MARINE MAMMAL MONITORING AND MITIGATION PLAN

for

Proposed Open Water Marine Survey Program in the Beaufort and Chukchi Seas, Alaska, During 2010

Shell Offshore Inc.
Shell Gulf of Mexico Inc.

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ACRONYMS

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

Introduction

Shell Offshore Inc., the lessee for Outer Continental Shelf (OCS) leases in the Beaufort Sea, and Shell Gulf of Mexico Inc., the lessee for OCS leases in the Chukchi Sea, collectively known as Shell submits the following Marine Mammal Monitoring and Mitigation Program (4MP) for site clearance and shallow hazards survey activities in the Beaufort Sea during the 2010 open-water season. The 4MP developed for Shell's 2010 site clearance and shallow hazards survey program is designed to protect the marine mammal resources in the area, fulfill reporting obligations to the Minerals Management Service (MMS), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS), and establish a means for gathering additional data on marine mammals for future operations planning.

Shell plans to conduct site clearance and shallow hazards survey within existing lease holdings of shell and partners in the Beaufort Sea. One vessel will be used in the Beaufort Sea during the 2010 open-water season.

Shell's 4MP is a combination of active monitoring of the area of operations and the implementation of mitigation measures designed to minimize project impacts to marine resources. If marine mammals are observed within or about to enter specific safety radii around the proposed survey activities, mitigation will be initiated by vessel-based marine mammal observers (MMOs). The size of the 180 and 190 dB re 1 μPa (rms) safety radii were modeled and are described below in the section *Mitigation Measures during Survey Activities.* These radii will be used to initiate mitigation during initial survey activities at which time an acoustics contractor will measure underwater sound propagation from the airguns to empirically determine the size of safety radii. These measured radii will be used for mitigation purposes as soon as they become available. An initial sound source analysis will be supplied to NMFS and the site clearance and shallow hazards survey operators within 120 hours of completion of the measurements. A more detailed report describing the sounds produced by the airguns will be provided to NMFS as part of the 90-day report following the end of the survey.

Monitoring during airgun activity and periods when airguns are not active will provide information on the numbers of marine mammals potentially affected by the survey activities and facilitate real time mitigation to prevent impacts to marine mammals by industrial sounds or activities. Vessel-based MMOs onboard the survey vessel will record the numbers and species of marine mammals observed in the area and any observable reaction of marine mammals to the survey activities. Aerial monitoring, designed primarily for detecting cetaceans during the bowhead migration, will be used to identify any large scale distributional changes of cetaceans relative to the activities and add to the existing database on the abundance and distribution of observed species. An acoustic program will characterize the sounds produced by the airguns and document the potential reactions of marine mammals in the area, particularly bowhead whales, to the 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) which will be issued by NMFS and USFWS, respectively, for this project, and to meet any other stipulation agreements between Shell and other agencies or groups. The objectives of the program will be:

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

The 4MP will be implemented by a team of experienced MMOs, including both biologists and Inupiat personnel. MMOs will be stationed aboard the survey vessel through the duration of the site clearance and shallow hazards survey. 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 survey activities near Harrison Bay in the Alaskan Beaufort Sea. The survey dates and specific operating areas will depend upon ice and weather conditions, along with Shell's arrangements with agencies and stakeholders. Survey activities are expected to occur during July through October 2010.

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 survey program is conducted,
- Information to compare the distances, distributions, behavior, and movements of marine mammals relative to the survey vessel at times with and without airgun 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 site clearance and shallow hazards surveys in 2006–2009 or such alternative requirements as may be specified in the IHA issued by NMFS for this project. Any other stipulation agreements between Shell and agencies or groups such as MMS, USFWS, 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 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 Survey Activities

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

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

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

Safety and Disturbance Zones

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

Initial safety and disturbance radii for the sound levels produced by the survey activities have been modeled. These radii will be used for mitigation purposes until results of direct measurements are available early during the exploration activities. The planned survey will use an airgun source composed of either 40 cubic inch airguns or 1 x 20-in^3

plus 2 x 10-in^3 airguns. The total source volume will be 4 x 10 in^3. Measurements of a 2 x 10-in^3 airgun array used in 2007 were reported by Funk et al. (2008). These measurements were used as the basis for modeling both of the potential airgun arrays that may be used in 2010. The modeling results showed that the 40 cubic inch array is likely to produce sounds that propagate further than the alternative array, so those results were used to estimate "takes by harassment" in the IHA application to NMFS and will also be used during initial survey activities prior to in-field sound source measurements. The modeled 190 and 180 dB distances from a 40 cubic inch array were 35 and 125 m, respectively. Because this is a modeled estimate, but based on similar measurements at the same location, the estimated distances for initial safety radii were only increased by a factor of 1.25 instead of a typical 1.5 factor. This results in a 190-dB distance of 44 m and a 180-dB distance of 156 m.

