Shell Exploration & Production Company
3601 C Street, Suite 1000
Anchorage, AK 99503
(907) 770-3700

February 20, 2013

Dear Recipient,

Enclosed is a copy of Marine Mammal Monitoring and Mitigation During Exploratory Drilling by Shell in the Alaskan Chukchi and Beaufort seas, July – November 2012: Draft 90-Day Report. This is the first draft submittal of this document to the National Marine Fisheries Service and the U.S. Fish and Wildlife Service in compliance with reporting requirements of the Incidental Harassment Authorizations issued by NMFS and the Letters of Authorization issued by USFWS to Shell for the 2012 season.

Please address any comments or questions to a.macrander@shell.com (907-646-7123).

Thank you,

A. Michael Macrander
Lead Scientist

MARINE MAMMAL MONITORING AND MITIGATION DURING EXPLORATORY DRILLING BY SHELL IN THE ALASKAN CHUKCHI AND BEAUFORT SEAS, JULY–NOVEMBER 2012: DRAFT 90-DAY REPORT

Prepared by

Alaska Research Associates, Inc.

2000 W International Airport Road, Suite C-1, Anchorage, AK 99502

and

4464 Markham St., Suite 2101, Victoria, BC V8Z 7X8, Canada

for

Shell Offshore, Inc.

P.O. Box 576, Houston, TX 77001-0576

and

National Marine Fisheries Service, Office of Protected Resources

1315 East-West Hwy, Silver Spring, MD 20910-3282

and

U.S. Fish and Wildlife Service, Marine Mammal Management

1101 E. Tudor Road, M.S. 341, Anchorage, AK 99503

LGL Report P1272D–1

February 2013

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Authored by

Lauren N. Bisson[a], Heather J. Reider[a], Heather M. Patterson[a], Melanie Austin[b], John R. Brandon[a], Tannis Thomas[a], and Marc L. Bourdon[a]

[a] **LGL Alaska Research Associates, Inc.**
2000 W International Airport Road, Suite C-1, Anchorage, AK 99502, USA

[b] **JASCO Research Ltd., Applied Sciences Division**
Suite 2101, 4464 Markham St., Victoria, BC V8Z 7X8, Canada

for

Shell Offshore, Inc.
P.O. Box 576, Houston, TX 77001-0576

and

National Marine Fisheries Service, Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

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LGL Report P1272D–1

February 2013

Suggested format for citation:

Bisson, L.N., H.J. Reider, H.M. Patterson, M. Austin, J.R. Brandon, T. Thomas, and M.L. Bourdon. 2013. Marine mammal monitoring and mitigation during exploratory drilling by Shell in the Alaskan Chukchi and Beaufort seas, July–November 2012: Draft 90-Day Report. Editors: D.W. Funk, C.M. Reiser, and W.R. Koski. LGL Rep. P1272D–1. Rep. from LGL Alaska Research Associates Inc., Anchorage, AK, USA, and JASCO Applied Sciences, Victoria, BC, Canada, for Shell Offshore Inc, Houston, TX, USA, Nat. Mar. Fish. Serv., Silver Spring, MD, USA, and U.S. Fish and Wild. Serv., Anchorage, AK, USA. 266 pp, plus appendices.

Individual chapters can also be cited as follows:

Reider, H.J., L.N. Bisson, and H.M. Patterson. 2013. Background and introduction. (Chapter 1) In: Bisson, L.N….

Reider, H.J., L.N. Bisson, and C.M. Reiser. 2013. Exploration drilling operations described. (Chapter 2) In: Bisson, L.N….

Austin, M., A. McCrodan, C. O'Neill, Z. Li, and A. MacGillivray. 2013. Underwater Sound Measurements. (Chapter 3) In: Bisson, L.N….

Patterson, H.M., L.N. Bisson, H.J. Reider, and C.M. Reiser. 2013. Vessel-based monitoring, mitigation, and data analysis methods. (Chapter 4) In: Bisson, L.N….

Bisson, L.N., H.J. Reider, H.M. Patterson, M.L. Bourdon, and C.M. Reiser. 2013. Chukchi Sea vessel-based marine mammal monitoring results. (Chapter 5) In: Bisson, L.N….

Patterson, H.M., Bisson, L.N., Reider, H.J., M.L. Bourdon, and C.M. Reiser. 2013. Beaufort Sea vessel-based marine mammal monitoring results. (Chapter 6) In: Bisson, L.N….

Thomas, T. and M.L. Bourdon. 2013. Chukchi sea aerial surveys. (Chapter 7) In: Bisson, L.N….

Brandon, J.R. and W.R. Koski. T. Thomas, and M. Bourdon. 2013. Beaufort Sea aerial survey results. (Chapter 8) In: Bisson, L.N….

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
AASM	Airgun Array Source Model
AEWC	Alaska Eskimo Whaling Commission
Bf	Beaufort Wind Force
BO	Biological Opinion
CAA	Conflict Avoidance Agreement
CFR	(U.S.) Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
cm	centimeter
CPA	Closest (Observed) Point of Approach
CTD	conductivity, temperature, depth
dB	decibel
EA	Environmental Assessment
EFD	Energy Flux Density
ESA	(U.S.) Endangered Species Act
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
FRC	Fast Rescue Craft
GI	Generator Injector
GIS	Geographic Information System
GMT	Greenwich Mean Time
GPS	Global Positioning System
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
hp	horse power
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kt	knots
LOA	Letter of Authorization
μPa	micro Pascal
m	meters
MBB	Multibeam Bathymetric (sonar)
MCS	Multi-Channel Seismic
min	minutes
MMPA	(U.S.) Marine Mammal Protection Act

MONM	Marine Operations Noise Model
n	sample size
n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number
PD	Power down of the airgun array to one airgun (in this study, from an output of 3147 in^3 to 30 or 155 in^3)
PE	Parabolic Equation
pk-pk	peak-to-peak
PSO	Protected Species Observer
RAM	Range-dependent Acoustic Model
re	in reference to
rms	root-mean-square: an average, in the present context over the duration of a sound pulse
s	seconds
SD	Shut Down of airguns not associated with mitigation
s.d.	standard deviation
SEL	Sound Exposure Level: a measure of energy content, in dB re 1 $\mu Pa^2 \cdot s$
SOI	Shell Offshore, Inc.
SPL	Sound Pressure Level; the SPL for a seismic pulse is equivalent to its rms level
SZ	Shut Down of all airguns because of a marine mammal sighting near or within the safety radius
TTS	Temporary Threshold Shift
UNEP	United Nations Environmental Programme

EXECUTIVE SUMMARY

Background and Introduction

Shell (Shell Offshore, Inc., and Shell Gulf of Mexico, Inc.) conducted exploratory drilling in the Chukchi and Beaufort seas during the 2012 open-water period. Operations were permitted as two programs: one in the Chukchi Sea and one in the Beaufort Sea. Exploratory drilling was conducted from the drill rig M/V *Noble Discoverer (Discoverer)* in the Chukchi Sea and the drill rig *Kulluk* in the Beaufort Sea. In addition, 15 support vessels operated by Shell supported the drill rigs with activities such as, ice management, anchor handling, oil spill response, refueling, and resupply.

Marine exploration drilling and other industrial activities emit sounds into the water at levels that could affect marine mammal behavior and distribution, or perhaps cause temporary or permanent reduction in hearing sensitivity. These effects could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA). The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) share jurisdiction over the marine mammal species that were likely to be encountered during the project.

Shell's exploratory drilling activities and other exploration activities in the Chukchi and Beaufort seas were conducted under the jurisdiction of Incidental Harassment Authorizations (IHAs) issued by NMFS and Letters of Authorization (LOAs) issued by the USFWS. The IHAs and LOAs included provisions to minimize the possibility that marine mammals might occur close to the continuous sound sources generated by exploratory drilling and be exposed to levels of sound high enough to cause hearing damage or other injuries, and to reduce behavioral disturbances that might be considered as "take by harassment" under the MMPA.

A mitigation program was conducted to avoid or minimize potential effects of Shell's marine surveys on marine mammals and subsistence hunting, and to ensure that Shell was in compliance with the provisions of the IHAs and LOAs. This program required protected species observers (PSOs) onboard all of the project vessels to detect and monitor marine mammals and their responses to industry activities, and to initiate mitigation measures if necessary.

The primary objectives of the monitoring and mitigation program were to:

1. provide real–time sighting data needed to implement the mitigation requirements;
2. estimate the numbers of marine mammals potentially exposed to low-level continuous sounds generated by the drilling operations and support activities near well sites; and
3. determine the reactions (if any) of marine mammals potentially exposed to exploratory drilling sounds and related activities.

This 90-day report describes the methods and results for the monitoring work specifically required to meet the above primary objectives.

Exploratory Drilling Operations Described

During exploration drilling operations, the drill rigs *Discoverer* and the *Kulluk* operated in the Chukchi and Beaufort seas, respectively. Each of the two drill rigs emitted near-continuous, low-energy sounds through the use of generators and drilling equipment. In addition, support vessels including ice-management and anchor-handling vessels operated in and around the exploratory drilling areas. A single, relatively-shallow top hole was completed in each sea without reaching hydrocarbon zones typically located at greater depths than were drilled in 2012.

Shell's exploratory drilling program in 2012 was conducted on or near the Outer Continental Shelf (OCS) lease holdings near the Burger prospect in the Chukchi Sea and the Sivulliq prospect near Camden bay in the eastern Beaufort Sea. Measurements of sound propagation from the drill rigs and all support vessels were conducted by JASCO Applied Sciences (JASCO) from 15 Sep to 1 Oct in the Chukchi Sea and 26 Sep through 22 Oct in the Beaufort Sea.

Heavy ice conditions near the Burger Prospect early in the season required Shell's Ice Management Plan (IMP) to be implemented in accordance with the LOAs. Ice management activities were conducted by the *M/V Fennica* and *M/V Tor Viking.* The actual amount of time spent actively pushing or breaking ice in the Chukchi Sea was limited to discrete, isolated events between 31 Aug–3 Sep and 11–13 Sep.

The *Discoverer*, an industry-standard, ice strengthened drillship, performed the exploratory drilling operations in the Chukchi Sea at the Burger-A drillsite. The drill rig arrived and departed the Chukchi Sea on 25 Aug and 31 Oct, respectively. Exploratory drilling was conducted using standard rotary drilling technology and seawater based drilling fluids from 23 Sep through 26 Oct. One top hole, which includes a pilot hole and construction of a mud-line cellar (MLC), was completed at the Burger-A drillsite. The top hole did not penetrate the hydrocarbon-bearing zones in compliance with BOEM and Bureau of Safety and Environmental Enforcement (BSEE) regulations.

Exploratory drilling operations in the Beaufort Sea were performed by the *Kulluk*, a conically shaped, ice-strengthened floating drill rig designed and constructed for extended season drilling operations in Arctic waters. The drill rig arrived and departed the Beaufort Sea on 10 Sep and 8 Nov, respectively. The *Kulluk* used similar exploratory drilling technology to the *Discoverer* and drilled from from 3 through 28 Oct. Similar to work in the Chukchi Sea, one top hole and MLC were completed at the Sivulliq-N drillsite and did not penetrate the hydrocarbon-bearing zones.

JASCO conducted measurements of underwater sound propagation from exploratory drilling activities and all support vessels as stipulated in the IHA in both the Chukchi and Beaufort Seas. These measurements included; anchor handling, ice management, and drilling activities including the MLC. Ice management activities only occurred and were measured in the Chukchi Sea.

Vessel-based marine mammal monitoring and mitigation was conducted from the drill rigs *Discoverer* and *Kulluk* and all support vessels throughout operations in the Chukchi and Beaufort seas. The primary support vessels for the Chukchi Sea included the M/Vs *Fennica*, *Tor Viking*, *Harvey Explorer, Harvey Spirit, Nanuq, Affinity,* and *Guardsman*. In the Beaufort Sea the *Nordica, Aiviq, Sisuaq, Lauren Foss, Arctic Seal, Warrior, Pt. Oliktok, Affinity* and *Nanuq* were the primary support vessels. Several vessels operated in both seas during different operational periods throughout the season.

Shell conducted aerial surveys of marine mammals using a team of PSOs over coastal and nearshore areas in the Chukchi Sea and a team of PSOs over the offshore operations areas in the Beaufort Sea in 2012. Additionally, aerial surveys were conducted over the Burger exploratory drillsite using high-definition cameras. The Chukchi Sea aerial survey program began on 18 Jul and was completed on 29 Oct and the Beaufort Sea program began on 19 Aug and was completed on 6 Nov.

Underwater Sound Measurements

Shell Exploration and Production Company (Shell) conducted exploratory drilling at two offshore sites in 2012, one at the Burger-A prospect in the Chukchi Sea and one at the Sivulliq-N prospect in the Beaufort Sea. Shell was required to monitor and report underwater sound levels from its 2012 offshore operations as stipulated in its Incidental Harassment Authorization (IHA) permit from NMFS for this work. JASCO Applied Sciences carried out the sound monitoring studies on behalf of Shell from August to October 2012. Chapter 3 of this report provides detailed descriptions of the methods employed for the sound study and gives the results of the measurements performed. An overview of the study and a summary of the results are given below.

Shell's 2012 IHAs stipulated a requirement to measure underwater sound levels for all vessels and equipment involved with the drilling program at each prospect. The measurements were to be analyzed to determine the distances corresponding to sound levels between 190 and 120 dB re 1 μPa (rms), reported in 10 dB steps. Source sound levels for all vessels and equipment were also to be provided.

The acoustic monitoring program was performed from the icebreaker vessels *MSV Fennica* (Chukchi Sea) and *MSV Nordica* (Beaufort Sea). Vessel sound source characterizations were conducted for every support vessel that operated at each respective prospect. Sounds from different phases of the drilling operations were characterized by activity. The activities considered included anchor laying, ice management, pilot hole drilling, and drilling of the mudline cellar. Measurements of sounds from anchor laying were only available from the Sivulliq prospect, and measured sounds from ice management were only available from the Burger prospect.

The acoustic measurements were made with seabed-deployed Autonomous Multichannel Acoustic Recorders (AMAR, JASCO Applied Sciences) recording at 64 kHz and equipped with calibrated GeoSpectrum M8E and M8K hydrophones. In-field calibrations of the AMARs were performed using GRAS 42AC pistonphone calibrators immediately before and after each measurement. Three AMARs were used at each prospect to measure vessel sounds and four AMARs were used at each prospect to measure sounds from drilling activities. An acoustic telemetry buoy deployed at 500 m (ft) from the Sivulliq-N drill site also provided real-time acoustic information for a portion of the *Kulluk*'s activities, allowing sound level information to be reported on a weekly basis as requested in the IHA. Real-time data were not available at the Burger prospect.

Distances to specific sound level thresholds for each vessel and for each of the activities characterized in this report are listed below. Table 1 and Table 2 list the radii for measurements from Burger-A; Table 3 and Table 4 are those from measurements from Sivulliq-N. The broadband (10 Hz–32 kHz) source level for drilling was calculated to be 181 dB re 1 µPa for the *Noble Discoverer* and 172 dB re 1 µPa for the *Kulluk*. These source levels were computed from measurements of drilling of a 26 in hole and of a pilot hole, respectively.

TABLE 1. Sound level threshold distances for drilling operations at the Burger-A drill site. Distances were obtained from best-fit lines to averaged sound levels versus range for the respective activity.

Drill Site Activity	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Drilling 8.5 in pilot hole (*Tor Viking II* nearby)	< 10	< 10	22	13,000*
Drilling 17.5 in pilot hole (*Tor Viking II* nearby)	< 10	< 10	< 10	10,000*
Drilling 36 in pilot hole (*Tor Viking II* nearby)	< 10	< 10	30	25,000*
Drilling 26 in hole (no ancillary vessels)	< 10	< 10	< 10	1500
Drilling of MLC	< 10	20	130	8100
Ice management	< 10	< 10	60	9600*

* Extrapolated beyond measurement range.

TABLE 2. Sound level threshold distances for vessels operating at the Burger-A drill site. Distances were obtained from the 90th percentile fits to sound level versus range for the respective vessels.

Vessel Name	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Affinity–8.8 kts	0	0	< 10	1300
Affinity–9.0 kts	0	0	< 10	1400
Aiviq (towing the Kulluk)	< 10	< 10	110	19,000
Fennica–8.0 kts	0	< 10	11	2000
Fennica–12.0 kts	< 10	< 10	26	5000
Guardsman (towing the *Klamath*)	< 10	< 10	70	4700
Harvey Explorer	0	< 10	16	2000
Harvey Spirit	0	0	< 10	2600
Nanuq–9.1 kts	< 10	< 10	42	5200
Nanuq–10.8 kts	< 10	< 10	60	6900
Noble Discoverer (towed by *Tor Viking II*)	0	0	< 10	740
Nordica	< 10	< 10	40	4600
Tor Viking II (towing the *Noble Discoverer*)	< 10	< 10	25	4800

TABLE 3. Sound level threshold distances for drilling operations at the Sivulliq-N drill site. Distances were obtained from the best-fit lines to averaged sound level versus range for the respective activity.

Drill Site Activity	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Anchor laying	< 10	< 12	63–120	12,000–29,000
Drilling of pilot hole	< 10	< 10	< 10	660
Drilling of MLC	< 10	20	140	6200

TABLE 4. Sound level threshold distances for vessels operating at the Sivulliq-N prospect, from measurements made from 28 Sep to 2 Oct 2012. Distances were obtained from the 90th percentile fits to sound level versus range for the respective vessels.

Vessel Name	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Affinity	0	< 10	< 10	3000
Aiviq	0	< 10	67	11,000
Arctic Seal	0	0	< 10	510
Lauren Foss (towing the *Tuuq*)	0	< 10	< 10	1500
Nordica	< 10	< 10	24	4200
Pt Oliktok	0	< 10	< 10	830
Sisuaq	< 10	< 10	25	3000
Tor Viking II	0	< 10	30	12,000
Warrior	< 10	< 10	42	4400

Vessel-Based Monitoring, Mitigation, and Data Analysis Methods

Marine mammal monitoring methods were designed to meet the requirements and objectives specified in the IHAs and LOAs. PSOs were stationed aboard the drill rigs and all support vessels to conduct visual watches for marine mammals to serve as the basis for implementation of mitigation measures, to collect observation data to estimate the numbers of marine mammals potentially exposed to low-level continuous sounds generated by drilling and ice-management activities, and to document any potential reactions of marine mammals to exploratory drilling and related support activities. Further these data were used to help discern whether there were potential effects on the accessibility of marine mammals to subsistence hunters in Alaska.

Mitigation protocols encompassing all aspects of operations during the 2012 season were in place to minimize the potential effects on marine mammals of drilling, ice-management, anchor handling, and transiting through and within the operational theatres. The most commonly implemented mitigation measure was a change in speed or course during routine vessel operations to increase the distances between ships and marine mammals or to prevent the separation of individuals from groups of marine mammals. Vessel-based PSOs also contributed information regarding the locations of large groups of walruses; this information was used in the planning of transit routes for vessels and flight paths of helicopters during crew changes so that interactions with congregations of marine mammals were avoided. Ice-scouting and ice-management activities were restricted to periods of good visibility, i.e. when it was possible for PSOs to detect walruses hauled out on ice even when the vessel remained a significant distance away from the main ice-edge. Only small amounts of hazardous ice were managed in the Chukchi Sea drilling area between 31 Aug and 13 Sep, and no ice with marine mammals directly associated with it was managed or approached closer than was operationally necessary. Potential impacts to local subsistence activities were mitigated by the timing and location of Shell's operations in the Chukchi Sea in accordance with the CAA, and also through communications from each vessel to the nearest communication center every six hours. Shell did not conduct ZVSP surveys at the Chukchi Sea drillsite in 2012, which precluded the establishment of 180 and 190 dB (rms) exclusion zones for marine mammals around the drill rigs as stipulated in Shell's Chukchi Sea IHA and LOA for periods with active airgun operations.

Observer effort and marine mammal sightings were divided into several analysis categories related to environmental conditions and vessel activity. These categories included the following: location in the Beaufort or Chukchi Sea, whether the vessel was moving or stationary, the activities of the source vessel and vessels in the surrounding area (e.g. drilling, ice-management), and environmental conditions such as Beaufort wind force.

Two methods were used to estimate the number of pinnipeds and cetaceans exposed to sound levels that may have caused disturbance or other effects. The first method was an estimate based upon direct observations made by PSOs aboard vessels throughout the 2012 season. The second method involved multiplying the most recently available values for densities of marine mammals by the area ensonified by drilling and ice-management activities during the 2012 season. During the migratory period for bowhead whales in the Beaufort Sea, an alternate method of estimation was also used. By using a ten-day moving average of the proportion of the bowhead population expected to pass within the ≥120 dB (rms) zone on any given day it was possible to estimate the number of animals potentially exposed to sounds from various activities.

Chukchi Sea Vessel-based Marine Mammal Monitoring Results

In total, 581 sightings of 1179 cetaceans, 938 sightings of 1386 seals, 338 sightings of 8678 Pacific walruses, and 49 sightings of 61 polar bears were recorded during Shell's 2012 Chukchi Sea exploratory drilling program. The most frequently sighted cetacean was the gray whale; 128 sightings of 256 individuals. However there were more individual bowhead whales seen, 117 sightings of 319 individuals. Approximately half of cetacean sightings could not be identified to species (~55%); it is likely that many unidentified mysticete whales were also bowheads or gray whales. Bearded seal was the most abundant seal species identified followed by ringed and spotted seals, respectively. Over half of the seals observed could not be identified to species. Many of the walrus sightings were of large groups (26 individuals per sighting on average) with some groups ~200-300 individuals. Of the 49 sightings of polar bears many were associated with the prevalent sea-ice conditions seen in August and September.

Sighting rates across species groups as expected were influenced by environmental conditions. When comparing sighting rates to operational activities the data showed no clear trend.

No cetaceans displayed any observable reaction to vessels. Most cetacean movements relative to vessels were "neutral" or "unknown." Cetaceans from ~18% of sightings were recorded as "swimming away" from the vessel compared to ~7% that were "swimming toward" the vessel.

The most frequently observed seal reaction to project vessels was to "look" at the vessel, followed by "no observable reaction." The majority of seal movement relative to vessels was "neutral" or "unknown;" smaller numbers of seals "swam away" or "toward" vessels.

Approximately half of the Pacific walruses demonstrated no observable reaction to vessels. The second most common reaction was "look". Approximately half of the polar bears reacted by "look" and a smaller number had "no observable reaction".

The implementation of mitigation measures during Shell's 2012 exploratory drilling program in the Chukchi Sea spanned all aspects of the operation. PSOs aboard the project vessels were on watch during all daylight operations, including periods of darkness when working on vessels engaged in drilling or ice management. Vessel activities related to transit, drilling, handling and setting of the anchors used to moor the *Discoverer*, and ice scouting and management activities all were mitigated by various actions requested by PSOs.

The most common forms of mitigation implemented by PSOs aboard vessels during 2012 in the Chukchi Sea were reductions in vessel speed and alterations of vessel headings during routine vessel operations. Mitigation also included reducing vessel speed for walrus sightings, altering course to avoid groups of marine mammals, maintaining a 805 m (0.5 mi) marine buffer from all walruses and polar bears (when practicable), and reducing vessel speed to below 10 kt during periods of poor visibility or when cetaceans were observed within or likely to come within 300 m (328 yd) of the vessel.

Marine mammal exposures to continuous sounds from drilling and ice-management activities were considered to estimate the number of marine mammals exposed to sound in the Chukchi Sea. Based on direct observations during drilling activities, no cetaceans were exposed to received sound levels ≥160 dB (rms). Two unidentified mysticete whales are estimated to have been exposed to continuous drilling sounds between 120 and 160 dB (rms). Of the 396 seals observed, two seals were observed in areas where received sound levels from drilling were ≥160 dB (rms), and 7 seals were estimated to be between 120 and 160 dB (rms). Of the 574 walrus observed, 480 were observed hauled out on ice in an area exposed to ≥120 dB (rms) during drilling. However, it is likely that the walrus on ice would not have been exposed to sound levels comparable to those in water. Six walrus were observed in the water where received sound levels from drilling were between 120 and 160 dB (rms). No polar bears were exposed to received sound levels ≥120 dB (rms).

Based on direct observations during ice management activities, no cetaceans were exposed to received sound levels ≥160 dB (rms) and only two of the 27 cetaceans seen during ice management were exposed to sound levels ≥120 dB (rms). Of the 34 seals observed during ice management seven seals were observed in areas where received sound levels from drilling were estimated to be between 120 and 160 dB (rms). The breakdown of walrus sightings observed during periods when ice-management activities were occurring in the Chukchi Sea in 2012 was similar to seals and cetaceans in that most individuals either were recorded outside the ≥120 dB (rms) radius or they were hauled out on ice. Two polar bears were in the water during ice management and where RSLs were recorded between 120 and 160 dB (rms). Three polar bears were observed within the ≥160 dB (rms) radius, this exposure-level classification is the result of conservatively categorizing broad periods of time as ice management rather than only the discrete, isolated moments when ice actively was being managed.

Based on density estimates used in Shell's 2012 IHA application, 47 individual cetaceans would have been exposed to continuous sound levels ≥120 dB (rms) if there was no avoidance of drilling activities. Based on similar density calculations for seals, 466 individual seals would have been exposed to continuous sound levels ≥120 dB (rms) assuming there was no avoidance of drilling activities. Based on similar density calculations for walrus and polar bear, 403 Pacific walrus and 4 polar bear would have been exposed to ≥120 dB (rms) from drilling activities in the Chukchi Sea.

Beaufort Sea Vessel-Based Marine Mammal Monitoring Results

In total, 160 sightings of 295 cetaceans, 593 sightings of 878 seals, 14 sightings of 24 Pacific walruses, and 13 sightings of 39 polar bears were recorded during Shell's 2010 Beaufort Sea marine surveys. Bowhead whale was the most commonly identified cetacean species, and it is likely that many unidentified mysticete whales were also bowheads. Ringed seal was the most abundant seal species identified followed by bearded and spotted seals, respectively. Over half of the seals observed could not be identified to species. Pacific walruses detected from moving vessels were on ice or in the water, but walruses detected from stationary vessels were only in the water. All polar bears detected from moving vessels were on ice or land, and polar bears detected from stationary vessels were on ice or in the water.

Sighting rates across groups were influenced by environmental conditions as expected. The data showed no clear trend when cetacean, seal, Pacific walrus, or polar bear sightings rates were compared across operational activities.

One cetacean reacted to a vessel with a "change in direction", the rest were recorded as having no observable reaction or unknown reaction. Most cetacean movements relative to vessels were "neutral" or "unknown." "Swim away" was also a frequently recorded movement relative to vessels.

The most frequently observed seal reaction to project vessels was to "look" at the vessel, followed by "splash." Over 50% of seals however, demonstrated no detectable reaction to the vessel. The majority of seal movement relative to vessels was "neutral" or "swim away;" smaller numbers of seals "swam towards" the vessels, or had no movement or unknown movement.

Observers did not detect a reaction to vessels in 9 of the 14 Pacific walrus sightings. The most frequent initial behavior was "swim" followed by "dive". About half of Pacific walrus movements relative to vessels were "swim away".

Seven of the polar bear sightings "looked" at the vessel, and the rest demonstrated no observable reaction. Polar bears on ice or land were frequently observed walking or resting. Polar bear movements relative to the vessel were "none", "neutral", and "unknown".

Vessel activities related to transit, drilling, handling and setting of anchors used to moor the *Kulluk*, and scouting for hazardous sea ice were all mitigated by various actions requested by PSOs. The most common forms of mitigation implemented were reductions in vessel speed and alterations of vessel headings. Other mitigation events included maintaining an 805 m (0.5 mi) marine buffer from all walruses and polar bears (when practicable), communication to shore-based command centers to inform helicopter operations of marine mammal sightings, and postponement of equipment deployments due to the presence of marine mammals in the deployment area. Potential impacts to local subsistence activities were mitigated by the timing and location of operations in accordance with the Conflict Avoidance Agreement.

Based on direct observations during drilling activities, three cetaceans were exposed to received sound levels ≥120 dB (rms) and no cetaceans were exposed to received sound levels ≥160 dB (rms). No walruses or polar bears were exposed to received sound levels ≥120 dB (rms). Forty one seals were observed in areas where received sound levels were ≥160 dB (rms).

Based on density estimates used in Shell's 2012 IHA application and bowhead whale density estimates from Shell's 2012 Beaufort Sea aerial surveys, ten individual cetaceans would have been exposed to continuous sound levels ≥120 dB (rms) if there was no avoidance of drilling activities. An alternative to the density based exposure estimates was considered for bowhead whales during the fall migration period. Using this method, a total of 277 individual bowhead whales would have been exposed to continuous sound levels ≥120 dB (rms) assuming no avoidance of drilling activities. Based on density estimates for seals, 43 individual seals would have been exposed to continuous sound levels ≥120 dB (rms) assuming there was no avoidance of drilling activities. Less than a single Pacific walrus or polar bear would have been exposed to ≥120 dB (rms) from drilling activities in the Beaufort Sea.

