Appendix D
Marine Mammal Monitoring and Mitigation Plan

THIS PAGE
INTENTIONALLY
LEFT BLANK

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.

May 2011

TABLE OF CONTENTS

Tables

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
BOEMRE	Bureau of Ocean Energy Management, Regulation and 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)
Discoverer	Motor Vessel *Noble Discoverer*
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
mi	mile(s)
MMPA	Marine Mammal Protection Act
MMO	Marine Mammal 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

THIS PAGE
INTENTIONALLY
LEFT BLANK

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, Regulation and Enforcement (BOEMRE), 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, 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 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 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 (MMOs) 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 exploratory activities. Aerial monitoring, designed primarily for detecting

cetaceans, will be used to identify any large scale distributional changes of cetaceans relative to the activities and add to the existing database on the abundance and distribution of observed species. The acoustic program will characterize the sounds produced by the 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 exploratory 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 MMOs, including both biologists and Inupiat personnel. MMOs 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 through October 31, 2012. 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 MMOs.

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 BOEMRE, the North Slope Borough (NSB), and the Alaska Eskimo Whaling Commission (AEWC) will also be fully incorporated. All MMOs 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;
- acoustic monitoring of the Kulluk and vessel sounds and marine mammal vocalizations; 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 back-propagated source level estimated by Greene (1987) from these measurements was 185 dB re 1 µPa 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*. Based on the models, source levels from exploration drilling are expected to fall below 180 dB rms approximately (~)43 ft (13 m) from the *Kulluk*. The 160 dB rms radius would extend ~180 ft (55 m) from the *Kulluk* and the 120 dB rms radius would be expected to be ~8 mi (~13 kilometer [km]) from the *Kulluk*.

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 µPa 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 µPa 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 mi^2 (78 square kilometers [km^2]).

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 MMOs 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 (in^3) (2,458 cubic meters [cm^3]) airguns and four 40 in^3 (655 cm^3) 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 in^3 (14,421 cm^3). 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*LogR – 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).

MMOs on the *Kulluk* or *Discoverer* will initially use these estimated safety radii for monitoring and mitigation purposes. An acoustics contractor 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. 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 MMOs to assure that no marine mammals are present. The entire safety zone must be visible during the 30-minutes 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-minutes 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).

Marine Mammal Observers

Vessel-based monitoring for marine mammals will be done by trained MMOs 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. MMO duties will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the exploration drilling operations; and documenting "take by harassment" as defined by NMFS.

Number of Observers

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

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

MMO teams will consist of Inupiat observers and experienced field biologists. An experienced field crew leader and an Inupiat observer will be members of every MMO team onboard the *Kulluk* or *Discoverer* and each support vessel during the exploration drilling program. The total number of MMOs may decrease later in the season as the duration of daylight decreases assuming NMFS does not require continuous nighttime monitoring. Inupiat MMOs 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 in incoming crew leader by the outgoing leader. Other communications such as email, fax, and/or phone communication between the current and oncoming crew leaders during each rotation will also occur when possible. In the event of an unexpected crew change Shell will facilitate such communications to insure monitoring consistency among shifts.

Observer Qualifications and Training

Crew leaders and most other biologists serving as observers in 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 MMO handbook, adapted for the specifics of the planned Shell exploration drilling program, will be prepared and distributed beforehand to all MMOs (see below).

Most observers, including Inupiat observers, will also complete a two-day training and refresher session on marine mammal monitoring, to be conducted shortly before the anticipated start of the 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 BOEMRE, 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.

MMO Handbook

A MMO 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 MMOs. The following topics will be covered in the MMO 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 state codes;
- data storage and backup procedures;
- list of species that might be encountered: identification, natural history;
- safety precautions while onboard;
- crew and/or personnel discord; conflict resolution among MMOs and crew;
- drug and alcohol policy and testing;
- scheduling of cruises and watches;
- communications;
- list of field gear that will be provided;
- suggested list of personal items to pack;
- suggested literature, or literature cited; and
- copies of the NMFS IHA and USFWS LOA when available.

Monitoring Methodology

The observer(s) will watch for marine mammals from the best available vantage point on the *Kulluk* or *Discoverer* and support vessels. Ideally this vantage point is an elevated stable platform from which the MMO has an unobstructed 360 degree (^{o}) view of the water. The observer(s) will scan systematically with the unaided eye and 7×50 reticle binoculars, supplemented with 20 x 60 image-stabilized Zeiss Binoculars or Fujinon 25 x 150 "Big-eye" binoculars and night-vision equipment when needed (see below). Personnel on the bridge will assist the MMOs in watching for marine mammals. New or inexperienced MMOs will be paired

with an experienced MMO or experienced field biologist so that the quality of marine mammal observations and data recording is kept consistent.

Information to be recorded by MMOs will include the same types of information that were recorded during recent monitoring programs associated with Industry activity in the Arctic (e.g. Ireland et al. 2009). When a mammal sighting is made, the following information about the sighting will be 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
- The 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 temperature, water depth, sea state, ice cover, visibility, and sun glare will also be recorded at the start and end of each observation watch, every 30 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 ±20% when given immediate feedback about actual distances during training.

Monitoring At Night and In Poor Visibility

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

Specialized Field Equipment

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

Field Data-Recording, Verification, Handling, and Security

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

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

Field Reports

Throughout the 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, BOEMRE and Shell as required.

Reporting

The results of the 2012 vessel-based monitoring, including estimates of "take by harassment", will be presented in the 90-day and final technical report(s). Reporting will address the requirements established by NMFS in the IHA, 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. 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; 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. 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. The aircraft will be provided with a comprehensive set of survival equipment appropriate to offshore surveys in the Arctic. For safety reasons, the aircraft will be operated with two pilots.

Survey Procedures

Flight and Observation Procedures

Aerial survey flights will begin 5 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; Patterson 2007). This will facilitate comparison and pooling of data where appropriate. However, the specific survey grids will be tailored to Shell's operations. During the 2012 drilling season Shell will coordinate and cooperate with the aerial surveys conducted by BOEMRE/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 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 but are suitable for both bowhead and beluga whales. The need for a 900-1000+ ft cloud ceiling will limit the dates and times when surveys can be flown. Selection of a higher minimum altitude for surveys (e.g. 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 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. All observers need bubble windows to facilitate downward viewing. For each marine mammal sighting, the observer will dictate the species, number, size/age/sex class when determinable, activity, heading, swimming speed category (if traveling), sighting cue, ice conditions (type and percentage), and inclinometer reading to the marine mammal into a digital recorder. The inclinometer reading will be taken when the animal's location is 90° to the side of the aircraft track, allowing calculation of lateral distance from the aircraft trackline.

