser rangefinder to test and improve their abilities for visually estimating distances to objects in the water. However, previous experience showed that a Class 1 eye-safe device was not able to measure distances to seals more than about 230 feet (ft) (70 meters [m]) away. The device was very useful in improving the distance estimation abilities of the observers at distances up to about 1,968 ft (600 m)—the maximum range at which the device could measure distances to highly reflective objects

such as other vessels. Humans observing objects of more-or-less known size via a standard observation protocol, in this case from a standard height above water, quickly become able to estimate distances within about $\pm 20\%$ when given immediate feedback about actual distances during training.

Maximizing time with eyes on the water is strongly promoted during training and is a goal of the PSO program. Each ship will have voice recorders available to PSOs. This will allow PSOs to remain focused on the water in situations where a number of sightings occur together. Additionally, we have moved entirely to real-time electronic data recording (described below) and automated as much of the process as possible to minimize time spend recording data as opposed to focusing eyes on the water.

PSO's are instructed to identify animals as unknown when appropriate rather than strive to identify an animal when there is significant uncertainty. We also ask that they provide any sightings cues they used and any distinguishable features of the animal even if they are not able to identify the animal and record it as unidentified. Emphasis is also placed on recording what was not seen, such as dorsal features.

Monitoring At Night and In Poor Visibility

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

Specialized Field Equipment

Shell will provide or arrange for the following specialized field equipment for use by the onboard PSOs: reticle binoculars, Big-eye binoculars, global positioning system (GPS) unit, laptop computers, night vision binoculars, and possibly digital still and digital video cameras. Big eye binoculars will be mounted and used on key monitoring vessels including the drill rig, ice management vessels and the anchor handler.

Field Data-Recording, Verification, Handling, and Security

The observers on the *Kulluk* or *Discoverer* and support vessels will record their observations into computers using a custom software package. The accuracy of the data entry will be verified in the field by computerized validity checks as the data are entered, and by subsequent manual checking of the database printouts. These procedures will allow initial summaries of data to be prepared during and shortly after the field season, and will facilitate transfer of the data to statistical, graphical or other programs for further processing. Quality control of the data will be facilitated by (1) the start-of-season training session, (2) subsequent supervision by the onboard field crew leader, and (3) ongoing data checks during the field season.

The data will be backed up regularly onto compact disks (CDs) and/or USB disks, and stored at separate locations on the vessel. If possible, data sheets will be photocopied

daily during the field season. Data will be secured further by having data sheets and backup data CDs carried back to the Anchorage office during crew rotations.

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

PSOs will be able to plot sightings in near real-time for their vessel. Significant sightings from key vessels (drill rigs, ice management, anchor handlers and aircraft will be relayed between platforms to keep observers aware of animals that may be in or near the area but may not be visible to the observer at any one time. Emphasis will be placed on relaying sightings with the greatest potential to involve mitigation or reconsideration of a vessel's course (e.g., large group of bowheads, walrus on ice).

Field Reports

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

Reporting

The results of the 2012 vessel-based monitoring, including estimates of exposures to key sound levels, will be presented in the 90-day and final technical report(s). Reporting will address the requirements established by NMFS in the IHA, and USFWS in the LOA (if so stipulated).

The technical report(s) will include:

- summaries of monitoring effort: total hours, total distances, and distribution of marine mammals through the study period accounting for sea state and other factors affecting visibility and detectability of marine mammals;
- analyses of the effects of various factors influencing detectability of marine mammals including sea state, number of observers, and fog/glare;
- species composition, occurrence, and distribution of marine mammal sightings including date, water depth, numbers, age/size/gender categories, group sizes, and ice cover;
- analyses of the effects of exploration drilling operations:
 - sighting rates of marine mammals during periods with and without exploration drilling activities (and other variables that could affect detectability);
 - initial sighting distances versus drilling state;

- closest point of approach versus drilling state;
- observed behaviors and types of movements versus drilling state;
- numbers of sightings/individuals seen versus drilling state;
- distribution around the drillship and support vessels versus drilling state;
- estimates of “take by harassment”.

Shell will consider requests for data collected during the marine mammal monitoring only after the data have been put through a quality control/quality assurance program. Such requests may include incorporating the data with other companies’ data and/or integrating the raw data with data from other marine mammal studies.

AERIAL SURVEY PROGRAM

Objectives

An aerial survey program will be conducted in support of the exploration drilling program in the Beaufort Sea during the summer and fall of 2012. In addition to the standard data collection by PSOs as has been done during 2006-2010, digital cameras and high definition (HD) video cameras on the survey aircraft will capture imagery that can later be compared to data collected by the PSOs. The exploration drilling program may start in the Beaufort Sea as early as 10 July 2012. The objectives of the aerial survey will be:

- to advise operating vessels as to the presence of marine mammals (primarily cetaceans) in the general area of operation;
- to collect and report data on the distribution, numbers, movement and behavior of marine mammals near the exploration drilling operations with special emphasis on migrating bowhead whales;
- to support regulatory reporting related to the estimation of impacts of exploration drilling operations on marine mammals;
- to investigate potential deflection of bowhead whales during migration by documenting how far east of exploration drilling operations a deflection may occur, and where whales return to normal migration patterns west of the operations;
- to collect marine mammal sighting data using both PSOs and digital media, and after the field season, to compare the data recorded by the two methods; and
- to monitor the accessibility of bowhead whales to Inupiat hunters.

Safety

Safety will be of primary importance in all decisions regarding the planning and conduct of the aerial surveys. Safety-related considerations during planning have included choice of aircraft, aircraft operator, and pilots; outfitting of the aircraft; lengths and locations of survey grids; and safety training. Safety during aerial survey operations will include careful and judicious consideration of weather and avoidance of flight in questionable

conditions. Although the pilots will have ultimate authority, the aerial survey crew will also be required to make their own judgments and to avoid flying in questionable circumstances. To this end, the aerial survey teams will have a crew leader with experience conducting this type of survey in arctic conditions, and will have the authority to cancel or (in agreement with the pilots) amend flight operations as necessary for safety.

Selection of Aircraft

Specially-outfitted deHavilland Twin Otter (Twin Otter) aircraft are expected to be the survey aircraft and have an excellent safety record operating in the Arctic and Antarctic. These aircraft will be specially modified for survey work and have been used extensively by NMFS, Alaska Department of Fish and Game (ADF&G), Coastal and Offshore Pacific Corporation (COPAC), NSB, and LGL during many marine mammal projects in Alaska, including Industry funded projects as recent as the 2006–2008, and 2010 seasons and in northern Canada. The aircraft will be provided with a comprehensive set of survival equipment appropriate to offshore surveys in the Arctic. For safety reasons, the aircraft will be operated with two pilots. The aircraft will be outfitted with a deHavilland-approved camera port to house collection of digital imagery below the floor of the aircraft so that movements in the aircraft are not compromised by the additional equipment.

Survey Procedures

Flight and Observation Procedures

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

The aerial survey procedures will be generally consistent with those used during earlier industry studies (Davis et al. 1985; Johnson et al. 1986; Evans et al. 1987; Miller et al. 1997, 1998, 1999, 2002; Brandon et al. 2011; Thomas and Koski 2011). This will facilitate comparison and pooling of data where appropriate. However, the specific survey grids will be tailored to Shell's operations, and in 2012 they have been modified to obtain higher levels of effort within 30 km of the exploration drilling operations as described below. During the 2012 exploration drilling season, Shell will coordinate and cooperate with the aerial surveys conducted by BOEM/NMFS and any other groups conducting surveys in the same region.