A single 10-in^3 airgun will be used as a mitigation gun during turns or if a power down of the full array is necessary due to the presence of a marine mammal close to the vessel. Underwater sound propagation of a 10-in^3 airgun was measured near Harrison Bay in 2007 and results were reported in Funk et al. (2008). The 190 dB and 180 dB distances from those measurements, 5 m and 20 m respectively, will be used as the pre-sound source measurement safety zones during use of the single mitigation gun.

An acoustics contractor will perform the direct measurements of the received levels of underwater sound versus distance and direction from the energy source arrays using calibrated hydrophones. The acoustic data will be analyzed as quickly as reasonably practicable in the field and used to verify (and if necessary adjust) the safety distances. The mitigation measures to be implemented at the 190 and 180 dB sound levels will include power downs and shut downs as described below.

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 array will be immediately powered down whenever a marine mammal is sighted approaching close to or within the applicable safety zone of the full array, but is outside the applicable safety zone of the single mitigation source. If a marine mammal is sighted within or about to enter the applicable safety zone of the single mitigation airgun, the entire array will be shut down (i.e., no sources firing).

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 site clearance and shallow hazards survey program, the seismic operator will ramp up the airgun arrays slowly. Full ramp ups (i.e., from a cold start after a shut down, when no airguns have been firing) will begin by firing a single airgun in the array. The minimum duration of a shut-down period, i.e., without air guns firing, which must be followed by a ramp up typically is the amount of time it would take the source

vessel to cover the 180-dB safety radius. The actual time period depends on ship speed and the size of the 180-dB safety radius. We estimate that period to be about 1-2 minutes based on the modeling results described above and a survey speed of 4 kts.

A full ramp up, after a shut down, will not begin until there has been a minimum of 30 min 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-minute lead-in to a full ramp up. If the entire safety zone is not visible, then ramp up from a cold start cannot begin. If a marine mammal(s) is sighted within the safety zone during the 30-minute watch prior to ramp up, ramp up will be delayed until the marine mammal(s) is sighted outside of the safety zone or the animal(s) is not sighted for at least 15-30 minutes: 15 minutes for small odontocetes and pinnipeds, or 30 minutes for baleen whales and large odontocetes.

During turns and transit between seismic transects, at least one airgun will remain operational. The ramp-up procedure still will be followed when increasing the source levels from one air gun to the full arrays. However, keeping one airgun firing will avoid the prohibition of a cold start during darkness or other periods of poor visibility. Through use of this approach, seismic operations can resume upon entry to a new transect without a full ramp up and the associated 30-minute lead-in observations. MMOs will be on duty whenever the airguns are firing during daylight, and during the 30-min periods prior to ramp-ups as well as during ramp-ups. Daylight will occur for 24 h/day until mid-August, so until that date MMOs will automatically be observing during the 30-minute period preceding a ramp up. Later in the season, MMOs will be called out at night to observe prior to and during any ramp up. The seismic operator and MMOs will maintain records of the times when ramp-ups start, and when the airgun arrays reach full power.

Monitoring Prior to and during AUV deployment

In addition to the site clearance and shallow hazards surveys in the Beaufort Sea, Shell plans to use a vessel equipped for seafloor sampling and deployment of an autonomous underwater vehicle (AUV) outfitted with sonar equipment for mapping the seafloor, in both the Beaufort and Chukchi Seas. The vessel will be operated for ~10 days in the Sivulliq prospect, and ~4 days in the Burger prospect. The AUV is more maneuverable and able to more quickly complete surveys compared to conventional methods, and operates without a towline which reduces potential impact to marine mammals. This reduces the duration during which vessels producing sound must operate. The AUV can record the gouges on the seafloor surface caused by ice keels and will be equipped with:

- Dual frequency sub-bottom profiler (2 to 7 kHz or 8 to 23 kHz);
- Multi-beam bathymetric sonar (240 Hz) or similar; and
- Side-scan sonar system (190 to 210 kHz) or similar.