Chukchi Sea Aerial Survey Program Results

Aerial surveys for marine mammals were conducted in the Alaskan Chukchi Sea from 14 Aug through 27 Oct 2012 in support of Shell's exploratory drilling activities. Surveys were flown to obtain data on the current distribution and relative abundance of marine mammals. The aircraft was outfitted with high-definition photographic and video-monitoring equipment used concurrently with PSO observations on flights. Aerial photographic surveys using these cameras and high-definition video were flown by a pilot and co-pilot without PSOs aboard over the offshore area in the Chukchi Sea. Twenty-three surveys were attempted in 2012, five in the nearshore area and 18 in the offshore area.

Seventeen cetacean sightings of an estimated 22 individuals were recorded during nearshore surveys within the Chukchi Sea. Gray whale was the most commonly identified cetacean (10 sightings of 13 individuals) followed by five sightings of bowhead whales (five individuals). In the offshore area, 37 cetacean sightings of an estimated 43 individuals were sighted on the photographs. Bowhead whale was the most commonly identified cetacean (13 sightings of 15 individuals), followed by 11 sightings of beluga whales (14 individuals).

Cetacean sightings during the 2012 survey period were consistent with the general pattern and distribution seen in previous years. Bowhead sightings were first observed in the nearshore survey area on 15 Sep and in the offshore survey area on 26 Sep, coinciding with the bowhead whale fall migration from the Beaufort Sea to overwintering areas in the Bering Sea. Belugas were seen early in the season on one of the ice reconnaissance surveys that were flown in Aug when there was still plenty of ice in the area. They weren't seen again until mid-Oct on two of the offshore surveys which would have been during the beluga fall migration through the eastern Chukchi Sea. Gray whales were seen on all of the nearshore surveys except the last one in late October. This is consistent with their distributions in previous years with most gray whales leaving the nearshore area by Oct.

Sixty-one pinniped sightings of an estimated 73 individuals were recorded during nearshore surveys within the Chukchi Sea. Unknown seal was the most commonly identified pinniped (33 sightings of 43 individuals) followed by 25 sightings of bearded seals (26 individuals). In the offshore area, 329 pinniped sightings of an estimated 1558 individuals were sighted on the photographs. Walrus was the most commonly identified pinniped (163 sightings of 1334 individuals) in the offshore area, followed by 161 sightings of unknown pinnipeds (219 individuals).

Despite the record low level of sea ice in the Arctic this year, walrus did not haul out in large numbers along the Chukchi coast as they did in the previous years. One possible reason for their absence at terrestrial haul out sites in 2012 may have been the presence of ice in the area of Hanna Shoal until mid-Sep. This ice may have provided haul out platforms for walruses over or near their feeding areas.

Beaufort Sea Aerial Survey Program Results

An aerial marine mammal monitoring program was conducted in the Central Alaskan Beaufort Sea from 15 Aug to 3 Nov 2012 in support of Shell's exploratory drilling activities. Surveys were flown to obtain detailed data on the occurrence, distribution, and movements of marine mammals, particularly bowhead whales as they approached and passed the drilling activities. In particular, the emphasis of this study was on the investigation of potential deflection around drilling activities by bowhead whales, and a stratified line transect survey design was implemented to maximize the probability of detecting such an effect.

Observations of bowhead whales were generally consistent with the expected pattern of the bowhead whale fall migration through this area. Peak sighting rates occurred during the middle of Sep, and whales were observed predominately traveling west, as would be expected by fall migrants.

An apparent near-shore shift in the bowhead migration occurred in late-Sep coinciding with the start of drilling activities. In addition to the observed distribution of sightings being more near-shore during late Sep and Oct, bowhead whales were also observed to have been moving more slowly and with more variable headings than during the peak of the migration. Two alternative hypotheses were possible explanations for this shift: 1) a possible reaction to drilling activities and, 2) natural variability in the migration, perhaps driven by an increase in near-shore foraging activity later in the season.

While foraging animals would be expected to have more variable headings, this variability (i.e. turning during surfacing) has also been observed in bowhead whales exposed to playback of underwater sound from exploration drilling activities, and responses to full-scale drilling programs indicate that at least some whales could deflect at 20+ km. By comparison, bowhead whales during this survey were observed to be moving slower and with more variable headings at distances beyond 30 km from drilling activity. This is farther than would be expected given previous studies of behavioral responses to drilling.

Although the alternative hypotheses proposed here as potential explanations for the apparent near-shore shift in the migratory corridor need not be mutually exclusive (or exhaustive), and while it is not possible to rule out the possibility that drilling activity may have contributed (at least at some level) to the observed shift, the evidence is consistent with natural variability in the migration (driven by increased near-shore prey availability starting in late Sep) which could explain the observed pattern. During future analyses, a wider range of data sets (e.g., acoustic call detections from Shell's monitoring efforts, locations and activities of drilling support vessels, National Marine Fisheries Service aerial sightings and Shell vessel sightings data) will be taken into account through a more complete assessment of the variability observed during the 2012 fall bowhead whale migration through the Central Alaskan Beaufort Sea.

Beluga sighting rates were highest in Sep during the pre-drilling period. Unfortunately, there were too few sightings (n = 2) during the drilling period to make any meaningful comparisons regarding potential effects of industrial activities for this species. In general, estimated densities of beluga whales were relatively low, which is consistent with previous research indicating that a high percentage of migrating belugas in the Central Alaskan Beaufort Sea are likely to be at (and beyond) the northern edge of the survey area, i.e. along the slope or in deeper waters farther offshore.

During Oct new sea-ice started to develop and spread north from the barrier islands. Prior to this ice development, there were very few polar bear sightings (the transect lines avoided the barrier islands). There were two polar bears sighted swimming in open water offshore (23 km and 64 km, 14 and 40 mi from shore, during the pre-drilling and drilling periods respectively), but the majority of sightings occurred during Oct and the distribution of these sightings traced the developing near-shore ice.

ACKNOWLEDGMENTS

We thank the captains and crews of the *Discoverer, Kulluk, Fennica, Nordica, Aiviq, Tor Viking II, Affinity, Harvey Explorer, Harvey Spirit, Sisuaq, Nanuq, Lauren Foss, Barbara Foss, Guardsman, Warrior, Point Oliktok,* and *Arctic Seal,* as well as the pilots of Bald Mountain Air Service for their support during this project. We also thank representatives of the National Marine Fisheries Service, U.S. Fish & Wildlife Service, North Slope Borough Department of Wildlife Management, Alaska Eskimo Whaling Commission, Bureau of Ocean Energy Management, and Bureau of Safety and Environmental Enforcement for their advice and comments throughout the operating season and during the “open-water meetings.” Carol Theilen, Darla Dare, Michael Macrander, Sean Churchfield, Susan Childs, Pete Slaiby, Karen Spring, Shell Alaska Journey Management and Logistics Teams, ASRC Energy Services and NANA Management Services provided valuable support prior to and throughout the field season. We also thank all of the protected species observers (PSOs) who participated in the project – they were essential to the completion and success of this endeavor.

1. BACKGROUND AND INTRODUCTION[1]

This report summarizes the marine mammal monitoring and mitigation efforts performed by Shell (Shell Offshore, Inc., and Shell Gulf of Mexico, Inc.) during the 2012 exploration drilling program in the Chukchi and Beaufort seas. Operations were permitted as two programs: one in the Chukchi Sea and one in the Beaufort Sea. This 90-day report describes the results of marine mammal monitoring and mitigation associated with each of these programs.

Marine exploration drilling and other industrial activities emit sound energy into the water (Greene and Richardson 1988; Richardson et al. 1995; Tolstoy et al. 2004, Tolstoy et al. 2009) and have the potential to affect marine mammals given the reported auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004). The effects could consist of behavioral or distributional changes, and perhaps (for animals very close to the sound source) temporary or permanent reduction in hearing sensitivity. Potential effects, however, may be reduced by marine mammals moving away from approaching sound sources or avoiding areas where stationary sound sources are operating (Reiser et al. 2009; Richardson et al. 1995, 1999; Stone and Tasker 2006; Gordon et al. 2004; Smultea et al. 2004). Either behavioral/distributional effects or auditory effects (if they occur) could constitute "taking" under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA), at least if the effects are considered to be "biologically significant."

A number of cetacean and pinniped species inhabit parts of the Chukchi and Beaufort seas. The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) share jurisdiction over the marine mammal species in this region. Three species under NMFS jurisdiction that may occur in these waters are listed as "Endangered" under the ESA, including bowhead whale (*Balaena mysticetus*), humpback whale (*Megaptera novaeangliae*), and fin whale (*Balaenoptera physalus*). Additionally, NMFS initiated a status review in 2008 to determine if listing as endangered or threatened under the ESA is warranted for ringed seal (*Phoca fasciata*), spotted seal (*Phoca largha*), bearded seal (*Erignathus barbatus*), and ribbon seal (*Histriophoca fasciata*; NMFS 2008a,b). In 2008, NMFS announced that listing of the ribbon seal as threatened or endangered was not warranted, however, on 30 August 2011 a new status review was initiated based on new information about the species and a determination is pending (NMFS 2011c). NMFS (2010a) determined that no listing action was warranted for the Bering Sea and Okhotsk populations of spotted seal. NMFS (2010b) determined that two distinct population segments (DPS) of bearded seals, the Beringia and Okhotsk DPSs, should be listed as a threatened species, but extended the public comment period for the listing. NMFS (2010c) also designated four subspecies of ringed seal, including Arctic, Okhotsk, Baltic, and Ladoga, as proposed threatened species but extended the public comment period for these listings as well. NMFS issued final determinations in late 2012 to list the Beringia and Okhotsk DPSs of bearded seal, and the Arctic, Okhotsk, and Baltic subspecies of ringed seal as threatened under the ESA (NMFS 2012a,b). These final determinations by NMFS for bearded and ringed seals were made after the completion of 2012 project operations, and remained open to public comment until 26 Feb 2013.

USFWS manages two marine mammal species occurring in the Chukchi and Beaufort seas, the Pacific walrus (*Odobenus rosmarus*) and polar bear (*Ursus maritimus*). The polar bear was listed as threatened under the ESA in 2008 (USFWS 2008). A petition to list Pacific walrus as threatened or

[1] By H.J. Reider, L.N. Bisson, and H.M. Patterson (LGL).

endangered was submitted to USFWS (CBD 2008) and resulted in their designation as an ESA candidate species (USFWS 2011).

Recognizing the potential for marine mammals to be encountered during planned exploration drilling activities in the Chukchi and Beaufort seas during the 2012 open-water season, Shell submitted an application to NMFS on 30 June 2011 for the Chukchi Sea and 10 May 2011 for the Beaufort Sea for Incidental Harassment Authorizations (IHAs) to authorize non-lethal "takes" of marine mammals incidental to Shell's proposed activities. Subsequently, NMFS requested that Shell revise the applications and Shell resubmitted the modified applications on 12 September 2011 for the Chukchi and 2 September 2011 for the Beaufort Sea (Shell 2011a,b). Notices announcing Shell's requests for the IHAs were published in the *Federal Register* on 9 November 2011 for the Chukchi Sea and 7 November 2011 for the Beaufort Sea and public comments were invited (NMFS 2011a,b). NMFS issued IHAs for the proposed activities in the Chukchi and Beaufort seas to Shell on 9 May 2012 (NMFS 2012c,d). The IHAs authorized "potential take by harassment" of various cetacean and seal species during offshore exploration drilling on the Outer Continental Shelf (OCS) leases from 1 July 2012 through 31 October 2012 (Appendix A).

Similarly, on 12 May 2012 for the Chukchi Sea and 4 May 2012 for the Beaufort Sea, Shell requested Letters of Authorization (LOAs) from USFWS for the 'incidental take by harassment' and 'take by harassment' of polar bears and walrus during open-water drilling exploration activities in the Chukchi and Beaufort seas in 2012. The USFWS issued a total of four LOAs to Shell for exploratory drilling activities. Two LOAs were issued on 4 Jun 2012 allowing Shell to "take" small numbers of polar bears and Pacific walruses incidental to proposed activities occurring in the Chukchi and the Beaufort seas during the 2012 open-water season. The USFWS issued two additional LOAs to 'take by harassment,' polar bears and Pacific walruses during the exploration drilling operations only for ice-management and scouting activities in the Chukchi and the Beaufort seas. The four LOAs were valid between 4 June 2012 and 30 November 2012 (Appendix B).

Having received these authorizations, Shell conducted exploratory drilling activities in the Chukchi and Beaufort seas during the open-water period of 2012 in support of potential future oil and gas development. Exploratory drilling in the Chukchi Sea was conducted by Noble Corporation using the industry-standard, ice-strengthened Motor Vessel (M/V) *Noble Discoverer (Discoverer)* drillship, attended by a minimum of eight support vessels for the purposes of ice management, anchor handling, oil spill response, refueling, and resupply. Exploratory drilling in the Beaufort Sea was also conducted by Noble Corporation using the conical drilling rig *Kulluk*, and was attended by a minimum of 11 support vessels for the purposes of ice management, anchor handling, oil spill response, refueling, and resupply.

This document serves to meet reporting requirements specified in the IHAs and LOAs. The primary purposes of this report are to describe project activities in the Chukchi and Beaufort seas, to describe the associated marine mammal monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially exposed to levels of sound generated by the exploratory drilling activities at or above presumed effect levels as prescribed by the respective agencies.

Incidental Harassment Authorizations and Letters of Authorization

IHAs typically include provisions to minimize the possibility that marine mammals close to the sound source might be exposed to levels of sound high enough to cause short– or long–term hearing loss or other physiological injury. During this project, sounds were generated by the drill rigs *Discoverer* and *Kulluk*, support vessels (including ice-management and anchor-handler vessels), and aircraft on and near Shell's lease holdings in the Chukchi and Beaufort seas. Shell was given authorization at the completion of each well to conduct zero-offset vertical seismic profile (ZVSP) surveys, which emit pulsed sounds. A top well and mud-line cellar (MLC) were completed in each of the OCS lease sites that did not enter the hydrocarbon-bearing zones, and as a result no ZVSP surveys were conducted by Shell in the Arctic in 2012. Given the nature of the operations and mitigation measures, no serious injuries or deaths of marine mammals were anticipated as a result of the activities, and no such injuries or deaths were attributed to these activities. Nonetheless, the sound produced by exploratory drilling and associated operations described in Chapter 2 had the potential to "take" marine mammals by harassment.

Marine mammals exposed to pulsed sounds ≥160 dB re 1 μPa (rms) or continuous sounds ≥120 dB re 1 μPa (rms) are assumed by NMFS to be potentially subject to behavioral disturbance. However, only the continuous sound sources that were authorized in Shell's IHAs were generated in 2012 due to the absence of ZVSP surveys. NMFS assumes that marine mammals exposed to continuous sounds from drilling activities with received levels ≥120 dB re 1 μPa (rms) are likely to be disturbed. That assumption is based mainly on data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of exposure, distance from the sound source, the received level of the sound and the associated water depth.

The IHAs issued by NMFS to Shell authorized incidental harassment "takes" of three ESA-listed species including bowhead whale, humpback whale, and fin whale, as well as several non-listed species including gray whale, Minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcincus orca*), beluga whale (*Delphinapterus leucas*), harbor porpoise (*Phocoena phocoena*), and ringed, spotted, bearded, and ribbon seals. As noted above, localized populations of ringed and bearded seals were listed as threatened after completion of Shell's 2012 operations in the Arctic (NMFS 2012c,d).

NMFS granted the IHA to Shell on the expectation that

- the numbers of whales and seals potentially harassed (as defined by NMFS criteria) during exploratory drilling operations would be "small",
- the effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed,
- there would be no unmitigated adverse effects on the availability of marine mammals for subsistence hunting in Alaska, and
- the agreed upon monitoring and mitigation measures would be implemented.

The LOAs issued to Shell by USFWS were based on similar expectations for polar bears and Pacific walruses as those described for cetaceans and seals in the IHAs. The polar bear is listed as threatened under the ESA and Pacific walrus is a candidate species for listing. Although Shell was issued 'take by harassment' LOAs by USFWS, there were no occurrences of "intentional take" of any marine mammal by Shell in 2012.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in Shell's IHA and LOA applications (Shell 2011a,b) and in the IHAs and LOAs issued to Shell (Appendices A and B). An explanation of the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2012c,d).

The primary objectives of the monitoring program were to

- provide real–time sighting data needed to implement the mitigation requirements;
- estimate the numbers of marine mammals potentially exposed to low-level continuous sounds generated by the drilling operations and support activities near well sites; and
- determine the reactions (if any) of marine mammals potentially exposed to exploratory drilling sounds and related activities.

Mitigation and monitoring measures that were implemented during the activities in the Chukchi and Beaufort seas are described in detail in Chapter 4.

The purpose of the mitigation program was to avoid or minimize potential effects of Shell's exploration drilling activities on marine mammals and subsistence hunting. To this end, trained Protected Species Observers (PSOs) were stationed onboard the drill rigs and the various support vessels to detect and monitor marine mammals and their responses to industry activities, and to initiate mitigation measures if required. PSOs stationed on drill rigs monitored for marine mammals during all daylight and night time periods during active operations, and during most daylight periods when exploration drilling operations were not occurring. PSOs aboard vessels in transit implemented general mitigation measures as stipulated in Shell's IHAs and LOAs (e.g. reduce speed, alter course, maximize distance from marine mammals) to minimize potential impacts. Vessel activity did not return to normal until all marine mammals were outside of zones that required mitigation. Regular aerial and support vessel surveys for marine mammals were conducted to further monitoring efforts in drilling areas.

Report Organization

This 90–day report summarizes the exploration drilling activities and describes the methods and results of the mitigation and monitoring performed to meet the above objectives as required by the IHAs and LOAs.

This report includes eight chapters:

1. Background and Introduction;
2. Description of Shell's Exploration Drilling Program;
3. Underwater Sound Measurements;
4. Vessel-based Monitoring, Mitigation, and Data-analysis Methods;
5. Chukchi Sea Vessel-based Marine Mammal Monitoring Results;
6. Beaufort Sea Vessel-based Marine Mammal Monitoring Results;
7. Chukchi Sea Aerial Survey Program Results;
8. Beaufort Sea Aerial Survey Program Results.

In addition, 12 appendices provide copies of relevant documents and details of procedures that are more–or–less consistent during marine surveys where marine mammal monitoring and mitigation measures are in place. These procedural details are only summarized in the main body of this report. The appendices include:

A. Copies of the IHAs issued by NMFS in 2012 to Shell;
B. Copies of the Chukchi and Beaufort sea LOAs issued by USFWS to Shell for 2012;
C. Copy of the Conflict Avoidance Agreement between Shell, the Alaska Eskimo Whaling Commission, and the Whaling Captains Associations;
D. Descriptions of Vessels and Equipment;
E. Details of Vessel-based Monitoring, Mitigation, and Data-analysis Methods;
F. Beaufort Wind Force Definitions;
G. Background on Marine Mammals in the Chukchi and Beaufort seas;
H. Acoustic Monitoring Results;
I. Vessel-based Marine Mammal Monitoring Results in the Chukchi Sea;
J. Vessel-based Marine Mammal Monitoring Results in the Beaufort Sea;
K. Aerial Survey Results in the Chukchi Sea;
L. Aerial Survey Results in the Beaufort Sea.

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2. EXPLORATORY DRILLING OPERATIONS DESCRIBED[1]

Shell conducted exploratory drilling activities in the Chukchi and Beaufort seas during the 2012 open-water period. A single, relatively-shallow top hole was completed in each sea without reaching hydrocarbon zones typically located at greater depths than were drilled in 2012. Marine mammal monitoring was conducted from two drill rigs and 15 support vessels operated by Shell in support of exploration drilling and related activities. During exploration drilling operations, the drill rigs M/V *Noble Discoverer (Discoverer*) and the *Kulluk* operated in the Chukchi and Beaufort seas, respectively.

The *Nordica* was the first Shell vessel to sail northward from Dutch Harbor in 2012 when it departed on 20 Jul. The *Nordica* passed through the Bering Strait and entered the Chukchi Sea on 23 Jul. The *Nordica* also was the first project vessel to enter the Beaufort Sea, which occurred on 15 Aug. All Shell vessels departed the Beaufort Sea on 25 Aug after laying anchors at the Sivulliq well site in preparation for anchoring the *Kulluk* drill rig later in the season. Several vessels returned to the Beaufort Sea on 8 Sep and staged in standby location to await the completion of Nuiqsut and Kaktovik whaling activities. Shell vessels departed the Beaufort Sea on 10 Nov 2012 when the *Aiviq*, which was towing the *Kulluk*, entered the Chukchi Sea. The *Aiviq* and *Kulluk* also were the last of Shell's vessel assets to depart the Chukchi Sea in 2012 when they entered the Bering Sea on 14 Nov en route to Dutch Harbor. Most 2012 project vessels arrived back in Dutch Harbor in early- to mid-Nov, and the *Aiviq* and *Kulluk* were the last to return to this port on 21 Nov. Most vessels operated primarily in either the Chukchi Sea or the Beaufort Sea, however, several vessels operated in both seas. Detailed date and location information for each vessel in Shell's 2012 drilling fleet are shown in Figures 2.1 and 2.2.

During drilling, each of the two drill rigs emitted near-continuous, low-energy sounds through the use of generators and drilling equipment. In addition, support vessels including ice-management and anchor-handling vessels operated in and around the exploratory drilling areas. These activities resulted in ensonification of limited areas of the ocean bottom and intervening water column around the drillsites. Shell was required to monitor and report underwater sound levels from its exploratory drilling and related support activities as stipulated in the Incidental Harassment Authorizations (IHAs) from the National Marine Fisheries Service (NMFS) for this work.

Sound source characterizations (SSCs) were performed on all vessels in each theatre of operation. In addition to measurements of vessel sounds, various drilling and support activities were also characterized. These included sounds associated with anchor placement and handling, and the drilling of top holes, which involves the boring of a pilot hole and the construction of a mudline cellar (MLC). Additionally, sounds associated with ice management were measured to better understand the potential for these underwater sounds to disturb marine mammals. The following sections detail the operations associated with exploratory drilling programs in the Chukchi and Beaufort seas, and in brief, the marine mammal monitoring programs that are described in greater detail in Chapters 4–8. Detailed descriptions of the methods employed for the measurement and analysis of underwater sounds can be found in Chapter 3.

Protected Species Observers (PSOs) were stationed aboard all vessels to collect data and request mitigation measures as necessary during 2012 operations throughout the Chukchi and Beaufort seas.

[1] By H.J. Reider, L.N. Bisson, and C.M. Reiser (LGL).

Detailed descriptions of the vessels and equipment can be found in Appendix D. The vessels used during Shell's 2012 program, all of which were staffed with PSOs, included:

- **Drill Rigs** – *Discoverer* (self-propelled drillship) and *Kulluk** (platform that requires towing)
- **Ice Management Vessels** – *Fennica* and *Nordica**
- **Anchor Handlers and Secondary Ice Management Vessels** – *Tor Viking* and *Aiviq**
- **Two Offshore Supply Vessels (OSVs)** – *Harvey Explorer* and *Harvey Spirit*
- **OSV and Waste Storage** – *Harvey Sisuaq**
- **Shallow-water Landing Craft** – *Arctic Seal**
- **Arctic Oil Storage Tanker (OST)** – *Affinity*
- **Offshore Spill Response (OSR) vessel** – *Nanuq* and *Guardsman*
- **General Logistics and Support** – *Pt. Oliktok*, *Barbara Foss*, *Lauren Foss** and *Warrior**

* Indicates vessel was dedicated primarily to the Beaufort Sea exploratory drilling program. Several vessels operated in both the Chukchi and Beaufort seas during different operational periods throughout the season

All of Shell's vessels operated in accordance with the provisions of the IHAs issued by NMFS (Appendix A) and Letters of Authorization (LOAs) issued by the U.S. Fish and Wildlife Service (USFWS; Appendix B), as well as a Conflict Avoidance Agreement (CAA) negotiated among various stakeholders including Shell, other industry operators, the Alaska Eskimo Whaling Commission (AEWC), and the Whaling Captains Associations from Barrow, Nuiqsut, Kaktovik, Wainwright, Pt. Lay, and Pt. Hope (Appendix C).

Throughout Shell's 2012 exploration drilling operation, vessel position, survey activity, water depth, and environmental information were collected by the PSOs on duty using a direct-entry computer software program designed specifically for this purpose. Data were collected not only while on prospect but also throughout the Chukchi and Beaufort seas during transit and stationary standby periods.

Chukchi Sea Exploration Drilling Program

The geographic region where the exploration drilling program occurred in the Chukchi Sea was on Bureau of Ocean Energy Management (BOEM) Alaska Outer Continental Shelf (OCS) lease holdings in the Chukchi Sea Planning Area designated by Oil and Gas Lease Sale 193 (Fig. 2.3). The Burger-A drillsite was located approximately 103 km (64 mi) offshore and approximately 126 km (78 mi) northwest of the closest village of Wainwright, which is located on the northwestern coast of Alaska. Water depths in the Burger prospect area averaged 40–48 m (131-157 ft) in depth.

The *Discoverer*, an industry-standard, ice strengthened drillship, performed the exploratory drilling operations in the Chukchi Sea at the Burger-A drillsite. Exploratory drilling was conducted using standard rotary drilling technology and seawater from 23 Sep through 26 Oct. One top hole, which included a pilot hole, construction of a MLC, and hole-opening operations to set conductor and surface casing, was completed at the Burger-A drillsite. The depth of the well was approximately (457 m (1500 ft). The top hole did not penetrate the hydrocarbon-bearing zones in compliance with BOEM and Bureau of Safety and Environmental Enforcement (BSEE) regulations.

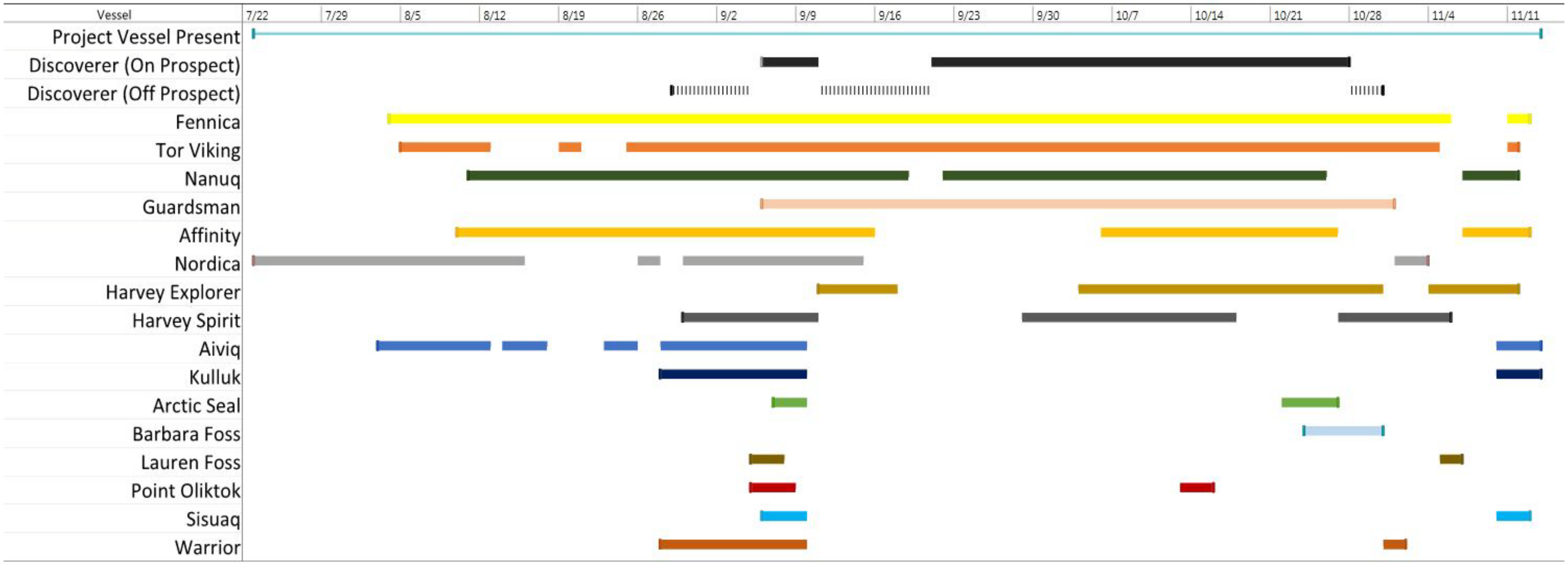


FIGURE 2.1. Periods when each project vessel was present in the Chukchi Sea during Shell's exploratory drilling program, 2012.

