# Marine Mammal Monitoring and Mitigation Plan

**for**

**Open Water Exploration Tophole Section Drilling and Geotechnical Programs in the Alaskan Beaufort Sea - 2008**

**Shell Offshore Incorporated**

Prepared by

Alaska Research Associates, Inc.

October 2007

# Marine Mammal Monitoring and Mitigation Plan

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**Open Water Exploration Tophole Section Drilling and Geotechnical Programs in the Alaskan Beaufort Sea - 2008**

Prepared by


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# INTRODUCTION

Shell Offshore Incorporated (SOI) has contracted LGL Alaska Research Associates, Inc. (LGL) to design and conduct a Marine Mammal Monitoring and Mitigation Program (MMMMP) for drilling activities in the Beaufort Sea and an open water geotechnical program during the open-water period of 2008. The goal of the MMMMP is to develop a program that supports protection of the marine mammal resources in the area, fulfills reporting obligations to the Minerals Management Service (MMS), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS), and provides useful baseline data on marine mammals for future operations planning.

For the open water exploration drilling program, SOI is proposing to utilize one drilling unit during the 2008 open water season to drill tophole sections for priority exploration targets on its U.S. Minerals Management Services (MMS) Outer Continental Shelf (OCS) leases in the Beaufort Sea acquired during MMS Lease Sale (LS) 195. SOI's highest priority exploratory target for the 2008 season is collectively known as Sivulliq. Sivulliq is located offshore of Pt. Thomson and Flaxman Island in Camden Bay.

The drilling unit to be used during 2008 is the floating, portable marine vessel, called the SOI "*Kulluk*". The *Kulluk* is 81 meters (m) (266 feet [ft]) in diameter with an 11.5 m (38 ft) draft when drilling. It is moored using 12 anchor cables, each connected to a 15 or 20-ton anchor.

The *Kulluk* will be accompanied by two ice management vessels or arctic class anchor handlers, and an estimated two support vessels. One of the arctic class supply vessels may make periodic re-supply trips from Tuktoyaktuk, Northwest Territories (NWT), Canada to the rig. The ice management vessels or arctic class anchor handlers which likely will be used are: M/Vs "Vladimir Ignatjuk" (VI) of the Murmansk Shipping Company fleet, and a vessel as yet to be contracted, but similar to the VI. If one or more of these specific vessels are not used, then similar vessel(s) will be substituted. The re-supply effort will be undertaken by the M/V "Jim Kilabuk" (Kilabuk) of the Northern Transportation Company Limited, and an additional multipurpose support vessel similar to the Kilabuk.

For the open water geotechnical program, up to 20 boreholes, each up to 500 feet in depth, will be bored to obtain geotechnical data for feasibility analyses of shallow sub-sea sediments. The boreholes will be completed to depths well above any liquid hydrocarbon-bearing strata. Approximately three potential locations will be investigated at Sivulliq, as well as locations along a prospective pipeline access corridor through Mary Sachs Entrance to landfall in the vicinity of Point Thomson.

The open water geotechnical program will use borehole excavating equipment mounted on a marine vessel (geotechnical vessel) to advance boreholes through a moonpool located approximately at mid-ship of the geotechnical vessel. The geotechnical vessel also will have an electronic cone penetrometer (CPT) mounted on it.

If used, the CPT unit will collect in-situ soil/sediment sub-sea samples to approximately 150 feet below the mudline.

Shallow sub-sea bottom sampling for geotechnical analyses at the Sivulliq Prospect and along the access corridor will use a seabed frame to either push a sample tube or a cone penetration test into the seafloor. Other bottom sediment sampling proposed includes piston coring to a maximum depth of 10 feet sub-sea bottom, and box coring to a maximum depth of 1-foot sub-sea bottom.

The MMMMP for drilling and the geotechnical program will consist of monitoring and mitigation during the exploratory drilling activities. Monitoring will provide information on the numbers of marine mammals potentially affected by these activities and permit 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 characterize the sounds produced by the drilling activities and support vessels, and to document the potential reactions of marine mammals in the area to those sounds and activities. Acoustic modeling will be used to predict the sound levels produced by the drilling equipment in the Beaufort Sea. Acoustic measurements will also be made to establish safety radii for real time mitigation around the activities. Aerial monitoring and reconnaissance of marine mammals and recordings of ambient sound levels and vocalizations of marine mammals along the Beaufort Sea coast will be used to interpret the reactions of marine mammals exposed to the activities.

### Vessel-based Drilling Activities

JASCO will measure the sound propagation of the vessel-based drilling rig during periods of drilling activity, and the drill ship and support vessels while they are underway in the early part of the field season. Noise from ships with ice-breaking capabilities will be measured if feasible during periods of ice-breaking activity. These measurements will be used to determine the sound levels produced by various equipment and to establish any safety and disturbance radii if necessary. Bottom-founded hydrophones will likely be used to determine the levels of sound propagation from the drill rig and associated vessels. Regular updates of operational sound levels will be provided to NMFS/MMS. A detailed report will be issued to NMFS as part of the 90 day report following completion of the drilling program.

## OPERATIONAL MITIGATION MEASURES

### Transit of Chukchi Sea

A Chukchi transit mitigation plan has been developed to identify transit strategies that will minimize and mitigate possible impacts to marine mammals and subsistence hunting activities in the offshore and adjacent coastal areas along the transit route if vessels associated with the drilling program transit through the Chukchi Sea on the way to the Sivulliq prospect in the eastern Alaskan Beaufort Sea. The plan relies principally on strategies of avoidance, minimization, monitoring and communication to reduce exposure of marine mammals to sound levels and visual stimuli that could be capable of disturbance, displacement, or significant alteration of behavior.

Avoidance of areas where exposure of marine mammals, primarily walrus and polar bears to disturbance will be accomplished in the Chukchi Sea by positioning the transit route > 50 miles offshore and, to the extent possible, in open water. By remaining in open water, where possible, the vessels will remain away from the ice edge and concentrations of ice, where marine mammals, including walrus and polar bears, are expected to concentrate. By remaining > 50 miles offshore, the transit route remains away from areas of coastal concentration of marine mammals, including seals, walrus, and beluga whales. By remaining in open water, to the greatest extent possible, sound levels will be kept to a minimum. In open water, transit will be relatively slow and steady and will not require engine revving or other operations that increase cavitation.

In the event that the presence of ice in the transit route makes the maintenance of a > 50 mile offshore buffer in the Chukchi Sea, this buffer will be reduced in favor of maintenance of a one-half mile buffer between the transit route and the ice edge. By staying out of the ice, the vessels will minimize sound emission levels and will remain away from hauled out concentrations of walrus and seals. The transit distance from shore may decrease below the desired 50 mile buffer but will not enter the polynia zone.

On-board marine mammal observers (MMOs) will be on duty on all vessels during the transit and will direct vessel transit to remain, where possible, one –half mile or greater from marine mammals (understanding that marine mammals may approach the vessels) and avoid collision. During ice transits, MMOs will supplement aerial surveys and assist in the maintenance of buffers and observation of marine mammal concentrations and behaviors. If such observations demonstrate disturbance behavior, buffers will be adjusted as appropriate.

An additional monitoring capacity will be added by the over-winter deployment of acoustic recorders (described later in this plan) in selected areas of the Chukchi. These recorders will provide information on the early spring season distribution and movement patterns of marine mammals in the Chukchi Sea and will provide sound level and sound characteristic data on early season transit through this area. Recorders will also be over-wintered in the Beaufort Sea to provide information on several points along the transit path.

In addition to avoidance, minimization, and monitoring, communication will be an integral component of this transit plan. SOI will operate communication centers in each of the coastal villages. Vessel movements will be posted in each communication center and available for review by residents and subsistence hunters. Residents are encouraged to inform SOI as to hunting activities, to request mitigation measures, and to report any concerns or observations.

As the vessels approach Barrow, presence of ice may mandate that the transit route pass within 20 miles or less from shore. Communication will become extremely vital during the approach to Barrow. Presence in the Barrow area will be minimized to the extent possible.

Transit through the Beaufort Sea will utilize leads and open water areas and will attempt to remain 20 plus miles from shore.

### Other Operational Mitigation Measures

Other mitigation measures will be employed to restrict timing, place, and extent of activity during sensitive periods for subsistence hunting or life history of animals. A bird monitoring and mitigation plan has been developed in consultation with the US Fish and Wildlife Services.

Mitigation measures have been developed in consultation with subsistence hunters and will be implemented to minimize and mitigate possible impacts to subsistence hunting activities.