Transect information, sighting data and environmental data will be entered into a GPS-linked computer by the third observer, and simultaneously recorded on digital voice recorders for backup and validation. At the start of each transect, the observer recording data will record the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction degrees True North (°T) and outside air temperature 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 data in units suitable for statistical summaries and analyses of effects of these variables (and position relative to the drillship) on the probability of detecting animals (see Davis et al. 1982; Miller et al. 1999; Thomas et al. 2002). The data logger will automatically record time and aircraft position (latitude and longitude) for sightings and transect waypoints, and at pre-selected intervals along the transects.

Supplementary Data

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

Shell will, as a high priority, assemble the information needed to relate marine mammal observations to the locations of the *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 BOEMRE/NMFS Aerial Surveys

BOEMRE/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 BOEMRE/NMML to share data, both during the drilling season and for use in analyses and reports.

Shell will also consult with BOEMRE/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 BOEMRE'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 BOEMRE 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 BOEMRE 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 surveys (COMIDA/BWASP 2009) 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) 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.

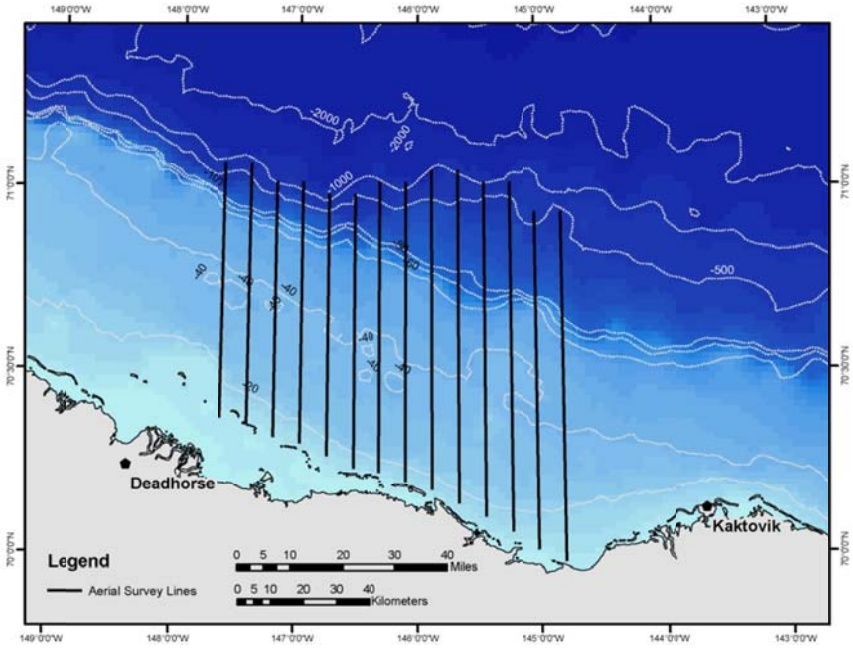

FIGURE 1. Central Alaskan Beaufort Sea showing a representative aerial survey pattern that will be flown daily during late summer and fall. The survey grid will be moved east or west depending on the precise location of the *Kulluk* or *Discoverer* and lines will be shifted slightly within the grid for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

Bowhead whale movements during the late summer/autumn are generally from east to west, and transects should be designed to intercept rather than parallel whale movements. The transect lines in the grid will be oriented north-south, equally spaced at 5 mi (8 km), and randomly shifted in the east-west direction for each survey by no more than the transect spacing. The survey grid will total about 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. 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 making up the grid in the Beaufort Sea will be flown in sequence from west to east. This decreases difficulties associated with double counting of whales that are (predominantly) migrating westward. The survey sequence around the exploration drilling

operation is designed to monitor the distribution of whales around the exploration drilling operation.

Analysis of Aerial Survey Data

During the field program, preliminary maps and summaries of the daily surveys will be provided to NMFS as normally required by the terms of the IHA, and USFWS and BOEMRE (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. Two levels of analyses will be conducted at the end of the season. The first level will consist of basic summaries that are required for the 90-day report specified by the IHA. These include summaries of numbers of marine mammals seen, survey effort by date, maps summarizing sightings, and estimates of numbers of marine mammals that are "taken" according to NMFS criteria. The second level of analyses will be presented in 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.

Estimation of Numbers "Taken"

Shell has used this methodology, which was developed using past studies in the Beaufort and Chukchi sea regions (Miller et al. 1999; Haley and Ireland 2006) and other areas of the world (Lawson et al. 1998; Holst et al. 2005; Ireland et al. 2005), for estimating the numbers of marine mammals that are "taken" (as defined by NMFS). These estimates require estimating the numbers of animals present near or passing the 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 ensonified 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 µPa, 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 1µ Pa rms when no monitoring observations were possible*. This will involve using the observations from the survey aircraft (Shell and BOEMRE/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 BPEMRE/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 estimate*d. 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 BOEMRE/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 receive 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 BOEMRE, formerly as Minerals Management Service (MMS) (Treacy 1998, 2000, 2002) and LGL (Patterson et al. 2007). Therefore, the proposed aerial surveys are expected to document the infrequent use of continental shelf waters of the Beaufort Sea by beluga whales, gray whales and walrus, but 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 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.

Equipment

The *Kulluk* or *Discoverer*, support vessels, and ZVSP sound measurements will be performed using one of two methods, both of which involve real-time monitoring. The first method would involve use of bottom-founded hydrophones cabled back to the *Kulluk* or *Discoverer* (Figure 2). These hydrophones weigh approximately 88 pounds (lb) (40 kilograms) with a footprint of approximately 2.7 ft^2 (0.5 m^2) and would be positioned between 1,640 ft (500 m) and 3,281 ft (1,000 m) from the *Kulluk* or *Discoverer*, depending on the final positions of the anchors used to hold the *Kulluk* or *Discoverer* in place. Hydrophone cables would be fed to real-time digitization systems on board. In addition to the cabled system, a separate set of bottom-founded hydrophones (Figure 3) may be deployed at various distances from the exploration drilling operation for storage of acoustic data to be retrieved and processed at a later date.