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

For marine mammal monitoring flights, aircraft will be flown at ~120 knots ground speed and usually at an altitude of 1,000 ft (305 m). Flying at a survey speed of 120 knots

greatly increases the amount of area that can be surveyed, given aircraft and pilot daily flight time limitations, with minimal effect on the ability to detect bowhead whales. Surveys in the Beaufort Sea are directed at bowhead whales and an altitude of 900-1,000 ft (274-305 m) is the lowest survey altitude that can normally be flown without concern about potential aircraft disturbance; it is also the altitude recommended by NMFS for IHA monitoring efforts for bowhead whales. Aerial surveys at an altitude of 1,000 ft (305 m) do not provide much information about seals and small cetaceans such as harbor porpoise, but they are suitable for both bowhead and beluga whales. The need for a 900-1000+ ft cloud ceiling will limit the dates and times when surveys can be flown. Selection of a higher minimum altitude for surveys (e.g. 1,500 ft [457 m]) would result in a significant reduction in the number of days where surveys would be possible, impairing the ability of the aerial program to meet its objectives. All other Shell-associated aircraft during the 2012 exploration drilling program shall not operate below 1,500 ft (457 m) unless the aircraft is engaged in marine mammal monitoring, approaching, landing, taking off, under poor weather (low ceilings) conditions, engaged in providing assistance to a whaling vessel in distress, or any other emergency situations.

Two primary observers will be seated at bubble windows on either side of the aircraft and a third observer will observe part-time and record data the rest of the time. A fourth observer will be present on the aircraft and will rest when not at one of the three positions noted above. Observers will rotate among the four positions so that individual observers do not observe for longer than two hours continuously. A fifth observer will collect observations. All observers will be seated at bubble windows to facilitate downward viewing. For each marine mammal sighting, the observer will dictate the species, number, size/age/sex class when determinable, activity, heading, swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading to the marine mammal into a digital recorder. The inclinometer reading will be taken when the animal's location is 90° to the side of the aircraft track, allowing calculation of lateral distance from the aircraft trackline.

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

Photographic and Video Imagery

DSLR and video cameras will be operated during all aerial surveys in the Beaufort Sea during 2012 and will collect imagery along the trackline concurrent with observations being made by PSOs. Data collected during these surveys will permit comparisons between data obtained by PSOs versus those that can be obtained from digital still images and video. The rationale for this component of the study is to validate the ability of the sensors to collect high quality data that will be collected using UAS in the future, and to obtain information on the biases of future UAS-collected data in comparison to manned surveys.

Two digital single lens reflex (DSLR) cameras will be mounted in the camera port in the aerial survey team's Twin Otter. They will be mounted so that the inner edge of each camera frame overlaps on the centerline of the aircraft flight path. In addition, a HD video camera will be tested and compared to the still camera for evaluation as a tool for real-time monitoring during future studies. Although a twin otter flies faster than an UAS, the slower airspeed and potentially lower flight altitude of the UAS would mean that the data quality would be better from the UAS and so any comparisons between PSOs and cameras made from imagery obtained in the Twin Otter should be valid when assessing the use of the same sensors in an UAS.

The camera that will likely be used is a Cannon 5D Mk II which is a 21.1 megapixel camera that stores imagery in a 5616×3744 pixel array. If it is possible to obtain Nikon D800 cameras, they are 36.3 megapixel cameras that store imagery in a 7360×4912 pixel array and image quality would be improved. The cameras will be triggered every five seconds providing 50% overlap with adjacent photos and 100% overlap among all imagery. If the Cannon camera is used, it will have a 20 mm lens which will cover a swath ~720 m on the water surface with one pixel representing a 12 cm square at the water surface. This pixel size is one quarter of the pixel size (25 cm square) tested by Koski et al. (2009) during their tests with a video camera for detection of kayaks and is a smaller pixel size (better resolution) than was tested by Amanda Hodgson (16.8 cm) during her surveys of humpback whales off Australia and which proved adequate for counting humpback whales in their imagery. It is expected that this resolution will permit identification of all medium and large cetaceans and counting of small cetaceans, except for perhaps harbor porpoises, and will permit counting of walrus/bearded seals. It may not permit differentiation of bearded seals from walrus, especially when they are in the water. This imagery resolution provides slightly better ability for determining species and detecting animals than people would have in an aircraft flying at 1000 feet above sea level.

The proposed aerial photographic coverage with two DSLR cameras pointed slightly obliquely would provide an Effective Strip Width (ESW) of ~700 m (each camera would cover one side of the aircraft out to 700 m from the center line). The ESW for manned surveys varies depending on the species being recorded due to different physical and behavioral characteristics of the species. The ESW for bowhead whales has varied between ~500 m and ~700 m during our 2006-2010 surveys in the Beaufort Sea. The ESW for belugas in the Chukchi Sea during the same period was ~300 m and the ESW for most other species was narrower. Thus the proposed coverage using a single DSLR swath width would be similar or slightly wider for the most obvious species such as gray whales and bowheads and much better (4 times wider) for smaller and more cryptic species such as walrus, bearded seals, belugas and minke whales.

The HD video that will be used is the Canon XF305 which has 1920×1080 resolution. This resolution is about 3 times better in width than the NTSC video (640×480) tested by Koski et al. (2009). This will allow the video to collect constant imagery along the flight path and will not require scanning back and forth as was done during earlier tests. It will be set to capture data along a 600 m wide swath at the same resolution as was tested during the Koski et al. (2009) study. By having the camera fixed on the trackline, the problems encountered by Koski et al. (2009) of uneven coverage, short time that many areas were in view, and different pixel size when the camera was pointed to the sides will be eliminated or reduced. Options for scanning and covering smaller or larger swaths may also be tested and compared to the data from the still cameras. Although video resolution is much poorer than the DSLR cameras, it may be possible to identify some animals in the video that are missed or difficult to detect on the still imagery because the video provides information on motion.

Route planning and data storage software are off-the-shelf products assembled by VDOS LLC. The set up includes a harness to connect the camera and GPS to the Photo Coupler Controller which is connected to a GPS for triggering capture of images and recording of metadata for each image (Fig. 2). The system can be powered by 10-32 volt DC or a custom power source and has a back-up battery power source to prevent interruption to data capture. Acquisition of imagery can be controlled from a laptop and/or preprogrammed route plan and there is live view of what the sensors are viewing on the water surface.

The system is “plug-and-play” and does not require input from persons on board the aircraft during the flight. The system can be pre-programmed to take photographs starting and stopping at predetermined locations or times. A laptop computer in the cockpit can be used to override the preprogrammed instructions and take additional images whenever desired.



Figure. 2. Camera mount and associated data storage and control devices that can be mounted as a module in a Twin Otter camera port.

Other Imagery and Sensors

In addition to the imagery indicated above, Shell is examining systems that are in development that would allow collection of additional imagery. They include collection of multi-spectral/hyperspectral imagery and a multi-camera system that would allow collection of imagery over a wider area. If these systems are ready for testing in 2012, Shell will attempt to incorporate these systems into the Chukchi Sea program.

Shell is also considering adding other types of sensors to the survey aircraft. One of these sensors, a sea surface temperature sensor, was tested successfully during 2009 surveys in the Canadian Beaufort Sea. We will install one of these sea surface temperature sensors on the Beaufort Sea survey aircraft in 2012.

Supplementary Data

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

In 2012, digital single lens reflex cameras and video will provide a permanent record of the sea surface within 700 m of the trackline during all flights. These data will also provide high resolution information on sea and ice conditions during the survey which can be used to supplement and validate data recorded by PSOs during the survey.