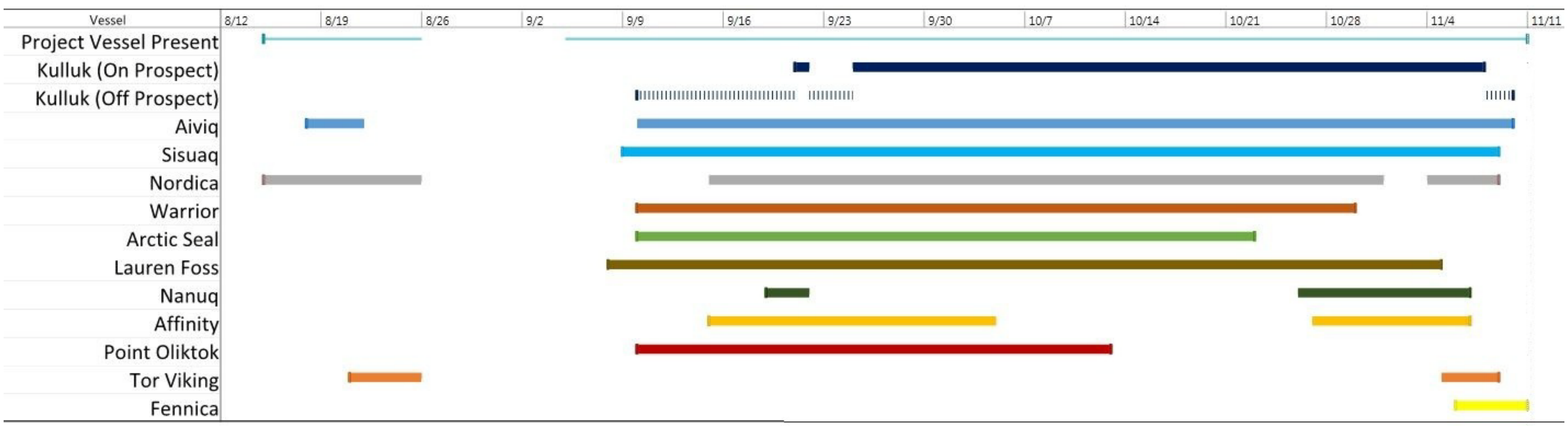


FIGURE 2.2. Periods when each project vessel was present in the Beaufort Sea during Shell's exploratory drilling program, 2012.

Anchor handling, ice management and support vessels were active on and near the drillsite site during exploratory drilling activities. The *Tor Viking* served as the primary anchor handling vessel in the Chukchi Sea. The *Fennica* and *Tor Viking* were involved in ice scouting and ice management activities near the drillsite in the Chukchi Sea, with the *Fennica* serving as the primary ice management vessel. Additional support vessels included the *Harvey Explorer, Harvey Spirit, Nanuq, Affinity,* and *Guardsman*. Due to changing operational needs throughout the season, certain support vessels worked in both the Chukchi and Beaufort seas (Figs. 2.1 and 2.2).

Exploratory Drilling Dates

The drillship *Discoverer*, tow-assist vessel *Lauren Foss*, and accompanying support vessels departed Dutch Harbor on 25 Aug and arrived in the Chukchi Sea on 29 Aug. On the evening of 29 Aug, the *Discoverer* disconnected from the *Lauren Foss* and connected to the *Tor Viking* for the continued tow-assist northward. The *Discoverer* arrived at the Burger-A drillsite on 7 Sep and began exploratory drilling at Burger-A site on 9 Sep (Fig. 2.4). On 10 Sep the *Discoverer* departed the prospect due to deteriorating ice conditions and staged nearby until ice conditions at the prospect area improved. The *Discoverer* returned to the prospect on 21 Sep and resumed exploratory drilling activities on 23 Sep. Shallow top-hole drilling activities continued until completion on 26 Oct. The *Discoverer* departed the prospect on 28 Oct and subsequently exited the Chukchi Sea on 31 Oct. The *Discoverer* spent a total of 64 days in the Chukchi Sea with 42 of those days on prospect and engaged in exploratory drilling or related activities. The following sections provide a more detailed description of anchor handling, ice management, boring of the pilot hole, and excavation of the MLC in the Chukchi Sea during 2012.

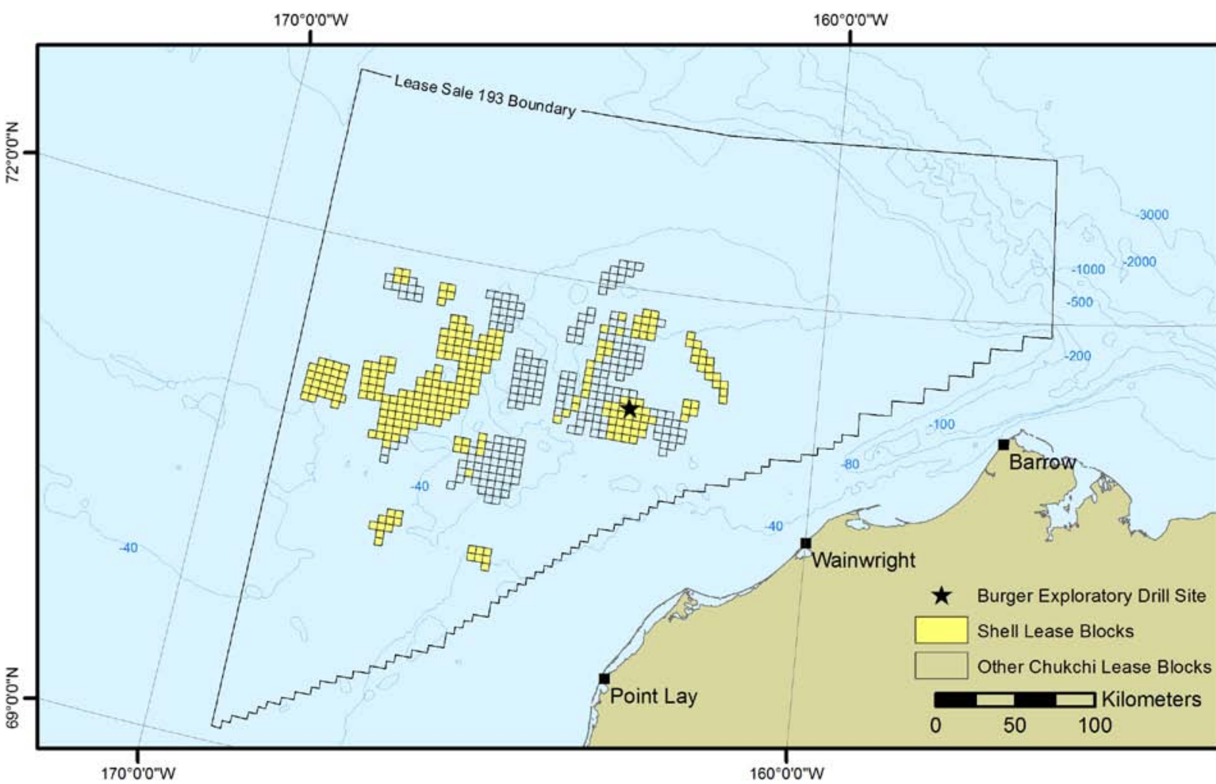


FIGURE 2.3. Location of Shell lease holdings in the Alaskan Chukchi Sea and the exploratory drillsite in 2012.

FIGURE 2.4. Periods when exploratory drilling and related support activities were conducted by Shell in the Chukchi Sea, 2012.

Anchor Handling

The drillship *Discoverer* had an 8-point anchored mooring system with a maximum anchor radius of ~910 m (2986 ft). The drillship was affixed to the seafloor using eight 7000 kg (15,432 lbs) Stevpris anchors arranged in a radial array. The drilling rig anchors were designed for rapid connect and disconnect using a Rig Anchor Release (RAR) system, with a submersible anchor buoy to ensure the line did not get stuck on the sea floor. The *Tor Viking* and *Aiviq* conducted the early season anchor handling operations. The different phases of anchor handling included anchor setting, anchor hook-up, anchor retrieval, and disconnection. Each phase of anchor handling was accomplished in relatively short time periods ranging from ~2 to 7 days. Underwater sound propagation during these activities was measured and is described in Chapter 3.

The *Tor Viking* and *Aiviq* arrived on prospect ahead of the drillship to set anchors from 8 Aug to 10 Aug. Connection of the anchors to the *Discoverer* occurred from 6 to 9 Sep. Deteriorating ice conditions resulted in anchor disconnection from the *Discoverer* and partial anchor retrieval on 9 and 10 Sep by the *Tor Viking*. The *Tor Viking* disconnected the *Discoverer* from anchors on 14 and 15 Sep, and subsequently departed the area. The *Tor Viking* and *Discoverer* returned to the Burger drillsite to reconnect the drill rig to anchors on 20 Sep. Drilling resumed on 23 Sep and was completed on 26 Oct. Anchors remained on the seafloor following the completing of drilling operations.

Pilot Hole

As part of the top-hole construction a series of holes with various diameters ranging from 21.6 cm (8.5 in) to 91.4 cm (36 in) were drilled. The initial pilot hole was drilled ~396 m (1300 ft) into the sea floor to check for any physical obstructions or shallow pockets of gas over the drillsite. A 91.4-cm (36-in) diameter hole was then drilled to ~106 m (350 ft) in preparation for a base conductor pipe, to which a blowout preventer (BOP) will be connected to in a subsequent season. The drilling of the various pilot hole diameters occurred during different time periods throughout the exploratory drilling period from 23 Sep through 26 Oct.

Mudline Cellar (MLC)

A MLC was constructed from 2 to 3 Oct to ensure that the wellhead and BOP were located below the maximum ice-keel gouge depth. The MLC was constructed in the seafloor using a large-diameter bit operated by hydraulic motors. The MLC bit was a two-part device; the upper section of the bit remained stationary while the bottom section rotated. Power was supplied by three hydraulic motors that operated a series of 0.9 m (3 ft) diameter disks angled to displace seafloor sediments. The resulting MLC was ~6.1 m (20 ft) in diameter and ~12.2 m (40 ft) deep.

Ice Management

The exploration drilling program was located in an area characterized by active sea-ice movement, ice scouring, and storm surges. Potentially hazardous ice was encountered during the 2012 program in the Chukchi Sea and ice management and scouting were a part of the exploration drilling activities. Shell implemented an Ice Management Plan (IMP) to provide real-time ice and weather forecasting to identify conditions that might put operations at risk. The IMP provided Shell with a mechanism to modify the drilling schedule and activities as necessary with changing weather and ice conditions.

The *Fennica* and *Tor Viking* scouted and managed ice to protect the anchor buoys and the *Discoverer* from heavy ice conditions experienced from 31 Aug through 3 Sep and from 11 through 13 Sep. In general, ice management activities included physical pushing or breaking of drift ice to prevent ice-floe collision with the drillship and anchoring equipment. Ice management occurred upwind within 10 km (6 mi) north-northeast of the Burger-A drillsite. The actual amount of time spent actively pushing or breaking ice in the Chukchi Sea was limited to discrete, isolated events between 31 Aug–3 Sep and 11–13 Sep.

Sound Source Characterization (SSC)

Acoustic measurements were conducted at Shell's OCS lease area in the Chukchi Sea, ~ 45 km (30 mi) south-southwest of the Burger-A drillsite (Fig. 2.3) by JASCO Applied Sciences (JASCO). Underwater measurements of sound propagation from each project vessel were conducted from 15 Sep to 1 Oct for vessel SSCs. The measurements were performed using three JASCO Autonomous Multi-channel Acoustic Recorders (AMARs) deployed from the M/V *Fennica* to capture sound levels as a function of distance and direction from each vessel. Additionally, four recorders were deployed within 8 km (5 mi) of the drillsite to record and characterize sounds associated with the drilling activities from 3 Aug to 26 Oct (see Chapter 3 for a complete description of the sound source measurements and analyses).

Beaufort Sea Exploration Drilling Program

The geographic region for the 2012 Beaufort Sea drilling program was in the eastern Beaufort Sea leases acquired from BOEM. The OCS lease site was located at the Sivulliq prospect north of Point Thompson near Camden Bay, AK approximately ~26 km (16 mi) offshore (Fig. 2.5). Water depth at the Sivulliq prospect was approximately 33 m (110 ft).

Exploratory drilling operations in the Beaufort Sea were performed by the *Kulluk,* a conically shaped, ice-strengthened floating drill rig designed and constructed for extended season drilling operations in Arctic waters. The *Kulluk* has an Arctic Class IV hull designed to maintain its location in drilling mode in moving ice with thickness up to 1.2 m (3.9 ft). One top hole with an MLC was completed at the Sivulliq-N drillsite in 2012. The top hole did not penetrate the hydrocarbon-bearing zones in compliance with BOEM and BSEE regulations and was drilled to a depth of less than 457 m (1500 ft). Exploratory drilling was conducted using standard rotary drilling technology and seawater from 3 through 28 Oct.

Ice management, anchor handling, oil spill response, refueling, and resupply vessels supported exploratory drilling operations in the Beaufort Sea. The support vessels included the *Nordica, Aiviq, Sisuaq, Lauren Foss, Arctic Seal, Warrior, Pt. Oliktok, Affinity* and *Nanuq*. Depending on operational needs the *Affinity* and *Nanuq* were operated in both Chukchi and Beaufort seas during the season (Figs. 2.1 and 2.2).

Exploratory Drilling Dates

The *Kulluk*, tow vessel and support vessel *Warrior* and the *Guardsman,* respectively, departed Dutch Harbor on 20 Aug. On 27 Aug, the *Kulluk* disconnected from the *Warrior* near St. Lawrence Island, Alaska and connected to the *Aiviq* to continue the tow north. The *Kulluk* entered the Chukchi Sea on 28 Aug. The *Kulluk* and support vessels entered the Beaufort Sea on 10 Sep (Fig. 2.2).

All Shell drilling program activities in the Beaufort Sea were suspended starting on 25 Aug due to the Nuiqsut (Cross Island) and Kaktovik subsistence bowhead whale hunts. On 11 Sep the drill rig and support vessels staged at the designated standby area north of Prudhoe Bay and west of the Nuiqsut and Kaktovik whale hunt blackout zone (see CAA, Appendix C). The *Kulluk* and support vessels entered the exploration drillsite briefly on 21 Sep and departed the same day (Fig. 2.2). This departure was in part due to discussions between Shell and the AEWC. Activities at the Sivulliq drillsite commenced on 25 Sep, including attachment of anchors to the *Kulluk*. Drilling began on 3 Oct. Shallow top-hole drilling activities concluded on 28 Oct and the *Kulluk* departed the prospect on 7 Nov. On 8 Nov PSOs disembarked from the *Kulluk;* however, PSOs remained aboard the tow vessel *Aiviq* during the tow south. The *Kulluk* spent a total of 62 days in the Beaufort Sea with 35 of those days on prospect engaged in exploratory drilling or related activities.

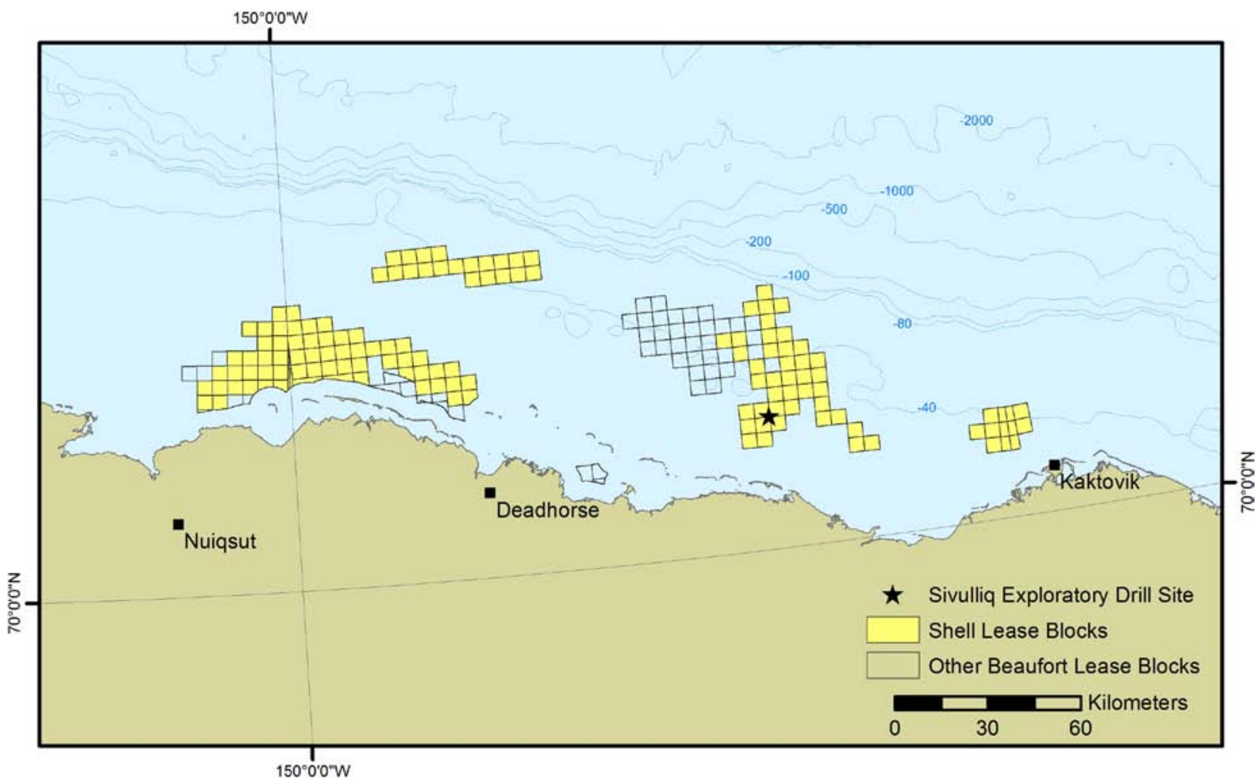


FIGURE 2.5. Location of Shell lease holdings in the Alaskan Beaufort Sea and the exploratory drillsite in 2012.

Anchor Handling

The *Kulluk* was moored using a 12-point anchor system and the maximum anchor radius was ~950 m (3117 ft). The *Kulluk* was affixed to the seafloor using 12, 15-metric ton (33,069 pounds) Stevpris anchors arranged in a radial array. The *Aiviq* was the primary anchor handling vessel in the Beaufort Sea. The different phases of anchor handling included anchor setting, anchor hook up, anchor retrieval and disconnection.

The *Aiviq* set anchors for the *Kulluk* from 18 through 22 Aug (Fig. 2.6). On 21 Sep, the *Aiviq* began partially hooking up anchors to the *Kulluk*. Due to continued discussions with the AEWC, the anchors were disconnected and the *Kulluk* departed the prospect temporarily. On 25 Sep, the *Kulluk* returned to the prospect and anchor hook-up was completed on 27 Sep. After the completion of top-hole drilling on 28 Oct by the *Kulluk*, the *Aiviq* disconnected anchors from the drill rig from 4 to 7 Nov (Fig. 2.6). Anchors remained on the seafloor following completion of drilling activities.

Pilot Hole

Pilot-hole construction was similar to the Chukchi Sea program mentioned above. The *Kulluk* drilled the pilot holes required for top-hole construction throughout the exploratory drilling period, from 3 Oct through 28 Oct.

Mudline Cellar (MLC)

MLC operations for the *Kulluk* occurred from 13 Oct to 23 Oct in the Beaufort Sea (Fig. 2.6). MLC operations were similar to the *Discoverer,* which is described above in detail. However, the resulting MLC constructed by the Kulluk was slightly larger in diameter, at least 7.3 m (24 ft) in diameter and ~11.3 m (41 ft) below the mudline.

Sound Source Characterization (SSC)

Acoustic measurements were conducted at Shell's OCS lease area in the Beaufort Sea, ~45 km (30 mi) west-northwest of the Sivulliq-N drillsite (Fig. 2.4) by JASCO. Five recorders were deployed for the measuring and characterizing underwater sounds associated with the Beaufort Sea program from 26 Sep through 22 Oct. Three JASCO AMARs were deployed from the *Nordica* specifically to capture underwater measurements of sound propagation from each project vessel from 28 Sep through 2 Oct. Additionally, an acoustic telemetry buoy was also deployed in the Beaufort Sea for real-time monitoring of the drilling sounds from 3 Oct through 21 Oct (see Chapter 3 for a complete description of the sound source measurements and analyses).

Figure 2.6. Periods when exploratory drilling and related support activities were conducted by Shell in the Beaufort Sea, 2012.

Vessel-based Marine Mammal Monitoring

Vessel-based marine mammal monitoring and mitigation was conducted from the drill rigs and support vessels throughout operations in the Chukchi and Beaufort seas. Permit stipulations required that two PSOs be on watch aboard drill rigs and ice management vessels during all active drilling and ice management operations from nautical twilight-dawn to nautical twilight-dusk. As a conservative approach, at least one PSO maintained an active watch during periods of darkness when drilling or ice management was occurring, and an additional PSO was on-call during these periods. At least one PSO was on watch on the additional support vessels when the vessel was engaged in active operational activities and at other times whenever practicable. During daylight hours, scans were made with Fujinon 7×50 reticle binoculars and the unaided eye. During periods with excellent visibility, Fujinon 25×50 "Big-Eye" binoculars or Zeiss 20×60 image stabilized binoculars were used to monitor for distant marine mammals. PSOs frequently scanned areas around the vessel during periods of darkness using Generation 3 night vision devices (NVDs).

Chapter 4 provides a detailed description of the vessel-based methods and equipment used for monitoring and mitigation during the exploratory drilling, MLC, anchor handling and ice management activities, as well as the data analysis methodology. Results of the vessel-based marine mammal monitoring program are presented in Chapters 5 and 6.

Aircraft Operations

Various aircraft were used in support of both marine mammal monitoring and the 2012 exploratory drilling program in the Chukchi and Beaufort seas. Two Twin Otter fixed-wing aircraft were flown to conduct aerial surveys for marine mammals over each of the drilling prospects as part of the program. Additionally, two S-92 helicopters were operated out of Barrow and Deadhorse and provided support for crew change and resupply. A third S-92 helicopter served as the search-and-rescue (SAR) asset operated by Shell during the drilling season, which was based in Barrow.

Chukchi Sea Aerial Monitoring

Shell conducted aerial surveys of marine mammals using a team of PSOs over coastal and nearshore areas in the Chukchi Sea in 2012. Additionally, aerial surveys were conducted over the Burger exploratory drillsite using high-definition cameras. Nearshore surveys were flown in a saw-toothed pattern between the shore and 37 km (23 mi) offshore as well as along the coast from Point Barrow to Point Hope. The nearshore/sawtooth surveys were flown with both a full PSO crew and digital still and video cameras, whereas the offshore surveys over the Burger exploratory drilling area in the Chukchi Sea were flown with only the pilots and the cameras. The Chukchi Sea aerial survey program in support of Shell's exploratory drilling program began on 18 Jul and was completed on 29 Oct. The primary objective of the Chukchi Sea aerial survey program was to collect data over the offshore exploratory drillsite. As a result, there were 18 offshore camera surveys flown over Burger in 2012 compared to five nearshore surveys with PSOs aboard. A description of the aerial survey equipment, methods, and preliminary monitoring results from the 2012 Chukchi Sea Aerial Survey Program is presented in Chapter 7.

Beaufort Sea Aerial Monitoring

Shell conducted aerial surveys of marine mammals using a team of PSOs over their offshore operations areas in the Beaufort Sea in 2012. The transect lines were oriented north-south and the total survey transect distance was similar to prior years (~1350 km or 839 mi), however, transects were stratified in 2012 with closer transect spacing over the drillsite compared to transects in the outer regions of the survey grid. Stratified sampling was implemented to increase the statistical power of analyses to detect a potential difference in bowhead whale densities in areas close to the drilling operation compared to those farther away from drilling activities. Aerial surveys in the Beaufort Sea were flown with a full PSO crew in addition to digital still and video camera systems aboard aircraft. The Beaufort Sea aerial survey program in support of Shell's 2012 exploratory drilling program began on 19 Aug and was completed on 6 Nov. There were 25 surveys flown during the 2012 season in and around the area of exploratory drilling at Sivulliq. A description of the aerial survey equipment, methods, and monitoring results from the 2012 Beaufort Sea Aerial Survey Program is presented in Chapter 8.

Aerial Crew Change, Resupply, and Search-and-rescue

Crew changes and resupply were conducted with two S-92 helicopters contracted from PHI Inc. A total of 210 crew-change and/or resupply flights were flown in support of Shell's 2012 exploratory drilling program in the Chukchi and Beaufort Seas. Crew-change and resupply flights were spread evenly between the two seas with 113 such flights flown out of Barrow in support of the Chukchi Sea program and the remaining 97 flights flown out of Deadhorse in support of the Beaufort Sea program. Crew-change flights were flown from 10 Jul through 11 Nov in the Chukchi Sea, and 9 Jul through 8 Nov in the Beaufort Sea.

Shell had one additional helicopter for SAR. This aircraft remained grounded at the Barrow shorebase except during training drills, emergencies, and other non-routine events. There were 49 SAR flights flown, with the majority of those occurring in the Chukchi Sea.

Shell Communications with Local Village Communication Centers

Various personnel contracted by Shell, most often the PSOs, aboard the drill rigs and support vessels routinely contacted Alaska Native communities via a network of communication centers (com centers). Com centers were established in Savoonga, Wales, Kotzebue, Kivalina, Pt. Hope, Pt. Lay, Wainwright, Barrow, Nuiqsut, Deadhorse, and Kaktovik during the 2012 exploratory drilling season. These communications between Shell and local communities were intended to ensure that project activities did not interfere with subsistence activities in the Chukchi and Beaufort seas and the Bering Strait region. Communications were made when the vessels were within 50 miles of the respective com center. Communications were made via phone, VHF radio, or email by each vessel every 6 hours on the synoptic hours. Information reported during each communication included the current vessel location, activity, heading and the proposed activities for the next 24 hours.

3. UNDERWATER SOUND MEASUREMENTS[1]

This chapter presents the results from an underwater acoustic monitoring study that characterized the sound emissions of vessels and equipment used during Shell Exploration and Production Company's 2012 drill programs in the Alaskan Chukchi and Beaufort Seas. Acoustic recordings were collected between 7 Aug and 26 Oct 2012 at the Burger-A prospect in the Chukchi Sea, and between 21 Sep and 22 Oct 2012 at the Sivulliq-N prospect in the Beaufort Sea. JASCO Applied Sciences Ltd. performed this study to fulfill the underwater acoustic monitoring requirements of Shell's Incidental Harassment Authorization (IHA) issued by the National Marine Fisheries Service (NMFS).

Conditions 10(c), 11(a), and 11(c) of the IHA define the reporting requirements for sound characterization measurements. When measurements of drilling sounds were available, weekly field reports were prepared as per Condition 11(a). Field reports of support vessel sounds were delivered to Shell within five days of the vessel sound characterization measurements. This chapter addresses the detailed reporting tasks of Condition 11 and provides further information about the measurements performed under Condition 10.

Vessel sounds were measured with three dedicated underwater acoustic recorders that measured sounds in the forward, aft, and broadside directions from every support vessel operating at each prospect site. This report presents these data in plots of sound pressure levels versus range. Also, source level estimates are reported for each support vessel in 1/3–octave bands. This report contains tables that list ranges at which sound pressure levels between 190 and 120 dB re 1 µPa (in 10 dB steps) were measured as per Condition 10(c) of the IHA.

Drilling sounds were measured at four (Chukchi Sea) or six (Beaufort Sea) underwater acoustic recording stations at each prospect site. This report provides sound characterizations of the following activities associated with the drilling operations: anchor laying, ice management, pilot hole drilling, and drilling of the mudline cellar. For each activity the sound levels received at each recorder are presented along with the spectral composition of the measured drilling sounds. These data yielded ranges at which sounds from drilling operations were at levels between 190 and 120 dB re 1 µPa (in 10 dB steps).

Goals of the Acoustics Study

The goals of the acoustic monitoring study were to:

- Establish distances from support vessels where rms sound pressure levels reached threshold levels between 190 dB re 1 µPa (rms) and 120 dB re 1 µPa (rms) in 10 dB steps.
- Characterize sound emissions from support vessels as a function of direction (fore, aft, and broadside) from the vessel.
- Establish the distances from drilling activities for which rms sound pressure levels reached threshold levels between 190 dB re 1 µPa (rms) and 120 dB re 1 µPa (rms) in 10 dB steps.
- Characterize the spectral composition of sounds from all vessels and drilling equipment.
- Establish source sound levels for vessels and drilling equipment.