As an alternative to the cabled hydrophone system (and possible inclusion of separate bottom-founded hydrophones), the second (or alternative) monitoring method would involve a radio buoy approach deploying four sparbuoys 4-5 mi (6-8 km) from the *Kulluk* or *Discoverer*. Additional hydrophones may be deployed closer to the *Kulluk* or *Discoverer*, if necessary, to better determine sound source levels. Monitoring personnel and recording/receiving equipment would be onboard one of the support vessels with 24-hr monitoring capacity. The system would allow for collection and processing of real-time data similar to that provided by the cabled system but from a wider range of locations. Processing would provide real-time localization of sound sources including seals and whales.

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

The deployment of drilling sound monitoring equipment will occur as soon as possible once 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.

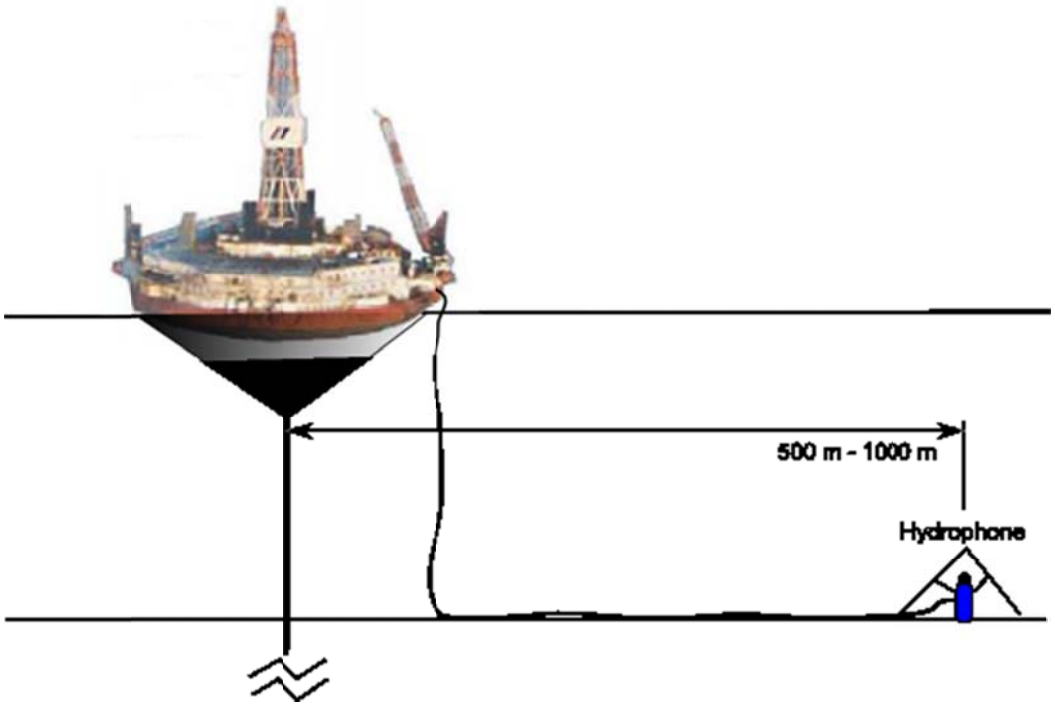

Figure 2: Cabled hydrophone method for real time monitoring of drilling sounds[1].

Note: [1] Drilling vessel *Kulluk* is pictured; however, either it, or the drillship *Discoverer* will be used.

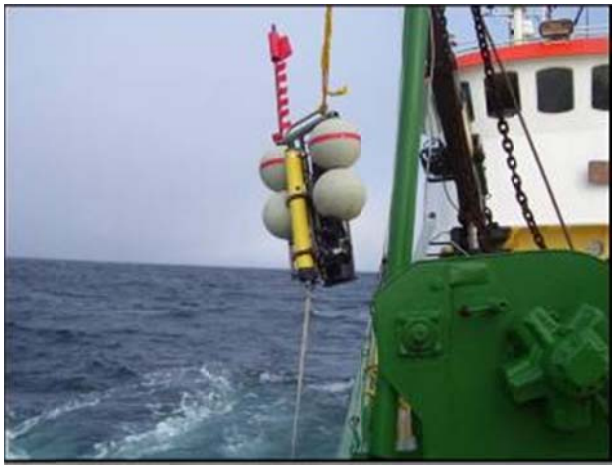

Figure 3. Hydrophone recording system being deployed at sea. The hydrophone system is an autonomous recorder with very high recording resolution. Acoustic data is stored internally on a hard-drive.

Vessel Sounds Monitoring

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

Zero Offset Vertical Seismic Profiling Sounds Monitoring

Sounds produced by the ZVSP survey at the end of each drill hole will be recorded using the drilling sounds monitoring equipment. 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 in^3 (2,458 cm^3) airguns and four 40 in^3 (655 cm^3) 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

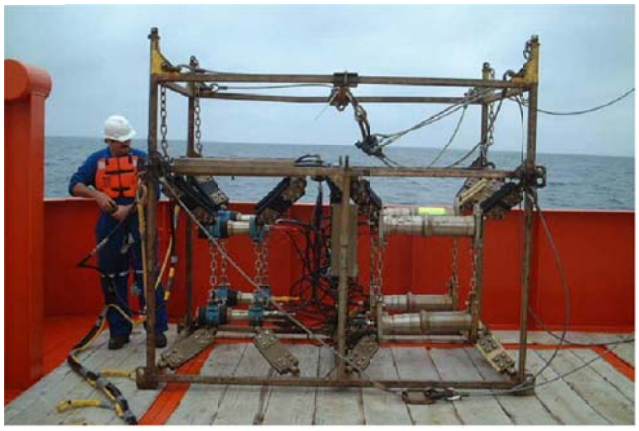

Table 1 Typical Sound Source (Airgun Array) Specifications for ZVSP

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.