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

Coordination with BOEM/NMFS Aerial Surveys

BOEM/NMFS are planning to continue its wide-ranging aerial surveys of bowhead whales and other marine mammals in the Beaufort Sea during the autumn of 2012. In 2012, the surveys will be contracted to the National Marine Mammal Laboratory (NMML) in Seattle. These surveys include the area where exploration drilling activities will occur. Shell will co-ordinate with BOEM/NMML to share data, both during the drilling season and for use in analyses and reports.

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

- to ensure aircraft separation when both crews conduct surveys in the same general region;

- to coordinate the 2012 aerial survey projects in order to maximize consistency and minimize duplication;
- to use data from BOEM's broad-scale surveys to supplement the results of the more site-specific Shell surveys for purposes of assessing the effects of exploration drilling activities on whales and estimating "take by harassment";
- to maximize consistency with previous years' efforts insofar as feasible.

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

Shell is not aware of any other related aerial survey programs presently scheduled to occur in the Alaskan Beaufort Sea in areas where Shell is anticipated to be conducting exploration drilling operations during July–October 2012. If another aerial survey project were planned, Shell would seek to coordinate with that project to ensure aircraft separation, maximize consistency, minimize duplication, and share data.

Survey Design

During the late summer and fall, the bowhead whale is the primary species of concern, but belugas and gray whales are also present. Bowheads and belugas migrate through the Alaskan Beaufort Sea from summering areas in the central and eastern Beaufort Sea and Amundsen Gulf to their wintering areas in the Bering Sea (Clarke et al. 1993; Moore et al. 1993; Miller et al. 2002). Small numbers of bowheads are sighted in the eastern Alaskan Beaufort Sea starting mid-August and near Barrow starting late August, but the main migration does not start until early September. Recent government and industry surveys (COMIDA/BWASP 2009; Funk et al. 2010) and GPS tagging (ADF&G 2009) have also recorded some bowheads in the western Alaskan Beaufort Sea in July and August. The bowhead migration tends to be through nearshore and shelf waters, although in some years small numbers of whales are seen near the coast and/or far offshore. Bowheads frequently interrupt their migration to feed (Ljungblad et al. 1986; Lowry 1993; Landino et al. 1994; Würsig et al. 2002; Lowry et al. 2004; Funk et al. 2010) and their stop-overs vary in duration from a few hours to a few weeks (Koski et al. 2002). A commonly used feeding area is in and near Smith Bay, east of Barrow. Less consistently used feeding areas are in coastal and shelf waters near and east of Kaktovik. In 2007 and 2008, bowhead whales also used areas near Camden Bay to feed during the migration (Ireland et al. 2008; Funk et al. 2010).

To address concerns regarding deflection of bowheads at greater distances, the survey pattern around exploration drilling operations has been designed to document whale distribution from about 25 mi (40 km) east of the exploration drilling operations to about 37 mi (60 km) west of operations (Figure 1). Aerial surveys will be conducted daily starting 5 to 7 days before exploration drilling operations begin until 5 to 7 days after they end.

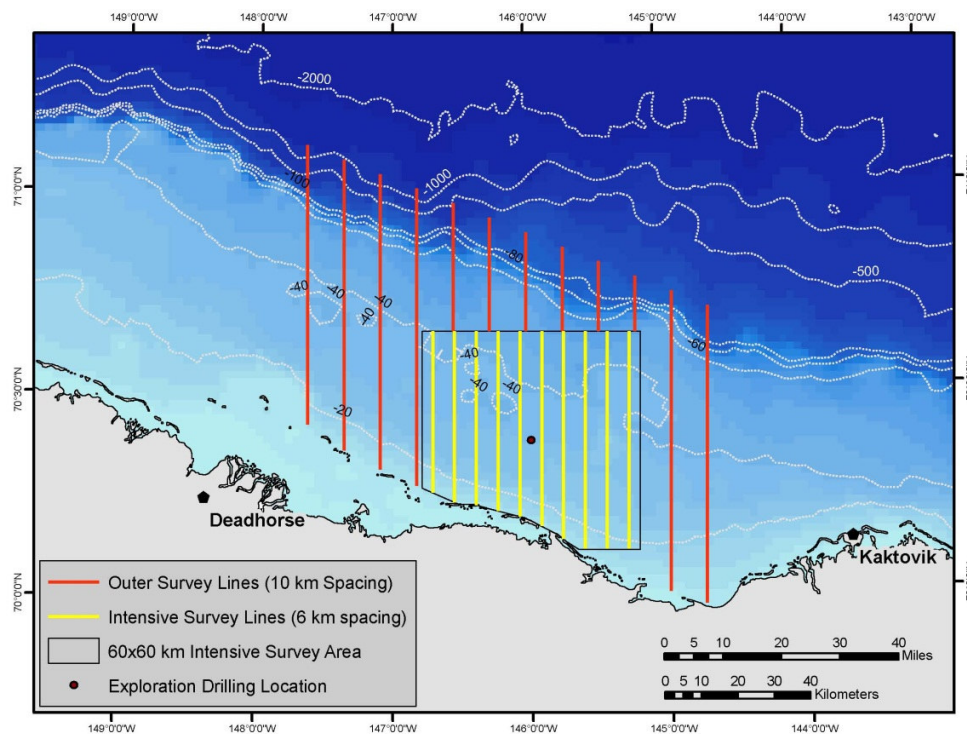


FIGURE 1. Central Alaskan Beaufort Sea showing a representative aerial survey pattern that will be flown daily during summer and fall. The survey grid will be moved east or west depending on the precise location of the *Kulluk* or *Discoverer* and lines will be shifted slightly within the grid for each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

Bowhead whale movements during the late summer/autumn are generally from east to west, and transects should be designed to intercept rather than parallel whale movements. The transect lines in the grid will be oriented north-south and randomly shifted in the east-west direction for each survey by no more than the transect spacing. The survey grid will total about 808 mi (1,300 km) in length, requiring ~6 hours (hr) to survey at a speed of 137 mi/hr (220 km/hr) (120 knots), plus ferry time. Completion of the entire grid will require 10 hours of total flight time, which is the maximum time that pilots can fly in a day. Exact lengths and durations will vary somewhat depending on the position of the exploration drilling operation and thus of the grid, the sequence in which lines are flown (often affected by weather), and the number of refueling/rest stops.

Weather permitting, transects flown during each flight will be flown in sequence but randomly from west to east or east to west. This approach was recommended by the Peer Review Panel evaluating Shell's monitoring plan, although this may, when surveys are flown from east to west, result in double counting whales that are (predominantly) migrating westward. The survey pattern around the exploration drilling operation is designed to monitor the distribution of whales around the exploration drilling operation.

A power analysis was conducted of the ability of our past surveys to detect differences in whale density assuming deflection at various distances from the drilling operation. The power analysis showed that the equal spacing of transects used during recent surveys would not allow detection of avoidance at close range because survey effort near the activity was too low. Figure 1 shows a survey design developed for the 2012 field season based on the output of the power analysis that maximizes the potential to detect differences in bowhead whale density within 20 km of the drilling operation. It includes an intensive grid covering out to ~30 km from the exploration drilling operation and an outer or extensive grid extending east, north and west of the intensive grid. The spacing between the lines in the intensive grid is ~6 km and spacing between the lines in the outer grid is ~10 km.

Analysis of Aerial Survey Data

During the field program, preliminary maps and summaries of the daily surveys will be provided to NMFS as normally required by the terms of the IHA, and USFWS and BOEM (if so stipulated). While in the field, data will be checked for entry errors and files will be backed up to CDs or portable memory drives and sent via the internet to the LGL office in Anchorage. Two levels of analyses will be conducted at the end of the season. The first level will consist of basic summaries that are required for the 90-day report specified by the IHA. These include summaries of numbers of marine mammals seen, survey effort by date, maps summarizing sightings, and estimates of numbers of marine mammals that are “taken” according to NMFS criteria. The data from the photographic survey will be analyzed as time permits during the season; the majority of the analyses of the photographs and video will be conducted after the field season, unless poor weather prevents much surveying.