1 By Melanie Austin, Andrew McCrodan, Caitlin O'Neill, Zizheng Li, Alexander MacGillivray (JASCO)

Methods

Equipment

Autonomous Multichannel Acoustic Recorder

Vessel and drilling sounds were measured with Autonomous Multichannel Acoustic Recorders (AMARs, JASCO Applied Sciences Ltd.) at both the Burger-A and the Sivulliq-N prospect sites. The AMARs were deployed directly on the seabed with their hydrophones approximately 30 cm (12 in) above the ocean floor. Each AMAR had an attached ground line and small anchor (Figure 3.1) to allow retrieval with a grapple hook. At each prospect site, three AMARs were outfitted with GeoSpectrum M8E hydrophones with nominal sensitivity −164 dB re V/µPa to measure support vessel sounds. A dual-channel configuration provided a wider dynamic range for measurements of the drilling activities. An additional four AMARs at each prospect site were outfitted with GeoSpectrum M8E and M8K hydrophones, on channels 1 and 2, respectively. The M8K hydrophones have nominal sensitivity −210 dB re V/µPa. Unless indicated otherwise, the results in this report were collected on channel 1. Each AMAR recorded acoustic data to internal memory at a 64 kHz sample rate with 24-bit resolution, a configuration that captured acoustic frequencies from 10 Hz to 32 kHz.

Each AMAR was calibrated before deployment and after retrieval with a 42AC pistonphone calibrator (G.R.A.S. Sound & Vibration A/S), which generates a known 250 Hz reference tone accurate to 0.1 dB at the AMAR hydrophone sensor. The pressure calibration of each AMAR was obtained from the level of the reference signal in the digital calibration recording. Typical calibration variance using this method is less than 0.5 dB absolute pressure. The pressure sensitivity obtained from the pistonphone calibration was used in subsequent data analysis.

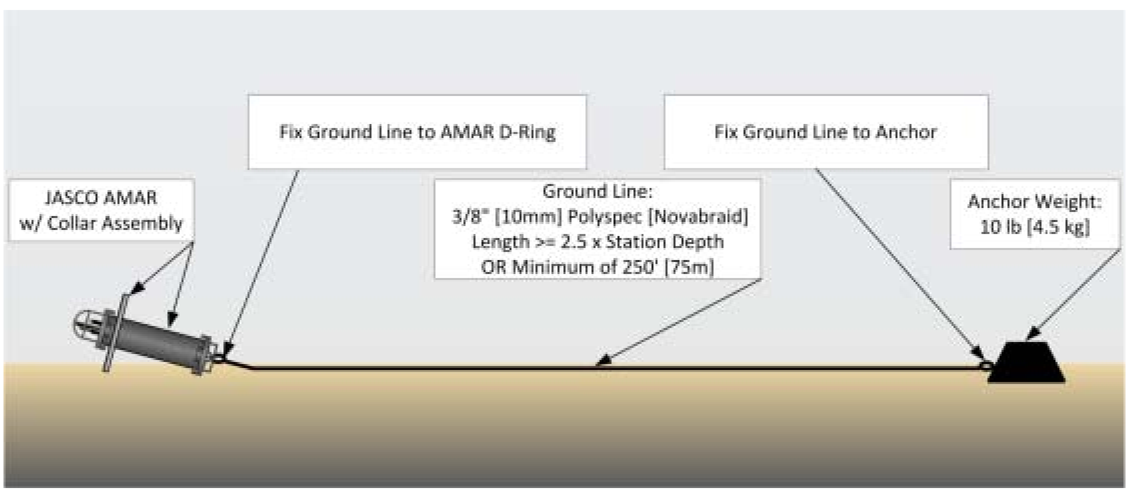


FIGURE 3.1. AMAR mooring design.

Acoustic Telemetry Buoy

An acoustic telemetry buoy (JASCO Applied Sciences) was deployed at Sivulliq-N to transmit real-time acoustic and acoustic Doppler current profiler (ADCP) data to computers on the *Kulluk*. The telemetry buoy (Figure 3.2) contained an AMAR and a downward-facing ADCP. A battery pack and hydrophone were mounted on a frame and deployed on the seabed beneath the buoy. The data were digitized at a 64 kHz sample rate and 24 bit sample resolution, then streamed back to the *Kulluk* with a digital radio system. A computer server on the *Kulluk* logged the acoustic and ADCP data in real time.

These data were accessed remotely through the *Kulluk's* satellite internet system and results were reported weekly throughout the telemetry buoy's deployment. ADCP data were used in real time for selecting the drilling discharge monitoring sites.

FIGURE 3.2. Acoustic telemetry buoy used for acquiring real-time acoustic and ADCP data.

Sound Sources Monitored

The acoustic monitoring study required measurements of underwater sound levels emitted by each support vessel operating at each prospect site. Fourteen support vessels were measured in total; nine were measured in the Chukchi Sea and nine in the Beaufort Sea, with some vessels operating at both prospect sites (Table 3.1).

TABLE 3.1. Specifications for the vessels measured in the sound source characterization studies.

Vessel	Operator	Type	Length	Width	Draft	Engine	Propeller
Affinity 	TransPetrol Maritime Services Ltd.	Fuel supply	228 m (748 ft)	32.3 m (106 ft)	10.5 m (34.3 ft)	STX MAN B&W 7S60MC-C 15820 kW @ 105 rpm	KH-40 4-blade, 6.0 m diameter 4.2 m pitch
Aiviq 	Edison Chouest Offshore	Oil spill response and waste	110 m (360 ft)	24 m (80 ft)	10 m (34 ft)	4 x Caterpillar C280 21,600 kW total	Rolls Royce CP
Arctic Seal 	Bering Marine Corp.	Supply boat	37 m (121 ft)	9.7 m (32 ft)	1.5 m (5 ft)	3408 Cat Diesel, 544 kW	5-blade, 4.5 in shaft, 54 in × 42 in
Fennica 	Arctia	Ice management	116 m (380 ft)	26 m (85 ft)	8.4 m (27.5 ft)	2 x Wärtsilä Vasa, 16 V 32/6000 kW 2 x Wärtsilä Vasa, 12 V 32/4500 kW	2 × azimuth, 4-blade, fixed pitch
Guardsman 	Crowley Marine Services Inc.	Oil spill response	38.8 m (127 ft)	11.1 m (36.5 ft)	3.3 m (10.8 ft)	2 x EMD 20-645-EG 5369 kW	2 × 5-blade, fixed pitch 3.4 m diameter
Harvey Explorer 	Harvey Gulf International Marine LLC	Oil spill response and waste	73.2 m (240 ft)	17.1 m (56 ft)	3.05 m (10.0 ft)	2 x CAT 3516B 3370 kW	2 × 5-blade, fixed pitch 2.6 m diameter

Vessel	Operator	Type	Length	Width	Draft	Engine	Propeller
Harvey Spirit 	Harvey Gulf International Marine LLC	Oil spill response and waste vessel	85.4 m (280 ft)	18.3 m (60 ft)	5.0 m (16.5 ft)	2 x GE 7FDM12 4579 kW total	2 × fixed pitch, 5-blades 2.4 m diameter
Kulluk 	Shell	Drilling unit	81 m (266 ft)	81 m (266 ft)	10 m (33 ft)	N/A	N/A
Lauren Foss 	Foss Maritime Company	Towing	45.5 m (150 ft)	12 m (40 ft)	5.8 m (19 ft)	Alco Diesel, 6189 kW	Twin screw conventional, Kort nozzle
Nanuq 	Edison Chouest Offshore	Oil spill response	91.9 m (301 ft)	18.3 m (60 ft)	5.0 m (16.5 ft)	2 x Caterpillar 3608 4920 kW	Controllable pitch
Noble Discoverer 	Noble Drilling	Drillship	157 m (514 ft)	26 m (85 ft)	8.2 m (27 ft)	Mitsubishi/UBE 6UEC 65/135A, 5369 kW	4-blades, fixed, 5.505 m diameter 3.7 m pitch
Nordica 	Arctia	Ice management	116 m (380 ft)	26 m (85 ft)	8.4 m (27.5 ft)	2 x Wärtsilä Vasa, 16 V 32/6000 kW 2 x Wärtsilä Vasa, 12 V 32/4500 kW	2 × azimuth, 4-blades, fixed pitch, variable rpm

Vessel	Operator	Type	Length	Width	Draft	Engine	Propeller
Pt Oliktok 	Crowley Marine Services Inc.	Towing	27 m (90 ft)	9.7 m (32 ft)	3.4 m (11 ft)	Caterpillar 3512, 1573 kW	2 73 × 74 Coolidge Stainless
Sisuaq 	Harvey Gulf International Marine LLC	Supply	88.5 m (292 ft)	19 m (64 ft)	5.8 m (19 ft)	4 x Cummins QSK60DM 7300 kW total	Schottell z-drive x2
Tor Viking II 	Viking Supply	Anchor handling and secondary ice management	83.7 m (275 ft)	18 m (59 ft)	6 m (20 ft)	2 x Mak 6 M32, 2880 kW 2 x Mak 8 M32, 3840 kW	2 × KaMeWa 4-blades, controllable pitch 4.1 m diameter
Warrior 	Crowley Marine Services	Tug	38.5 m (12 ft)	11 m (36 ft)	3.3 m (10.8 ft)	20 cyl., 2 x 645EMD	5-blade

There are several sources of noise associated with drilling operations. These include sounds that emanate through the drillship's hull from equipment such as generators, pumps, engines, pipe-handling equipment, cranes, winches etc., as well as sounds from support vessels performing drilling-related tasks.

To characterize the sound emissions from different aspects of the operations, the following activities were identified and considered separately in this report:

- Drilling pilot hole
- Drilling mudline cellar
- Ice management
- Anchor handling

These activities are collectively referred to as 'drilling activities' throughout this report, even though ice management and anchor handling do not physically involve drilling—they form part of the drilling operation. Activity logs from each vessel were maintained throughout operations by Protected Species Observers (PSOs) onboard the vessel. These logs were used to identify times when drilling activity occurred.

Data Acquisition

Vessel Sound Source Characterization

Vessel sound source characterization (SSC) measurements were performed at each prospect site with three AMARs to capture sound levels as a function of distance and direction from every vessel working at the prospect. The three AMARs were deployed on a line perpendicular to a 15 km (9.3 mi) vessel track line—at 0, 500, and 1000 m (0, 1640, and 3280 ft) (Figure 3.3). The vessel operators were provided with instructions to sail from the start to the end of the track at the vessel's normal operating speed. The vessels digitally logged their GPS location as they transited along the track; these navigation logs were used to calculate the range between the vessels and the AMARs. Each vessel completed the SSC transit under instruction to maintain a separation of 25 km (13.5 nmi) from all other vessels to avoid noise contamination in the sound recordings.

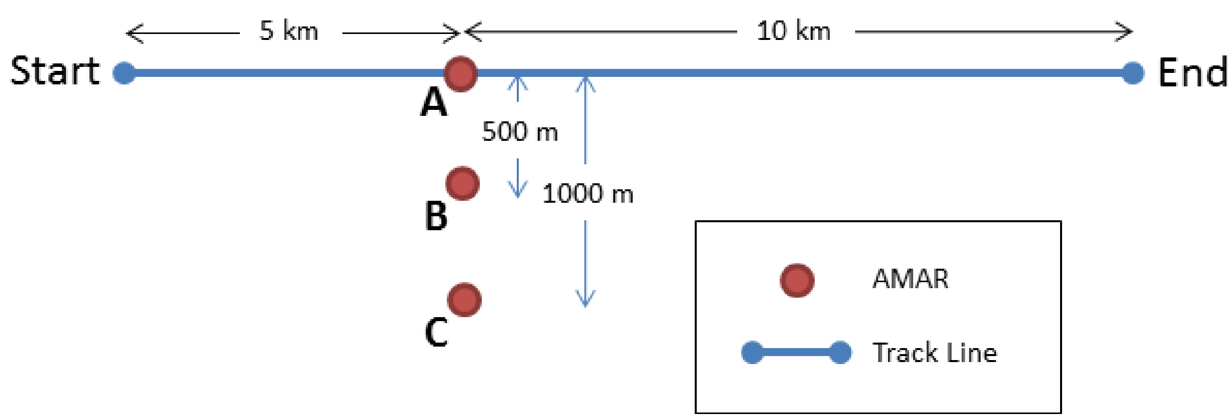


FIGURE 3.3. AMAR deployment geometry and vessel track line for the vessel SSC.

Burger-A Prospect, Chukchi Sea

The vessel SSC site for the Chukchi Sea drill program was south-southwest of the Burger-A drill site (Figure 3.4). The water depths along the SSC vessel track line were similar to those at Burger-A. Table 3.2 lists AMAR deployment coordinates and vessel track line start and end points. Measurements were carried out between 7 Aug and 27 Sep 2012; Table 3.3 shows when the sounds were measured from each vessel in the Chukchi Sea. In the first deployment, AMAR B failed, so data at the 500 m (1,640 ft) range were unavailable before the second deployment.

TABLE 3.2. AMAR deployment locations, deployment and retrieval times (UTC), and track line start and end points for the vessel SSCs from two deployments at the Burger-A prospect in the Chukchi Sea.

	Latitude	Longitude	Water Depth (m)	Deployed	Retrieved
Track line start	70°55.147′ N	163°57.834′ W	–	–	–
Track line end	70°54.982′ N	163°33.174′ W	–	–	–
Deployment 1					
A	70°55.098′ N	163°49.607′ W	45.2	07 Aug 22:33	09 Sep 03:19
B	70°55.367′ N	163°49.586′ W	46	07 Aug 21:57	09 Sep 00:42
C	70°55.635′ N	163°49.582′ W	46	07 Aug 21:19	08 Sep 23:20
Deployment 2					
A	70°55.092′ N	163°49.613′ W	44.5	16 Sep 03:45	01 Oct 23:10
B	70°55.366′ N	163°49.603′ W	44.5	16 Sep 03:16	01 Oct 08:10
C	70°55.639′ N	163°49.590′ W	44.5	16 Sep 02:42	01 Oct 07:24

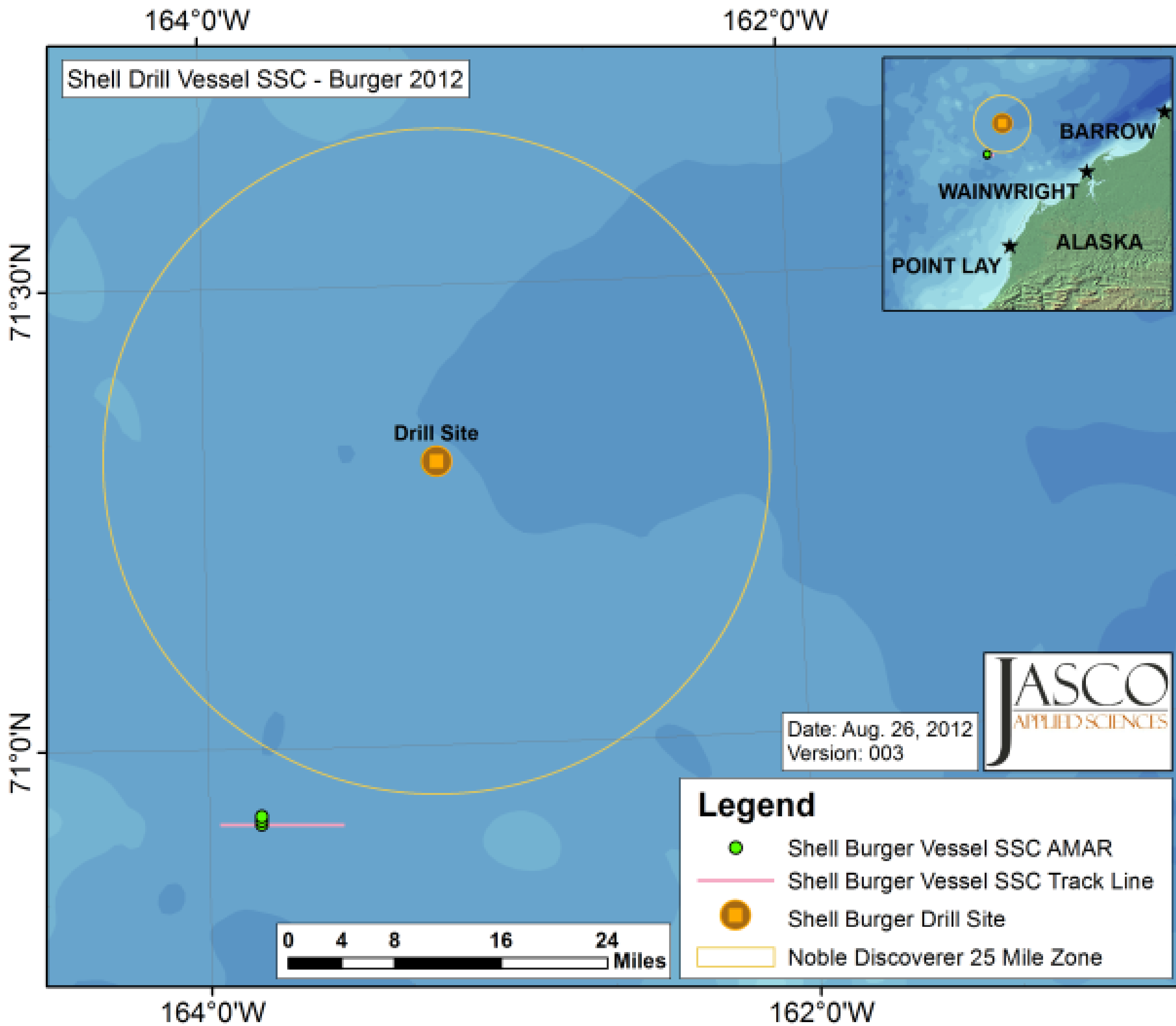


FIGURE 3.4. Vessel SSC location relative to Burger-A drill site in the Chukchi Sea.

TABLE 3.3. Schedule of underwater acoustic measurements for the vessel SSC at the Burger-A prospect in the Chukchi Sea. Dates and times are given in UTC.

Source	Date	Start	End	Transit Speed (kts)	Wind (kts)	Wave Height (m)
Affinity	28 Aug 2012	03:46:16	04:40:22	8.8	20 W	2
	28 Aug 2012	06:14:16	07:09:16	9.0		
Aiviq (towing *Kulluk*)	03 Sep 2012	04:16:38	06:41:38	3.4	22 NE	1–2
Fennica	08 Aug 2012	00:17:49	00:57:49	12.0	20 SW	1–1.5
	05 Sep 2012	20:09:30	21:10:30	8.0	16 NE	
Guardsman (towing *Klamath*)	27 Sep 2012	06:07:26	07:06:02	9.4	20 NNW	2.5–3
Harvey Explorer	16 Sep 2012	10:46:09	11:43:22	8.5	10 N	2–3
Harvey Spirit	04 Sep 2012	03:25:11	04:43:32	6.2	20 ENE	0.5–1
Nanuq	22 Aug 2012	06:43:58	07:37:40	9.1	20–25	2
	22 Aug 2012	08:28:58	09:13:34	10.8		
Noble Discoverer (towed by *Tor Viking II*)	01 Sep 2012	21:33:44	22:27:56	9.0	22 NE	1–2
Nordica	10 Aug 2012	05:59:33	06:39:53	12.1	9 N	1–2
Tor Viking II (towing *Noble Discoverer*)	01 Sep 2012	21:31:21	22:25:32	9.0	22 NE	0.2–0.5

Sivulliq-N Prospect, Beaufort Sea

The vessel SSC measurements for the Beaufort Sea drill program were collected at three locations: two located west-northwest of Sivulliq-N and one 1.5 km (4920 ft) southwest of the Sivulliq-N drill site. The first location, SSC Track Line 1, was selected because it had a similar water depth to the drill site (Figure 3.5). Six of the measured vessels transited this track. Some of the vessel's navigational charts indicated a region of shallow water along the track, so on 1 Oct AMARs were moved to deeper water (SSC Track Line 2) as a precaution to allow the tanker *Affinity* to transit the SSC track safely (Figure 3.5). The *Affinity* and *Pt Oliktok* transited the second track. The anchor handler *Tor Viking II* was working at the prospect site before the vessel SSC AMARs were deployed so could not transit either Track Line 1 or Track Line 2. The *Tor Viking II* transited a third track line, which passed over a single AMAR that was in place to record noise from anchor handling activities.

The AMAR deployment coordinates, deployment and retrieval times, and the start and end points of the vessel SSC track lines are listed in Table 3.4. Table 3.5 lists each vessel's measurement dates and the track lines they transited.

TABLE 3.4. AMAR deployment locations, deployment and retrieval times, and track line start and end points for vessel SSCs from three deployments at the Sivulliq-N prospect in the Beaufort Sea. Dates and times are given in UTC.

	Latitude	Longitude	Water Depth (m)	Deployed	Retrieved
Track Line 1					
Track line start	70°34.696′ N	147°32.911′ W			
Track line end	70°30.741′ N	147°11.807′ W			
A	70° 32.067′ N	147° 18.829′ W	32.8	21 Sep 12:37	01 Oct 02:45
B	70° 32.306′ N	147° 18.430′ W	33.8	21 Sep 11:56	01 Oct 05:15
C	70° 32.544′ N	147° 18.018′ W	33.8	21 Sep 11:19	01 Oct 06:09
Track Line 2					
Track line start	70°40.614′ N	147°33.072′ W			
Track line end	70°36.659′ N	147°11.864′ W			
A2	70° 37.985′ N	147° 18.912′ W	38.3	01 Oct 18:05	04 Oct 23:11
B2	70° 38.212′ N	147° 18.514′ W	37.8	01 Oct 18:37	04 Oct 23:54
C2	70° 38.445′ N	147° 18.104′ W	38.3	01 Oct 19:06	05 Oct 00:31
Track Line 3					
Track line start	70°22.937′ N	145°52.571′ W			
Track line end	70°22.937′ N	146°16.611′ W			
AL	70° 22.937′ N	146° 00.596′ W	34.0	12 Aug 19:29	22 Oct 19:20

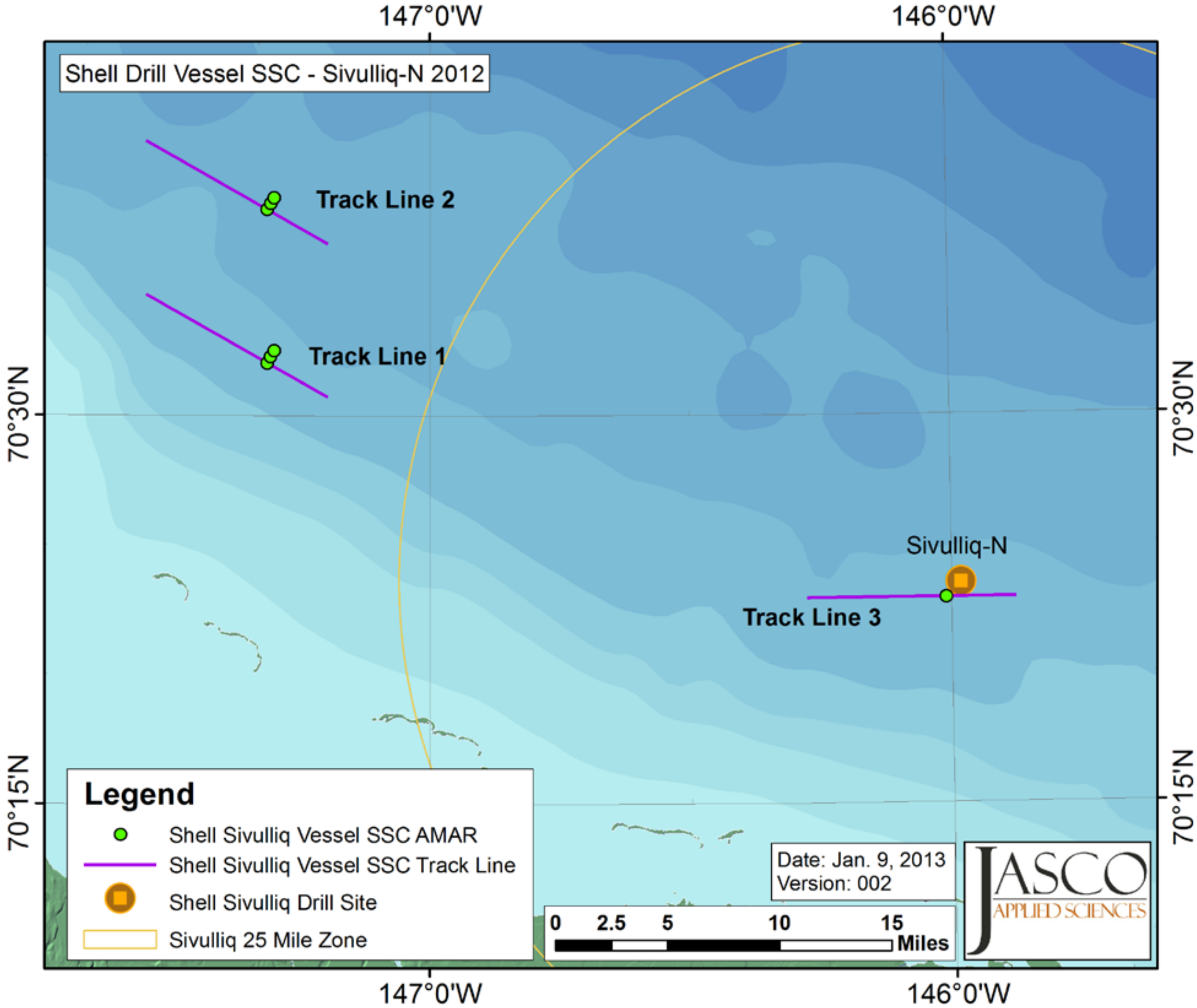


FIGURE 3.5. Vessel SSC locations relative to Sivulliq-N drill site in the Beaufort Sea.

TABLE 3.5. Schedule of underwater acoustic measurements for the vessel SSCs in the Beaufort Sea. Dates and times are given in UTC.

	Date	Start Time	End Time	Transit Speed (kts)	Wind (kts)	Wave Height (m)
Track Line 1						
Aiviq	29 Sep 12	04:19:55	05:14:51	8.8	5-10 N	1-2
Arctic Seal	29 Sep 12	00:08:16	01:02:00	9.0	10 SE	1-1.5
Lauren Foss	29 Sep 12	20:44:47	22:00:09	6.5	10 NE	1-1.5
Nordica	29 Sep 12	15:20:00	16:24:00	9.0	13 NW	2
Sisuaq	28 Sep 12	21:01:31	21:58:00	8.6	10-15 NW	0.5-1
Warrior	28 Sep 12	17:10:12	18:06:12	8.7	10 N	1-2
Track Line 2						
Affinity	02 Oct 12	01:48:22	02:42:03	9.0	8 W	1
Pt Oliktok	02 Oct 12	21:44:22	22:41:00	8.7	10-15 SSE	0.5-1
Track Line 3						
Tor Viking II	23 Aug 12	08:41:42	09:36:18	9.0	10 E	calm

Noise from Drilling Activities

Four AMARs, deployed at ranges of 1, 2, 4, and 8 km (3280, 6560, 13,120, and 26,240 ft) from the drilling site at each prospect, recorded sounds from drilling activities. In addition, an acoustic telemetry buoy was deployed at Sivulliq-N at 500 m (1640 ft) from the drilling site. Also, before the *Kulluk*'s arrival at the Sivulliq-N prospect, an AMAR was deployed at 1500 m (4920 ft) from the drilling site to measure sounds from anchor laying activities. This AMAR remained in place throughout the drilling, providing an additional point of measurement at the Sivulliq-N prospect.

Burger-A Prospect, Chukchi Sea

The four AMARs deployed to measure noise from drilling activities in the Chukchi Sea were set along a radial oriented northeast from the Burger-A drill site (Figure 3.6) between *Discoverer*'s anchors 1 and 7. This orientation of the recorder array relative to the drilling location was selected to provide sound measurements along the principle axis of bowhead whale migration that might be approaching the operating rig. Table 3.6 lists the AMAR locations and deployment and retrieval dates. The recording capacity of the AMARs was exceeded part way through the drilling program so they were retrieved on 3 Oct (11 Oct for AMAR D) to download data and then re-deployed.

TABLE 3.6. AMAR deployment locations and deployment and retrieval times for drilling SSC at the Burger-A prospect in the Chukchi Sea. Dates and times are given in UTC.