# AERIAL SURVEY PROGRAM

## Objectives

An aerial survey program will be conducted in support of the drilling program in the Beaufort Sea during summer and fall of 2008. The objectives of the aerial survey will be:

- to advise operating vessels as to the presence of marine mammals in the general area of operation;
- to collect and report data on the distribution, numbers, movement and behavior of marine mammals near the drilling operations with special emphasis on migrating bowhead whales;
- to support regulatory reporting and Inupiat communications related to the estimation of impacts of drilling operations on marine mammals;
- to monitor the accessibility of bowhead whales to Inupiat hunters and
- to document how far west of drilling activities bowhead whales travel before they return to their normal migration paths, and if possible, to document how far east of drilling operations the deflection begins.

## Survey Considerations

The same aerial survey design will be implemented during the summer (one week prior to beginning of operations until August 20) and fall (August 20– five days after cessation of operations, or until agreement among stakeholders that bowhead migration is ended) periods, but during the early summer, the surveys will be flown twice a week and during the late summer and fall, flights will be conducted daily. During the early summer, few cetaceans are expected to be encountered in the nearshore Alaskan Beaufort Sea where the drilling operation will be conducted (see particularly Moore et al. 1989b, but also Moore and Clarke 1989, 1991; Moore 1992; Moore et al. 1989a, 1993, 2000;

Moore and Reeves 1993; Moore and DeMaster 1997; Miller et al. 1998, 1999, 2002), and those that are encountered are expected to be either along the coast (gray whales: Maher 1960; Rugh and Fraker 1981; Miller et al. 1999; Treacy 2000) or among the pack ice (bowheads: Moore et al. 1989b; and belugas: Moore et al. 1993; Clarke et al. 1993) north of the area where drilling activities are to be conducted. During some years a few gray whales are found feeding in shallow nearshore waters from Barrow to Kaktovik but most sightings are in the western part of that area.

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. The bowhead migration tends to be through nearshore and shelf waters, although in some years small numbers of whales are seen near the coast and/or far offshore. Bowheads frequently interrupt their migration to feed (Ljungblad et al. 1986a; Lowry 1993; Landino et al. 1994; Würsig et al. 2002; Lowry et al. 2004) and their stop-overs vary in duration from a few hours to a few weeks (Koski et al. 2002). A commonly used feeding area is in and near Smith Bay, east of Barrow. Less consistently used feeding areas are in coastal and shelf waters near and east of Kaktovik.

The aerial survey procedures will be generally consistent with those during earlier industry studies (Davis et al. 1985; Johnson et al. 1986; Evans et al. 1987; Brueggeman et al. 1992; 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 SOI's operations and the time of year. During the 2008 field season we will coordinate and cooperate with the aerial surveys conducted by MMS and any other groups conducting surveys in the same region, as we have when conducting aerial surveys on behalf of industry and MMS.

It is understood that the timing, duration, and location of SOI's drilling operations are subject to change as a result of unpredictable weather and ice issues, as well as regulatory and stakeholder concerns. The recommended approach is flexible and able to adapt at short notice to changes in the operations.

## Safety Considerations

Safety considerations 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-related considerations 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 extensive experience (~5000 h in the case of the team leader) with this type of survey flying in arctic conditions, and will have the authority to cancel or (in agreement with the pilots) amend flight operations as necessary for safety.

## Survey Procedures

### *Flight and Observation Procedures*

Standard aerial survey procedures as used by ourselves and others in many previous marine mammal projects will be followed (Ljungblad et al. 1986b; Miller et al. 1999, 2002; Monnet and Treacy 2005). This will facilitate comparisons and (as appropriate) pooling with other data, and will minimize any controversy about the chosen survey procedures. The aircraft will be flown at 120 knots ground speed and usually at an altitude of 1000 ft. 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 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 altitude for surveys 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.

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 data logger by the third observer, and simultaneously recorded on digital recorders for backup and validation. At the start of each transect, the observer recording data will record the transect start time and position, ceiling height (ft), cloud cover (in 10ths), wind speed (knots), wind direction (°T) and outside air temperature (°C). In addition, each observer will record the time, visibility (subjectively classified as excellent, good, moderately impaired, seriously impaired or impossible), sea state (Beaufort wind force), ice cover (in 10ths) and sun glare (none, moderate, severe) at the start and end of each transect, and at 2-min intervals along the transect. This will provide data in units suitable for statistical summaries and analyses of effects of these variables (and position relative to seismic 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 the transects. The primary data logger will be a laptop computer with Garmin Mapsource (ver 6.9) data logging software. Mapsource automatically stores the time and aircraft position at pre-selected intervals (typically 2-6 sec for straight-line transect surveys) as they are obtained from the GPS unit.

*Selection of Aircraft*

Specially-outfitted Twin Otter aircraft 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 LGL projects as recent as 2006. These types of aircraft have been found to be very suitable for survey work, and are safer than potential alternatives. Among the essential or desirable features are standard IFR instrumentation, STOL kit, radar altimeter with output for computerized data recording, high wing, dual GPS systems with output for computerized data recording, bubble windows, VHF/SSB/FM radios, AC inverter, high-quality intercom, active noise-canceling headsets, adjustable seating positions, and movable computer desk. Endurance depends on fuel tank configuration, load and airspeed, but is generally 3.25 to 6.5 h after allowance for one hour of fuel reserves. The aircraft needs a comprehensive set of survival equipment appropriate to offshore surveys in the Arctic; the suggested aircraft are provided with the appropriate gear. For safety reasons, the aircraft should be operated with two pilots.

*Avoiding Fatigue*

The sizes of the survey grids planned for late August–October 2008 are comparable in total length to grids flown during earlier industry surveys. The planned surveys will require up to 8 hours or more of flying per day, depending on the survey grid. A single team of observers cannot survey for that many hours on a daily basis without becoming fatigued and missing more mammals than normal. This is especially so when good flying weather persists for 2 or 3 days in a row. Fatigue is exacerbated by the need to spend considerable time on the ground coordinating with other vessel-based and aerial field crews in the morning and evening, and organizing each day's data for the required evening transmissions to MMS and NMFS. To minimize the fatigue problem, during periods when daily surveys are required (late August–October), a four or five-person aerial survey crew will be used: two primary observers; data-logger/secondary observer; and one or two additional alternate observers. The alternates will rotate observation duties with the other three observers, and will share the coordination and data summarization responsibilities. It will often be feasible for the "extra" observers to remain on the ground, with rotation occurring when the aircraft lands to refuel or for a brief break. However, at some times the off-duty observers will need to ride in the aircraft and rotate while in flight. During times when surveys are less intensive, e.g., July–August, a three-person survey crew will be used. Inupiat observers were trained as observers during our 2006 and 2007 surveys and one or more Inupiat observers will be present during surveys. Use of additional Inupiat observers (trainees) will further reduce fatigue associated with conducting the long survey routes.

*Supplementary Data*

Weather, ice and sightability data will be recorded systematically during all surveys. Percent ice cover and severity of sun glare will be recorded by each primary observer for every 2-minute interval along transects. Ice observations during aerial surveys will be mapped when ice is present and satellite imagery will be used, where available, to document 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.

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

*Coordination with MMS Aerial Surveys*

The Minerals Management Service is planning to continue its wide-ranging aerial surveys of bowhead whales and other marine mammals in the Beaufort Sea during the autumn of 2008 (Dr. C. Monnett, MMS, pers. comm.). In 2007, the surveys were contracted to the National Marine Mammal Laboratory in Seattle. These surveys include the Beaufort Sea part of the SOI study area. SOI will co-ordinate with MMS/NMML to obtain access to their data, both during the field season and for use in analyses and reports.

SOI will also consult with MMS/NMML regarding coordination during the field 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 2008 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 SOI surveys for purposes of assessing the effects of drilling activities on whales and estimating "take by harassment";
- to maximize consistency with previous years' efforts insofar as feasible.

It is expected that raw bowhead sighting and flightline data will be exchanged between MMS and LGL on a daily basis during the field season, and that each team will also submit its sighting information to NMFS in Anchorage each day. After the SOI and MMS data files have been reviewed and finalized, they will be exchanged in digital form. These practices will be consistent with what has been done in the past, and will likely be required by permits and authorizations.

We are not aware of any other related aerial survey programs presently scheduled to occur in the Alaskan Beaufort Sea in areas where SOI is anticipated to be conducting seismic during September–October 2008. However, one or more other programs are possible in support of other anticipated industry and research operations. If another aerial survey project were planned, SOI or LGL (with SOI's approval) would seek to coordinate with that project to ensure aircraft separation, maximize consistency, minimize duplication, and share data.

As during previous studies, we propose that, while whaling is underway we will not survey the southern portions of survey lines over or near hunting areas unless the whalers agree that this can be done without interfering with their activities. This will reduce (but not eliminate) the potential for overflying whalers and whales that are being approached by whalers. Some of the autumn bowhead sightings in the region do occur in this "nearshore" area, and these whales will not be documented if the survey aircraft remains 15+ km offshore in this area at all times. If we do not survey this area while whaling is occurring, we will reduce the potential for aircraft-whaler interactions at the expense of reducing our ability to assess the effects of drilling activities on bowheads, other marine mammals, and subsistence activities in that nearshore area.