The AUV will be deployed from the vessel and travel in the water column autonomously along pre-programmed survey lines. The AUV will be remotely operated within 1 km (0.6 mi) of the deployment vessel. Because the vehicle travels under the surface of the water, the vehicle will not be visible by MMOs once deployed from the vessel. However,

the vehicle will have a collision avoidance system that will keep it from coming in contact with marine mammals. The AUV will detect a marine mammal or other object at 100 meters. Should the AUV avoidance system detect an object the vehicle will veer away from the detected object, returning to its programmed course after the vehicle has cleared the object. The AUV will be in the range within which MMOs can effectively monitor marine mammals. In addition, MMOs will advise the vehicle operators prior to deployment if aggregations of marine mammals have been observed in the survey area which might increase the likelihood of the vehicle encountering an animal or otherwise disturbing a group of animals.

Marine Mammal Observers

Vessel-based monitoring for marine mammals will be done by trained MMOs throughout the period of survey activities 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 survey vessel during all daylight periods during operation, and during most daylight periods when airgun operations are not occurring. MMO duties will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the survey operations; and documenting "take by harassment" as defined by NMFS.

Number of Observers

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

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

MMO teams will consist of Inupiat observers and experienced field biologists. An experienced field crew leader will supervise the MMO team onboard the survey vessel. At least one MMO will be on duty during all daylight operations and two MMOs during 30 min pre-ramp up watches and ramp ups. Consistent with previous years surveys, two MMOs will likely be on duty during most daylight operations. The total number of MMOs may decrease later in the season as the duration of daylight decreases assuming NMFS does not require continuous nighttime monitoring.

Crew Rotation

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

Observer Qualifications and Training

Crew leaders and most other biologists serving as observers in 2010 will be individuals with experience as observers during one or more of the 1996-2009 seismic or site clearance and 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 and mitigation projects. Resumés for those individuals will be provided to NMFS for review and acceptance of their qualifications. Inupiat observers will be experienced in the region, familiar with the marine mammals of the area, and complete a NMFS approved observer training course designed to familiarize individuals with monitoring and data collection procedures. A marine mammal observers' handbook, adapted for the specifics of the planned survey program will be prepared and distributed beforehand to all MMOs (see below).

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

Primary objectives of the training include:

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

MMO Handbook

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

- Summary overview descriptions of the project, marine mammals and underwater noise, the marine mammal monitoring program (vessel-based, aerial, acoustic measurements), the NMFS IHA and USFWS LOA and other regulations/permits/agencies, the Marine Mammal Protection Act;
- Monitoring and mitigation objectives and procedures, initial safety radii;
- Responsibilities of staff and crew regarding the marine mammal monitoring plan;
- Instructions for ship crew regarding the marine mammal monitoring plan;
- Data recording procedures: codes and coding instructions, common coding mistakes, electronic database; navigational, marine physical, field data sheet;
- Use of specialized field equipment (reticle binoculars, NVDs, laser rangefinders);
- Reticle binocular distance scale;
- Table of wind speed, Beaufort wind force, and sea state codes;
- Data storage and backup procedures;
- List of species that might be encountered: identification, natural history;
- Safety precautions while onboard;
- Crew and/or personnel discord; conflict resolution among MMOs and crew;
- Drug and alcohol policy and testing;
- Scheduling of cruises and watches;
- Communications;
- List of field gear that will be provided;
- Suggested list of personal items to pack;
- Suggested literature, or literature cited; and
- Copies of the NMFS IHA and USFWS LOA when available.

Monitoring Methodology

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

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

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

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

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

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

When a marine mammal is seen within the safety radius applicable to that species, the geophysical crew will be notified immediately so that mitigation measures called for by the IHAs can be implemented. As in 2006–2009, it is expected that the airgun arrays will be shut down within several seconds—often before the next shot would be fired, and almost always before more than one additional shot is fired. The marine mammal observer will then maintain a watch to determine when the mammal(s) appear to be outside the safety zone such that airgun operations can resume.