	Range from Drill Site (km)	Latitude	Longitude	Water Depth (m)	Deployed	Retrieved
Deployment 1						
A	1	71°18.806' N	163°11.299' W	48.0	03 Aug 05:17	03 Oct 06:57
B	2	71°19.095' N	163°09.893' W	48.5	03 Aug 03:38	03 Oct 08:35
C	4	71°19.677' N	163°07.075' W	48.1	03 Aug 03:03	03 Oct 10:30
D	8	71°20.839' N	163°01.433' W	48.0	03 Aug 00:20	11 Oct 18:55
Deployment 2						
A	1	71°18.802' N	163°11.300' W	48.0	03 Oct 07:35	26 Oct 05:50
B	2	71°19.094' N	163°09.896' W	48.0	03 Oct 09:00	26 Oct 04:58
C	4	71°19.672' N	163°07.088' W	48.0	03 Oct 10:58	26 Oct 04:12
D	8	71°20.836' N	163°01.414' W	48.0	11 Oct 20:05	26 Oct 03:18

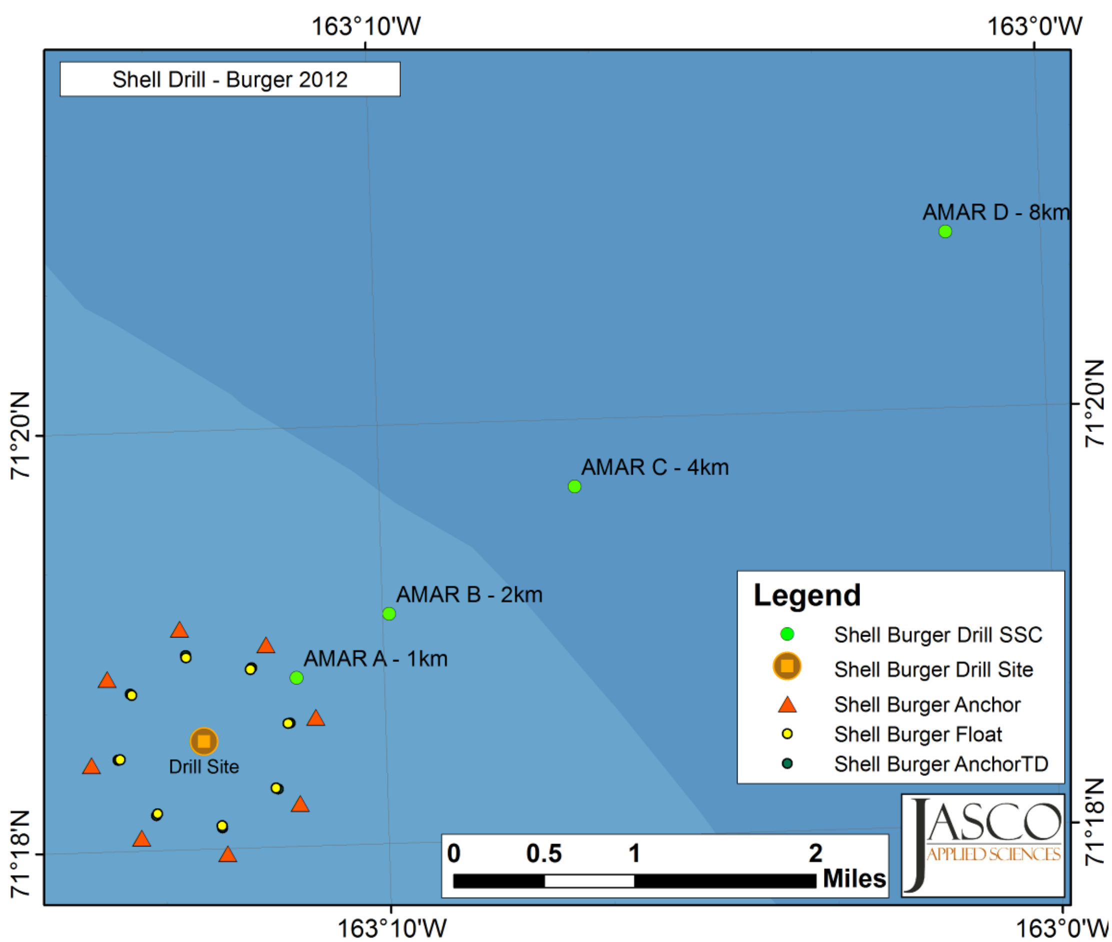


FIGURE 3.6. Drill SSC recorder deployment locations relative to Burger-A drill site.

Sivulliq-N Prospect, Beaufort Sea

The AMARs deployed to measure noise from drilling activities in the Beaufort Sea were set along a radial oriented south-west from the Sivulliq-N drill site (Figure 3.7) between *Kulluk's* anchors 9 and 10. The telemetry buoy was deployed between anchors 7 and 8. Table 3.7 lists the locations and deployment and retrieval dates for the AMARs and the telemetry buoy. The orientation of this array was selected based upon the anchoring plan to place the array on the side of the rig closest to the power generators.

TABLE 3.7. Deployment locations and deployment and retrieval times for drilling SSC at the Sivulliq-N prospect. Dates and times are given in UTC.

AMAR	Range from Drill Site (km)	Latitude	Longitude	Water Depth (m)	Deployed	Retrieved
A	1	70°23.124′ N	146°00.005′ W	33.2	26 Sep 21:05	22 Oct 18:35
AL	1.5	70°22.937′ N	146°00.596′ W	34.0	17 Aug 19:31	22 Oct 19:15
B	2	70°22.744′ N	146°01.194′ W	32.5	26 Sep 18:04	22 Oct 20:10
C	4	70°21.991′ N	146°03.497′ W	31.5	26 Sep 16:43	22 Oct 20:51
D	8	70°20.498′ N	146°08.089′ W	29.5	26 Sep 15:26	22 Oct 21:57
Buoy	0.5	70°23.239′ N	145°58.684′ W	34.0	03 Oct 19:39	21 Oct 20:00*

* The telemetry buoy stopped transmitting on 13 Oct.

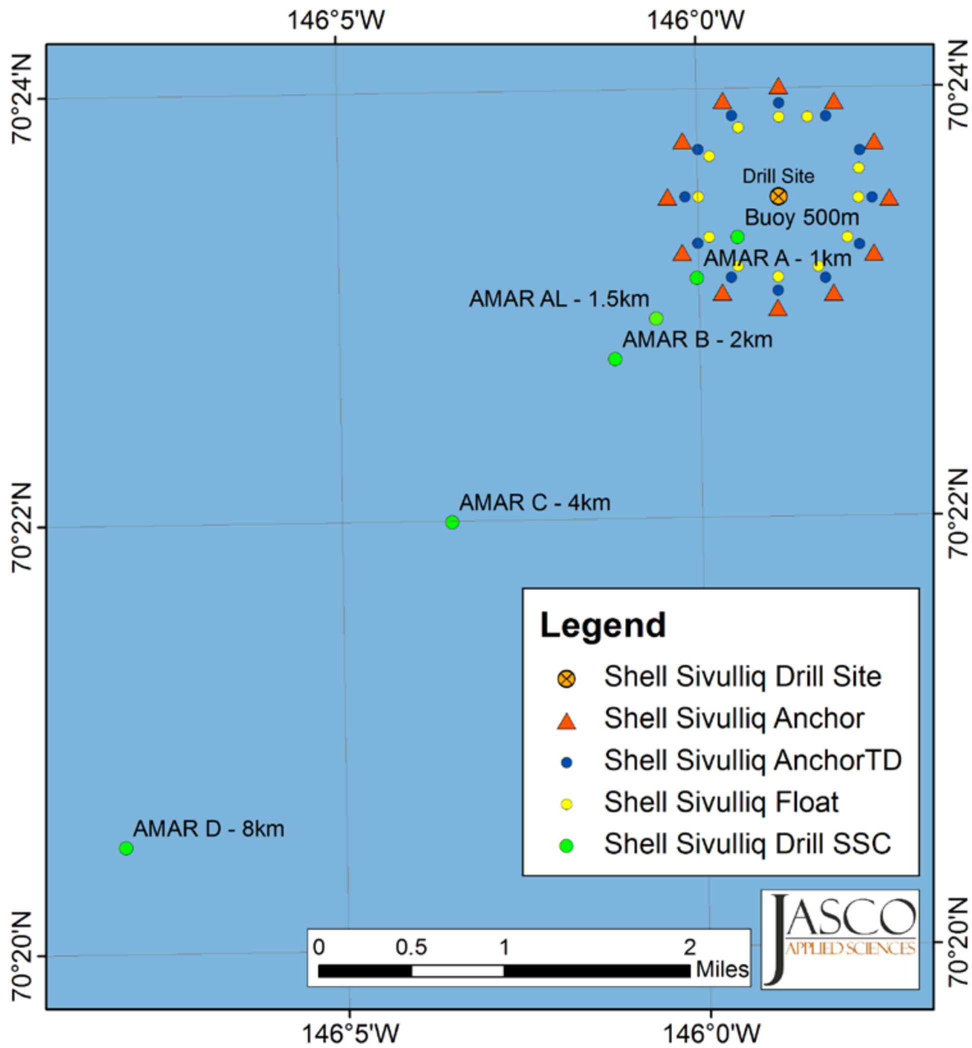


FIGURE 3.7. Drill SSC recorder deployment locations relative to Sivulliq-N drill site.

Data Analysis

Acoustic data from the vessel SSC measurements were analyzed using JASCO's custom processing software. This software outputs spectral and broadband sound pressure levels (SPLs) versus range from each sound source in specified time windows. Ranges were calculated from the time-stamped vessel GPS logs.

Acoustic Metrics

Underwater sound amplitude is measured in decibels (dB) relative to a fixed reference pressure (p_o) of 1 µPa. Several sound level metrics are commonly used to evaluate the loudness or effects of underwater noise. The noise sources considered in this report are sources of continuous noise, and therefore the primary sound level metric of importance is the root-mean-square (rms) sound pressure level (denoted by L_P). This metric was computed from the measured pressure time series, $p(t)$ according to this equation:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_o^2\right) \qquad (1)$$

The rms SPLs were calculated with Hanning-weighted time windows with 50% overlap. A 1-second time window was applied for data from the support vessel SSCs. For data from drilling activities a 1-minute window length was used to compute rms SPL.

Spectral Analysis

The broadband frequency content of the recorded sounds was characterized in several formats for this report. Daily spectrogram plots were generated to visually present the distribution of sound energy with frequency and time. Sounds specific to the defined drilling activities were also characterized in 10-minute averaged power spectral density plots. Finally, support vessel and drilling source sound levels were computed in 1/3-octave bands.

The acoustics community has adopted standard 1/3-octave frequencies (more precisely these are tenth-decade band frequencies) (ISO R 266 and ANSI S1.6-1984) to facilitate comparisons between studies; the central frequency of the *i*th standard passband is:

$$f_{ci} = 10^{i/10},\ i = 1, 2, 3, \ldots \tag{2}$$

The bandwidth of a single 1/3-octave band is ~23% of the central frequency of the band.

Distances to SPL Thresholds

Ranges to various SPL thresholds were computed for each vessel pass and for each drilling activity by fitting the SPL data to an empirical propagation loss curve of one of the following forms:

$$\mathrm{RL} = \mathrm{SL} - A\log_{10} R \tag{3}$$

$$\mathrm{RL} = \mathrm{SL} - A\log_{10} R - \alpha R \tag{4}$$

where *R* is the slant range (m) from the source to the acoustic recorder, RL is the received sound level, SL is the estimated source level (dB re 1 µPa @ 1 m), *A* is the geometric spreading loss coefficient, and α is the absorption loss coefficient. The second equation was used if absorptive losses were present or if apparent curvature existed in the received level versus log(range) data trend, whereas the first was used if significant absorptive losses were not observed.

The appropriate equation was fit to the SPL data by using least squares to minimize the difference between the trend line and the measured level-range samples. Ranges to SPL thresholds between 120 and 190 dB re 1 µPa, in 10 dB increments, were obtained from these fits. To provide a conservative estimate of the radii, the best-fit line was shifted upwards so that the trend line exceeded 90% of all data. The 90th percentile and best-fit values for SL and *A (*and α, when applicable) are shown in the SPL versus range plot annotations in the following sections.

Source Level Calculations

Source sound levels, defined at a standard reference range of 1 m, were derived from measurements obtained at ranges much greater than 1 m. An adjustment referred to as “back-propagation” was used to convert the measured levels to source levels. A common practice is to apply a back-propagation correction that assumes that sound waves spread away from a source uniformly in all directions, decaying in proportion to the geometric spreading of the acoustic wavefront. Often a simple “spherical-spreading loss” correction factor of 20 times the logarithm of the measurement distance is applied–expressed 20 log(r) for distance r, in meters. For low frequencies and shallow water conditions, where interactions with the surface and bottom strongly influence the sound propagation, the spherical-spreading loss approximation is generally only valid for measurements taken at close range. Vessel sound levels were measured at appropriately short ranges that we applied spherical-spreading back-propagation to derive source levels for each of the support vessels. The closest-range vessel sound data were band-pass filtered into 1/3-octave frequency bins, and the level of each bin was computed. These levels were then back-propagated to a range of 1 m.

This approach was not used to estimate source levels for the drilling sounds, however, since the measurement range of 1 km (3280 ft) invalidated the spherical-spreading loss assumption. Instead, sound transmission loss values calculated from a numerical sound propagation model were used to back-propagate the drilling sound levels. The numerical model fully accounted for both seafloor and water surface reflections along with the acoustic properties of the water column and of the seafloor. The model was used to compute sound transmission loss between the source location and a receiver at 1 km (3280 ft), in 1/3-octave bands.

For frequencies below 2 kHz transmission losses were calculated using the wide-angled parabolic equation model RAM (Collins, 1993), adapted to account for shear wave loss through a complex density approximation. Frequencies of 2 kHz and greater were modelled using the ray tracing code Bellhop (Porter and Liu, 1994). In each case, the model input parameters included the geo-acoustic properties of the sub-bottom, as well as a definition of the bathymetry at the site and of the sound speed in the water column as a function of depth. The geo-acoustic properties input to the model (Table 3.8 and Table 3.9) were those from a previous modeling study that considered noise from zero-offset vertical seismic profiling at Burger and Sivulliq (Warner and Li, 2013). The water depth was assumed to be constant at a value of 48 m (144 ft) for Burger and 33 m (108 ft) for Sivulliq. Sound speed profiles for the water column were obtained from temperature and salinity profiles collected at the study sites during the acoustic monitoring program (Figure 3.8).

TABLE 3.8 Geo-acoustic parameters input to the numerical model used to back-propagate the received sound levels from drilling at Burger-A.

Depth (m)	Density (g/cm^3)	Compressional Wave Speed (m/s)	Compressional Wave Attenuation (db/ λ)	Shear Wave Speed (m/s)	Shear Wave Attenuation (dB/ λ)
0-20	1.49-1.51	1563-1589	0.1	113	1.7
20-70	1.83-1.89	1701-1763	0.2		
70-170	1.99-2.12	1813-1927	0.2		
>170	2.12	1927	0.2		

TABLE 3.9 Geo-acoustic parameters input to the numerical model used to back-propagate the received sound levels from drilling at Sivulliq-N.

Depth (m)	Density (g/cm^3)	Compressional Wave Speed (m/s)	Compressional Wave Attenuation (dB/ λ)	Shear Wave Speed (m/s)	Shear Wave Attenuation (dB/ λ)
0-2	1.6-2.0	1550	0.1-0.3	200	2.6
2-30	2.2-2.4	1674-1702	0.3-0.2		
30-200	2.4	1673-1843	0.2		
>200	2.4	1843	0.2		

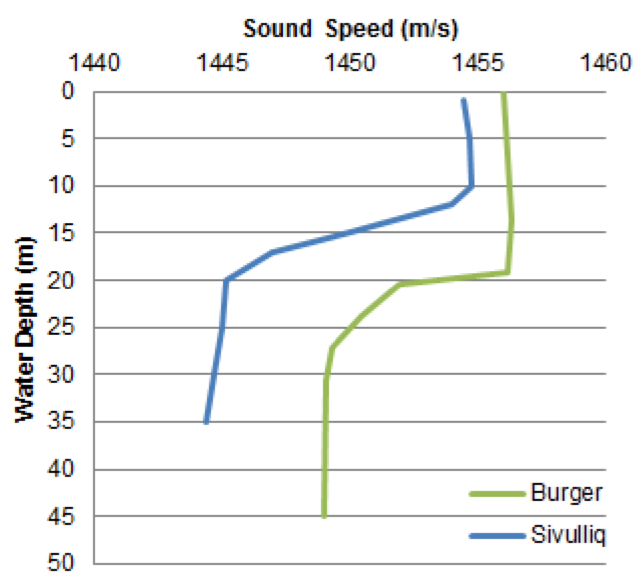


FIGURE 3.8 Water column sound speed as a function of water depth, derived from temperature and salinity profiles measured at Burger and at Sivulliq.

Results

Results are presented separately for the Burger-A and Sivulliq-N prospect sites. For each prospect, results are first presented for the drilling sounds then for the support vessel SSC measurements.

Plots of hourly SPL versus time show the sound levels measured on all AMARs at each drill site when the drillships were active. Daily spectrogram plots, with corresponding decade band levels (Appendix H) show the spectral distribution of sound energy at a finer time scale. A panel above each spectrogram shows the range between the AMAR and ancillary vessels as a function of time. These plots illustrate that fluctuations in the received sound levels often corresponded with the approach and departure of support vessels relative to the AMARs. The spectrogram annotations highlight particular drilling activities and times when a vessel was within 5 km (16,400 ft) of the AMAR. Average SPLs were computed for the times that related to particular drilling activities and, from these data, ranges to sound thresholds between 190 and 120 dB re 1 µPa were computed for each activity. Source levels for each drill rig were computed for times when drilling occurred without the presence of nearby support vessels.

Support vessel SSC results are presented in plots of SPL versus range as well as in tables of ranges to sound thresholds between 190 and 120 dB re 1 µPa. 1/3-octave band source level plots are also provided for each support vessel.

Burger-A Prospect Site, Chukchi Sea

Noble Discoverer Drilling Activities

The drillship *Noble Discoverer* moved into the Burger-A prospect area and began mooring on 7 Sep. Mooring was complete on 9 Sep, and then drilling an 8.5 in pilot hole commenced. Soon after, a field of ice encroached upon the prospect site. From 11 to 21 Sep the *Tor Viking II, Fennica,* and *Nordica* monitored and managed the ice at Burger-A drill site, meaning they maneuvered slowly through the ice field pushing on ice floes to keep them clear from *Noble Discoverer's* anchor buoys. On 10 Sep, the *Noble Discoverer* departed the site to avoid damage. The *Tor Viking II* and the *Fennica* remained at the prospect site to manage ice and to protect the mooring anchor buoys. Sound levels generated by the *Tor Viking II* during part of this period were processed to characterize the noise from ice management. Once the ice cleared the prospect on 21 Sep, the *Noble Discoverer* returned to its position to resume drilling. Between 23 Sep and 28 Oct, the following activities took place: drilling 8.5 in pilot hole, drilling 17.5 in hole, drilling 36 in hole, drilling mudline cellar (MLC), drilling 26 in hole, installing well casings, cementing well casings, and capping the well. The daily spectrogram plots in Appendix H contain annotations that indicate the received sound levels when these activities took place.

Figure 3.8 through Figure 3.15 show hourly SPL values (broadband and decade band) for two deployments of the four AMARs at 1, 2, 4, and 8 km (3280, 6560, 13,120, and 26,240 ft) from the Burger-A drill site. The deployments cover the period from 6 Sep to 27 Oct. The spectral distribution shows that the sound energy was concentrated in the decade band from 100–1000 Hz. To some extent, fluctuations in the levels in the 10–100 Hz band track the presence and absence of ancillary vessels. The levels in this band are close to the broadband value when vessels are near the AMAR (e.g., the peak on 17 Sep in Figure 3.8) but are lower than the broadband value when ancillary vessels are absent (e.g., 1–4 Oct in Figure 3.8).

The received SPLs were greatest when other vessels (most often the *Tor Viking II*) were performing duties within 5 km (16,400 ft) of the AMARs. This can be discerned more clearly in the spectrogram plots in Appendix H. Elevated sound levels, with SPLs around 140 dB re 1 µPa at 1 km

(3280 ft), were also measured during the drilling of the MLC between 1 and 5 Oct. There were no ancillary vessels within 10 km of the AMARs at that time; the increased sound levels were attributed to MLC drilling. With the exception of the MLC drilling, received SPLs did not exceed 130 dB re 1 µPa unless a vessel was within 5 km (16,400 ft) of an AMAR.

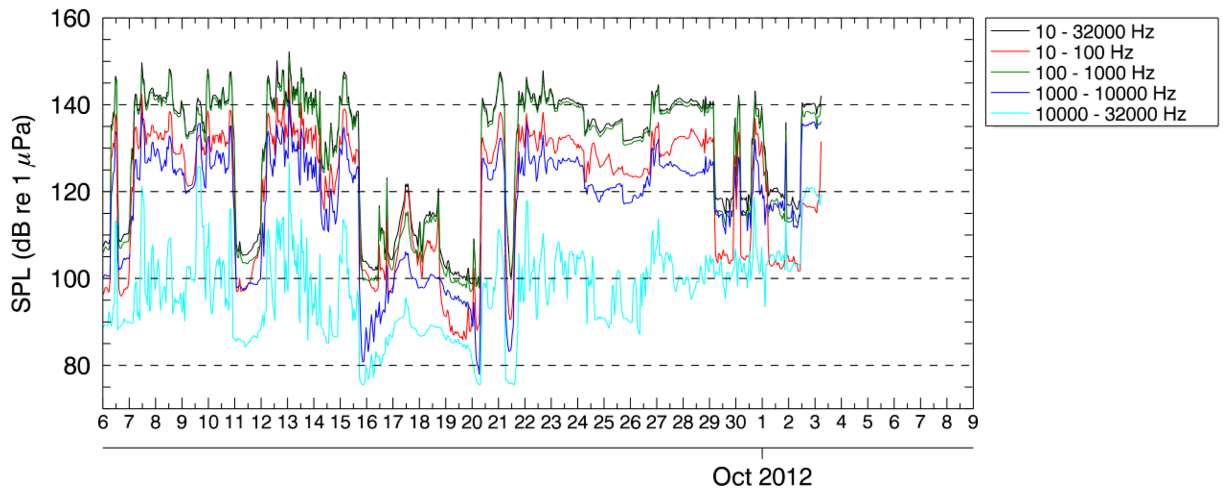


FIGURE 3.9. Hourly SPLs from the first AMAR deployment (6 Sep to 9 Oct 2012 UTC) at 1 km (3280 ft) from the Burger-A drill site.

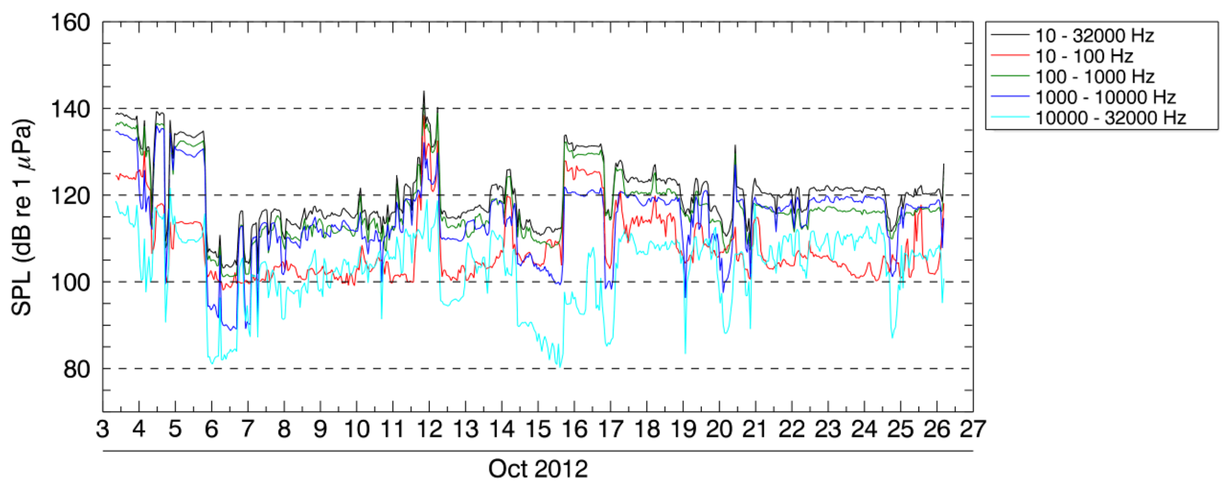


FIGURE 3.10. Hourly SPLs from the second AMAR deployment (3–27 Oct 2012 UTC) at 1 km (3280 ft) from the Burger-A drill site.

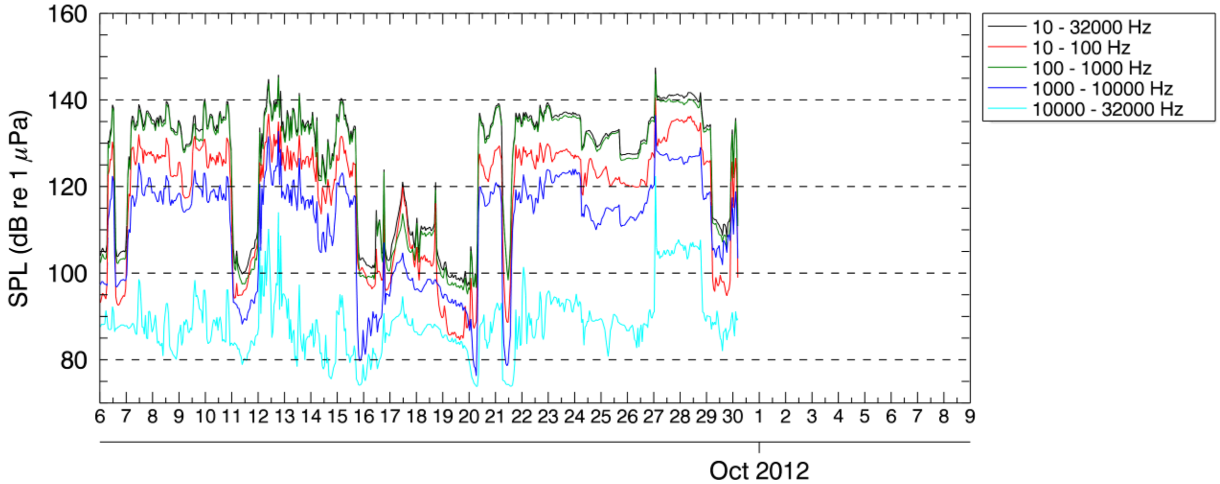


FIGURE 3.11. Hourly SPLs from the first AMAR deployment (6 Sep to 9 Oct 2012 UTC) at 2 km (6560 ft) from the Burger-A drill site. Recordings stopped on 30 Sep.

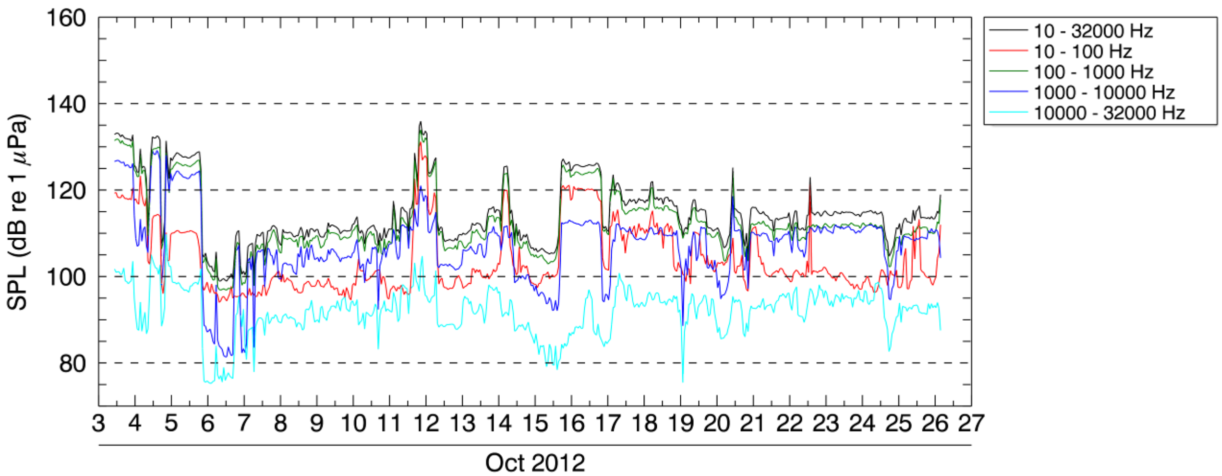


FIGURE 3.12. Hourly SPLs from the second AMAR deployment (3–27 Oct 2012 UTC) at 2 km (6560 ft) from the Burger-A drill site.