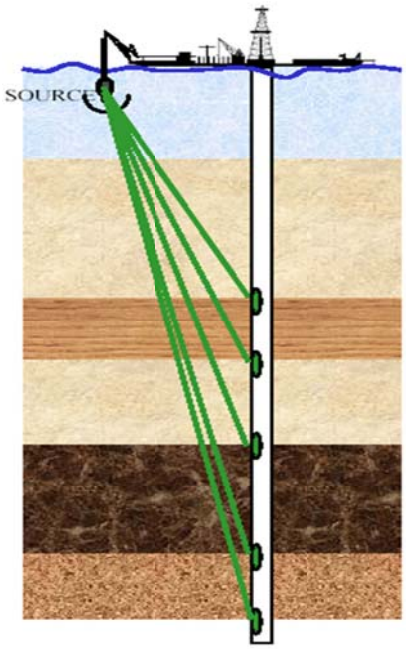

Figure 4. Schematic of ZVSP.[1]

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

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). 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 a bottom-founded 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. 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.

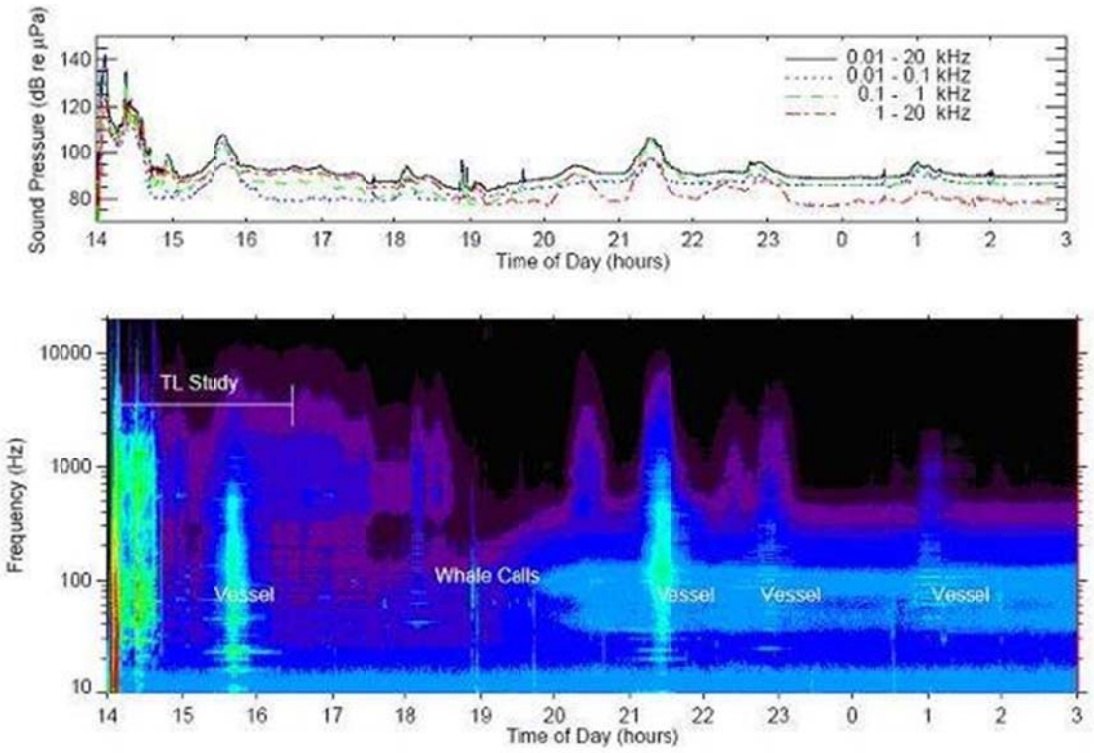

Figure 5. Lower: spectrogram of sound level measurements obtained from a hydrophone recording system. Upper: broadband and selected band level variation with time.

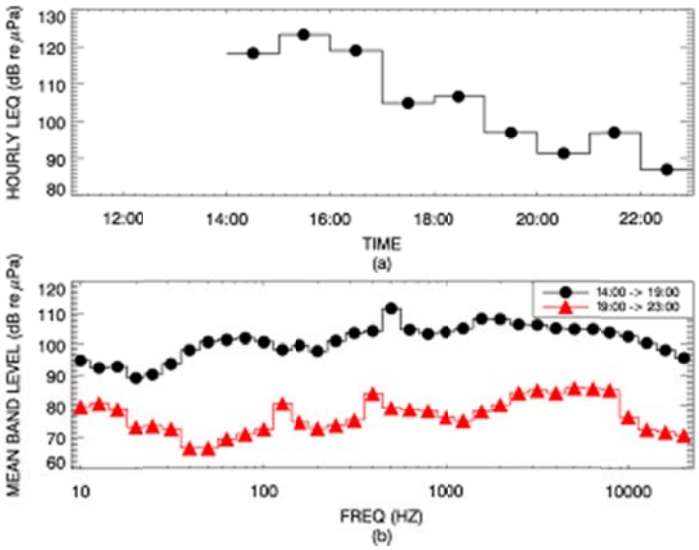

Figure 6. Upper: 1-hr Leq levels that will be calculated from acoustic measurements for use in correlating with bowhead whale deflection data.

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 Deflections

Shell plans to deploy arrays of acoustic recorders in the Beaufort Sea in 2012, similar to that which was done in 2007 through 2010, and will be again in 2011 using DASARs supplied by Greeneridge. These directional acoustic systems permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document sound characteristics and propagation resulting from vessel-based exploration drilling operations that may have the potential to cause deflections of bowhead whales from their migratory pathway. Of particular interest will be the east-west extent of deflection, if any (i.e., how far east of a sound source do bowheads begin to deflect and how far to the west beyond the sound source does deflection persist). Of additional interest will be the extent of offshore (or towards shore) deflection that might occur.

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

Objective

The objective of this study is to provide information on bowhead migration paths along the Alaskan coast, particularly with respect to industrial operations, and whether and to what extent

there is deflection due to industrial sound levels. Using passive acoustics with directional autonomous recorders, the locations of calling whales will be observed for a six- to ten-week continuous monitoring period at five coastal sites (subject to favorable ice and weather conditions). Essential to achieving this objective is the continuous measurement of sound levels near the *Kulluk* or *Discoverer*. 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).