Monitoring At Night and In Poor Visibility

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

Specialized Field Equipment

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

Field Data-Recording, Verification, Handling, and Security

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

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

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

Field Reports

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

Reporting

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

The technical report(s) will include:

- Summaries of monitoring effort: total hours, total distances, and distribution of marine mammals through the study period accounting for sea state and other factors affecting visibility and detectability of marine mammals;
- Analyses of the effects of various factors influencing detectability of marine mammals including sea state, number of observers, and fog/glare;

- Species composition, occurrence, and distribution of marine mammal sightings including date, water depth, numbers, age/size/gender categories, group sizes, and ice cover;
- Analyses of the effects of survey operations:
- Sighting rates of marine mammals during periods with and without airgun activities (and other variables that could affect detectability);
- Initial sighting distances versus airgun activity state;
- Closest point of approach versus airgun activity state;
- Observed behaviors and types of movements versus airgun activity state;
- Numbers of sightings/individuals seen versus airgun activity state;
- Distribution around the survey vessel versus airgun activity state;
- Estimates of "take by harassment".

Aerial Survey Program

Objectives

An aerial survey program will be conducted in support of the site clearance and shallow hazards program in the Beaufort Sea during the fall of 2010. The site clearance and shallow hazards survey program may start in the Beaufort Sea as early as July 2010, however, aerial surveys would not begin until the start of the bowhead whale migration, ~20 August. 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 survey operations with special emphasis on migrating bowhead whales;
- To support regulatory reporting related to the estimation of impacts of survey operations on marine mammals;
- To investigate potential deflection of bowhead whales during migration by documenting how far east of survey operations a deflection may occur, and where whales return to normal migration patterns west of the operations, and
- To monitor the accessibility of bowhead whales to Inupiat hunters.

Safety

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

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

Selection of Aircraft

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

Survey Procedures

Flight and Observation Procedures

Aerial survey flights will begin ~20 August. Surveys will then be flown daily during site clearance and shallow hazards survey operations, weather and flight conditions permitting, and continued for 5 to 7 days after all activities at the site have ended.

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

It is understood that site clearance and shallow hazards survey timing and specific location offshore of Harrison Bay are subject to change as a result of unpredictable weather and ice conditions. The aerial survey design is therefore intended to be flexible and able to adapt at short notice to changes in the operations.

For marine mammal monitoring flights, aircraft will be flown at ~120 knots ground speed and usually at an altitude of 1000 ft. Flying at a survey speed of 120 knots greatly increases the amount of area that can be surveyed, given aircraft limitations, with minimal effect on the ability to detect bowhead whales. Surveys in the Beaufort Sea are directed at bowhead whales and an altitude of 900-1000 ft is the lowest survey altitude that can normally be flown without concern about potential aircraft disturbance; it is also the altitude recommended by NMFS for IHA monitoring efforts for bowhead whales. Aerial surveys at an altitude of 1000 ft do not provide much information about seals but are suitable for both bowhead and beluga whales. The need for a 900-1000+ ft cloud ceiling will limit the dates and times when surveys can be flown. Selection of a higher minimum altitude for surveys (e.g. 1500 ft) would result in a significant reduction in the

number of days surveys would be possible, impairing the ability of the aerial program to meet its objectives.

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

Transect information, sighting data and environmental data will be entered into a GPS-linked computer by the third observer, and simultaneously recorded on digital voice recorders for backup and validation. At the start of each transect, the observer recording data will record the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction (°T) and outside air temperature (°C). In addition, each observer will record the time, visibility (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, moderate, severe) at the start and end of each transect, and at 2-min intervals along transect. This will provide data in units suitable for statistical summaries and analyses of effects of these variables (and position relative to the survey vessel) 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 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 survey vessel, 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 observed in the survey area.

Coordination with MMS/NMFS Aerial Surveys

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

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

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

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

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

Survey Design

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

To address concerns regarding deflection of bowheads at greater distances the survey pattern around site clearance and shallow hazards operations has been designed to

document whale distribution from about 40 km east of the vessel operations to about 60 km west of operations (Fig. 1).