## Surveys during Drilling Activities

*Survey Design in the Beaufort Sea in Summer*

As noted above, few cetaceans are expected to be found in the central and western Beaufort Sea during summer. A few gray whales may be found in nearshore areas during years with light ice cover. Most belugas and bowheads in the central and western Beaufort Sea during summer will be offshore amongst the pack ice (see Fig. 3 in Moore and Clark 1989 and below). Thus few cetaceans are expected to be seen during the summer surveys. The survey pattern is shown in Fig. 1. Surveys will start about one week before drilling operations begin and will be conducted twice per week. If unexpectedly large numbers of cetaceans are seen near drilling activities during the summer, the frequency of surveys will be increased to 3-4 times per week.

*Survey Design in the Beaufort Sea in Fall*

Past studies have suggested that most migrating bowhead whales will avoid offshore drilling operations by 10-20 km (Koski and Johnson 1987), although some whales will approach closer to the activity. Furthermore, studies suggest that changes in bowhead distribution due to drilling activities did not extend much beyond 20 km west of the drilling operation (Davies 1997). As a consequence, the survey pattern around drilling operations is designed to document whale distribution from about 40 km east of the drilling operations to about 40 km west of operations (Fig. 1). Surveys will be conducted daily starting in late August, if drilling operations are being conducted at that time. If drilling operations do not start until later in the season, daily aerial surveys will begin 2-3 days before drilling operations start.

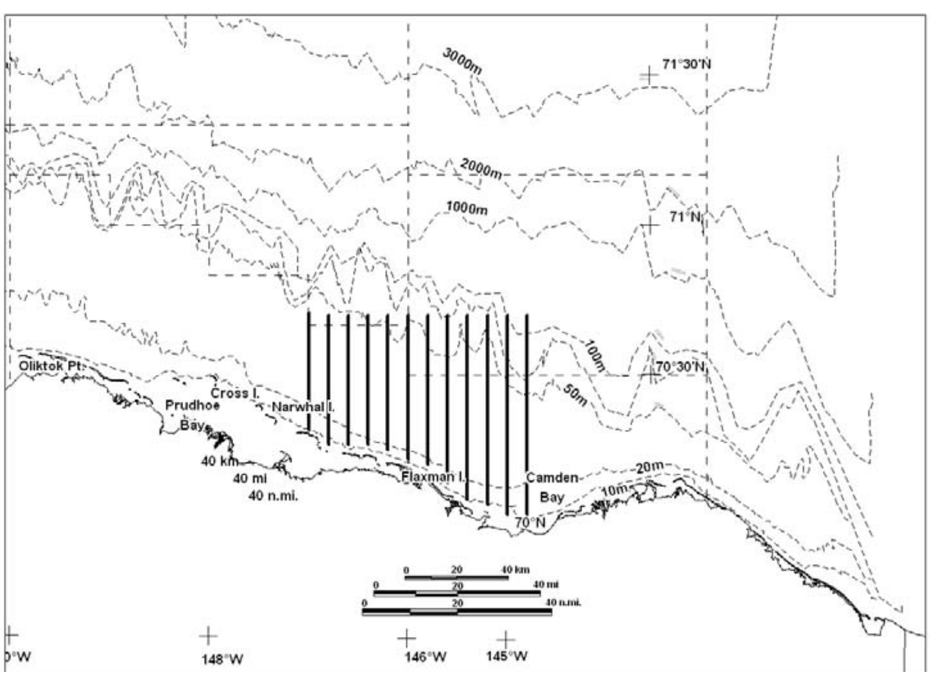

*FIGURE 1. Central Alaskan Beaufort Sea showing aerial survey pattern that will be flown 2 days per week during mid-summer and daily during late summer and fall if a drillship were centered on the middle of the grid. Survey grids will be moved east or west depending on the location of the drillship.*

The survey grid will total about 1000 km in length, requiring ~4.6 h to survey at a speed of 220 km/h (120 knots), plus ferry time. Exact lengths and durations will vary somewhat depending on the position of the drilling operation and thus of the grid, the sequence in which lines are flown (often affected by weather), and the number of refueling/rest stops.

*Transect Positions and Sequence*

For the purposes of this part of the project, which primarily concern migrating bowheads near drilling activities, the transect lines in the grid should be oriented north-south, equally spaced, and at consistent locations from day to day relative to the location of drilling operations. 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.

Weather permitting, transects making up the grid in the Beaufort Sea will be flown in sequence from west to east. This decreases difficulties associated with double counting of whales that are (predominantly) migrating westward. The survey sequence around the drilling operation is different than that around the seismic operation because the objectives of the surveys are different. In this case, we are monitoring the distribution of whales around the drilling operation, and during seismic operations, surveys can be designed to detect mother-calf pairs approaching close enough to the seismic operation that they would be exposed to seismic sounds in excess of sound criteria to be defined by the IHA (e.g.>120 dB re 1 µPa).

## Analysis of Aerial Survey Data

During the field program, preliminary maps and summaries of the daily surveys will be provided to NMFS and AEWC, as normally required by the terms of the IHA. While in the field, data will be checked, data files will be backed up onto CDs, and data files will be transferred each day (if possible) to a secure FTP site where they can be accessed by LGL data analysts for validation and further processing of the data. Two levels of analyses will be conducted. The first level will consist of basic summaries that are required for the 90-d report(s) specified by the IHA(s). These include summaries of numbers of marine mammals seen, survey effort by date, maps summarizing sightings, and estimates of numbers of marine mammals that are “taken” according to NMFS criteria. The second level of analyses will be presented in the subsequent technical report. The technical report will provide more detailed analyses of the data to quantify the effect of the drilling program on the distribution and movements of marine mammals. The latter analyses will emphasize the bowhead whale, which is the primary species of concern to NMFS and AEWC in the Beaufort Sea region.

*Estimation of Numbers "Taken"*

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

The main purposes of the 2008 aerial programs insofar as the IHA requirements are concerned are (1) to monitor the area east of the drilling operation, (2) to monitor the numbers of mother-calf pairs subjected to sounds in excess of sound criteria (e.g. >120 dB re 1 µPa), (3) to provide the data needed to determine how many marine mammals of each species are "taken by harassment" by the drilling program, (4) to document the nature of those "takes", (5) to estimate the likely consequences for the marine mammal populations, and (6) to determine whether there was any effect on the accessibility of marine mammals to subsistence hunters. NMFS requires these data to ensure that the drilling program has no more than a negligible impact on species or stocks of marine mammals, and no unmitigable adverse impact on their availability for subsistence hunting. The data to be collected by the vessel-based observers, aerial surveys, and acoustic programs, and the associated analyses of these data, in conjunction with prior years' data, will provide the needed information.

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 1996-2006 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, we anticipate that there will be four components:

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

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

3. *Numbers of cetaceans estimated to have been subjected to sound levels ≥120, ≥160 and ≥180 dB re 1µ Pa (rms) when no monitoring observations were possible*. This will involve using the observations from the survey aircraft (SOI/LGL and MMS), supplemented by relevant vessel-based observations, to estimate how many cetaceans were exposed, over the full course of SOI's 2008 drilling program, to situations where exposures to ≥120, ≥160 and ≥180 dB were likely. In the case of the bowhead whale,

we will estimate the proportions of the observed whales that were close enough to shore to have passed through the area where exposure might occur, and could have passed while drilling operations were underway. Our aerial survey design, together with the complementary aerial surveys to be conducted by MMS, will provide the needed data.

4. *The number of bowheads whose migration routes came within 20 km of the drilling activity, or would have done so if they had not been displaced farther offshore, will be estimate*d. If the 2008 data indicate that the avoidance distance exceeds 20 km, the larger avoidance distance will also be used. These estimates will be obtained by determining the displacement distance based on the aerial survey results, and then estimating how many bowheads were likely to approach the avoided area during times while the drillship and support vessels were present.

*Location of Migration Corridor*

The location of the bowhead migration corridor in 2008 will be determined by examining data from periods with drilling activities and data from east of those operations. The MMS aerial survey data will be a useful supplement for areas well east of the drilling program. We will contrast the numbers of bowhead sightings and individuals vs. distance from shore:

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

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

*Effects of Drilling Program on Bowhead Migration Corridor*

To determine how far east, north and west displacement effects extend, additional analyses will be conducted on bowhead sightings and survey effort in relation to distance and bearing from the drilling operations during times with and without operations. We anticipate applying a logistic or Poisson regression approach to assess the effects of distance and direction from the drilling operations on sighting probability of bowhead whales, allowing for the confounding influence of sightability (sea state, ice conditions, etc) and other covariates. We have already used that approach extensively in analyses of whale and seal distribution in the Beaufort Sea (Manly et al. 2004; Moulton et al. 2005). Biostatistician Dr. Trent McDonald of WEST, who was instrumental in some of these past analyses, will assist with analyses of marine mammal data. Other analyses that may be useful to describe the effects of the drilling operation on the bowhead migration path, including summaries of headings, behavior and swimming speeds, will be included in the technical report.