The second level of analyses will be presented in a subsequent comprehensive report. The comprehensive report will provide more detailed analyses of the data to quantify the effect of the exploration drilling program on the distribution and movements of marine mammals. Real-time data from the manned surveys will be the primary source of information and it will be integrated with similar data from earlier years. The comprehensive report will also incorporate the data from the photographic surveys and will include comparisons of the photographic data with those collected in real time by the PSOs. This will form the basis for interpretation of data obtained during photographic surveys in the Chukchi Sea in 2012 and will be the basis for interpretation of future data collected using the same sensors in UAS.

Estimation of Numbers Exposures

Shell has used the following methodology, which was developed using past studies in the Beaufort and Chukchi sea regions (Miller et al. 1999; Haley and Ireland 2006) and other areas of the world (Lawson et al. 1998; Holst et al. 2005; Ireland et al. 2005), for estimating the numbers of marine mammals that are exposed to various sound levels. Depending on the context and level of exposure, some of these animals are considered to be “taken” by harassment (as defined by NMFS). These estimates of number of animals exposed require estimating the numbers of animals present near or passing the exploration drilling program during periods without exploration drilling activity and

assuming that similar numbers would have passed during those activities if the activities were not conducted. The planned approach has been accepted by NMFS as satisfying the requirements for “take” estimates for previous monitoring programs.

The criteria to be used in tabulating and estimating numbers of cetaceans potentially exposed to various sound levels will be consistent with those used during previous related projects in 1996-2010, unless otherwise directed by NMFS. Only cetaceans will be addressed using the aerial survey data because the altitude of the surveys is too high to reliably detect and identify pinnipeds. As in previous studies, Shell anticipates that there will be four components:

1. *Numbers of cetaceans observed within the area ensounded strongly by the exploration drilling operations.* For cetaceans, Shell will estimate the numbers of animals exposed to received rms levels of sounds exceeding 120, 160 dB and 180 dB re 1 μ Pa, as required by NMFS.
2. *Numbers of cetaceans observed showing apparent reactions to exploration drilling operations, e.g., heading in an “atypical” direction.* Animals exhibiting apparent responses to the activities will be counted as affected by the programs if they were exposed to sounds from those activities.
3. *Numbers of cetaceans estimated to have been subjected to sound levels ≥ 120 , ≥ 160 and ≥ 180 dB re 1 μ Pa rms when no monitoring observations were possible.* This will involve using the observations from the survey aircraft (Shell and BOEM/NMFS), supplemented by relevant vessel-based observations, to estimate how many cetaceans were exposed over the full course of Shell’s 2012 exploration drilling season to situations where received sound levels were ≥ 120 , ≥ 160 and ≥ 180 dB rms. In the case of the bowhead whale, Shell will estimate the proportions of the observed whales that were close enough to shore to have passed through the area where exposure might occur, and could have passed while exploration drilling operations were underway. Shell’s aerial survey design, together with the complementary aerial surveys to be conducted by BOEM/NMFS, will provide the needed data.
4. *The number of bowheads whose migration routes came within 12 mi (20 km) of the drilling activity, or would have done so if they had not been displaced farther offshore, will be estimated.* If the 2012 data indicate that the avoidance distance exceeds 12 mi (20 km), the larger avoidance distance will also be used for estimating the numbers of whales potentially responding to the exploration drilling activity. These estimates will be obtained by determining the displacement distance based on the aerial survey results, and then estimating how many bowheads were likely to approach the avoided area during times while the *Kulluk* or *Discoverer* and support vessels were present.

Effects of Exploration Drilling Program on Bowhead Migration

The location of the bowhead migration corridor in 2012 will be determined by examining data from periods with exploration drilling activities and data from east of those operations. The BOEM/NMFS aerial survey data will be a useful supplement for areas

well east of the drilling locations. Shell will contrast the numbers of bowhead sightings and individuals vs. distance from shore:

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

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

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

The data from the current survey may not provide enough sightings to be able to quantify the effects of Shell's 2012 activities on the bowhead whale migration path. That could occur if Shell's operations in the Beaufort Sea during the bowhead whale migration season were limited due to ice or other factors, or if 2012 is a year when weather conditions are poorer than average, which would limit the periods when surveys could be conducted.

The aerial survey data pertaining to other species of marine mammals will also be mapped and analyzed insofar as this is useful. However, the main migration corridor of belugas is far offshore, and generally north of the survey area proposed here. Few gray whales and walrus are likely to be seen because of their rarity in the Beaufort Sea area (although gray whales were seen in the area in 1998 (Miller et al. 1999) and small numbers have been seen during several recent surveys by BOEM, formerly as Minerals Management Service (MMS) (Treacy 1998, 2000, 2002) and LGL (Brandon et al. 2011; Thomas and Koski 2011). Therefore, the proposed aerial surveys are expected to document the infrequent use of continental shelf waters of the Beaufort Sea by beluga whales, gray whales and walrus, and detailed analyses for these species probably will not be warranted. Seals cannot be surveyed quantitatively by aerial surveys at altitudes 900-1,500 ft (274- 457 m) over open water. The aerial surveys will provide only incidental data on the occurrence of bearded and especially ringed seals in the area.

ACOUSTIC MONITORING PLAN

Drilling, ZVSP and Vessel Sound Measurements

Objectives

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

- to quantify the absolute sound levels produced by drilling, and to monitor their variations with time, distance and direction from the drilling vessel;
- to measure the sound levels produced by vessels operating in support of exploration drilling operations. These vessels will include crew change vessels, tugs, ice-management vessels and spill response vessels; and
- to measure the sound levels produced by an end-of-hole ZVSP survey using a stationary sound source.

Drilling Sound Characterization

Sound characterization and measurements of all drilling activities will be performed using autonomous and real-time acoustic monitoring systems deployed relative to the drillship as depicted in Figure 2. One real-time monitoring station will be deployed at 1640 to 3280 feet (500-1000 m) off the side of the drillship on the side that houses the main generator room. This system will consist of a bottom-mounted hydrophone that is cabled to a surface float housing a JASCO AMAR 24-bit digital acquisition system. The AMAR will stream digital audio data, sampled at least at 32 kHz, through a radio-telemetry system back to a monitoring station on the drillship. Here, the data will be stored and analyzed on an hourly basis to calculate rms levels and hourly 1/3-octave band SEL. Spectrograms will be calculated daily, and all information will be included in a weekly report that discusses the drillship and vessel activities that occurred during the week.

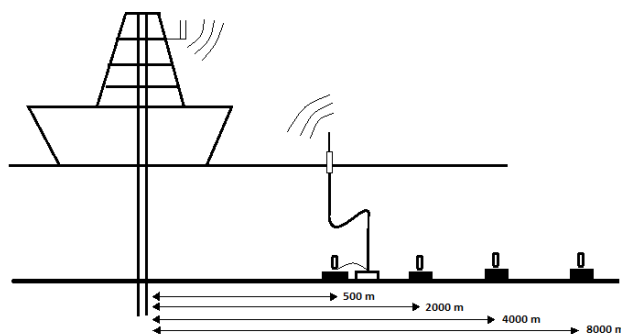


FIGURE 2. Geometry of the real-time telemetered acoustic system and three autonomous acoustic recorders that will sample sound produced by drilling operations of drillship *Kulluk*

The real-time acoustic measurement station will be augmented by 3 more AMAR autonomous acoustic recording stations (Figure 3) deployed on the seabed along the same radial at distances of 1.2, 2.5 and 5 mi (2, 4 and 8 km) from the drillship. The telemetered station nearest the drillship will also record autonomously to ensure data are acquired even in the case of interrupted radio transmissions. All four recording stations will sample at least at 32 kHz, providing precisely calibrated acoustic measurements in the 5 Hz to 16 kHz frequency band. The logarithmic spacing of the recorders is designed to sample the attenuation of drillship sounds with distance. The autonomous recorders will sample through completion of the first well, to provide a detailed record of sounds emitted from all activities. These recorders will be retrieved and their data analysed and reported in the project's 90-day report.