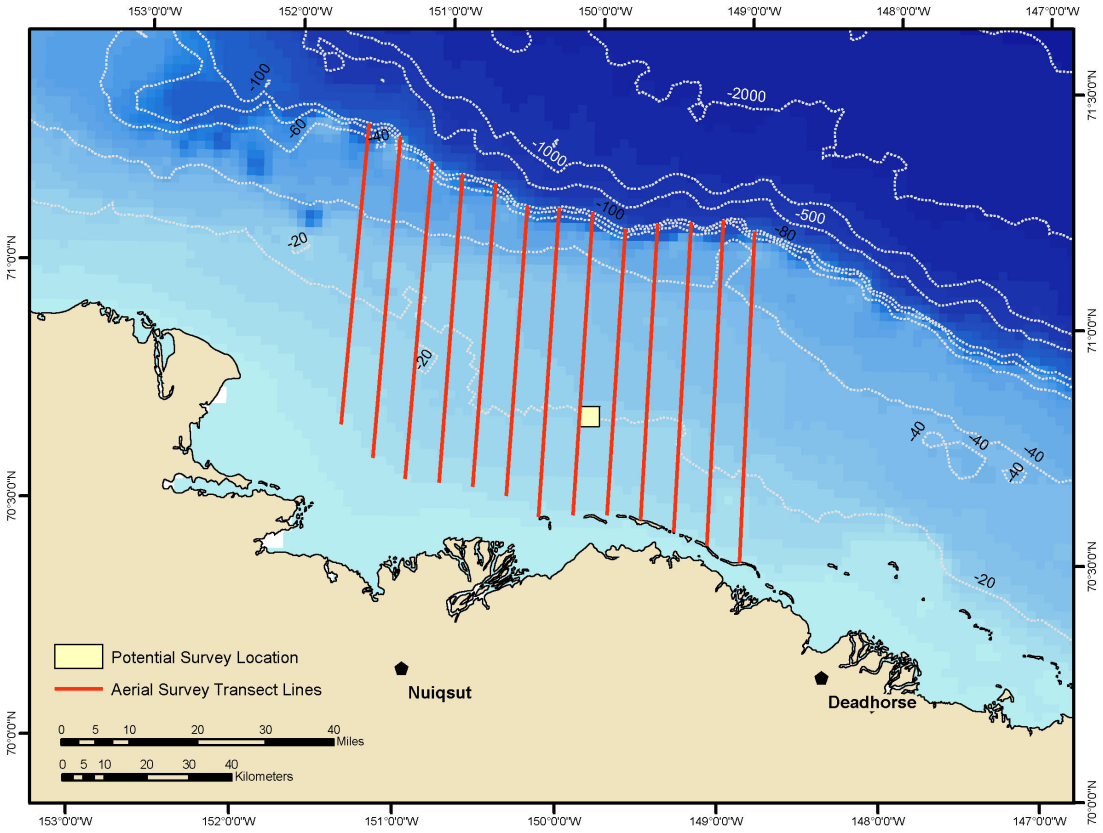

FIGURE 1. Central Alaskan Beaufort Sea showing a representative aerial survey pattern that will be flown daily during late summer and fall. The survey grid will be moved east or west depending on the precise location of the survey activities and lines will be shifted slightly within the grid for each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

Bowhead whale movements during the late summer/autumn are generally from east to west, and transects should be designed to intercept rather than parallel whale movements. The transect lines in the grid will be oriented north-south, equally spaced at 8 km, and randomly shifted in the east-west direction for each survey by no more than the transect spacing. The survey grid may total up to 1100 km in length, requiring 5-6 h to survey at a speed of 220 km/h (120 knots), plus ferry time. Exact lengths and durations will vary somewhat depending on the position of the survey 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.

Analysis of Aerial Survey Data

During the field program, preliminary maps and summaries of the daily surveys will be provided to NMFS as normally required by the terms of the IHA. While in the field, data will be checked for entry errors and files will be backed up to CDs or portable memory drives. Two levels of analyses will be conducted at the end of the season. The first level will consist of basic summaries that are required for the 90-day report specified by the IHA. These include summaries of numbers of marine mammals recorded, survey effort by date, maps summarizing sightings, and estimates of numbers of marine mammals that are "taken" according to NMFS criteria. The second level of analyses will be presented in the subsequent comprehensive report. The comprehensive report will provide more detailed analyses of the data to quantify the effect of the survey 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). "Take" numbers are determined by estimating the numbers of animals present near or passing the survey activities during periods without airgun activity and assuming that similar numbers would have passed during periods when airguns were active. 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 1996-2009, 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 by the survey activities.* For cetaceans, Shell will estimate the numbers of animals exposed to received levels of sounds exceeding 120, 160 dB and 180 dB rms re 1 µPa, as required by NMFS.