The data from the current survey may not provide enough sightings to be able to quantify the effects of SOI’s 2008 activities on the bowhead whale migration path. That could occur if SOI’s operations in the Beaufort Sea during the bowhead whale migration season were limited due to ice or other factors, or if 2008 is a year when weather conditions were poorer than average, which would limit the periods when surveys could be conducted.

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

# VESSEL-BASED MARINE MAMMAL MONITORING PROGRAM

## Introduction

The vessel-based operations will be the core of SOI's MMMMP. The MMMMP will be designed to meet the requirements of the IHA(s) issued by the NMFS and USFWS for this project, and to meet any other stipulation agreements between SOI and other agencies or groups. The objectives of the program will be to ensure that disturbance to marine mammals and subsistence hunts is minimized, that effects on marine mammals are documented, and to collect baseline data on the occurrence and distribution of marine mammals in the study area. Those objectives will be achieved, in part, through the vessel-based monitoring and mitigation program.

The MMMMP will be implemented by a team of experienced marine mammal observers (MMOs), including both biologists and Inupiat personnel. The MMOs will be stationed aboard the drilling vessel, geotechnical vessel, and associated support vessels throughout the drilling period. The duties of the MMOs will include watching for and identifying marine mammals; recording their numbers, distances, and reactions to the drilling operations; initiating mitigation measures when appropriate; and reporting the results. Reporting of the results of the vessel-based monitoring program will include the estimation of the number of "takes" as stipulated in the IHA.

The vessel-based operations of SOI's MMMMP will be required to support the vessel based drilling or geotechnical activities in the central and eastern Alaskan Beaufort Sea (July through October). The dates and operating areas will depend upon ice and weather conditions, along with SOI's arrangements with agencies and stakeholders. Exploratory drilling activities are expected to occur after whaling during 2008, whereas geotechnical activities are expected to occur prior to whaling during 2008. Vessel-based monitoring for marine mammals will be done throughout the period of drilling operations to comply with anticipated provisions in the IHA(s) that SOI expects to receive from NMFS and USFWS.

The vessel-based work will provide:

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

The MMMMP will be operated and administered consistent with MMS NTL 2004-G01 or such alternative requirements as may be specified in the IHA(s) issued by NMFS for this project. Any other stipulation agreements between SOI and agencies or groups such as MMS, USFWS, NSB, and AEWC will also be fully taken into account. All MMOs will be provided training through a program approved by NMFS and SOI, as described later. At least one observer on each vessel will be an Inupiat who will have the additional responsibility of communicating with the Inupiat community and (during the whaling season) directly with Inupiat whalers. Details of the vessel-based marine mammal monitoring program are described below.

## Mitigation Measures during Drilling Activities

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

- timing and locating some drilling support activities to avoid interference with the annual fall bowhead whale hunts from Kaktovik, Nuiqsut (Cross Island), and Barrow;
- conducting pre-season modeling to establish the appropriate safety zones and behavioral radii, and;
- vessel-based (and aerial) monitoring to implement appropriate mitigation and to determine the effects of project activities on marine mammals.

The potential disturbance of marine mammals during drilling operations will be minimized further through the implementation of several ship-based mitigation measures as discussed below.

*Safety 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 pulse 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 pulses 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. Initial safety and behavioral radii based on the sound levels produced by the drilling activities will be modeled prior to the exploratory activities. It is not anticipated (given prior investigations) that sound levels associated with drilling activities or vessel activities, including ice breaking, will exceed these safety criteria. These radii, however, will be used for mitigation purposes until direct measurements are available early during the exploratory activities. An acoustics contractor will measure the received levels of underwater sound versus distance and direction from the sound sources 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.

## Marine Mammal Observers

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

*Number of observers*

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

- availability for monitoring and consultation coverage during periods of drilling operations in daylight;
- maximum of 4 consecutive hours on watch per MMO;
- maximum of approx. 12 hours on watch per day per MMO;

MMO teams will consist of Inupiat observers and LGL biologists. An experienced field crew leader will be a member of every MMO team onboard the drillship and geotechnical vessel during the drilling program. The total number of MMOs aboard may decrease later in the season as the duration of daylight decreases and if NMFS does not require continuous nighttime monitoring. If operations occur during the whaling season, the Inupiat observer(s) also will be employed as a part-time Communicator with whaling crews and with an industry/whaler coordination center. The requirement for, and role of, the Inupiat observers are expected to be defined in the "Conflict Avoidance Agreement" between SOI and the hunters.

## Vessel-based Drilling Activities

One drill ship, the *Kulluk* will be used in the Beaufort Sea during the exploratory drilling activities in 2008. In addition to the *Kulluk*, and geotechnical vessel, several support vessels will be required, each of which will contribute noise into the environment. These support vessels will include tugs and barges, anchor handling vessels and ice-breaking supply ships. Class III icebreakers have also been used during previous offshore drilling activities in the Arctic.

Sound produced during drilling operations will be continuous as opposed to the pulsed sound produced during seismic activities. Greene (1987) reported SPLs ranging from 130-136 dB (rms) at 0.2 km from the *Kulluk* during drilling activities (drilling, tripping, and cleaning) in the Arctic. Higher received levels up to 148 dB (rms) were recorded for supply vessels that were underway and for icebreaking activities. The exploratory drilling and the activities of the support vessels are not likely to produce sound levels sufficient to cause temporary hearing loss or permanent hearing damage to any marine mammals. Consequently, mitigation as described for seismic activities including ramp ups, power downs, and shut downs should not be necessary for drilling activities. However, SOI plans to use MMOs onboard the drillship, geotechnical vessel, and the various support and supply vessels to monitor marine mammals and their responses to industry activities. In addition, an acoustical program and an aerial survey program which are discussed in other sections of the MMMMP will be implemented to determine potential impacts of the drilling program on marine mammals.

*Crew Rotation*

SOI anticipates that there will be provision for crew rotation every six weeks. Should an unexpected crew rotation be required we will facilitate monitoring consistency by preparing detailed hand-over notes for the oncoming crew leader. If possible, there will also be communications (e.g., email, fax, and/or phone) between the current and oncoming crew leaders during each cruise.

*Observer Qualifications and Training*

Crew leaders and most other biologists serving as observers in 2008 will be individuals with experience as observers during one or more of the 1996-2001 seismic monitoring projects for Western Geophysical or BP, and/or subsequent seismic monitoring projects for other clients in Alaska, the Canadian Beaufort, or other offshore areas in more recent years.

Biologist-observers to be assigned by LGL will have previous marine mammal observation experience, in many cases aboard seismic vessels, and LGL's field crew leaders will be highly experienced with previous vessel-based marine mammal monitoring projects. Resumés for those individuals will be provided to NMFS so that NMFS can review and accept their qualifications. Inupiat observers will be experienced in the region, and familiar with the marine mammals of the area. A marine mammal observers' handbook, adapted for the specifics of the proposed SOI seismic program from the handbooks created for previous LGL monitoring projects 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 2008 open-water season. (Any exceptions will have or receive equivalent experience or training.) The training session(s) will be conducted by LGL 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 adopted at the open-water peer review meeting, or specified by NMFS or USFWS in the IHAs, by MMS, or by SOI's Conflict Avoidance Agreement with the AEWC;
- review of marine mammal sighting, identification, and distance estimation methods, including any amendments specified by NMFS or USFWS in the 2008 IHAs;
- review of operation of specialized equipment (reticle binoculars, night vision devices, and GPS system);
- review of, and classroom practice with, LGL's data recording and data entry systems, including procedures for recording data on mammal sightings, seismic and 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 2008 Conflict Avoidance Agreement, including the specific tasks of the Inupiat part-time Communicator.

*MMO Handbook*

A Marine Mammal Observers' Handbook has been prepared for most of the monitoring programs in which LGL has been involved. The handbook contains maps, illustrations, and photographs as well as text and is intended to provide guidance and reference information to trained individuals who will participate as MMOs. The following topics will be covered in the MMO Handbook for the SOI project:

- summary overview descriptions of the project, marine mammals and underwater noise, the marine mammal monitoring program (vessel-based, aerial, acoustic measurements, special studies), the NMFS and USFWS IHAs and other regulations/permits/agencies, the Marine Mammal Protection Act,
- monitoring and mitigation objectives and procedures, 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, and seismic data recording, 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;
- copies of the NMFS and USFWS IHAs and the Conflict Avoidance Agreement will be made available.