To sample directivity in drilling-related sounds, measurements from the DASAR recorder array will be included in a post-season analysis. The DASAR deployment locations are discussed in the later section: Acoustic Study of Bowhead Call Distributions. This array will incorporate several recorders at 4-8 km at multiple directions from each wellsite. While those recorders sample only at 1000 Hz, their data will be useful for examining the primary sound emission frequencies from the drillship, below 500 Hz.



FIGURE 3. AMAR autonomous acoustic recorder for acoustic monitoring of drilling activities.

The deployment of drilling sound monitoring equipment will occur before, or as soon as possible after the *Kulluk* or *Discoverer* is on site. Activity logs of exploration drilling operations and nearby vessel activities will be maintained to correlate with these acoustic

measurements. All results, including back-propagated source levels for each operation, will be reported in the 90-day report.

Vessel Sound Characterization

Vessel sound characterizations will be performed using dedicated recorders deployed at sufficient distance from drilling operations so that sound produced by those activities does not interfere. Three AMAR acoustic recorders will be deployed on and perpendicular to a sail track on which all Shell vessels will transit. The deployment geometry will be as shown in Figure 4. This geometry is designed to obtain sound level measurements as a function of distance and direction. The fore and aft directions are sampled continuously over longer distances to 3 and 6 miles (5 and 10 km) respectively, while broadside and other directions are sampled as the vessels pass closer to the recorders.

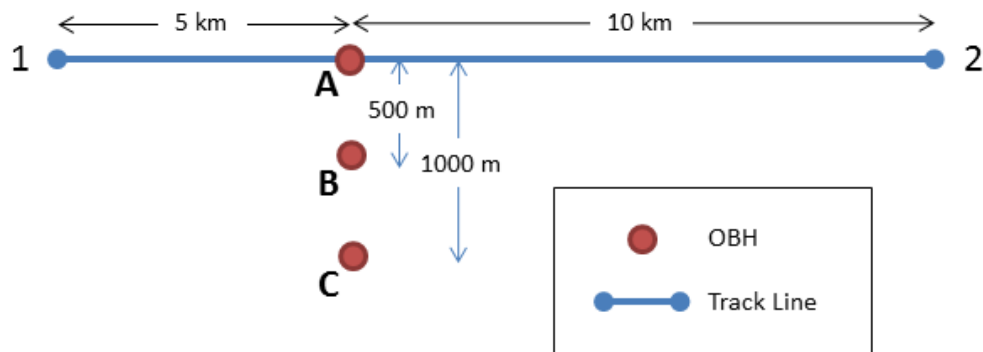


FIGURE 4. AMAR recorder deployment geometry relative to vessel sail track for support vessel sound characterization measurements.

Vessel sound measurements will be processed and reported in a manner similar to that used by Shell and other operators in the Beaufort Sea during seismic survey operations. The measurements will further be analyzed to calculate source levels. Source directivity effects will be examined and reported. Preliminary vessel characterization measurements will be reported in a field report to be delivered 120 hours after the recorders are retrieved and data downloaded. Those results will include sound level data but not source level calculations. All vessel characterization results, including source levels, will be reported in 1/3-octave bands in the project 90-day report.

Zero Offset Vertical Seismic Profiling Sounds Monitoring

During ZVSP surveys, an airgun array, which is typically much smaller than those used for routine seismic surveys, is deployed at a location near or adjacent to the *Kulluk* or *Discoverer*, while receivers are placed (temporarily anchored) in the wellbore. The sound source (airgun array) is fired repeatedly, and the reflected sonic waves are recorded by receivers (geophones) located in the wellbore. The geophones, typically in a string, are then raised up to the next interval in the wellbore and the process is repeated until the entire wellbore has been surveyed. The purpose of the ZVSP is to gather geophysical

information at various depths, which can then be used to tie-in or ground-truth geophysical information from the previous seismic surveys with geological data collected within the wellbore.

During the ZVSP, the sound source is maintained at a constant location near the wellbore (Figure 4). A typical sound source that would be used by Shell in 2012 is the ITAGA eight-airgun array, which consists of four 150 in³ (2,458 cm³) airguns and four 40 in³ (655 cm³) airguns. These airguns can be activated in any combination and Shell would utilize the minimum airgun volume required to obtain an acceptable signal. Current specifications of the array are provided in Table 1. The airgun array is depicted within its frame or sled, which is approximately 6 ft (2 m) x 5 ft (1.5 m) x 10 ft (3 m), in the photograph below. Typical receivers would consist of a Schlumberger wireline four level Vertical Seismic Imager (VSI) tool, which has four receivers 50-ft (15.2-m) apart.

Photograph of ITAGA 8-airgun Array in Sled

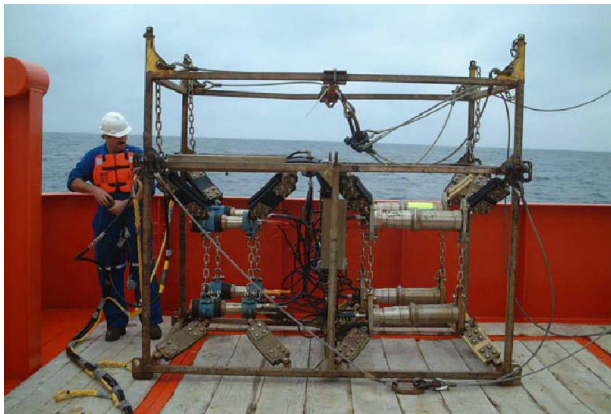


Table 1 Typical Sound Source (Airgun Array) Specifications for ZVSP

Source Type	Number of Sources	Maximum Total Chamber Size	Pressure	Source Depth	Calibrated Peak-Peak Vertical Amplitude	Zero-Peak Sound Pressure Level
SLB, ITAGA Sleeve Array	8 airguns (4) 150 in ³ (2,458 cm ³) (4) 40 in ³ (655 cm ³)	760 in ³ (12,454 cm ³)	2,000 psi 140 bar	9.8 ft / 3.0 m 16.4 ft / 5.0 m	16 bar @1 m 23 bar @1 m	238 dB re1μPa @1 m 241 dB re1μPa @1 m

A ZVSP survey is normally conducted at each well after total depth is reached. For each survey, Shell would deploy the sound source (airgun array) over the side of the *Kulluk* or *Discoverer* with a crane (sound source will be 50-200 ft (15-60 m) from the wellhead depending on crane location), to a depth of approximately 10-23 ft (3-7 m) below the water surface. The VSI with its four receivers will be temporarily anchored in the wellbore at depth. The sound source will be pressured up to 2,000 pounds per square inch (psi) (138 bar), and activated 5-7 times at approximately 20-second intervals. The VSI will then be moved to the next interval of the wellbore and re-anchored, after which

the airgun array will again be activated 5-7 times. This process will be repeated until the entire well bore is surveyed in this manner. The interval between anchor points for the VSI usually is between 200-300 ft (60-91 m). A normal ZVSP survey is conducted over a period of about 10-14 hr depending on the depth of the well and the number of anchoring points.