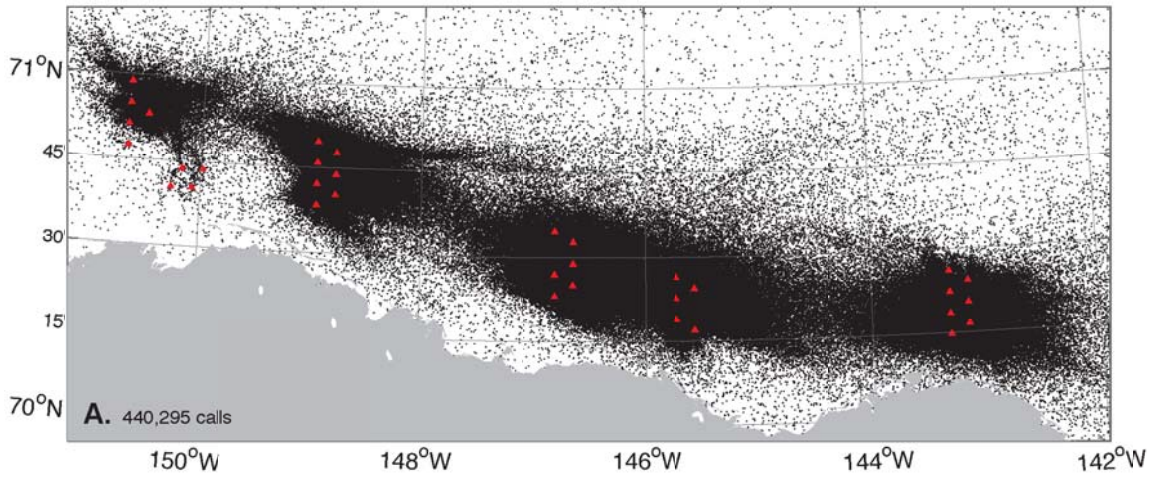

Figure 7. Bowhead whale call locations determined from the received bearings at five arrays of DASARs in the Beaufort Sea in 2008.

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 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 arrival angles of bowhead calls at known locations, then triangulating to locate the calling whale. Hundreds of thousands, of whale calls were successfully located in 2007 and 2008.

In attempting to assess the responses of bowhead whales to the planned industrial operations, it will be essential to monitor whale locations at sites both near and far from industry activities. Shell plans to monitor at five sites along the Alaskan Beaufort coast, as shown in Figure 8. The eastern-most site (#5 in Figure 8) will be just east of Kaktovik ~62 mi [~100 km] west of the Sivulliq drilling area) and the western-most site (#1) will be in the vicinity of Harrison Bay (~47 mi [~175 km] west of Sivulliq). Site 2 will be located west of Prudhoe Bay (~68 mi [~110 km] west of Sivulliq). Site 4 will be ~6.2 mi (~10 km) east of the Sivulliq drilling area and site 3 will be ~15.5 mi (~25 km) west of Sivulliq. These five sites will provide information on possible migration deflection well in advance of whales encountering an industry operation and on "recovery" after passing such operations should a deflection occur.

The proposed geometry of DASARs at each site is comprised of seven DASARs oriented in a north-south pattern so that five equilateral triangles with 4-mi (7-km) element spacing are achieved. This geometry is illustrated in Figure 8. Three mi (5 km) spacing has been used successfully in the migration studies at Northstar, but whale calls are received reliably at greater

spacing and the 4 mi (7 km) spacing will result in greater coverage of whales along the north-south dimension, important in studying possible deflection.

DASARs will be installed at planned locations using a GPS. However, each DASAR's orientation, once it settles on the bottom, is unknown and must be determined to know how to reference the call angles measured to the whales. That is, where is true north relative to the DASAR orientation? Also, the internal clocks used to sample the acoustic data typically drift slightly, but linearly, by an amount up to a few seconds after six weeks of autonomous operation. Knowing the time differences within a second or two between DASARs is essential for identifying identical whale calls received on two or more DASARs. Solving these two problems is accomplished by transmitting known sounds at known times from known locations (by GPS) at six points around each DASAR at the beginning and at the end of the operational period. (Shell also will use a mid-season calibration.) Because of the equilateral triangular geometry, it requires 25 transmission stations for each site. Each set of transmissions requires less than half a minute. For the 3-mi (5-km) spacing, experience has been that it requires an hour to do 4 calibration transmissions, including transit. For our planned 4 mi (7-km) spacing, we estimate three calibration transmissions per hour. With 25 to do at each site, calibration of a site will require ~8 hours.