## Monitoring Methodology

The observer(s) will watch for marine mammals from the best available vantage point on the drillship, geotechnical vessel, and support vessels. The observer(s) will scan systematically with the naked eye and 7 × 50 reticle binoculars, supplemented with night-vision equipment when needed (see below). Personnel on the bridge will assist the marine mammal observer(s) in watching for pinnipeds and whales.

Information to be recorded by marine mammal observers will include the same types of information that were recorded during Western Geophysical's 1998-2001 monitoring projects (Moulton and Lawson 2002). 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, and water temperature, water depth, sea state, ice cover, visibility, and sun glare will also be recorded at the start and end of each observation watch, every 30 minutes during a watch, and whenever there is a change in any of those variables.

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

Observers may use a laser rangefinder to test and improve their abilities for visually estimating distances to objects in the water. However, previous experience showed that this 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. In our experience, 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 needed. However, our past experience with night-vision devices (NVDs) in the Beaufort Sea and elsewhere shows 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*

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

*Field Data-Recording, Verification, Handling, and Security*

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

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

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

*Field Reports*

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

## Reporting

The results of the 2008 vessel-based monitoring, including estimates of “take by harassment”, will be presented in the 90-day and final technical report(s). Reporting will address the requirements established by NMFS in the IHA.

The technical report(s) will include:

- summaries of monitoring effort: total hours, total distances, and distribution of marine mammals through study period 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: sea state, number of observers, and fog/glare;
- species composition, occurrence, and distribution of marine mammal sightings including date, water depth, numbers, age/size/gender categories, group sizes, and ice cover;
- analyses of the effects of drilling operations:
    - sighting rates of marine mammals versus 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”.

# 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* . SOI has contracted LGL Alaska Research Associates Inc., and JASCO Research Ltd to measure absolute sound levels in vicinity of the operating drill rig. The goals of these measurements are (1) to quantify the absolute sound levels produced by drilling and to monitor their variations with time, distance and direction from the rig, and (2) to measure the sound levels produced by vessels operating in support of drill operations. These vessels will include crew change vessels, tugs, and ice-handling vessels.

*Equipment*

The drilling and vessel sound measurements will be performed using two methods that may be implemented separately or together. The first method will involve real time monitoring using bottom-mounted hydrophones that are cabled back to the drill rig. These hydrophones will be positioned between 500 m and 1000 m away from the rig, depending on the final positions of the anchors used to hold the rig in place. Hydrophone cables will be fed to real-time digitization systems on board (see Figure 2). The second sound monitoring method will be to deploy OBH systems (see Figure 3) at various distances from the drilling operations. Sound level monitoring with one or both methods will occur on a continuous basis throughout all drill activities. Both types of systems will be set to record digital acoustic data at sample rate 32 kHz, providing useful acoustic bandwidth to at least 15 kHz. Both the cabled hydrophone system and OBH use Reson TC4032 hydrophones with sensitivity -170 dB re V/μPa. These systems are capable of measuring absolute broadband sound levels between 90 dB re μPa and 180 dB re μPa.

The deployment of drill sound monitoring equipment is scheduled to occur, or as soon as practicable after arrival on site and anchor setting. Retrieval of these systems will be performed in early-mid October 2008. The long duration recordings will capture many different operations performed at the drill rig. Accurate activity logs of drilling operations and nearby vessel activities will be maintained to correlate with these acoustic measurements.

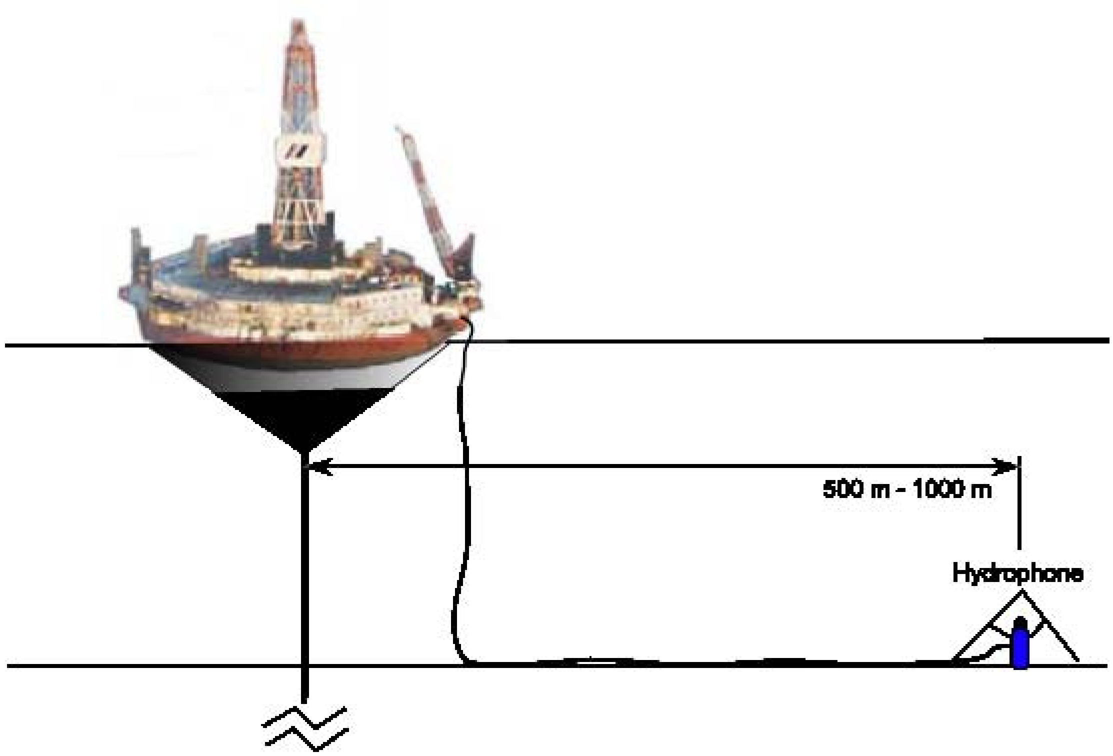


Figure 2: Cabled hydrophone method for real time monitoring of drill noise.

Figure 3: Ocean Bottom Hydrophone (OBH) recording system being deployed at sea. The OBH is a pop-up style autonomous recorder with very high recording resolution. Acoustic data is stored internally on hard-drive.

*Vessel Sounds Monitoring*

Sound produced by the vessels supporting drilling operations will be recorded by the drill sounds monitoring equipment and by DASARs (described below). Logs of vessel position and activity will be used to determine the time varying contribution of each vessel to the overall sound level measurements.

*Acoustic Data Analyses*

An important purpose of the measurements of sound level variation with time is to provide information that can be correlated with observations of bowhead whale deflections around the drilling operations. Deflections will be monitored by arrays of directional acoustic recorders (DASARS) as proposed in SOI's Chukchi and Beaufort monitoring plan. The goal of that work will be to determine if changes in deflection patterns can be correlated with changes in sound level output from the drilling operations.