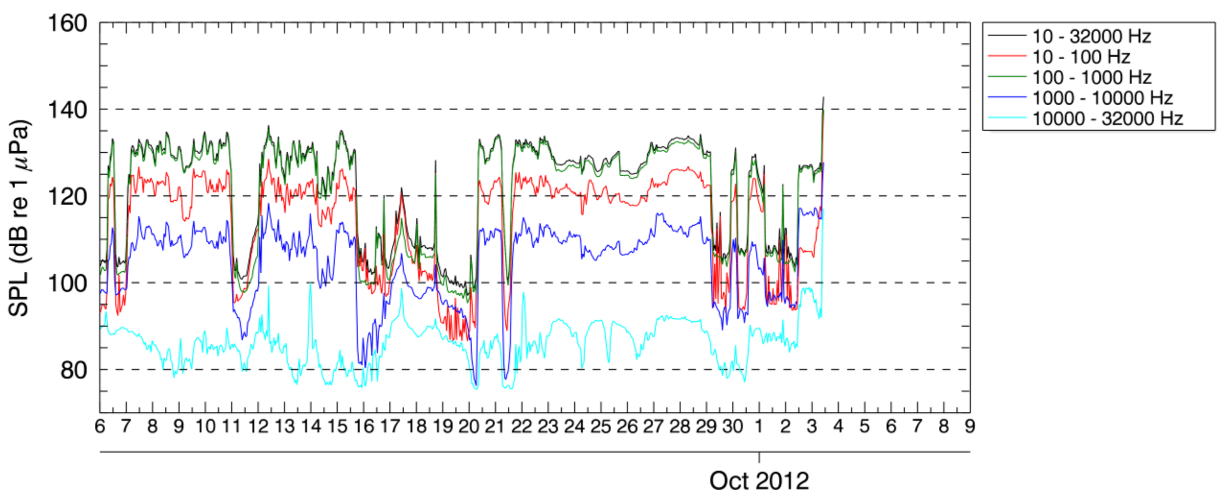


FIGURE 3.13. Hourly SPLs from the first AMAR deployment (6 Sep to 9 Oct 2012 UTC) at 4 km (13,120 ft) from the Burger-A drill site.

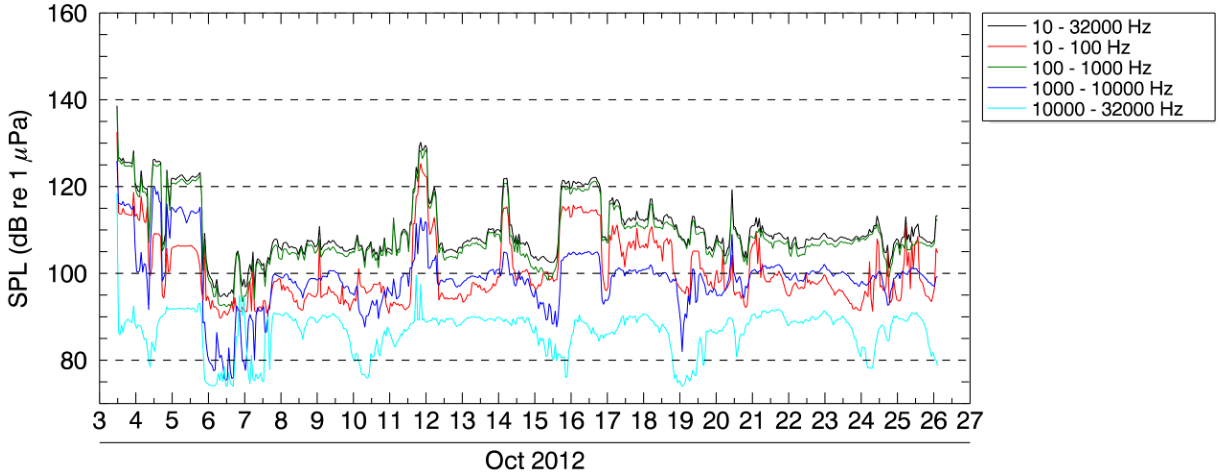


FIGURE 3.14. Hourly SPLs from the second AMAR deployment (3–27 Oct 2012 UTC) at 4 km (13,120 ft) from the Burger-A drill site.

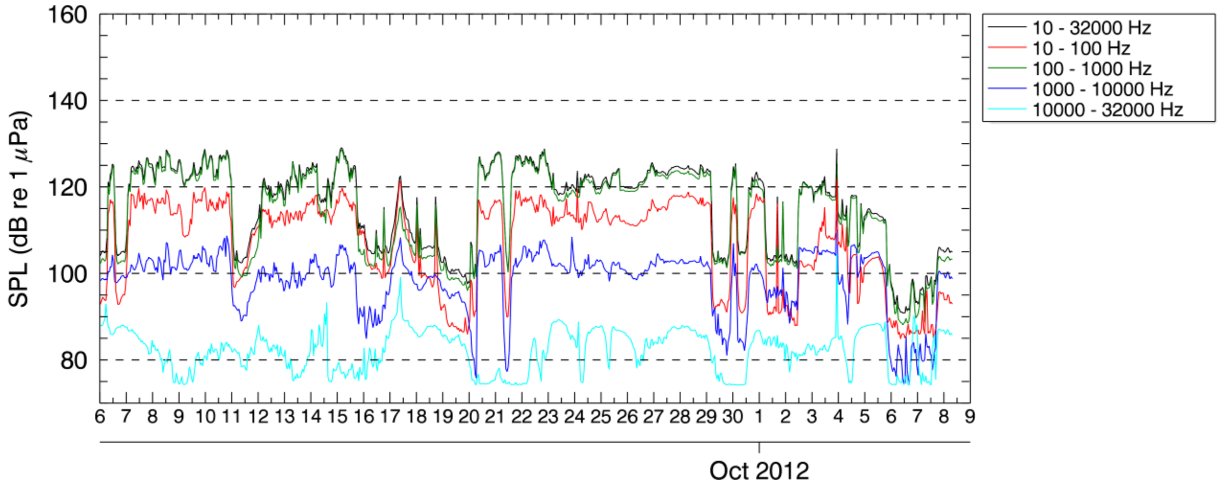


FIGURE 3.15. Hourly SPLs from the first AMAR deployment (6 Sep to 9 Oct 2012 UTC) at 8 km (26,240 ft) from the Burger-A drill site.

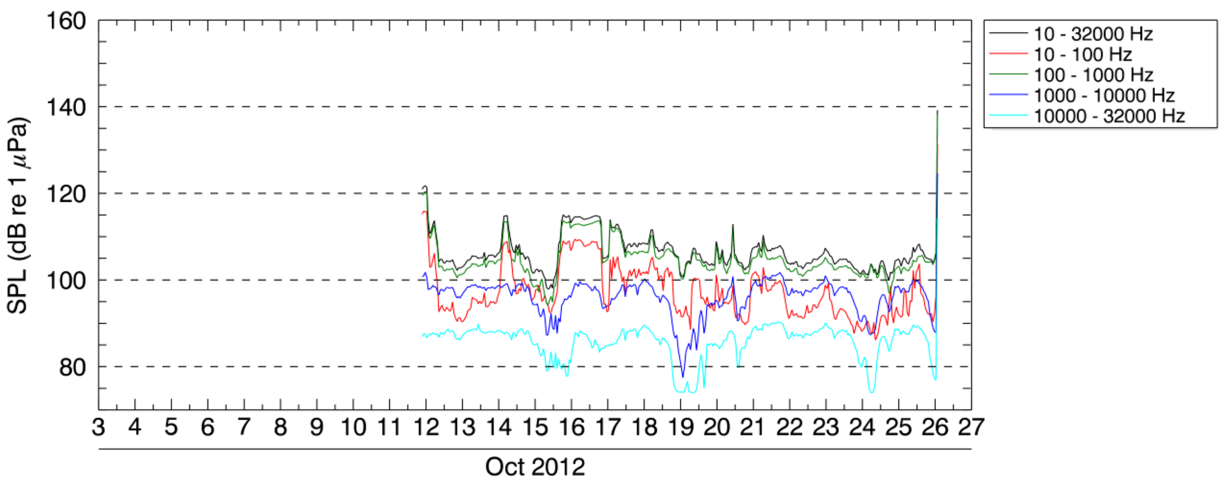


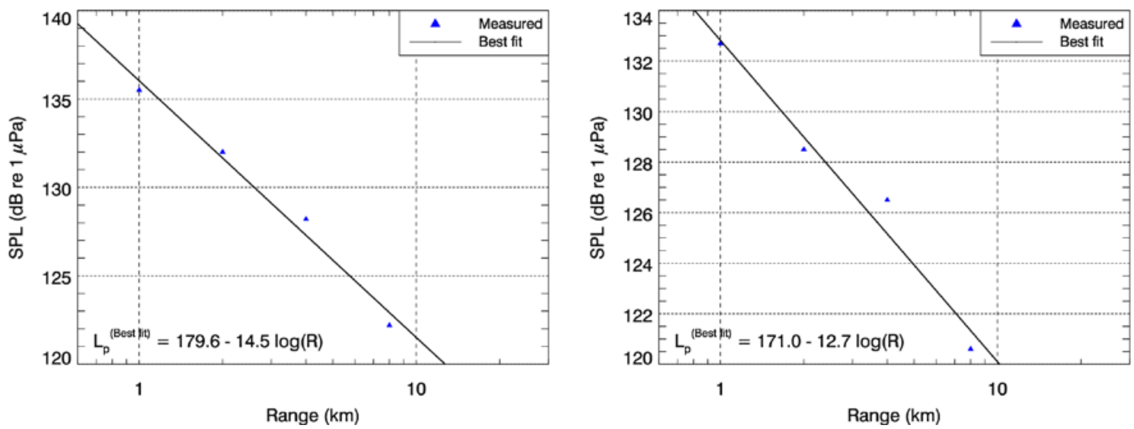
FIGURE 3.16. Hourly SPLs from the second AMAR deployment (11–27 Oct 2012 UTC) at 8 km (26,240 ft) from the Burger-A drill site.

Table 3.8 lists the periods chosen to represent some of the drilling activities based on entries in the PSO activity logs. Since support vessels working near the AMARs emanated sounds that often masked recordings of the drilling sounds, vessel GPS logs (also provided by the PSOs) were used to identify times at which the sound recordings were the least affected by nearby vessels. As much as possible, analysis times were chosen so ancillary vessels were separated from the AMARs by at least 5 km (16,400 ft). However, the *Tor Viking II* was often close to the AMARs from 24–26 Sep when the pilot holes were being drilled; as such, sound levels received during these times were dominated by noise from the *Tor Viking II*. These measured sound levels were considered as a combined signature of the support vessel and drilling noise.

For each of the chosen activities, the rms SPLs from each AMAR were averaged over the duration of the activity. These values were plotted versus distance and used to estimate sound-level-threshold ranges (Figure 3.18 through Figure 3.21, Table 3.9). Note that at the times considered for composite drilling and support vessel activities the *Tor Viking II* was moving. As a result, the measured data from those times do not follow the expected trend of sound decay for a stationary source so the data-fit used to extract sound level threshold ranges may be biased. In particular, the resulting radii to 120 dB for these activities are extrapolations beyond the maximum measurement range, which likely overestimate the true ranges.

TABLE 3.10. Periods selected as representative of drilling activities at Burger-A.

Activity	Analysis Period (UTC)	Note
Drilling 8.5'' pilot hole with *Tor Viking II* nearby	05:20 Sep 24–13:30 Sep 24	Drilling noise masked by noise from *Tor Viking II*.
Drilling 17.5'' pilot hole with *Tor Viking II* nearby	16:00 Sep 25–02:00 Sep 26	Drilling noise masked by noise from *Tor Viking II*.
Drilling 36'' pilot hole with *Tor Viking II* nearby	21:20 Sep 26–22:17 Sep 26	Drilling noise masked by noise from *Tor Viking II*.
Drilling 26'' hole	09:00 Oct 17–03:00 Oct 18 07:00 Oct 18–18:40 Oct 18 07:30 Oct 19–10:00 Oct 19	
Drilling Mudline cellar	11:50 Oct 2–18:00 Oct 2 20:10 Oct 2–01:00 Oct 3 02:00 Oct 3–04:00 Oct 3	
Ice Management	18:50 Sep 13–19:10 Sep 13	*Tor Viking II* performing ice management to protect anchor buoys



(a) (b)

FIGURE 3.17. Average SPL versus range while the *Noble Discoverer* was drilling at Burger-A drill site with the *Tor Viking II* operating nearby; (a) 8.5 in pilot hole on 24 Sep (b) 17.5 in pilot hole on 25 Sep.

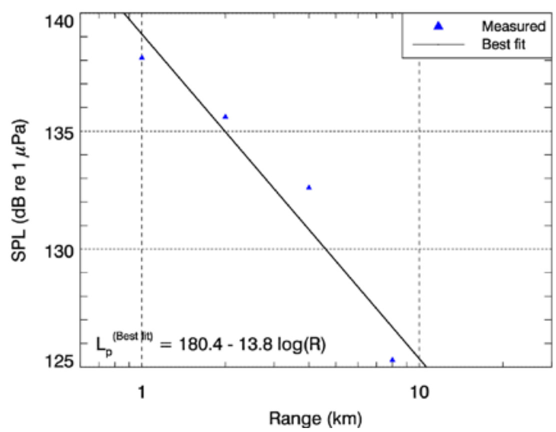
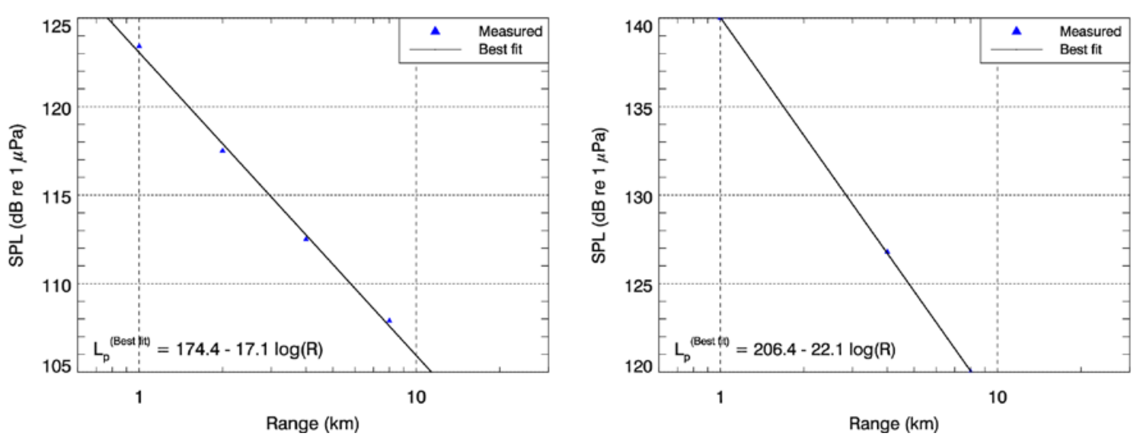


FIGURE 3.18. Average SPL versus range while the *Noble Discoverer* was drilling a 36 in pilot hole at Burger-A drill site with the *Tor Viking II* operating nearby on 26 Sep.



(a) (b)

FIGURE 3.19. Average SPL versus range while the *Noble Discoverer* drilling at Burger-A drill site; (a) 26 in hole from 17–19 Oct (b) mudline cellar from 2–3 Oct.

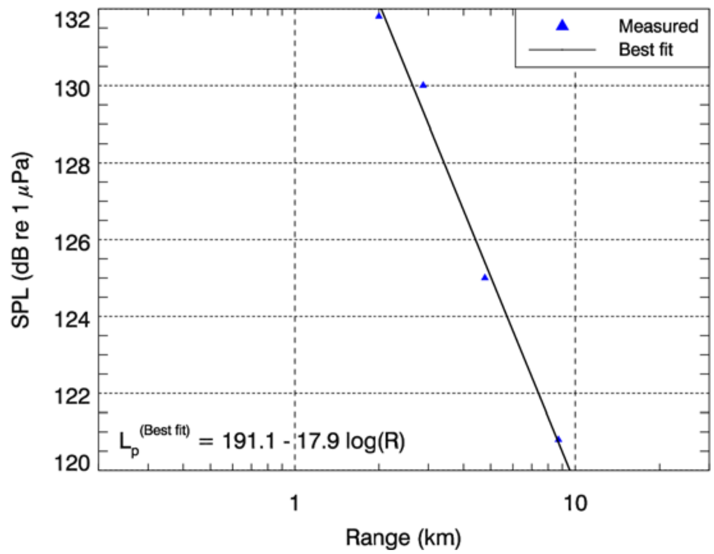


FIGURE 3.20. Average SPL versus range while the *Tor Viking II* was managing ice at the Burger-A drill site from 18:50 to 19:10 on 13 Sep.

TABLE 3.11. Radii to sound levels between 190 and 120 dB re 1 µPa for several drilling activities. Based on a linear fit to average sound levels recorded at four ranges at the Burger-A prospect in the Chukchi Sea.

	Drilling with *Tor Viking II* Nearby			No Vessels Nearby		
	8.5 in pilot hole	17.5 in pilot hole	36 in pilot hole	26 in hole	MLC	Ice Management
rms SPL (dB re 1 µPa)	Range (m)	Range (m)	Range (m)	Range (m)	Range (m)	Range (m)
190	< 10	< 10	< 10	< 10	< 10	< 10
180	< 10	< 10	< 10	< 10	20	< 10
170	< 10	< 10	< 10	< 10	40	20
160	22	< 10	30	< 10	130	60
150	110	45	160	30	350	200
140	530	270	860	100	1000	730
130	2600	1700	4600	390	2800	2600
120	13,000*	10,000*	25,000*	1500	8100	9600*

* Extrapolated beyond measurement range.

Recordings of drilling noise, free from noise of nearby vessels, were measured while the *Noble Discoverer* drilled the 26 in hole and the MLC. Spectral density plots were generated from a 10-minute sample of noise from each of these activities. Distinct tones are apparent in the spectra for 26 in hole drilling (Figure 3.16), which indicates that the noise arose from machinery vibrations on the *Noble Discoverer*. These sounds radiated through the hull into the water. Because the high frequency tones (> 1 kHz) decay with range and experience strong absorption in the water column, they are not evident in the recordings at 8 km. The spectrum for MLC drilling (Figure 3.17) did not have this same tonal structure. This likely indicates that the noise from mudline cellar drilling is predominantly from sounds of physical grinding of the large MLC bit into the seafloor. The broadband sounds from the MLC drilling obscure the tones emitted by the drillship. At frequencies greater than approximately 300 Hz, the received levels from drilling the 26 in hole were generally lower than those received during MLC drilling.

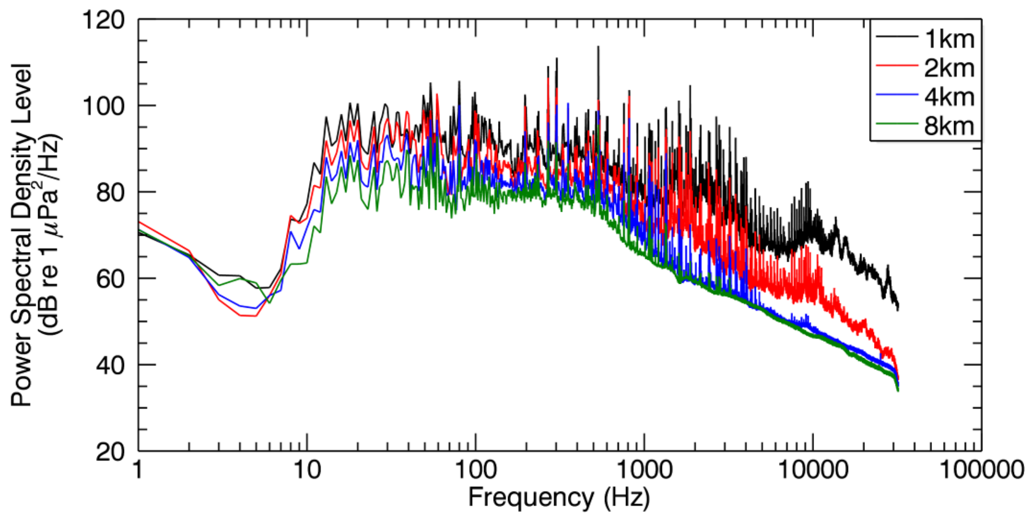


FIGURE 3.21. Power spectral density for drilling a 26 in hole at the Burger-A drill site on 18 Oct as received on AMARs at four ranges.

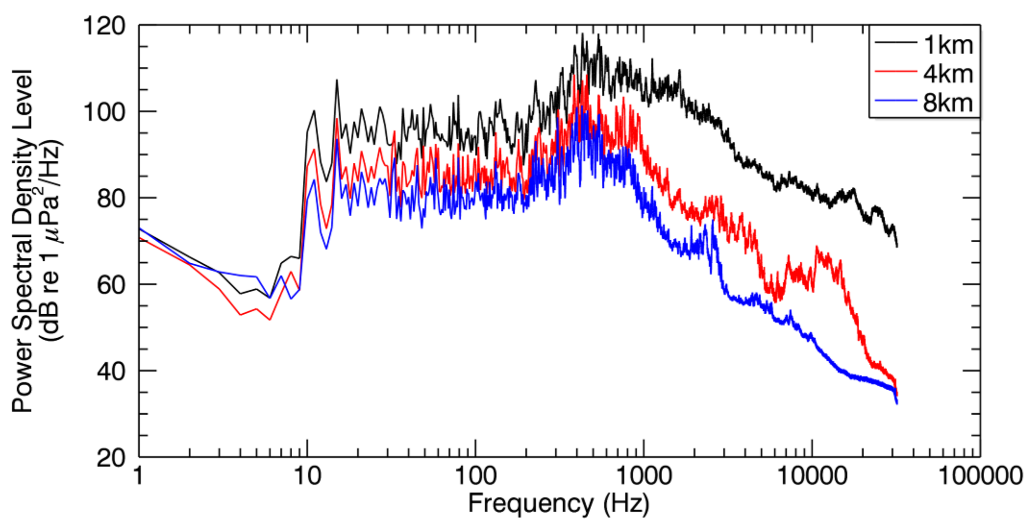


FIGURE 3.22. Power spectral density for MLC drilling at the Burger-A drill site on 2 Oct as received on AMARs at three ranges.

A broadband (10 Hz–32 kHz) source level of 181 dB was calculated for the *Noble Discoverer* based on the measurements for drilling of the 26 in hole. Figure 3.23 is a plot of the 1/3-octave band source level distribution for this activity.

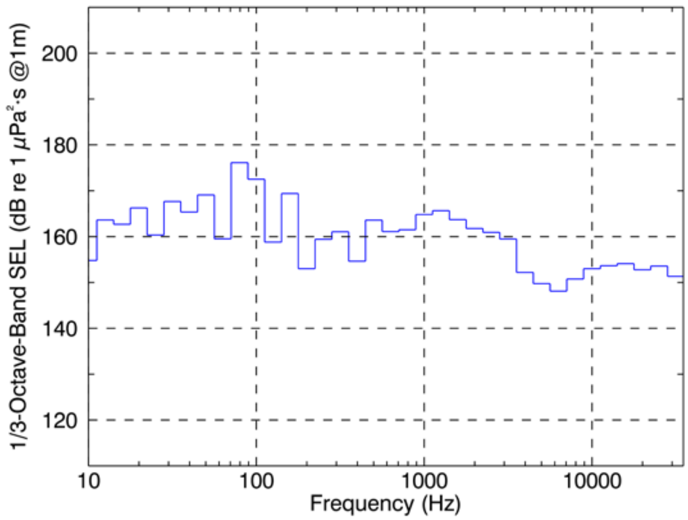
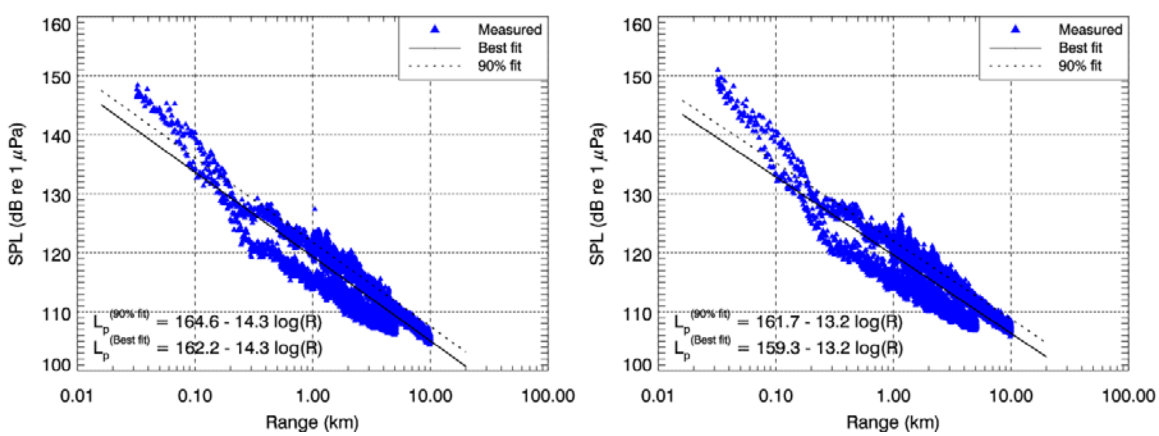


FIGURE 3.23 1/3-octave band source level for the *Noble Discoverer,*drilling a 26 in hole at the Burger-A drill site.

Support Vessels

Affinity

Figure 3.22 shows vessel sound levels as a function of range as measured on the recorders at 0 and 1000 m (0 and 3280 ft) from the vessel SSC track line in the Chukchi Sea. The *Affinity* completed two transits along the SSC track line at two different speeds; results from both transits are shown. Table 3.10 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.23).



(a)

(b)

FIGURE 3.24. Vessel SPL (rms) from AMAR A and AMAR C for the *Affinity* transiting at (a) 8.8 kts and (b) 9.0 kts in the Chukchi sea. The higher levels represent the aft direction from the vessel.

TABLE 3.12. Measured radii for the *Affinity* in the Chukchi Sea, as determined from fits to rms SPL versus range data.

rms SPL (dB re 1 µPa)	Transiting at 8.8 kts		Transiting at 9.0 kts	
	Best-Fit Line Radius (m)	90th Percentile Radius (m)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0	0	0
180	0	0	0	0
170	0	0	0	0
160*	< 10	< 10	< 10	< 10
150*	< 10	11	< 10	< 10
140*	36	53	29	44
130	180	270	160	250
120	900	1300	930	1400

* Ranges are underestimated by trend lines.

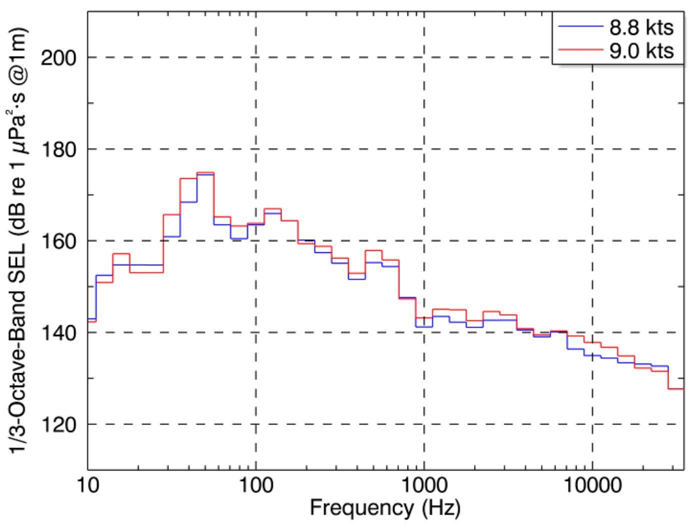


FIGURE 3.25. 1/3-octave band source levels for the *Affinity* from data measured in the Chukchi Sea.

Aiviq (towing the Kulluk)

Figure 3.24 shows vessel sound levels as a function of range as measured on the recorders at 0 and 1000 m (0 and 3280 ft) from the vessel SSC track line in the Chukchi Sea. Because SPLs measured at ranges less than 250 m (820 ft) saturated AMAR A, these SPLS are underestimated; however, this minimally affected the calculated threshold radii. Table 3.11 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. As mentioned, the data at CPA from this measurement were not reliable due to hydrophone saturation. In this case, 1/3-octave band source levels were calculated from the data recorded at 250 m (820 ft) fore and aft. First, these data were back-propagated to a synthetic CPA of 38 m (125 ft) using the per-band propagation loss observed over this distance for the *Fennica*, a vessel with similar size and draft. The synthetic CPA was chosen to match the measured CPA for the *Fennica*. These synthetic CPA levels were then back-propagated to 1 m range assuming spherical spreading as for the other vessels. The resulting 1/3-octave band source levels are shown in Figure 3.25.

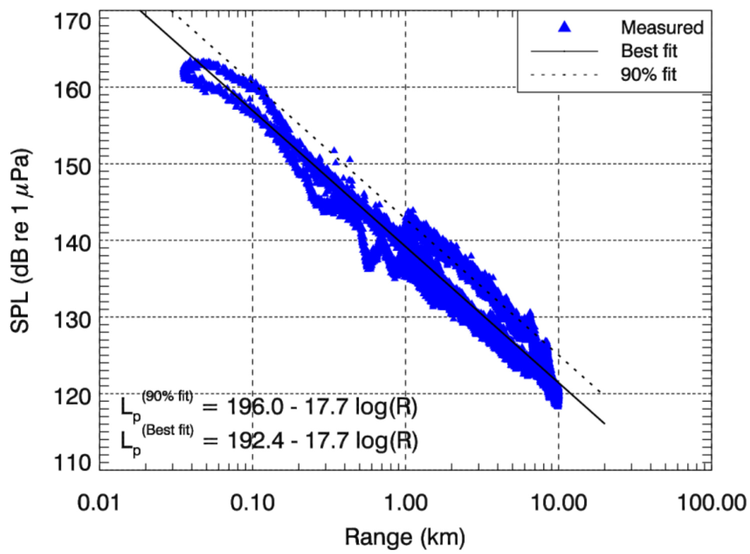


FIGURE 3.26. Vessel SPLs (rms) from AMAR A and AMAR C for the *Aiviq* transiting at 3.4 kts in the Chukchi Sea while towing the *Kulluk*. The higher levels represent the aft direction from the vessel.