2. *Numbers of cetaceans observed showing apparent reactions to survey activities, 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 ≥160 and ≥180 dB re 1µ Pa (rms) when no monitoring observations were possible.* This will involve using the observations from the survey aircraft, supplemented by relevant vessel-based observations, to estimate how many cetaceans were exposed over the full course of Shell's 2010 site clearance and shallow hazards survey program to situations where received sound levels were ≥160 and ≥180 dB rms. In the case of bowhead whale, Shell will estimate proportions of observed whales that were close enough to shore to have passed through the area where exposure might occur, and could have passed

while survey operations were underway. Shell's aerial survey design, together with the complementary aerial surveys to be conducted by MMS, will provide the needed data.

4. *The number of bowheads whose migration routes came within 20 km of the survey activity, or would have done so if they had not been displaced farther offshore, will be estimate*d. If the 2010 data indicate that the avoidance distance exceeds 20 km, the larger avoidance distance will also be used for estimating the numbers of whales potentially responding to the survey 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 survey vessel was active.

Effects of Survey Activities on Bowhead Migration

The location of the bowhead migration corridor in 2010 will be determined by examining data from periods without survey activities and/or from east of the operations. The MMS aerial survey data will be a useful supplement for areas well east of the survey program. Shell will contrast the numbers of bowhead sightings and individuals vs. distance from shore:

- During periods with vs. without survey operations, and
- Near vs. east vs. west of the survey areas.

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

To determine how far east, north and west displacement effects (if any) extend, additional analyses will be conducted on bowhead sightings and survey effort in relation to distance and bearing from the survey vessel during times with and without airgun activity. Shell anticipates applying a logistic or Poisson regression approach to assess the effects of distance and direction from the survey activities 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 survey activities on the bowhead migration path, including summaries of headings, behavior and swimming speeds, will be included in the technical report.

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

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

Acoustic Monitoring Plan

Sound Source Measurements

As described above, previous measurements of airguns in the Harrison Bay area were used to model the distances at which received levels are likely to fall below 160, 180, and 190 dB rms from the planned airgun sources. These modeled distances will be used as temporary safety radii until measurements of the airgun sound source are conducted. The measurements will be made at the beginning of the field season and the measured radii used for the remainder of the survey period.

The objectives of the sound source verification measurements planned for 2010 in the Beaufort Sea will be (1) to measure the distances in the broadside and endfire directions at which broadband received levels reach 190, 180, 170, 160, and 120 dB_{rms} re 1 µPa for the energy source array combinations that may be used during the survey activities. The configurations will include at least the full array and the operation of a single source that will be used during power downs. The measurements of energy source array sounds will be made at the beginning of the survey and the distances to the various radii will be reported as soon as possible after recovery of the equipment. The primary radii of concern will be the 190 and 180 dB safety radii for pinnipeds and cetaceans, respectively, and the 160 dB disturbance radii. In addition to reporting the radii of specific regulatory concern, nominal distances to other sound isopleths down to 120 dB_{rms} will be reported in increments of 10 dB.

Data will be previewed in the field immediately after download from the ocean bottom hydrophone (OBH) instruments. An initial sound source analysis will be supplied to NMFS and the airgun operators within 120 hours of completion of the measurements, if possible. The report will indicate the distances to sound levels between 190 dB_{rms} re 1 µPa and 120 dB_{rms} re 1 µPa based on fits of empirical transmission loss formulae to data in the endfire and broadside directions. The 120-hour report findings will be based on analysis of measurements from at least three of the OBH systems. A more detailed report including analysis of data from all OBH systems will be issued to NMFS as part of the 90-day report following completion of the acoustic program.

Airgun pressure waveform data from the OBH systems will be analyzed using JASCO's suite of custom signal processing software that implements the following data processing steps:

- Energy source pulses in the OBH recordings are identified using an automated detection algorithm. The algorithm also chooses the 90% energy time window for rms sound level computations.
- Waveform data is converted to units of microPascals (μPa) using the calibrated acoustic response of the OBH system. Gains for frequency-dependent hydrophone sensitivity, amplifier and digitizer are applied in this step.
- For each pulse, the distance to the airgun array is computed from GPS deployment positions of the OBH systems and the time referenced DGPS navigation logs of the survey vessel.
- The waveform data are processed to determine flat-weighted peak sound pressure level (PSPL), rms sound pressure level (SPL) and sound exposure level (SEL).
- Each energy pulse is Fast Fourier Transformed (FFT) to obtain 1-Hz spectral power levels in 1-second steps.
- The spectral power levels are integrated in standard 1/3-octave bands to obtain band sound pressure levels (BSPL) for bands from 10 Hz to 20 kHz. M-weighted SPL's for each airgun pulse may be computed in this step for species of interest.