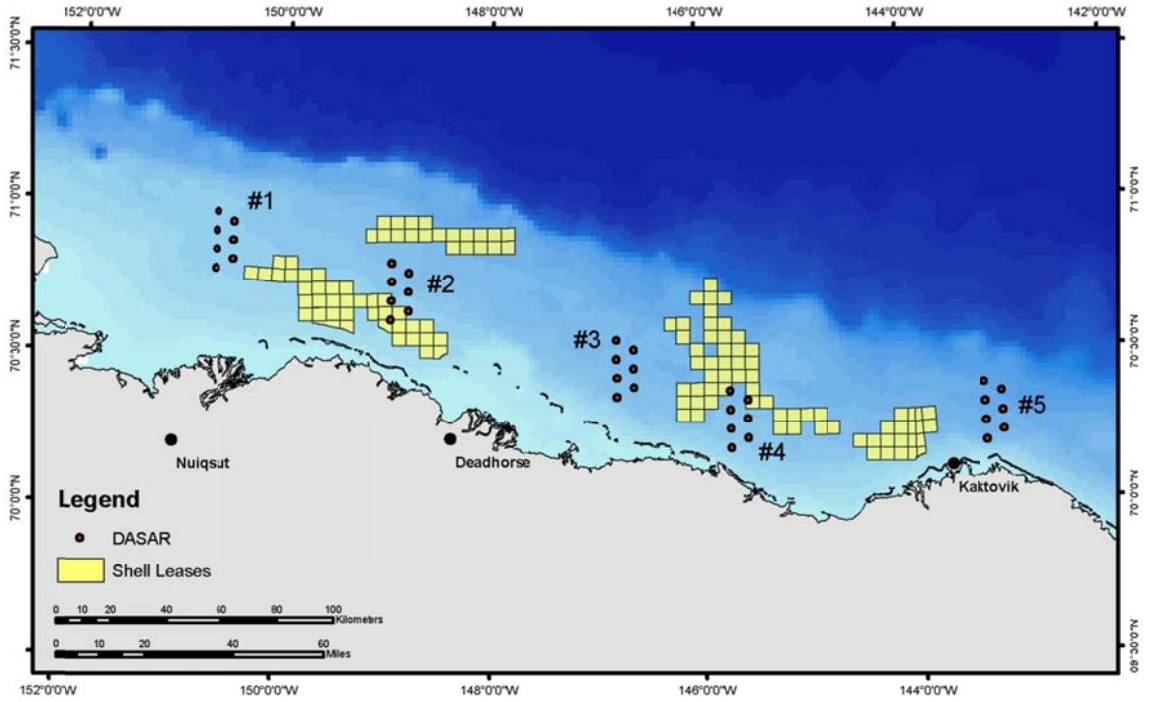

Figure 8. The Alaskan Beaufort Sea coast showing DASAR site locations for whale call location studies. The DASAR array locations at the five sites are shown to scale, with seven DASARs forming five equilateral triangles with a unit spacing of 4 mi (7 km) and a north-south extent of 13 mi (21 km) to aid being able to observe possible offshore deflection.

The calibration transmissions are made using a small projector easily deployed and retrieved over the side of a vessel by a single person. Maximum source level is only 150 dB re 1µPa at 1 m.

The received level at a distance of 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. However, because of the exploration drilling schedule, we will attempt to install the 21 DASARs at three sites (#3, #4 and #5 in Figure 8) in early August. The remaining 14 DASARs will be installed at sites #1 and #2 in late August. Thus, we propose to be monitoring for whale calls from before 15 August until sometime before 15 October.

At the end of the season the 4th DASAR in each array will be refurbished, recalibrated, and redeployed to collect data through the winter. The other DASARs in the arrays will be recovered. The redeployed DASARs will be programmed to record 35 minute every three hours with a disk capacity of 10 months at that recording rate. This should be ample space to allow over-wintering from ~mid-October 2012 through mid-July 2013.

Whale call analysis for the Northstar DASARs has been a manual process in which analysts observe acoustic spectrograms in one-minute periods, looking for patterns caused by a whale call. Listening to the sound, the analyst verifies that a sound is or is not a whale call, and when it is, the bearing is calculated and stored for localization if the same call is present at one or more other DASARs in an array. In the proposed 2012 project, machine-aided call detection software will be used to simplify and accelerate the call analysis. Such software was developed with Shell's sponsorship in 2006 and is described in Greene et al. (2007). The software has been tested and refined during data collection efforts in 2008 through 2010, and will be again with 2011 results.

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

Many interesting analyses will be available from the data collected by the five array sites. Only two analyses are discussed here. One analysis will estimate the location of the migration corridor across the extent of our study area. The migration corridor will be estimated by contours for the distribution of whale locations along the coast from array #1 to array #5. Density contours will be estimated using kernel density estimation (Silverman 1998). To be included in this analysis, call precision must be high, or alternatively, calls will be inversely weighted according to the size of their error ellipse. Because Shell anticipates that calls occurring between arrays will have very low precision, the variance of density estimates in these areas will be high. If the migration corridor is generally close to shore at arrays #5 and #4, but far offshore at the locations of array #3, #2, and #1, an offshore displacement of the corridor near the planned exploration drilling activity might be inferred. Shell plans to use block bootstrapping (Lahiri 2003) of raw data to

assess variation in contours, when appropriate. Block bootstrapping accounts for potential autocorrelation among locations collected during short time intervals. This analysis does not depend on quantification of underwater industrial sounds emanating from exploration drilling operations.

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

To illustrate the second analysis, consider DASAR sites #4 and #3 in Figure 8. Over a standard reporting period, for example 6 hr, calls located by these two arrays will be collected, as well as other environmental covariates such as water depth, ambient sound levels, time of day, etc. From these data, summary statistics for offshore distribution, and all covariates of interest will be calculated. For example, the 25th percentile of offshore distance may be calculated, as well as the average water depth of all call locations in the 6-hour reporting period. Differences in offshore summary statistics among arrays will then be calculated and used in a regression or quantile regression analysis. Using the example above, the difference in 25th percentile of offshore distance between array #4 and array #3 could be related to the average industrial sound level output by the source. Assuming displacement occurs somewhere between arrays #4 and #3, a constant difference in the 25th percentile of offshore distance when sound levels are low, and larger differences in offshore distance when industrial sound levels increase would be expected. A significant slope of the regression relating offshore distance difference to sound levels will indicate a statistically significant displacement between the arrays in question. This type of analysis can be run using any pair of DASAR arrays (e.g., between #5 and #3 or between #4 and #1, etc.).

Analysis Assumptions:

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

Post-90-day Report Analysis

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

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

Following the 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.

LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 2009. Satellite Tracking of Western Arctic Bowhead Whales. Preliminary reports and summaries available at: http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.bowhead

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

Austin, M. and G. Warner. 2010. Acoustic monitoring of the drillship Frontier Discoverer. Technical report prepared by JASCO Applied Sciences, Victoria, BC, Canada, for Shell International Exploration and Production Inc. 45 pp.

Blackwell, S.B., C.R. Greene, H.K. Kim, T.L. McDonald, C.S. Nations, R.G. Norman, and A. Thode. 2010. Beaufort Sea acoustic monitoring program. (Chapter 9) In: Funk, D.W, D.S. Ireland, R. Rodrigues, and W.R. Koski (eds.). 2010. Joint Monitoring Program in the Chukchi and Beaufort seas, open-water seasons, 2006–2008. LGL Alaska Report P1050-3, Report from LGL Alaska Research Associates, Inc., LGL Ltd., Greeneridge Sciences, Inc., and JASCO Research , Ltd., for Shell Offshore, Inc. and Other Industry Contributors, and National Marine Fisheries Service, U.S. Fish and Wildlife Service. 499 p. plus Appendices.

Brewer, K.D., M.L. Gallagher, P.R. Regos, P.E. Isert, and J.D. Hall. 1993. Kuvlum #1 exploration prospect final report – site specific monitoring program. Report from Coastal & Offshore Pacific Corporation, Walnut Creek, CA, for ARCO Alaska. Inc.

Clarke, J.T., S.E. Moore, and M.M. Johnson. 1993. Observations on beluga fall migration in the Alaskan Beaufort Sea, 1982-87, and northeastern Chukchi Sea, 1982-91. Rep. Int. Whal. Comm. 43:387-396.