TABLE 3.13. Measured radii for the *Aiviq* transiting at 3.4 kts in the Chukchi Sea while it was towing the *Kulluk*, as determined from the rms SPL versus range data.

rms SPL (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	< 10	< 10
180	< 10	< 10
170	19	30
160	68	110
150	250	400
140	900	1400
130	3300	5200
120	12000	19000

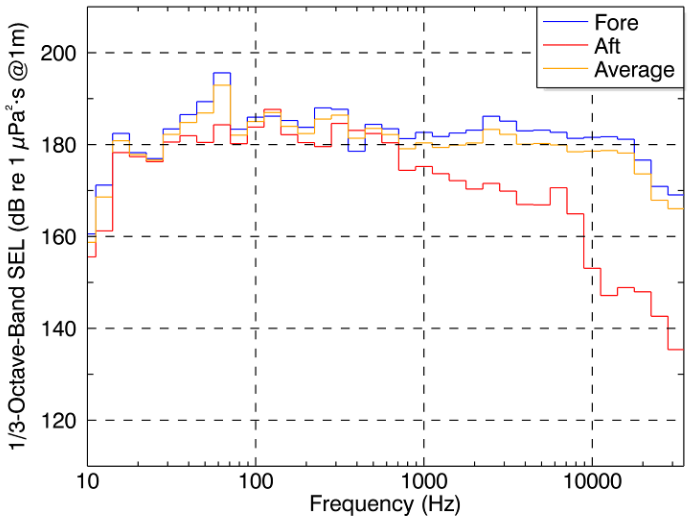
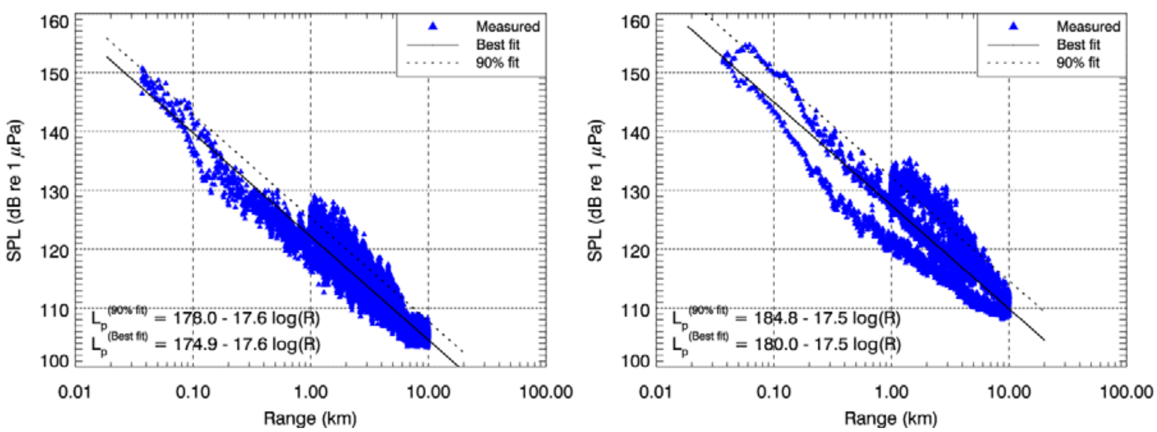


FIGURE 3.27. 1/3-octave band source levels for the *Aiviq*, towing the *Kulluk*, from data measured in the Chukchi Sea. Source levels computed from measurements at 250 m (820 ft) in both the fore and aft directions are shown, as is the average.

Fennica

Figure 3.26 shows vessel sound levels as a function of range as measured on the recorders at 0 and 1000 m (0 and 3280 ft) from the vessel SSC track line in the Chukchi Sea. Table 3.12 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.27).



(a) (b)

FIGURE 3.28. Vessel SPLs (rms) from AMAR A and AMAR C for the *Fennica* transiting at (a) 8.0 kts and (b) 12.0 kts in the Chukchi Sea. The higher levels represent the aft direction from the vessel. The increased levels at ranges greater than 1 km are data from AMAR C.

TABLE 3.14. Measured radii for the *Fennica*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL (dB re 1 µPa)	Transiting at 8.8 kts		Transiting at 9.0 kts	
	Best-Fit Line Radius (m)	90th Percentile Radius (m)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0	0	< 10
180	< 10	< 10	< 10	< 10
170	< 10	< 10	< 10	< 10
160*	< 10	11	14	26
150*	26	39	52	97
140*	97	150	190	360
130	360	540	710	1300
120	1300	2000	2700	5000

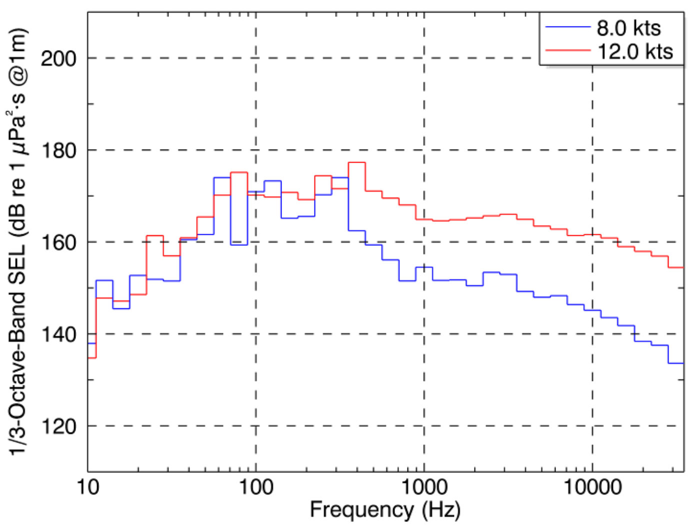


FIGURE 3.29. 1/3-octave band source levels for the *Fennica* from data measured in the Chukchi Sea.

Guardsman (towing the Klamath)

Figure 3.28 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.13 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.29).

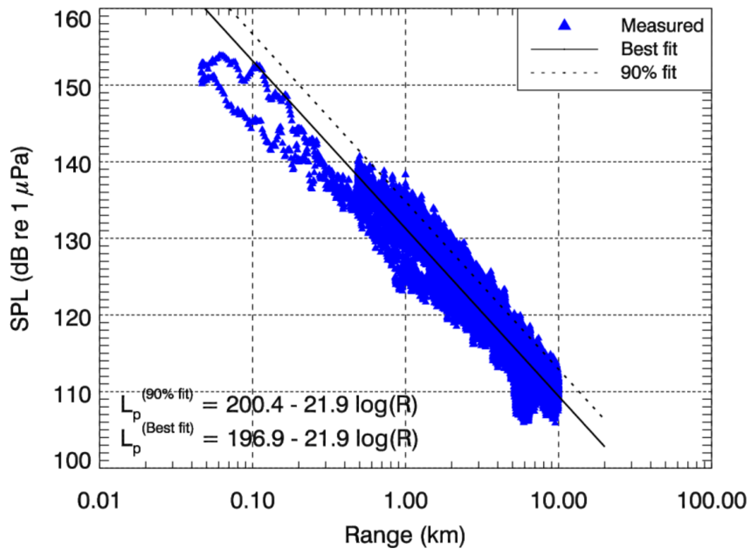


FIGURE 3.30. Vessel SPLs (rms) from each AMAR for the *Guardsman*, which is towing the *Klamath* at 9.4 kts in the Chukchi Sea. The higher levels at ranges less than 500 m represent the aft direction from the vessel. The increased levels at ranges greater than 500 m are data in the broadside direction.

TABLE 3.15. Measured radii for the *Guardsman*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	< 10	< 10
180	< 10	< 10
170	17	25
160	49	70
150	140	200
140	400	580
130	1100	1700
120	3300	4700

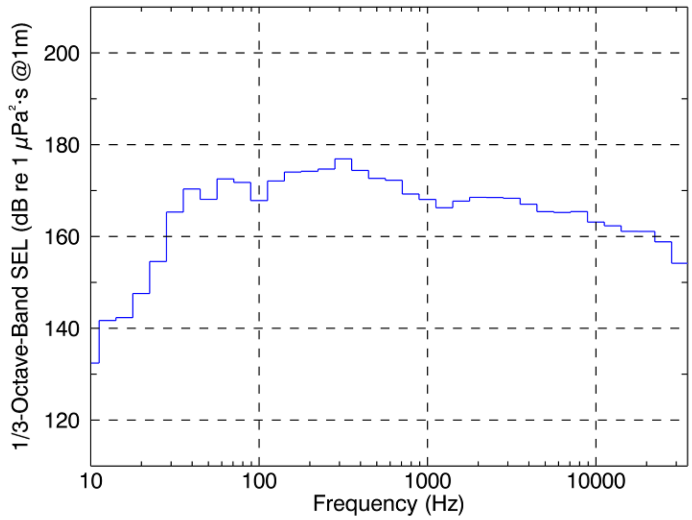


FIGURE 3.31. 1/3-octave band source levels for the *Guardsman* from data measured in the Chukchi Sea.

Harvey Explorer

Figure 3.30 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.14 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.31).

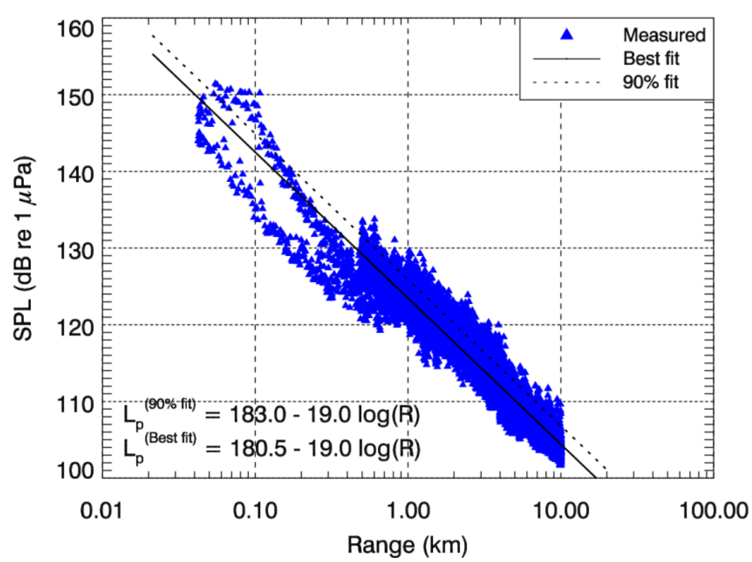


FIGURE 3.32. Vessel SPLs (rms) from each AMAR for the *Harvey Explorer* transiting at 8.5 kts in the Chukchi Sea. The higher levels at ranges less than 500 m represent the aft direction from the vessel. The increased levels at ranges greater than 500 m are data in the broadside direction.

TABLE 3.16. Measured radii for the *Harvey Explorer*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	< 10	< 10
170	< 10	< 10
160	12	16
150	40	54
140	140	180
130	450	610
120	1500	2000

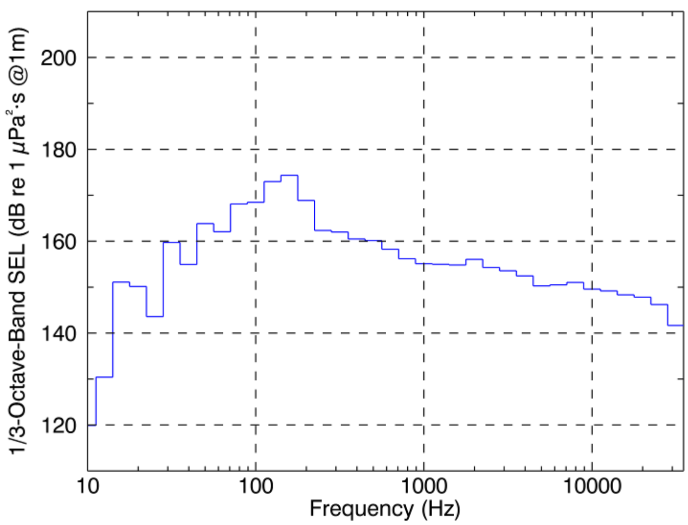


FIGURE 3.33. 1/3-octave band source levels for the *Harvey Explorer* from data measured in the Chukchi Sea.

Harvey Spirit

Figure 3.32 shows vessel sound levels as a function of range as measured on the recorders at 0 and 1000 m (0 and 3280 ft) from the vessel SSC track line in the Chukchi Sea. Table 3.15 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.33).

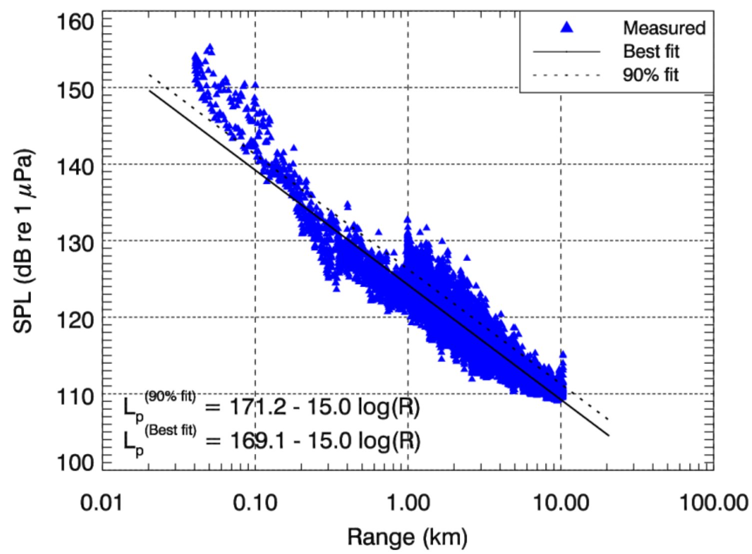


FIGURE 3.34. Vessel SPL (rms) from AMAR A and AMAR C for the *Harvey Spirit* transiting at 6.2 kts in the Chukchi Sea. The higher levels represent the aft direction from the vessel. The increased levels at ranges greater than 1 km are data from AMAR C.

TABLE 3.17. Measured radii for the *Harvey Spirit*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	0	0
170	< 10	< 10
160	< 10	< 10
150	19*	26*
140	88	120
130	410	560
120	1900	2600

* Ranges are underestimated by trend lines.

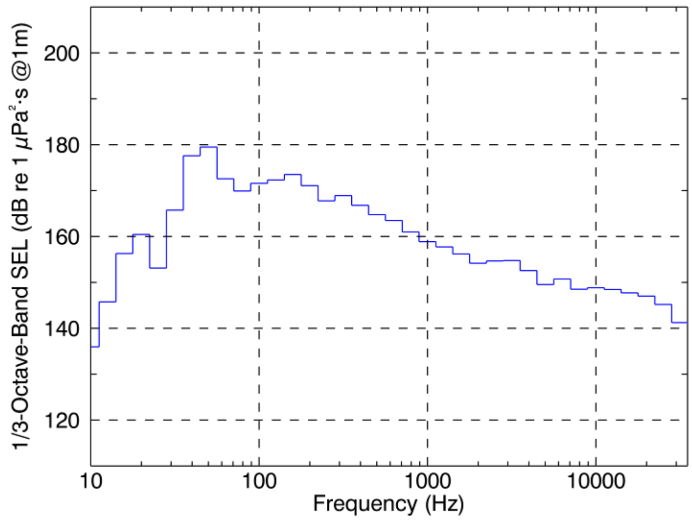


FIGURE 3.35. 1/3-octave band source levels for the *Harvey Spirit* from data measured in the Chukchi Sea.

Nanuq

Figure 3.34 shows vessel sound levels as a function of range as measured on the recorders at 0 and 1000 m (0 and 3280 ft) from the vessel SSC track line in the Chukchi Sea. The *Nanuq* completed two passes along the SSC track at two different speeds; results from both transits are shown. Table 3.16 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.35).

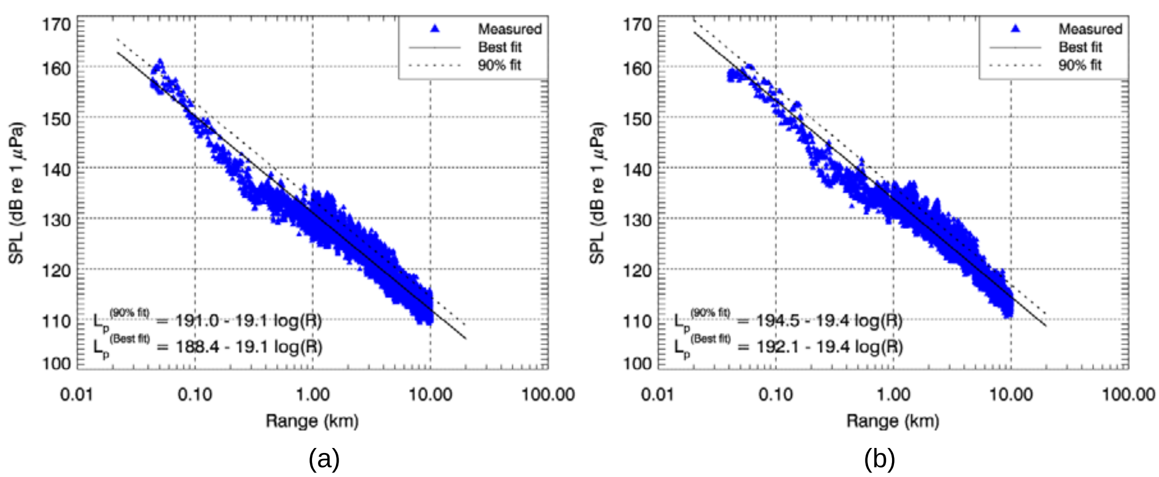


FIGURE 3.36. Vessel SPLs (rms) from AMAR A and AMAR C for the *Nanuq* transiting at (a) 9.1 kts and (b) 10.8 kts in the Chukchi Sea.

TABLE 3.18. Measured radii for the *Nanuq*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL (dB re 1 µPa)	Transiting at 9.1 kts		Transiting at 10.8 kts	
	Best-Fit Line Radius (m)	90th Percentile Radius (m)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	< 10	< 10	< 10	< 10
180	< 10	< 10	< 10	< 10
170	< 10	13	14	18
160	31	42	45	60
150	100	140	150	200
140	340	460	480	640
130	1100	1500	1600	2100
120	3800	5200	5200	6900

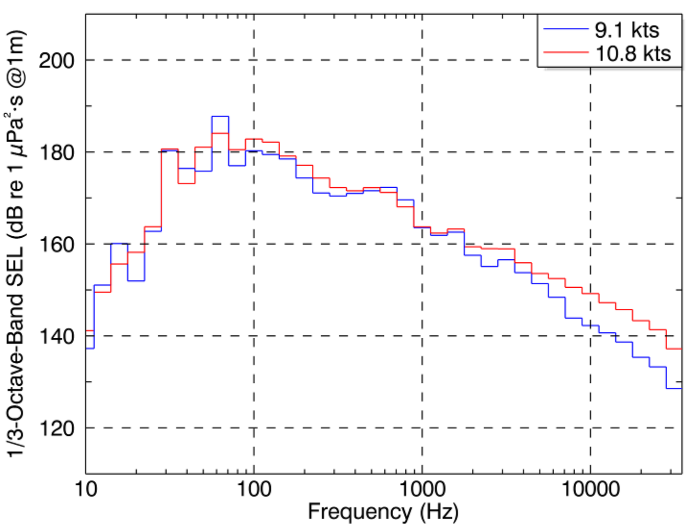


FIGURE 3.37. 1/3-octave band source levels for the *Nanuq* from data measured in the Chukchi Sea.

Noble Discoverer (towed by Tor Viking II)

Figure 3.36 shows vessel sound levels as a function of range as measured on AMAR A at ranges up to 100 m. Data beyond 100 m were dominated by sound from the *Tor Viking II*, and are thus not included in the plot. Table 3.17 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.37).

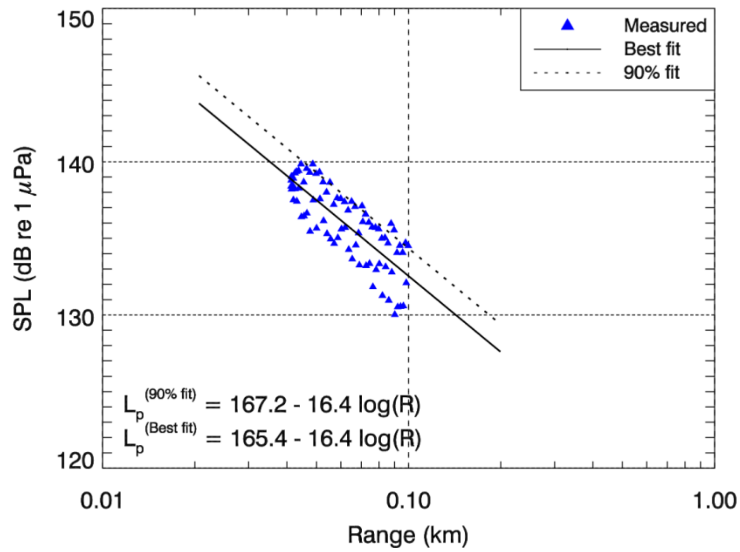


FIGURE 3.38. Vessel SPLs (rms) from AMAR A for the *Noble Discoverer* transiting at 9.0 kts while being towed by the *Tor Viking II* in the Chukchi Sea. The higher levels represent the aft direction from the vessel.

TABLE 3.19. Measured radii for the *Noble Discoverer* transiting at 9.0 kts while being towed by the *Tor Viking II*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	0	0
170	< 10	< 10
160	< 10	< 10
150	< 10	11
140	35	45
130*	140	180
120*	580	740

* Extrapolated beyond measurement range.

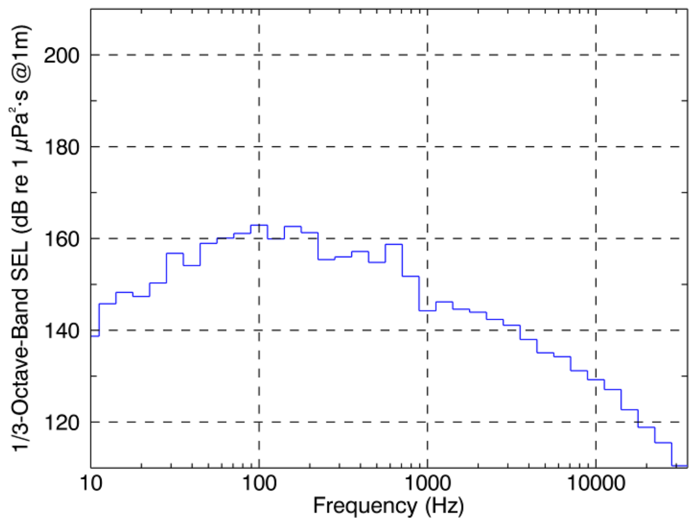


FIGURE 3.39. 1/3-octave band source levels for the *Noble Discoverer* from data measured in the Chukchi Sea.

Nordica

Figure 3.38 shows vessel sound levels as a function of range as measured on the recorders at 0 and 1000 m (0 and 3280 ft) from the vessel SSC track line in the Chukchi Sea. Table 3.18 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.39).

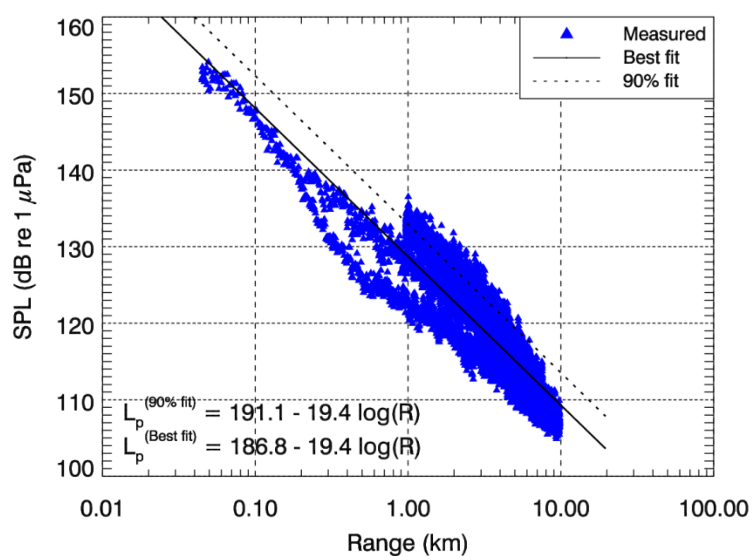


FIGURE 3.40. Vessel SPLs (rms) from AMAR A and AMAR C for the *Nordica* transiting at 12.1 kts in the Chukchi Sea. The higher levels represent the aft direction from the vessel. The increased levels at ranges greater than 1 km are data from AMAR C.

TABLE 3.20. Measured radii for the *Nordica*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	< 10	< 10
180	< 10	< 10
170	< 10	10
160	24	40
150	80	130
140	260	430
130	860	1400
120	2800	4600

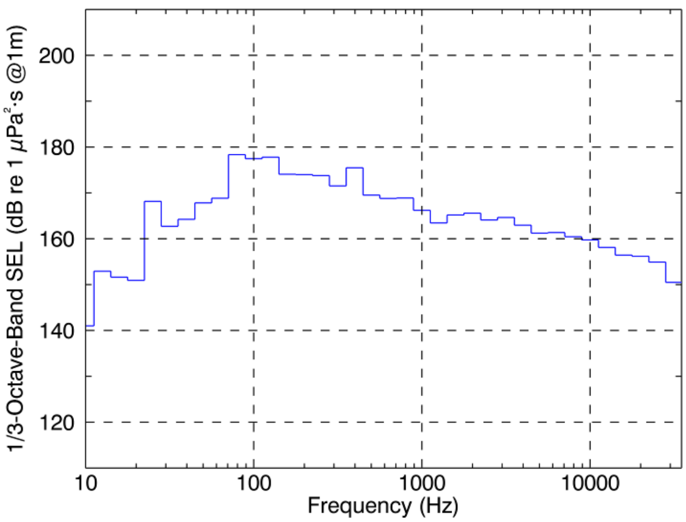


FIGURE 3.41. 1/3-octave band source levels for the *Nordica* from data measured in the Chukchi Sea.

Tor Viking II (towing the Noble Discoverer)

Figure 3.40 shows vessel sound levels as a function of range as measured on the recorders at 0 m (0 ft) and 1000 m (3280 ft) from the vessel SSC track line in the Chukchi Sea. Table 3.19 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.41).

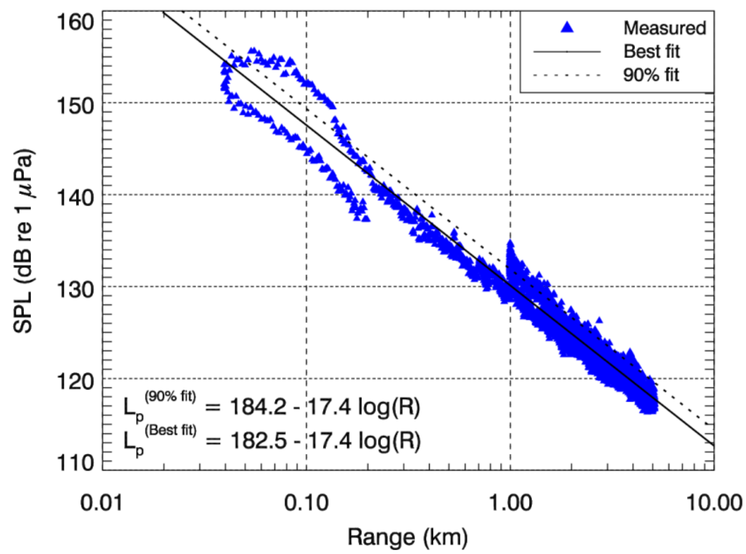


FIGURE 3.42. Vessel SPLs (rms) from AMAR A and AMAR C for the *Tor Viking II* transiting at 9.0 kts while towing the *Noble Discoverer* in the Chukchi Sea. The higher levels represent the aft direction from the vessel. The increased levels at ranges greater than 1 km are data from AMAR C.