The output of the above data processing steps includes listings and graphs of airgun array narrow band and broadband sound levels versus range, and spectrograms of shot waveforms at specified ranges. Of particular importance are the graphs of level versus range that are used to compute representative radii to specific sound level thresholds.

Acoustic Study of Bowhead Deflections

Shell plans to deploy arrays of acoustic recorders in the Beaufort Sea in 2010, similar to those deployed in 2007 and 2008 using DASARs supplied by Greeneridge. These directional acoustic systems permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document sound characteristics and propagation resulting from site clearance and shallow hazards surveys 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 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 and 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 survey 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). An example of the whale call locations measured from a similar array of DASARs in 2008 is presented in Figure 2 (Blackwell et al. 2009).

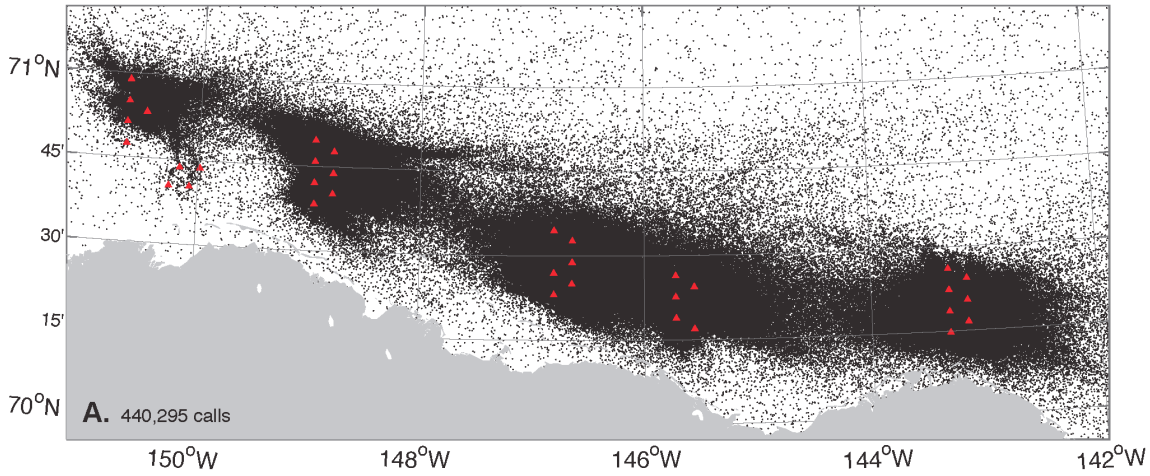

Figure 2. Bowhead whale call locations determined from the received bearings at five arrays of DASARs in the Beaufort Sea in 2008.

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 2007–2009 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 3. The eastern-most site (#5 in Fig.3) will be just east of Kaktovik and the western-most site (#1) will be in the vicinity of Harrison Bay. Site 2 will be located west of Prudhoe Bay. Sites 4 and 3 will be west of Camden Bay. 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 comprising five equilateral triangles with 7-km element spacing. This geometry is illustrated in Figure 3. Five kilometer spacing has been used successfully in the migration studies at Northstar, but whale calls are received reliably at greater spacing and the 7 km spacing will result in greater coverage of whales along the north-south dimension, which will aid in detecting 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 during calibration by transmitting known sounds at known times from known locations (by GPS) at six points around each DASAR at the beginning and at the end of the operational period. (Shell also will use a mid-season calibration.) Because of the equilateral triangular geometry, it requires 25 transmission stations for each site. Each set of transmissions requires less than half a minute. For the 5-km spacing, experience has been that it requires an hour to do 4 calibration transmissions, including transit. For our planned 7-km spacing, we estimate three calibration transmissions per hour. With 25 transmissions at each site, calibration of a site will require ~8 hours.