COMIDA. 2009. Chukchi Offshore Monitoring in Drilling Area. National Marine Mammal Laboratory Cetacean Assessment and Ecology Program, Bowhead Whale Aerial Surveys: Preliminary Data. Available at: http://www.afsc.noaa.gov/nmml/cetacean/bwasp/index.php.

Davis, R.A., W.R. Koski, W.J. Richardson, C.R. Evans, and W.G. Alliston. 1982. Distribution, numbers and productivity of the Western Arctic stock of bowhead whales (Balaena mysticetus) in the eastern Beaufort Sea and Amundsen Gulf, summer 1981. SC/34/PS20. Int. Whal. Comm., Cambridge, UK. 13 p.

Davis, R.A., C.R. Greene, and P.L. McLaren. 1985. Studies of the potential for drilling activities on Seal Island to influence fall migration of bowhead whales through Alaskan nearshore waters. Rep. from LGL Ltd., King City, Ont., for Shell Western E & P Inc., Anchorage, AK. 70 p.

Evans, C.R., S.R. Johnson, and W.R. Koski. 1987. Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea, autumn 1986: Aerial surveys of whale distribution. Rep. by LGL Ltd., King City, Ontario, for Shell Western E& P Inc., Anchorage. 69 p.

Funk, D.W., D.S. Ireland, R. Rodrigues, and W.R. Koski (eds.). 2010. Joint Monitoring Program in the Chukchi and Beaufort Seas, Open Water Seasons 2006–2008. LGL Alaska Rep. P1050-1. Rep. from LGL Alaska Research Associates Inc., Anchorage, AK, LGL Ltd., JASCO Research Ltd. and

Greeneridge Sciences, Inc. for Shell Offshore Inc, Houston, TX, ConocoPhillips Alaska Inc., Anchorage, AK and Nat. Mar. Fish. Serv., Silver Spring, MD. and U.S. Fish and Wildlife Service. 488 p. plus appendices.

Greene, C.R. 1987. Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. J. Acoust. Soc. Am. 82(4):1315-1324.

Greene, C.R. Jr., R.G. Norman, S.B. Blackwell, M.W. McLennan, and A. Thode. 2007. Acoustics research for studying bowhead migration, 2006. Technical report for Shell Offshore International, Houston, Texas, by Greeneridge Sciences Inc., Santa Barbara, California, and LGL Alaska environmental research associates Inc., Anchorage, Alaska. 24 p.

Haley, B. and D. Ireland. 2006. Marine mammal monitoring during University of Alaska Fairbank's marine geophysical survey across the Arctic Ocean, August-September 2005. LGL report 4122-3. Report from LGL Alaska Research Associates, Anchorage, AK and LGL Ltd, King City, Ont., for Geophysical Institute, University of Alaska, Fairbanks, AK, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Hall, J.D., M.L. Gallagher, K.D. Brewer, P.R. Regos, and P.E. Isert. 1994. 1993 Kuvlum exploration area site specific monitoring program – final report. Report from Coastal & Offshore Pacific Corporation, Walnut Creek, CA, for ARCO Alaska, Inc.

Harris, R.E., G.W. Miller, R.E. Elliott, and W.J. Richardson. 1997. Seals [1996]. p. 4-1 to 4-42 In: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Harris, R.E., A.N. Balla-Holden, S.A. MacLean, and W.J. Richardson. 1998. Seals [1997]. p. 4-1 to 4-54 In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska's) open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatán Peninsula in the Gulf of Mexico, January–February 2004. LGL Rep. TA2822 31. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 96 p.

Ireland, D., M. Holst, and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program off the Aleutian Islands, Alaska, July–August 2005. LGL Rep. TA2822-32. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 67 p.

Ireland D.S., D.W. Funk, R. Rodrigues, and W.R. Koski (eds.). 2008. Joint Monitoring Program in the Chukchi and Beaufort Seas, July-November 2007. LGL Alaska Rep. P971-1. Rep. from LGL Alaska Research Associates Inc., Anchorage, AK, LGL Ltd., and JASCO Research Ltd. and Greeneridge Sciences, Inc. for Shell Offshore Inc, Houston, TX, ConocoPhillips Alaska Inc.,

Anchorage, AK and Nat. Mar. Fish. Serv., Silver Spring, MD and U.S. Fish and Wildlife Service. 445 p. plus appendices.

Ireland, D.S., R. Rodrigues, D. Funk, W.R. Koski, and D. Hannay. (eds.). 2009. Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. In the Chukchi and Beaufort Seas, July–October 2008 : 90-day report. LGL Rep. P1049-1. Rep from LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. For Shell Offshore Inc., Nat. Mar. Fish. Serv., and U.S. Fish and Wild. Serv. 277 pp, plus appendices.

Johnson, S.R., C.R. Greene, R.A. Davis, and W.J. Richardson. 1986. Bowhead whales and underwater noise near the Sandpiper Island drillsite, Alaskan Beaufort Sea, autumn 1985. Rep. from LGL Ltd., King City, Ont., for Shell Western E & P Inc., Anchorage, AK. 130 p.

Koenker, R. and O. Geling. 2001. Reappraising medfly longevity: a quantile regression survival analysis. Journal of the American Statistical Association, 95, p. 458-468.

Koenker, R. and B. J. Park. 1996. An interior point algorithm for nonlinear quantile regression. Journal of Econometrics, 71, p. 265-283.

Koenker, R. and Z. Xiao. 2002. Inference on the quantile regression process. Econometrica, 70, p. 1583-1612.

Koski, W.R., Thomas, T.A., G.W. Miller, R.A. Davis, and W.J. Richardson. 2002. Residence times and rates of movement of bowhead whales in the Beaufort Sea and Amundsen Gulf during summer and autumn. Chapter 11. In: W.J. Richardson and D.H. Thomson (eds). Bowhead whale feeding in the eastern Alaskan Beaufort Sea: Final Report. Report by LGL Ltd., King City, for Minerals Management Service, Anchorage, AK.

Lahiri, S.N. (2003). Resampling Methods For Dependent Data. Springer, New York. 374 pp.