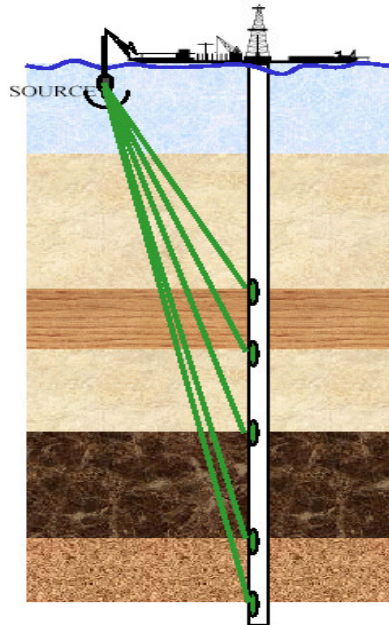


Figure 4. Schematic of ZVSP.¹

Note: ¹Drillship *Discoverer* is shown; however, either it, or the drill vessel *Kulluk* will be used.

ZVSP sound verification measurements will be performed using either the AMARs, that are deployed for drillship sound characterizations, or by JASCO Ocean Bottom Hydrophone (OBH) recorders. The use of AMARs or OBH's depends on the specific timing these measurements will be required by NMFS; the AMARs will not be retrieved until several days after the ZVSP as they are intended to monitor during retrievals of drillship anchors. If the ZVSP acoustic measurements are required sooner, four OBH recorders would be deployed at the same locations and those could be retrieved immediately following the ZVSP measurement. We propose that these measurements be performed using the AMARs as their data and measurement results will be available before any subsequent ZVSP operations. The ZVSP measurements can be delivered within 120 hours of retrieval and download of the data from either instrument type.

Acoustic Data Analyses

An important purpose of the measurements of sound level variation with time is to provide information that can be correlated with observations of bowhead whale deflections around the exploration drilling operations, should they occur. The calls of bowhead whales will be detected and located by the arrays of directional autonomous

seafloor acoustic recorders (DASARs) as discussed in the next section. The goal of that work will be to determine if changes in migration patterns can be correlated with changes in sound level output from the exploration drilling operations.

Drilling sound data will be analyzed to extract a record of the frequency-dependent sound levels as a function of time. Figure 5 shows the results of this type of analysis for a previous deployment of an OBH recorder. These results are useful also for correlating measured noise events with specific exploration drilling operations and also for capturing marine mammal vocalizations. The analysis also provides absolute sound levels in finite frequency bands that can be tailored to match the highest-sensitivity hearing ranges for the various species of interest. For example, bowhead hearing is thought to be most acute in the 100 Hz – 1,000 Hz frequency range which corresponds with the blue dotted line in the upper plot of Figure 5.

The analyses will also consider sound level integrated through 1-hr durations (referred to as noise equivalent level (Leq)[1-hr]). Figure 6 (upper) shows an example of a Leq analysis of hydrophone data. It is often useful to calculate Leq in 1/3-octave frequency bands to examine how those sounds might be perceived by different species with different frequency-dependent hearing acuity. Similar graphs for long time periods will be generated as part of the data analysis performed for indicating drilling sound variation with time in selected frequency bands. These levels will be of particular importance for correlation with bowhead location data obtained from directional acoustic recording arrays deployed for Shell's 2012 bowhead migration study.

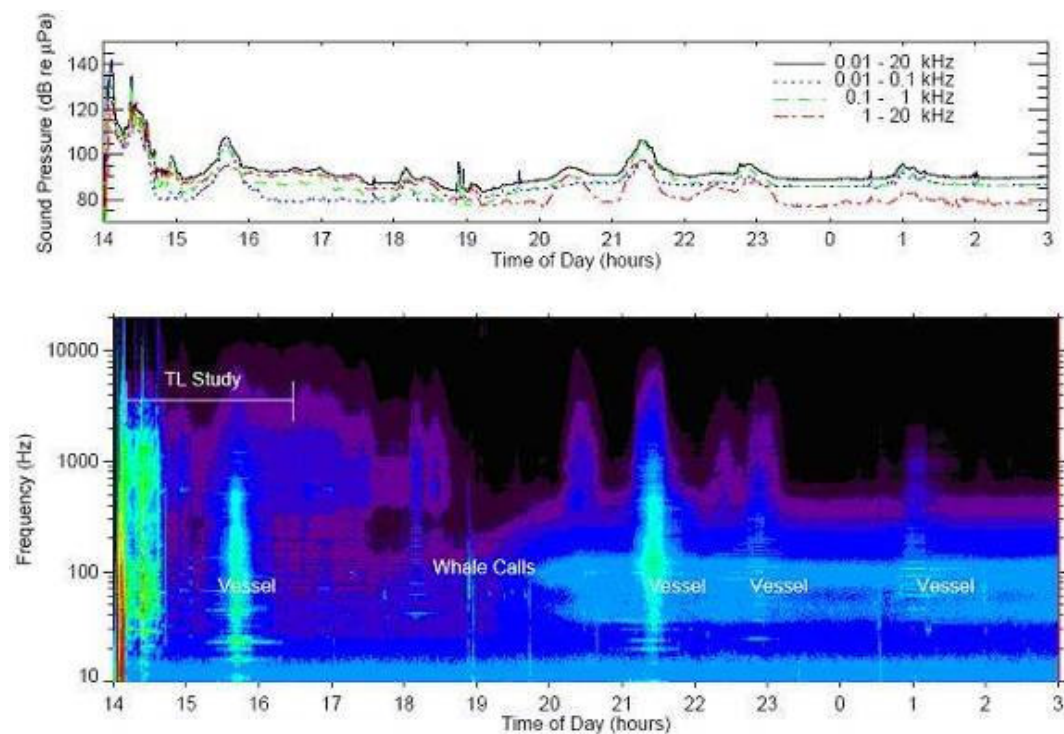


Figure 5. Lower: spectrogram of sound level measurements obtained from a hydrophone recording system. Upper: broadband and selected band level variation with time.

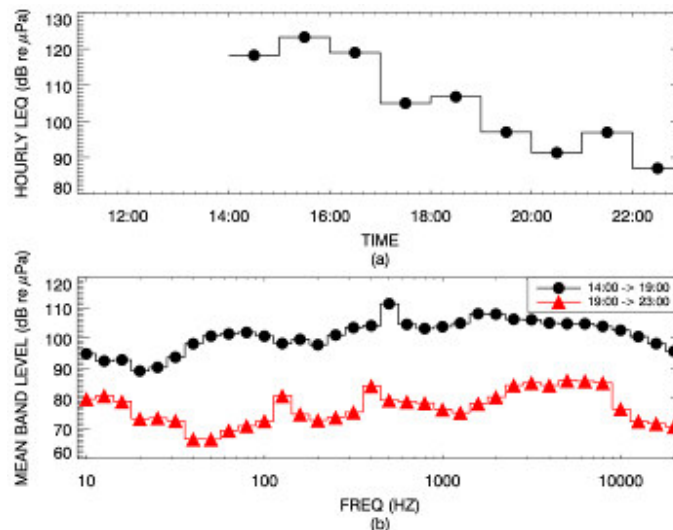


Figure 6. Upper: 1-hr Leq levels that will be calculated from acoustic measurements for use in correlating with bowhead whale deflection data.