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

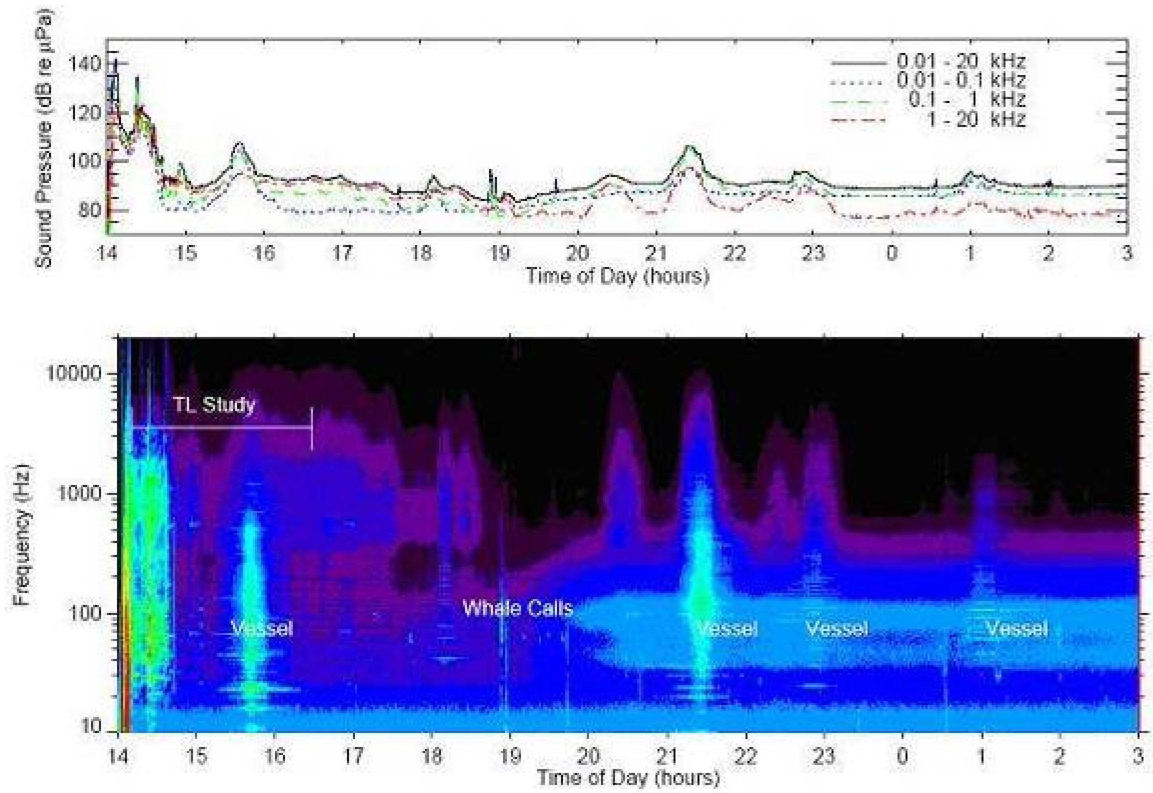


Figure 4: Lower: spectrogram of sound level measurements obtained from Ocean Bottom Hydrophone (OBH) recording system. Upper: broadband and selected band level variation with time.

The analyses will also consider sound level integrated through 1-hour durations (referred to as noise equivalent level Leq(1-hour)). Figure 5 (upper) shows an example of a Leq analysis of OBH 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 deflection data obtained from directional acoustic recording arrays deployed for SOI's 2008 bowhead migration study.

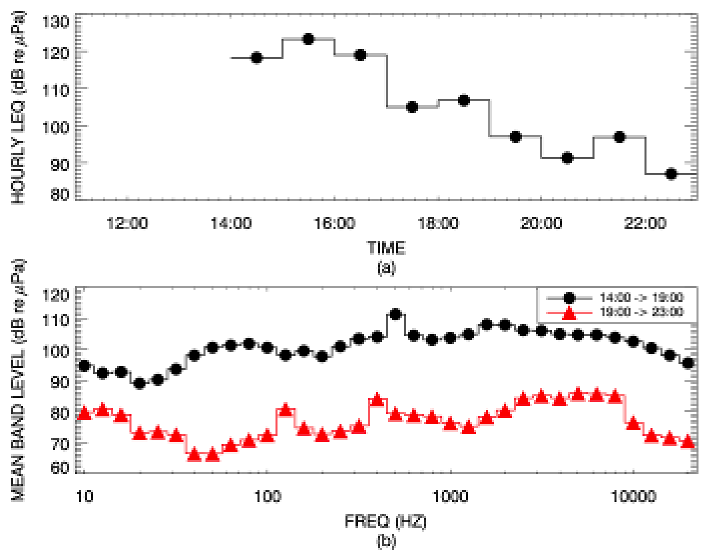


Figure 5: Upper: 1-hour Leq levels that will be calculated from OBH acoustic measurements for use in correlating with bowhead whale deflection data.

*Reporting of Results*

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

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

## Acoustic Study of Bowhead Deflections

SOI plans to deploy an acoustic net array program in the Beaufort Sea in 2008, similar to that which was done in 2007, but enhanced by the use of directional acoustic systems that permit localization of bowhead whale and other marine mammal vocalizations. The purpose of the array will be to further understand, define, and document sound characteristics and propagation resulting from vessel-based drilling operations that may have the potential to cause deflections of bowhead whales from their migratory pathway. Of particular interest will be the east-west extent of deflection (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 occurs.

In previous work around seismic and drill-ship 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. As compared with 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 do 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 very useful in assessing the potential effects of drilling operations on migrating bowhead whales.

*Objective*

The objective of this study is to provide information on bowhead migration paths along the Alaskan coast, particularly with respect to industrial operations and whether and to what extent there is deflection due to industrial sound levels. Using passive acoustics with directional autonomous recorders, the locations of calling whales will be observed for a six- to ten-week continuous monitoring period at five coastal sites (subject to favorable ice and weather conditions). Essential to achieving this objective is the continuous measurement of sound levels near the drillship.

An example of the whale call locations measured from a pair of Directional Autonomous Seafloor Acoustic Recorders (DASARs) about 25 km (15 mi) NNE of Cross Island in 2006 is presented in Figure 6 (Greene et al. 2007). The element spacing was 5 km oriented east-west and the water depth was 37 m (122 ft).

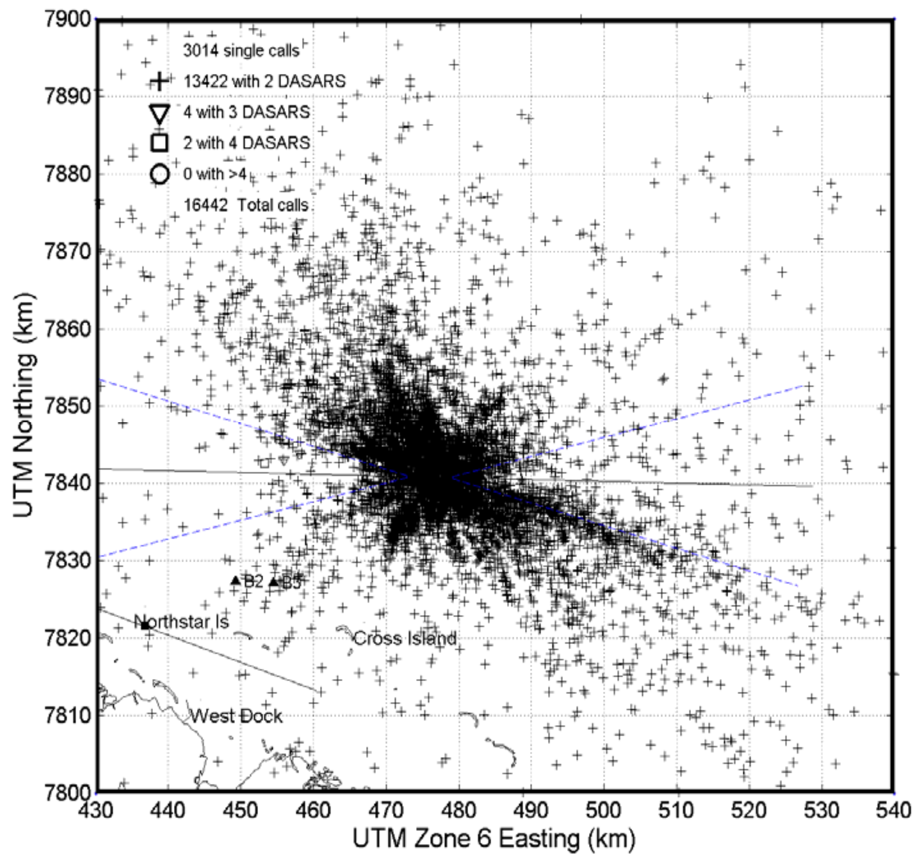


Figure 6. Bowhead whale call locations determined from the received bearings at a pair of DASARbs 25 km NNE of Cross Island. The pair spacing was 5 km. There were 13,422 locations determined for the period from 12 September to 1 October.

*Description of Directional Autonomous Seafloor Acoustic Recorder (DASAR)*

The key requirements for Greeneridge's new DASAR design were for a low profile to resist motion in water currents and a new directional sensor. The housing is 9" high and 18" in diameter with the sensor suspended elastically about 5" above. A latex "sock" stretched over a tubular frame protects the sensor from water currents. The housing is secured to a weighted square frame 30" on a side. The in-air weight is 115 lb and the in-water weight is 40 lb.

The concept for the new sensor is to use three-axis geophone elements for the directional sensors and a flexural pressure transducer for the omni-directional sensor (necessary to resolve the directional ambiguities from the geophone response patterns). Using a geophone element with a 28-Hz resonant frequency, critical damping, and spurious frequency response behavior only at frequencies >500 Hz resulted in a frequency response essentially flat from about 20 Hz to 500 Hz, the range within which most bowhead calls occur. The vector sensor so constructed is ideally suited for this application where low-power consumption is imperative.

DASARs are designed to be installed on the bottom with no surface expression, important to avoid entanglement with ice floes. A small Danforth anchor and chain is attached to a 100 m "tag line" of ground rope that is stretched out during deployment and attached to a corner of the frame. By noting the GPS coordinates of the Danforth anchor and the DASAR, it is straightforward to retrieve everything by using grapnel anchors and chain dragged over the center of the tag line. With an average of 11 DASARs deployed every year 2000-2004 and seven deployed during the two years 2005-2006 (almost 80 units) in BP's Northstar project, every unit was retrieved. (Water depths range from 20 to 25 m, but similar retrievals have been effective in water 50 m deep.)