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

Lawson, J.W., W.R. Koski, D.H. Thomson, and W.J. Richardson. 1998. Chapter 4.7 Marine Mammals: Environmental Consequences. In: Environmental Impact Statement/Overseas Environmental Impact Statement Point Mugu Sea Range. Prepared by LGL Limited, King City, Ontario, and Ogden Environmental and Energy Services, Santa Barbara, CA, for Dep. Navy, Naval Air Warfare Center Weapons Division, Point Mugu, CA and Southwest Division Naval Facilities Engineering Command, San Diego, CA.

Ljungblad, D.K., S.E. Moore, and J.T. Clarke. 1986. Assessment of bowhead whale (Balaena mysticetus) feeding patterns in the Alaskan Beaufort and northeastern Chukchi seas via aerial surveys, fall 1979-84. Rep. Int. Whal. Comm. 36:265-272.

Lowry, L.F. 1993. Foods and feeding ecology. p. 201-238 In: J.J. Burns, J.J. Montague and C.J. Cowles (eds) The Bowhead Whale. Special Publication. No. 2. Society for Marine Mammalogy, Lawrence, Kansas. 787 p.

Lowry, L.F., G. Sheffield, and J.C. George. 2004. Bowhead whale feeding in the Alaskan Beaufort Sea based on stomach contents analyses. J. Cetacean Res. Manage. 63: 223.

Manly, B.F.J., V.D. Moulton, R.E. Elliott, G.W. Miller, and W.J. Richardson. 2004. Analysis of covariance of fall migrations of bowhead whales in relation to human activities and environmental factors, Alaskan Beaufort Sea: Phase I, 1996-1998. Report by LGL Limited, King City, ON, and WEST Inc., Cheyenne, WY, for Minerals Management Service, Herndon, VA and Anchorage, AK. 128 p.

Miles, P.R., C.I. Malme, and W.J. Richardson. 1987. Prediction of drilling site-specific interaction of industrial acoustic stimuli and endangered whales in the Alaskan Beaufort Sea. BBN Rep. 6509; OCS Study MMS 87-0084. Rep. from BBN Labs Inc., Cambridge, MA, and LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK. 341 p. NTIS PB88-158498.

Miller, G.W., R.E. Elliott, W.R. Koski and W.J. Richardson. 1997. Whales. p. 5-1 to 5-115 In: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1996: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2121-2. Rep. from LGL Ltd., King City, ON and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc. and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Miller, G.W., R.E. Elliott, and W.J. Richardson. 1998. Whales. p 5-1 to 5-123 In: W.J. Richardson (ed.), Northstar marine mammal monitoring program, 1997: marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. LGL Rep. 2150-3. Rep. from LGL Ltd., King City, ON and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc. and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

Miller, G.W., R.E. Elliott, W.R. Koski, V.D. Moulton, and W.J. Richardson. 1999. Whales. p. 5-1 to 5-109 In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA2230-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Miller, G.W., R.E. Elliott, T.A. Thomas, V.D. Moulton, and W.R. Koski. 2002. Distribution and numbers of bowhead whales in the eastern Alaskan Beaufort Sea during late summer and autumn, 1979-2000. p. 9-1 to 9-39 (Chap. 9) In: W.J. Richardson and D.H. Thomson (eds.), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, vol. 1. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. 420 p. NTIS PB2006-100382.

Monnett, C. and S.D. Treacy. 2005. Aerial surveys of endangered whales in the Beaufort Sea, fall 2002-2004. U.S. Minerals Manage. Serv., Anchorage, AK. 153 p.

Moore, S.E., J.T. Clarke, and M.M. Johnson. 1993. Beluga distribution and movements offshore northern Alaska in spring and summer, 1980-84. Rep. Int. Whal. Comm. 43:375-86.

Moulton, V.D. and J.W. Lawson. 2002. Seals, 2001. p. 3-1 to 3-48 In: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of WesternGeco's open water seismic program in the Alaskan Beaufort Sea, 2001. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for WesternGeco, Houston, TX, and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. LGL Rep. TA2564-4.

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

NMFS. 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. Fed. Regist. 65(60, 28 Mar.):16374-16379.

Patterson, H., S.B. Blackwell, B. Haley, A. Hunter, M. Jankowski, R. Rodrigues, D. Ireland, and D.W. Funk. 2007. Marine mammal monitoring and mitigation during open water seismic exploration by Shell Offshore Inc. in the Chukchi and Beaufort Seas, July–September 2006: 90-day report. LGL Draft Rep. P891-1. Rep. from LGL Alaska Research Associates Inc., Anchorage, AK, LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Goleta, CA, for Shell Offshore Inc, Houston, TX, and Nat. Mar. Fish. Serv., Silver Spring, MD. 119 p.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA.

Silverman, B.W. 1998. Density estimation for statistics and data analysis. Chapman & Hall/CRC, Boca Raton.

Thomas, T.A., W.R. Koski, and W.J. Richardson. 2002. Correction factors to calculate bowhead whale numbers form aerial surveys of the Beaufort Sea. Chapter 15. In: W.J. Richardson and D.H. Thomson (eds.). Bowhead whale feeding in the eastern Alaskan Beaufort Sea: Update of Scientific and Traditional Information. 28pp. OCS Study MMS 2002-012.

Treacy, S.D. 1998. Aerial surveys of endangered whales in the Beaufort Sea, fall 1997. OCS Study MMS 98-059. U.S. Minerals Manage. Serv., Anchorage, AK. 143 p.

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

Treacy, S.D. 2002. Aerial surveys of endangered whales in the Beaufort Sea, fall 2000. OCS Study MMS 2002-014. U.S. Minerals Manage. Serv., Anchorage, AK. 111 p.

Warner, G. and D. Hannay. 2011. Acoustic modeling of underwater noise from the Frontier Discoverer in the Chukchi and Beaufort seas. Version 1.0. Technical report for Shell Exploration and Production Company by JASCO Applied Sciences.

Würsig, B., W.R. Koski, T.A. Thomas, and W.J. Richardson. 2002. Activities and behavior of bowhead whales in the eastern Alaskan Beaufort Sea during late summer and autumn. Chapter 12. In: W.J. Richardson and D.H. Thomson (eds). Bowhead whale feeding in the eastern Alaskan Beaufort Sea: Final Report. Report by LGL Ltd., King City, for Minerals Management Service, Anchorage, AK.