Reporting of Results

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

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

Acoustic Study of Bowhead Call Distributions

Shell plans to deploy arrays of acoustic recorders in the Beaufort Sea in 2012, similar to that which was done in 2007–2011. As in previous years, the recorders (DASARs, or directional autonomous seafloor acoustic recorders) will be supplied by Greeneridge

Sciences. These directional acoustic systems permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document sound characteristics and propagation resulting from vessel-based exploration drilling operations that may have the potential to cause changes in the distribution of bowhead whales—as witnessed by their calls—within their migration pathway. Of particular interest will be the east-west changes in call distribution, if any. In other words, how far east or west of a sound source can changes in the distribution of calls be detected? Similarly, will the presence of a sound source result in a shift of calling whales offshore or towards shore?

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

Objective

The objectives of this study are (1) to provide information on bowhead migration paths along the Alaskan coast, particularly with respect to industrial operations, and to determine whether and to what extent there are changes in the distribution of calls due to industrial sound levels; and (2) to provide information on the broadband sound levels produced by the *Kulluk* or *Discoverer*, their frequency composition, and how they decrease with distance from the source. Using passive acoustics with directional autonomous recorders, the locations of calling whales will be observed for a six- to ten-week continuous monitoring period at five coastal sites (subject to favorable ice and weather conditions). An example of the whale call locations measured from a similar array of DASARs in 2008 is presented in Figure 7 (Blackwell et al. 2010). Concurrently, continuous measurements of sound levels near and at increasing distances from the drill ship will be obtained.

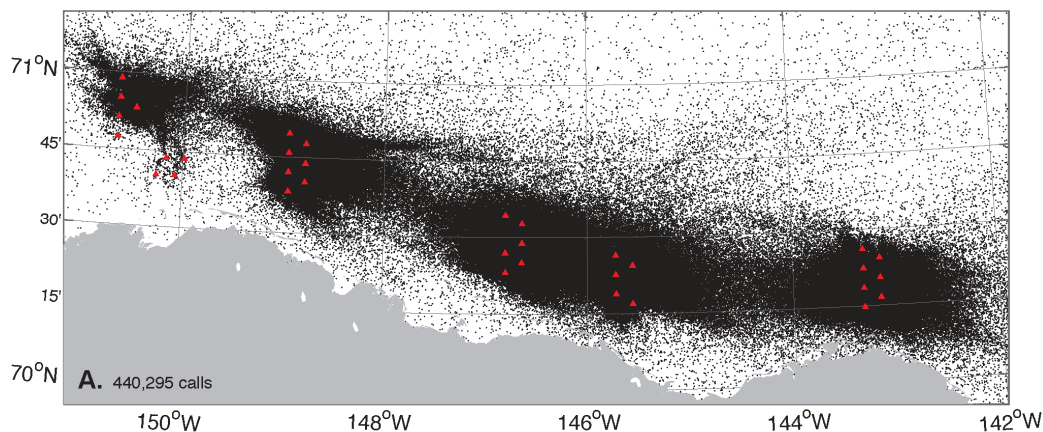


Figure 7. Bowhead whale call locations determined from the received bearings at five arrays of DASARs in the Beaufort Sea in 2008.

Monitoring Plan

Shell plans to conduct the whale migration monitoring using the passive acoustics techniques developed and used successfully since 2001 for monitoring the migration past the Northstar production island northwest of Prudhoe Bay and from Kaktovik to Harrison Bay during the 2007 through 2011 migrations. Those techniques involve using DASARs to measure the bearings to bowhead calls and, when two or more recorders detected the same call, obtaining the calling whale's location by triangulation. A total of about a million whale calls were successfully located during the years 2007–2011.

In attempting to assess the responses of bowhead whales to the planned industrial operations, it will be essential to monitor whale locations at sites both near and far from industry activities. Shell plans to monitor at five sites along the Alaskan Beaufort coast, as shown in Figure 8. The sites are the same as used since 2007, but the layout of the DASAR recorders will be somewhat different from previous years, in order to improve our ability to detect calls during the drilling operations. The eastern-most site (site 5 in Figure 8) is just east of Kaktovik ~62 mi [~100 km] west of the Sivulliq drilling area) and the western-most site (site 1) is in the vicinity of Harrison Bay (~112 mi [~180 km] west of Sivulliq). Site 2 is located west of Prudhoe Bay (~73 mi [~117 km] west of Sivulliq). Site 4 is ~10 mi (~16 km) east of the Sivulliq drilling area and site 3 is ~20 mi (~32 km) west of Sivulliq.

The proposed geometry of the DASAR array at each site is shown in Figure 8, while Figure 9 zooms in on the two sites (3 and 4) adjacent to the Sivulliq and Torpedo prospects. In 2007–2011 each array was comprised of seven DASARs placed at the vertices of five stacked equilateral triangles with 7-km (4.3-mi) sides, as exemplified by sites 2, 3, or 5 in Figure 8. DASARs were labelled A–G from south to north. In 2012 the following changes are planned in the DASAR layout of sites 1 and 4:

- At site 1 the three adjacent DASARs that have detected the most calls in 2007–2011 (1D, 1E, and 1F) will be kept in place, to continue collecting data that can be compared with previous years. The remaining four DASARs

(1A, 1B, 1C, and 1G) will be moved to site 4 (see below). These four low-performance DASAR locations have, on average (2007–2011), detected as little as 1/100th of the calls detected at high-performance locations.

- At site 4 the four central DASARs (4A, 4C, 4E, and 4G) will be moved to their mirror-image position east of DASARs 4B, 4D, and 4F. This is shown in Figures 8 and 9. The main reason for doing this is to improve our ability to detect whale calls by placing these DASARs farther away from the drilling operation, where background sound levels will likely be lower. The four DASARs removed from site 1 will be added to the northern end of site 4 (4J, 4K, 4L, and 4M in Figure 9). This will improve the detection of calls from whales that choose a more northern route while migrating westward past the drilling operation.

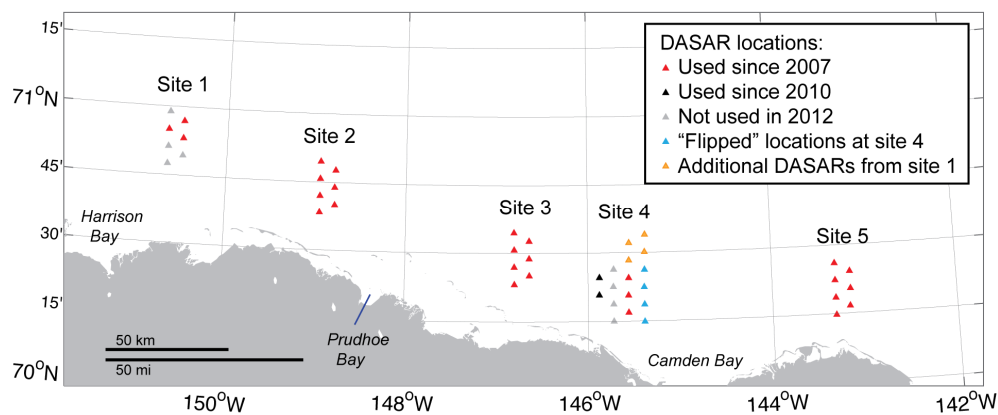


Figure 8. The Alaskan Beaufort Sea coast showing the five DASAR arrays (sites 1–5) for whale call location studies. DASAR deployments in 2012 are planned for all but the gray locations. See text for more information.