The four data channels in each sensor (two horizontal, one vertical, and one omni) are sampled at 1000 samples/sec, 16-bits/sample. That sample rate supports a data bandwidth of 450 Hz, allowing for anti-aliasing. The samples are buffered, then written to an internal hard drive. A 40 GB hard drive will store the data from 60 days of continuous operation.

Figure 7 illustrates the DASAR assembly configuration. Figure 8 is a top-view photograph of a DASAR on the deck of *M.V. Henry Cristoffersen* after retrieval. One of the grapnel anchors with chain is in the picture. Figure 9 is the calibrated pattern of the two directional sensors in the new DASAR.

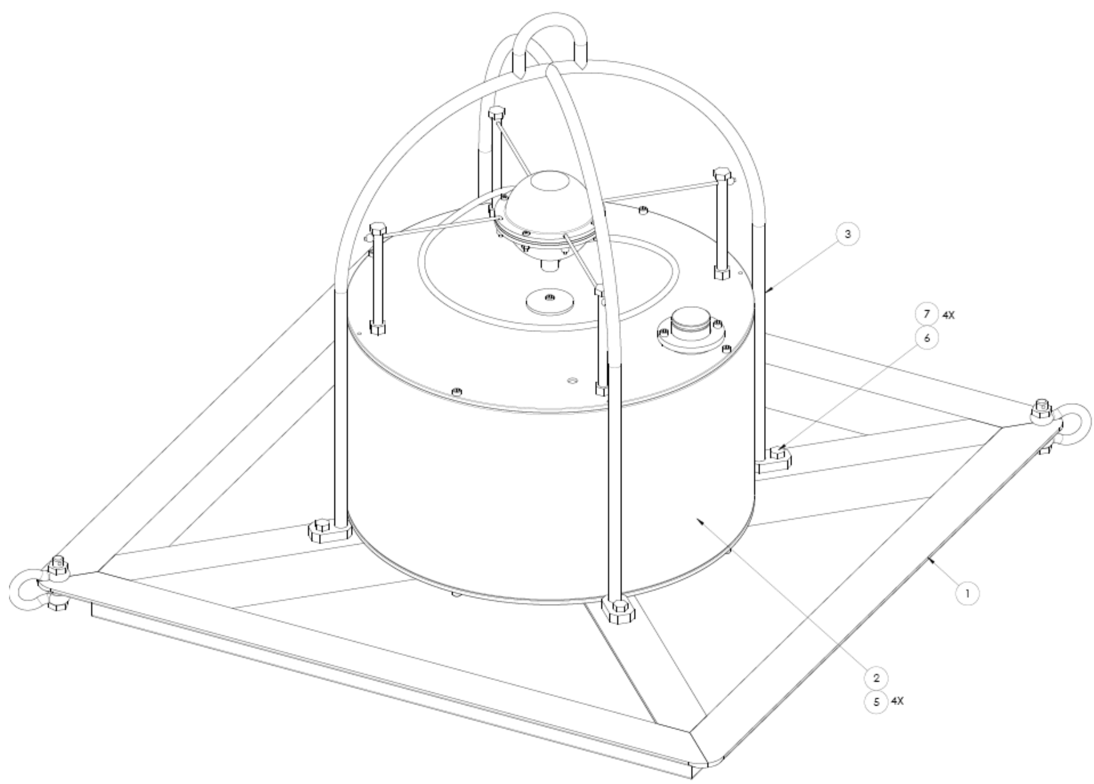


Figure 7: The assembly drawing for the DASARb. The small loop at the top is for the lowering line. The sensor is directly beneath the small loop and over the housing. The loop coming from the back-left of the sensor and disappearing beyond the sensor on the housing top is the tube with the electrical signal wires. The sensor is attached by four elastic strings to four vertical posts. The "knob" drawn on the right side of the housing

holds the transponder transducer. A shackle on the left or right side of the frame is for attaching the tag line.

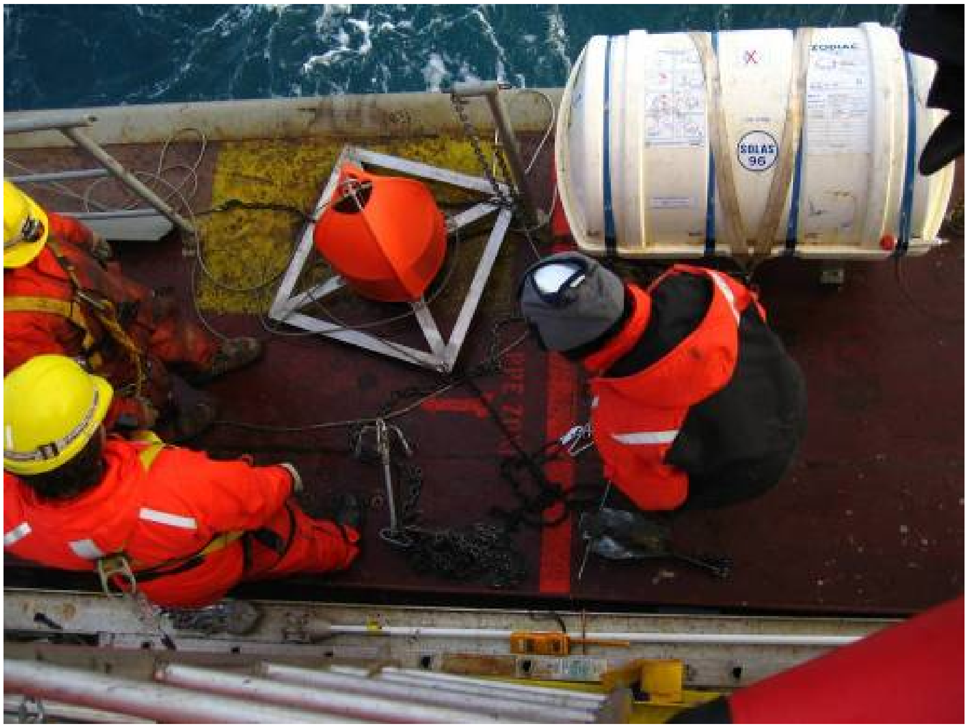

Figure 8: Photograph of a DASARb on deck after retrieval. Note the latex sock over the frame and a grapnel anchor and chain on the deck.

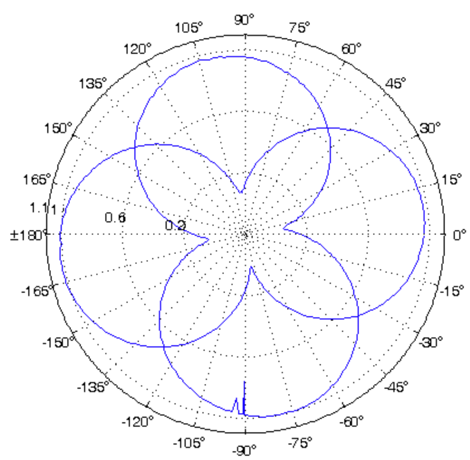


Figure 9: Azimuthal calibration responses of the two horizontal directional sensors. Note that the calibration setup was not aligned with the sensors' main response axes and that averaging filled in the response nulls. The notch near -90° is from the calibration facility instrumentation.

*Monitoring Plan*

Greeneridge plans to conduct the whale migration monitoring using the passive acoustics techniques developed and used successfully since 2001 for monitoring the migration past BP's Northstar production island northwest of Prudhoe Bay. Those techniques involve using directional autonomous seafloor acoustic recorders (DASARs) to measure the arrival angles of bowhead calls at known locations, then triangulating to locate the calling whale. Thousands, in some years tens of thousands, of whale calls have been located each year since 2001.

Greeneridge Sciences developed and tested a new model of DASAR under SOI's sponsorship in 2006. The new design proved to be operational during field deployment in 2006 and is proposed for use in the 2008 migration monitoring.

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. SOI plans to monitor at five sites along the Alaskan Beaufort coast as shown in Figure 10. The eastern-most site (#5 in fig.10) will be just east of Kaktovik and the western-most site (#1) will be in the vicinity of Harrison Bay. Site 4 will be 15 km (9.3 mi) east of the Sivulliq drilling area and site 3 will be 20 km (12.4 mi) west of Sivulliq. These five sites will provide information on possible migration deflection well in advance of whales encountering an industry operation and on "recovery" after passing such operations.