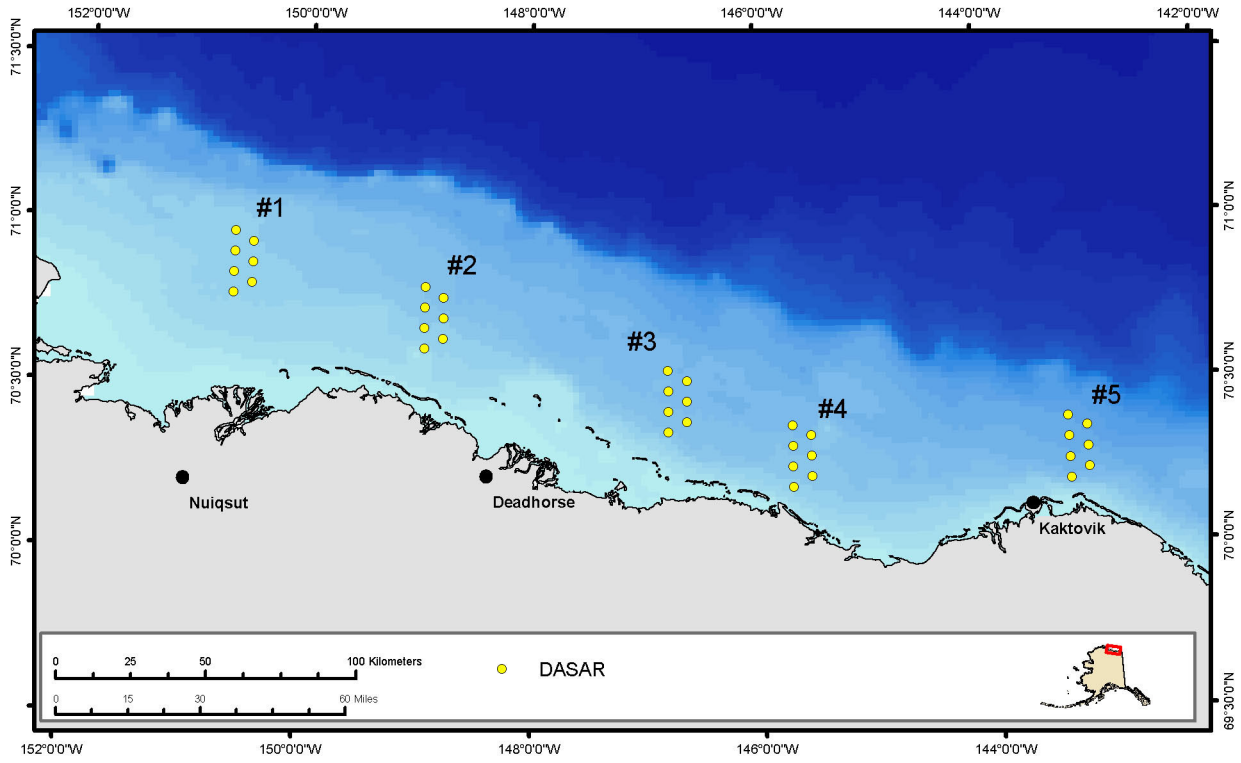

Figure 3. The Alaskan Beaufort Sea coast showing DASAR site locations for whale call location studies. The DASAR array locations at the five sites are shown to scale, with seven DASARs forming five equilateral triangles with a unit spacing of 7 km and a north-south extent of 21 km to aid being able to observe possible offshore deflection.

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

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

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

Whale call analysis for the Northstar DASARs has been a manual process in which analysts observe acoustic spectrograms in one-minute periods, looking for patterns

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

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 arrays #2, and #1, an offshore displacement of the corridor near the planned survey 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 survey 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 #1 and #2 in Figure 3. Over a standard reporting period, for example 6 hours, calls located by these two arrays will be collected, as well as other environmental covariates such as water depth, ambient sound levels, time of day, etc. From these data, summary statistics for offshore distribution, and all covariates of interest will be calculated. For example, the 25th percentile of offshore distance may be calculated, as well as the average water depth of all call locations in the 6-hour reporting period. Differences in offshore summary statistics among arrays will then be calculated and used in a regression or quantile regression analysis. Using the example above, the difference in 25th percentile of offshore distance between array #1 and array #2 could be related to the average industrial sound level output by the source. Assuming displacement occurs somewhere between arrays #1 and #2, 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:

- Changes in the offshore distribution of call locations reflect either changes in whale locations or changes in calling behavior.
- Industrial sound levels will vary substantially throughout the season. "Substantial" means by a level that is both detectable and biologically 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 airgun 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.

Analysis Report

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 airgun activities. The bowhead detection data will be used to develop spatial and temporal animal distributions. Statistical analyses will be used to test for changes in animal detections and distributions as a function of different variables (e.g., time of day, time of season, environmental conditions, ambient noise, vessel type, operation conditions).

Comprehensive Report on industry activities and marine Mammal monitoring efforts in the Beaufort and Chukchi Seas

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

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