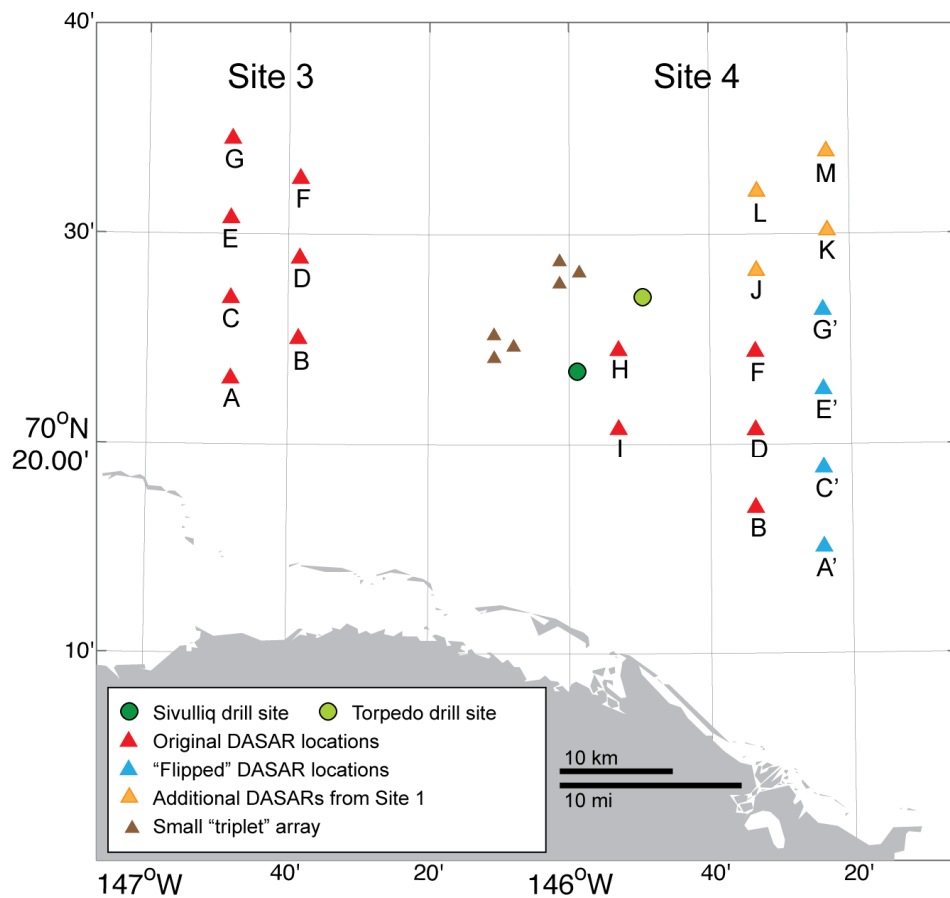


Figure 9. DASAR deployments at sites 3 and 4. DASARs are shown with triangles and the two drill sites, Sivulliq and Torpedo, are shown with green dots. The drill sites will be used consecutively. The triplets of DASARs (small brown triangles) will be retrieved when and if the drillship is moved and redeployed in the new location in the same relative positions. All other DASARs will remain in place over the entire season.

In addition, a small array of three DASARs with 2 km spacing—referred to as a triplet—will be deployed northwest of each drillsite, with the closest DASAR 6 km from the drill ship. When and if the drill ship is moved to another site, the triplet of DASARs will be retrieved and redeployed in the same relative locations. The triplets are shown in Figure 9 as small brown triangles.

DASARs will be installed at planned locations using a GPS. However, each DASAR’s orientation, once deployed on the bottom, is unknown and must be determined to know how to reference the bearings measured to the whales. That is, where is true north relative to the DASAR orientation? Also, the internal clocks used to sample the acoustic data typically drift slightly, but linearly, by an amount of up to about three minutes after six weeks of autonomous operation. Synchronizing DASARs to within a second is essential for identifying identical whale calls received on two or more DASARs. Solving these two problems is accomplished by transmitting known sounds at known times from known locations (by GPS) at three points around each DASAR at the beginning and at

the end of the operational period. Each set of transmissions requires about two minutes. With 12 calibration locations for a 7-DASAR array, calibration of a “standard” site will take 4 hrs. Calibration of site 4 will take longer, on the order of ~12 hours in good weather.

The calibration transmissions are made using a J9 projector easily deployed and retrieved over the side of a vessel by a single person. Maximum source level is 150 dB re 1 μ Pa at 1 m. The received level at a distance of 328 ft (100 m) will be ~110 dB, a level less than any known to cause disturbance to marine life.

Bowhead migration begins in late August with the whales moving westward from their feeding sites in the Canadian Beaufort Sea. It continues through September and well into October. We are planning to deploy the DASAR arrays in late July 2012 and retrieve them in early October, before they become inaccessible because of ice.

Whale call analysis will be done using an automated algorithm developed by Dr. Aaron Thode at Scripps Institution of Oceanography and described in Thode et al. (in press). Concurrently, about 10% of the collected data will also be analyzed manually, to provide a dataset with which to train the automated algorithm and then check its performance. During the manual analysis analysts will examine spectrograms in one-minute periods, looking for patterns identifying a whale call. The analyst will then confirm that a sound is indeed a whale call by listening to it. The call’s bearing is then calculated and stored for localization if the same call is detected by other DASARs in the array being analyzed.

The distributions of bowhead calls will be analyzed in relation to the presence of industrial activities, and the amplitude of the sounds produced by these activities. Received levels of sound at DASARs will be matched with the number of calls detected at each DASAR. This will provide information on whether certain received levels of sounds, i.e., a certain “dose” of sound, result in whales stopping to call, as seen with airgun pulses (Blackwell et al., in preparation). Call numbers at each DASAR will also be compared to the call numbers obtained in previous years at the same locations, to see whether call distributions in 2012 differ from previous years. The distribution and density of bowhead calls will be assessed as a function of activities at the drill rig and the movements of vessels.

DASAR records will also be analyzed for broadband background levels and the frequency composition of the recorded sounds will be determined. In addition to being influenced by anthropogenic activities, background levels are tightly linked to sea state. Therefore, even in the complete absence of anthropogenic sound sources, background sound levels show substantial variation over time. For each DASAR, narrowband spectral densities (1 Hz intervals, 1.7 Hz bandwidth, 23.5% overlap) will be determined for a one-min period about every 5 min. One-third octave band and broadband levels will be derived from the narrowband spectral densities. These narrowband, one-third octave, and broadband data will provide a continuous record, with 1 min resolution, of the levels of low-frequency underwater sounds at each location.

The narrowband data will also be summarized over periods of interest to derive “statistical spectra” showing, for each frequency, the levels exceeded during various

percentages of the 1-min samples. This type of analysis is useful for describing the frequency composition of sounds received at a particular location over long periods of time (like the entire deployment of the recorder) or, alternatively, during particular shorter-term events.

Received levels of sound at DASARs at various distances from the drillship will be used to describe how sounds from the drilling operation—the drillship and attending vessels—decrease as a function of distance. For example, for the Sivulliq prospect DASARs at sites 3 and 4 will be deployed at approximate distances of 4, 6, 6.5, 7.5, 8, 16, 17, 18, 20, 22, 22.5 (twice), 23.5, 25, 25.5, 26.5, 27, 29, 30, 31, 32, 34, and 37 km from the drillship, in many different directions (see Figure 9). This information will be used to create 3-D maps of received levels of sound as a function of the activities at the drill site.

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

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

Following the 2012 exploration drilling season a comprehensive report describing the vessel-based, aerial, and acoustic monitoring programs will be prepared. The comprehensive report will describe the methods, results, conclusions and limitations of each of the individual data sets in detail. The report will also integrate (to the extent possible) the studies into a broad based assessment of industry activities, and other activities that occur in the Beaufort and/or Chukchi seas, and their impacts on marine mammals. The report will help to establish long-term data sets that can assist with the evaluation of changes in the Chukchi and Beaufort Sea ecosystems. The report will attempt to provide a regional synthesis of available data on industry activity in offshore areas of northern Alaska that may influence marine mammal density, distribution and behavior.

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