The proposed geometry of DASARs at each site is to use seven DASARs oriented in a north-south pattern so that five equilateral triangles with 7-km element spacing is achieved. This geometry is illustrated in Figure 10. Five kilometer spacing has been used successfully in the migration studies at Northstar, but whale calls are received reliably at greater spacing and the 7 km spacing will result in greater coverage of whales along the north-south dimension, important in studying possible deflection.

DASARs are 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 drifts 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. (We also propose a mid-season calibration.) Because of the equilateral triangular geometry, it requires 25 transmission stations for each site. Each set of transmissions requires less than half a minute. For the 5-km spacing, experience has been that it requires an hour to do 4 calibration transmissions, including transit. For our planned 7-km spacing, we estimate three calibration transmissions per hour. With 25 to do at each site, calibration of a site will require ~8 hours.

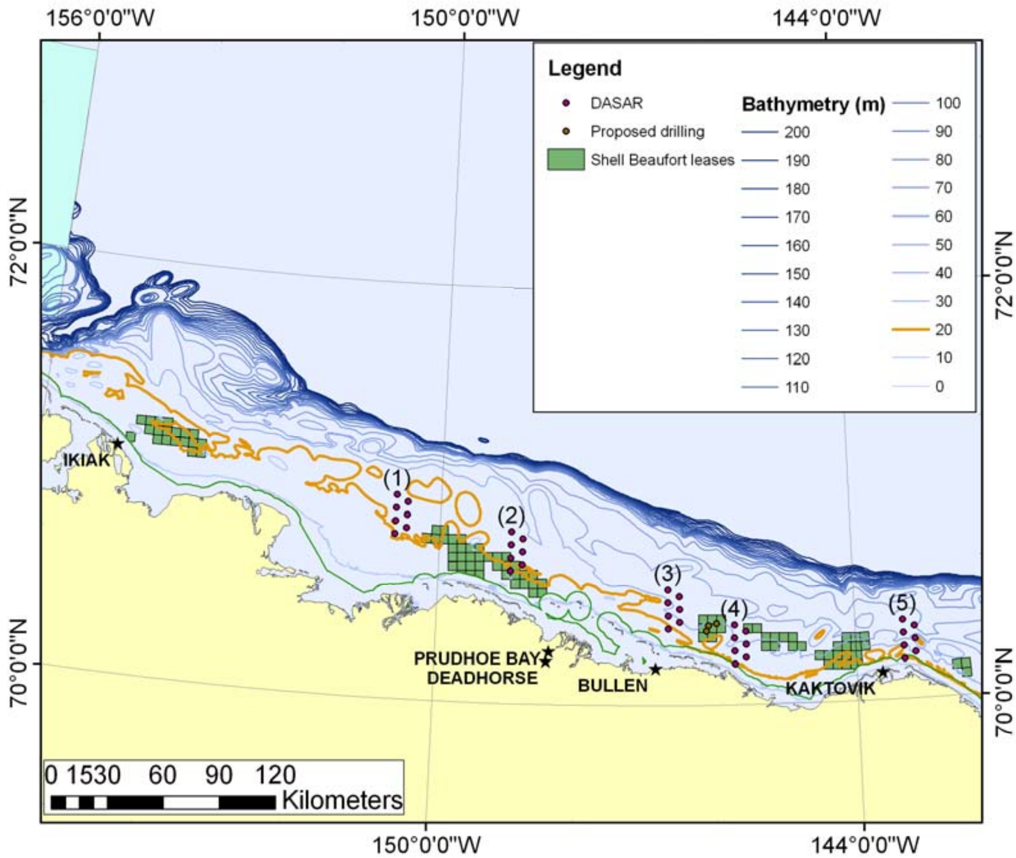


Figure 10. The Alaskan Beaufort Sea coast showing DASAR site locations for whale call location studies. The DASAR array locations at the five sites are shown to scale, with seven DASARs forming five equilateral triangles with a unit spacing of 7 km and a north-south extent of 21 km to aid being able to observe possible offshore deflection.

The calibration transmissions are made using a model J-9 sound projector. The J-9 is 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.

The DASAR installation configuration includes a small (5 lb) Danforth anchor and 5 ft of chain attached to a stretched-out, 100-m tag line attached to the DASAR. GPS locations are marked for the anchor and the DASAR. For retrieval, two grapnel anchors attached by a 20-ft chain with a heavy shackle (~40 lbs for weight, to assure the grapnel anchors will be on the bottom) are deployed at one side of the tag line, then dragged over the line to snag it for retrieval. This scheme has worked reliably with all the DASARs installed at Northstar since 2000 without loss, as well as with the four DASARs installed for SOI in 2006.

Bowhead migration begins in late August with the whales moving westward from their feeding sites in the Canadian Beaufort Sea. It continues through September and well into October. However, because of the drilling schedule, we will attempt to install the 21 DASARs at three sites (3, 4 and 5 in Figure 10) 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.

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 2008 project, machine-aided call detection software will be used to simplify and accelerate the call analysis. Such software was developed with SOI's sponsorship in 2006 and is described by A. Thode in Greene et al. (2007).

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 our five array sites. We discuss only two that assess whether whales are being displaced farther offshore (or nearshore) during periods of high industrial sound production.

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 we anticipate 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, we might infer an offshore displacement of the corridor near the proposed drilling activity. Likewise, if the migration corridor appears to follow the coastline from the locations of array #2 through #5, but deviates offshore at #1, we might infer an offshore displacement of the corridor near the proposed seismic activity. We plan 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. We note that this analysis does not depend on quantification of underwater industrial sounds emanating from seismic or drilling operations.

A second analysis we will use 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 our second analysis, consider DASAR sites #4 and #3 in Figure 10. Over a standard reporting period, for example 6 hours, we will collect calls located by these two arrays, as well as other environmental covariates such as water depth, ambient sound levels, time of day, etc. From these data, we will calculate summary statistics for offshore distribution, and all covariates of interest. For example, we may calculate the 25th percentile of offshore distance, and the average water depth of all call locations in the 6 hour reporting period. Differences in offshore summary statistics between arrays will then be calculated and used in a regression or quantile regression analysis. For example, 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, we would expect 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. 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:*

- We assume that changes in the offshore distribution of call locations reflect either changes in whale locations or changes in calling behavior.
- We assume 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 seismic and drilling sources need to be accurately quantified at varying distances in such a way that we can temporally match industrial sound levels and whale locations. We assume that an accurate propagation model for industrial sounds can be constructed from the collected data.
- A large number of whales will swim through the areas where our arrays can reliably locate their calls.

*Tasks*

The bowhead migration path study includes the following tasks:

1. Test and prepare the DASARs for deployment.
2. Sail to three early-deployment sites (3, 4, and 5) and install seven DASARs and project calibration sounds.
3. Repeat step 2 in late August for 14 DASARs at sites 1 and 2.
4. Mid-season, around 1-20 September, conduct another set of calibration transmissions at each of the first three sites (3, 4, and 5).
5. Retrieve the 21 DASARs from sites 3, 4, and 5, replace batteries in the 21 DASARs, install new data-storage disks, re-install, and conduct calibration transmissions for those three sites.
6. As soon a good operating weather is available on or after 1 October, conduct final calibration transmissions and retrieve all 35 installed DASARs.
7. Convert raw DASAR data into multi-channel WAV format for automated analysis.
8. Obtain sound level histories for the drillsites and the seismic and shallow hazard survey vessel location histories for use in conducting the deflection analyses.
9. Analyze all calibration transmission data to determine clock correction functions and DASAR reference axis directions.
10. Analyze the omnidirectional hydrophone data from each DASAR to determine percentile distributions for narrowband and one-third octave band level statistics.
11. Analyze whale calls for directions, call type, and source location.
12. Conduct the statistical deflection analyses.
13. Prepare preliminary technical (90-day) report.
14. Prepare deflection analysis section (acoustics study) for comprehensive report.

## 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 DASARb, (b) analyse data as a whole to determine offshore distributions as a function of time, (c) quantify spatial and temporal variability in the ambient noise, and (d) measure received levels of seismic survey events and drill ship activities. The detection data will be used to develop spatial and temporal animal detection 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 2008 open-water season a comprehensive report describing the proposed acoustic, vessel-based, and aerial 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 their impacts on marine mammals in the Beaufort Sea during 2008. The report will form the basis for future monitoring efforts and will establish long term data sets to help evaluate changes in the Beaufort Sea ecosystem. The report will also incorporate studies being conducted in the Chukchi Sea and 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.

This report will consider data from many different sources including two relatively different types of aerial surveys; several types of acoustic systems for data collection (net array, vertical array, DASARB, and OBH systems), and vessel based observations. Collection of comparable data across the wide array of programs will help with the synthesis of information. However, interpretation of broad patterns in data from a single year is inherently limited. Much of the 2008 data will be used to assess the efficacy of the various data collection methods and to establish protocols that will provide a basis for integration of the data sets over a period of years.

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