TABLE 3.21. Measured radii for the *Tor Viking II* transiting at 9.0 kts while it was towing the *Noble Discoverer*, as determined from the rms SPL versus range data from the Chukchi Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	< 10
180	< 10	< 10
170	< 10	< 10
160	19	25
150	73	92
140	270	340
130	1000	1300
120	3800	4800

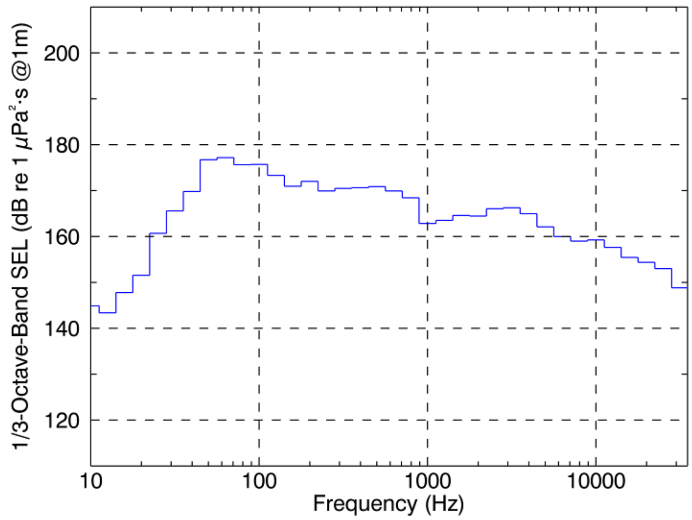


FIGURE 3.43. 1/3-octave band source levels for the *Tor Viking II* from data measured in the Chukchi Sea.

Sivulliq-N Prospect Site, Beaufort Sea

Kulluk Drilling Activities

The mooring anchors for the *Kulluk* were deployed by the *Aiviq* and the *Tor Viking II* from 18–22 Aug. An AMAR deployed at 1.5 km (4920 ft) from the drill site recorded sounds from these activities. Daily spectrogram plots for this period are shown in Appendix H. The *Kulluk* moved onto the Sivulliq-N drill site on 25 Sept and commenced drilling the pilot hole on 3 Oct. MLC drilling began on 14 Oct, continued through 18 Oct, then occurred again from 22–23 Oct, at which time the AMARs were retrieved. Daily spectrogram plots in Appendix H show the sound levels recorded from 3–23 Oct, annotated to indicate drilling activities and the presence of ancillary vessels (within 5 km (16,400 ft) of the AMARs).

Figure 3.42 through Figure 3.46 show hourly SPL values (broadband and decade band) from 3–23 Oct for the five AMARs at 1, 1.5, 2, 4, and 8 km (3280, 4920, 6560, 13,120, and 26,240 ft) from the Sivulliq-N drill site. Elevated SPLs from 3–4 Oct are attributed to vessel noise from the *Nordica*, *Sisuaq*, and *Aiviq* (refer to the daily spectrogram plots in Appendix H for annotations relating vessel presence to received levels). However, elevated received levels also occurred during MLC drilling (14–18 Oct and 22 Oct) when there were no ancillary vessels near the AMARs.

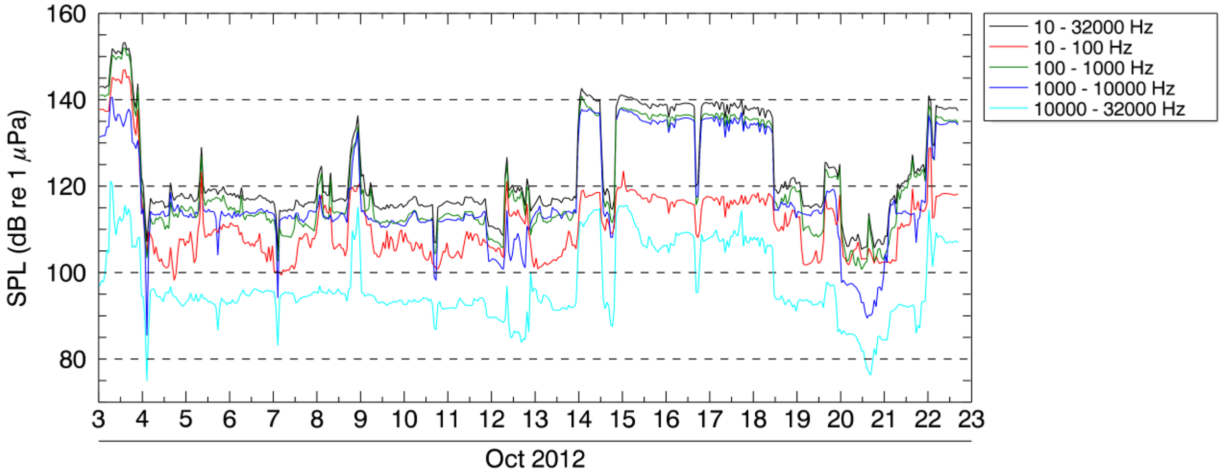


FIGURE 3.44. Hourly SPLs during drilling activities at Sivulliq-N, 3-23 Oct 2012 UTC, at 1 km (3280 ft) from the drill site.

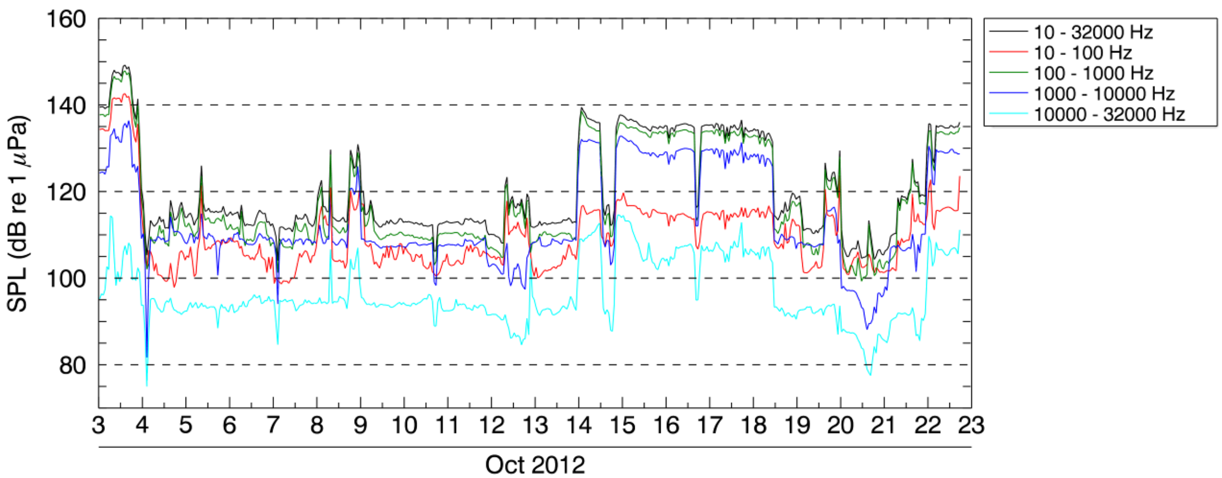


FIGURE 3.45. Hourly SPLs during drilling activities at Sivulliq-N, 3-23 Oct 2012 UTC, at 1.5 km (4920 ft) from the drill site.

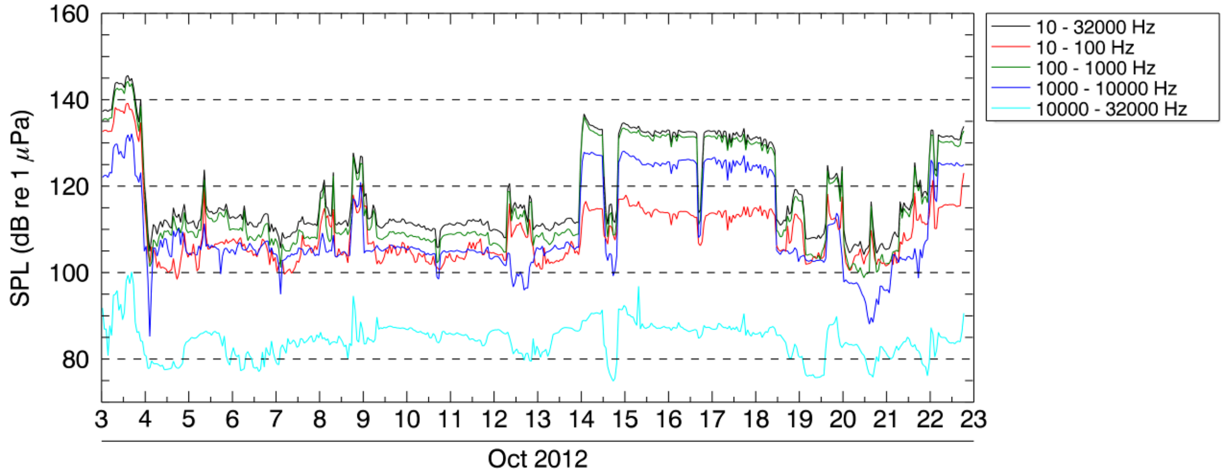


FIGURE 3.46. Hourly SPLs during drilling activities at Sivulliq-N, 3-23 Oct 2012 UTC, at 2 km (6560 ft) from the drill site.

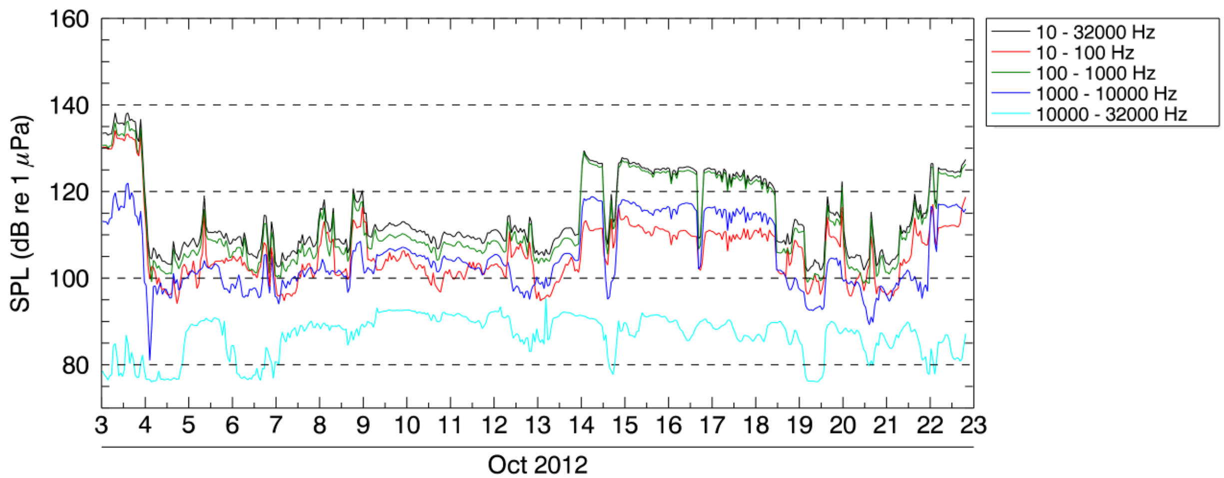


FIGURE 3.47. Hourly SPLs during drilling activities at Sivulliq-N, 3-23 Oct 2012 UTC, at 4 km (13,120 ft) from the drill site.

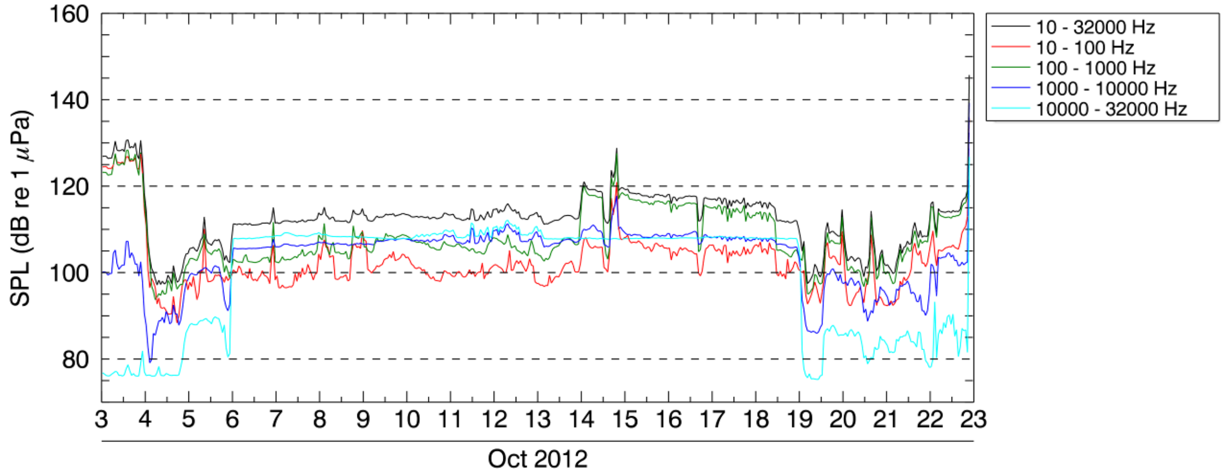


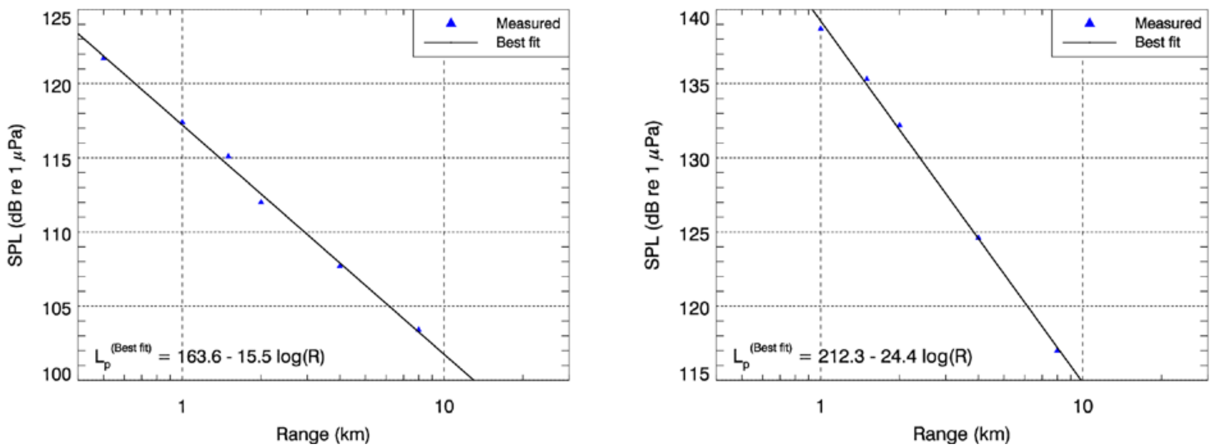
FIGURE 3.48. Hourly SPLs during drilling activities at Sivulliq-N, 3–23 Oct 2012 UTC, at 8 km (26,240 ft) from the drill site. Data from 6–19 Oct were recorded on channel 2 due to a problem with channel 1 at those times. The remaining data came from channel 1.

Vessel GPS logs (provided by the PSOs) and PSO effort logs were used to identify representative periods for drilling activities at Sivulliq-N (Table 3.20). The rms SPLs from each AMAR were averaged over the duration of each identified activity and were plotted versus range (Figure 3.49) to estimate sound level threshold ranges (Table 3.21).

Sound levels recorded while the *Tor Viking II* deployed the *Kulluk* mooring anchor 10 were selected to represent the SPL associated with anchor laying activities. The average SPL received during this activity was 143 dB re 1 µPa at an average range of 860 m (2820 ft). Since there was only a single measurement range for this activity, distances to sound level thresholds were estimated assuming spreading losses of 15log(range) and 20log(range). The true sound threshold ranges would have likely fallen between these two estimates.

TABLE 3.22. Periods selected as representative of drilling activities at Sivulliq-N.

Activity	Analysis Period (UTC)
Drilling pilot hole	03:30–05:00 Oct 4
	19:30–21:00 Oct 4
	01:00–03:30 Oct 5
Drilling mudline cellar	09:00 Oct 15–14:30 Oct 15
	15:30 Oct 15–01:30 Oct 16
	02:30 Oct 16–04:30 Oct 16
	05:00 Oct 16–14:30 Oct 16
	20:00 Oct 16–16:30 Oct 17
	17:30 Oct 17–07:00 Oct 18
Tor Viking II setting *Kulluk* anchor 10, measured at approx. 860m range	13:00 Aug 22–18:00 Aug 22



(a) (b)

FIGURE 3.49. Average SPL versus range while the *Kulluk* was drilling at Sivulliq-N drill site; (a) pilot hole from 4–5 Oct (b) mudline cellar from 15–18 Oct.

TABLE 3.23. Radii to sound levels between 190 and 120 dB re 1µPa for several drilling activities. Based on a linear fit to average sound levels recorded at four ranges at the Sivulliq-N prospect in the Beaufort Sea.

rms SPL (dB re 1 µPa)	Pilot hole Radius (m)	Mudline cellar Radius (m)	Laying anchor #10 15log(range) spreading loss Radius (m)	Laying anchor #10 20log(range) spreading loss Radius (m)
190	< 10	< 10	< 10	< 10
180	< 10	20	< 10	12
170	< 10	60	14	38
160	< 10	140	63	120
150	< 10	360	290	380
140	30	930	1400	1200
130	150	2390	6300	3800
120	660	6200	29,000	12,000

Figure 3.47 and Figure 3.48 are spectral density plots for 10-minute samples of noise from the *Kulluk* during pilot hole drilling and MLC drilling, respectively. The tonal structure is more evident for pilot hole drilling compared to MLC drilling. As explained above, this is due to the different mechanisms of sound generation for the two activities. The received levels are also lower during pilot hole drilling, particularly for frequencies between approximately 300 Hz and 10 kHz. The strong decay of the high frequency tones (> 1 kHz) is again noted, as for the Burger-A results above, due to absorption in the water column.

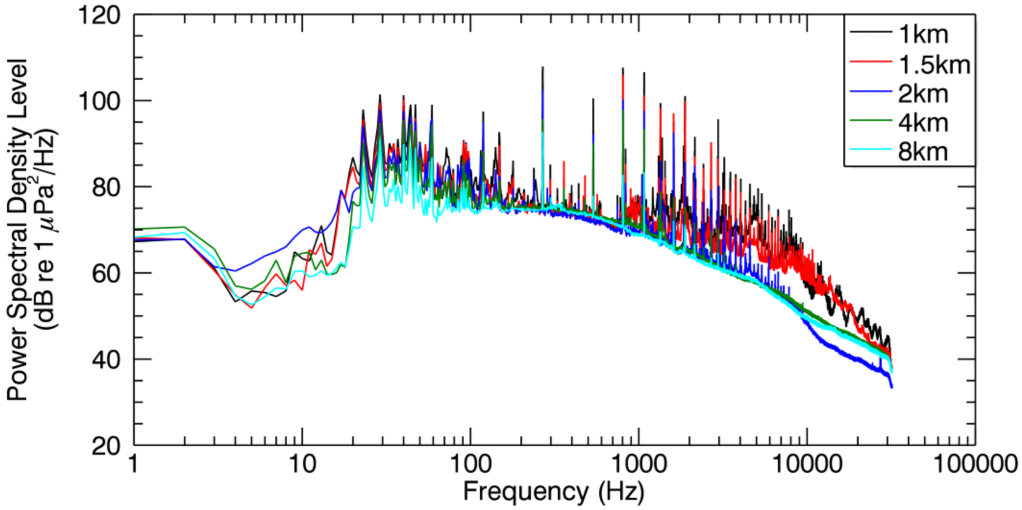


FIGURE 3.50. Power spectral density for drilling a pilot hole at the Sivulliq-N drill site on 5 Oct as received on AMARs at five ranges.

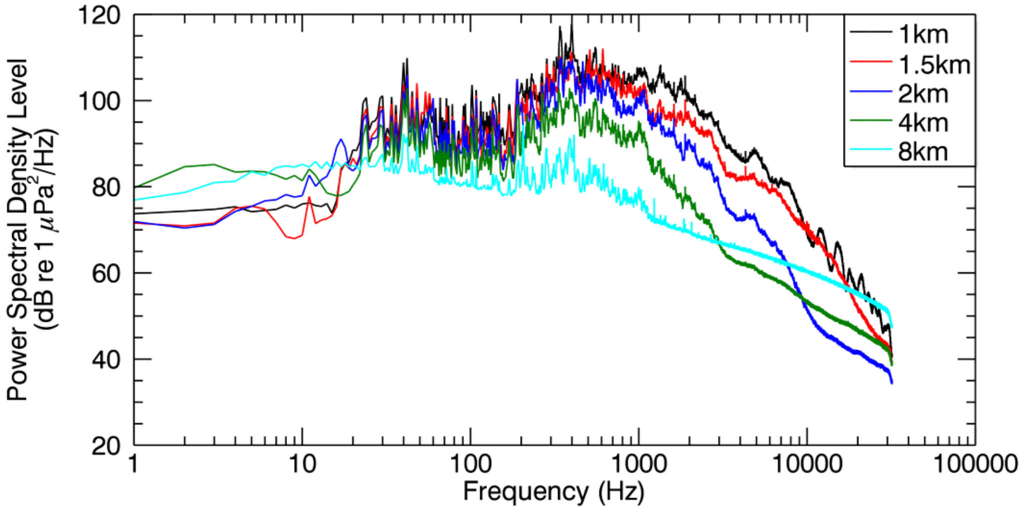


FIGURE 3.51. Power spectral density for drilling a pilot hole at the Sivulliq-N drill site on 15 Oct as received on AMARs at five ranges.

A broadband (10 Hz–32 kHz) source level of 172 dB was calculated for the *Kulluk* based on the measurements for drilling of the pilot hole. Figure 3.52 is a plot of the 1/3rd-octave band source level distribution for this activity.

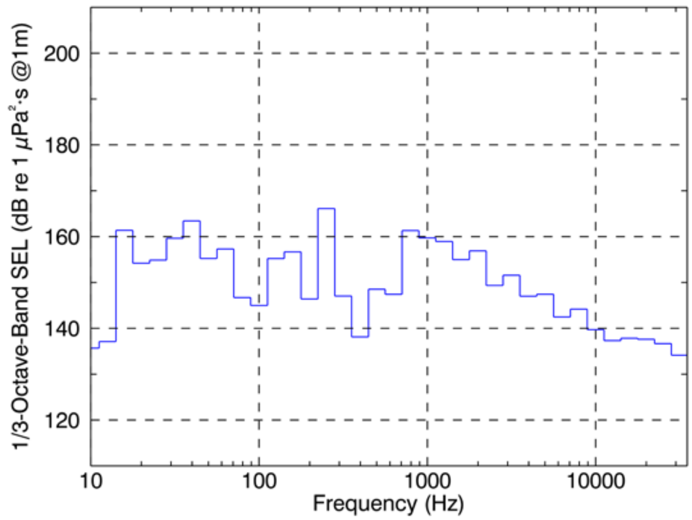


FIGURE 3.52 1/3-octave band source level for the *Kulluk*,drilling a pilot hole at the Sivulliq-N drill site.

Support Vessels

Affinity

Figure 3.50 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.22 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.51).

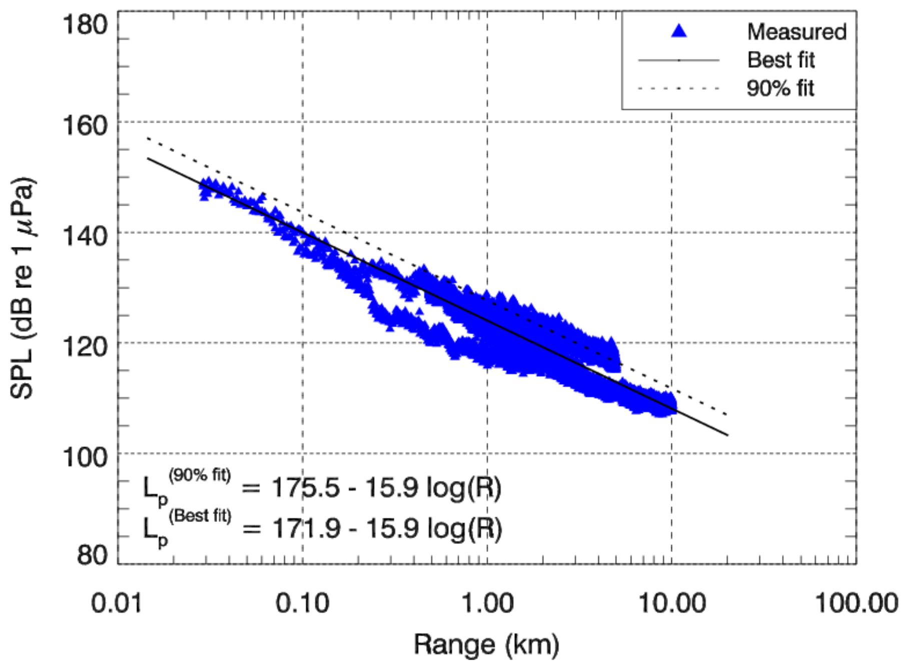


FIGURE 3.53. Vessel SPLs (rms) from AMAR A, B, and C for the *Affinity* transiting at 9.0 kts in the Beaufort Sea. The higher levels represent the aft direction from the vessel.

TABLE 3.24. Measured radii for the *Affinity* transiting at 9.0 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	0	< 10
170	< 10	< 10
160	< 10	< 10
150	24	40
140	100	170
130	420	720
120	1800	3000

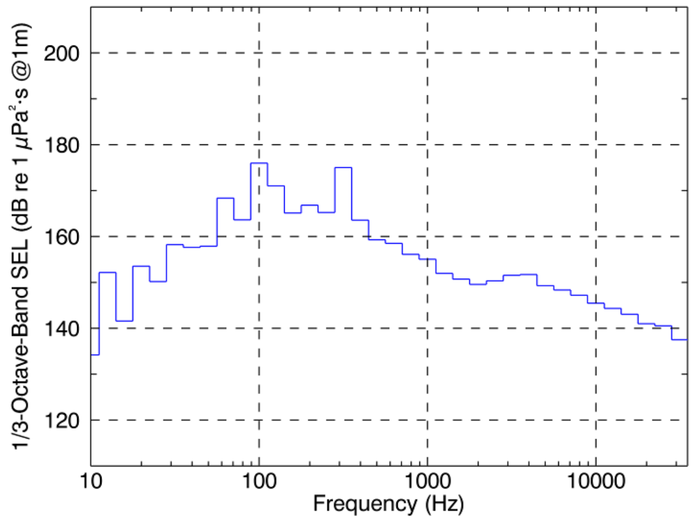


FIGURE 3.54. 1/3-octave band source levels for the *Affinity* from data measured in the Beaufort Sea.

Aiviq

Figure 3.52 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.23 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.53).

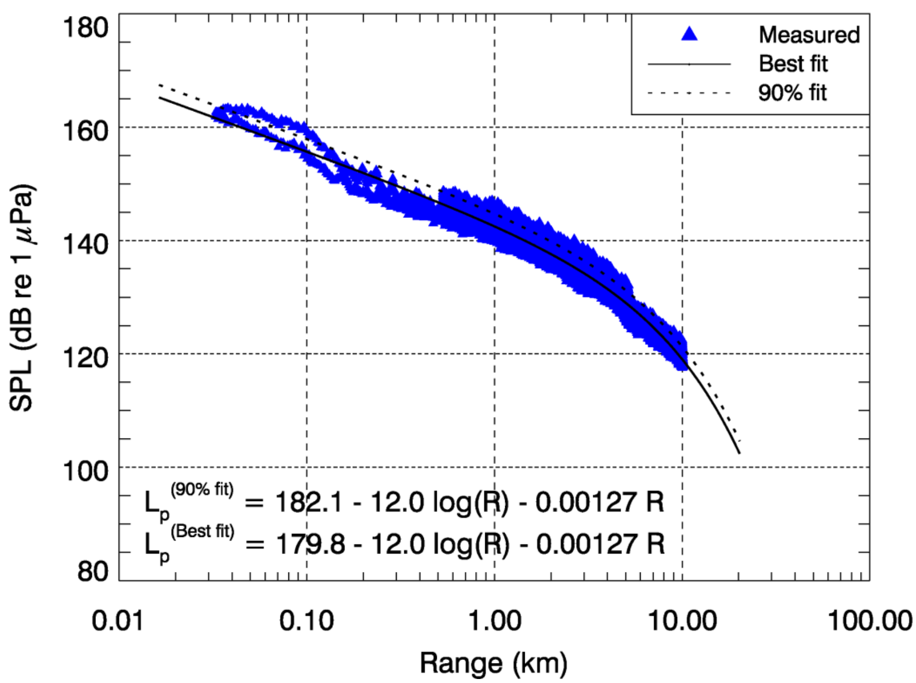


FIGURE 3.55. Vessel SPLs (rms) from AMARs A, B, and C for the *Aiviq* transiting at 8.8 kts in the Beaufort Sea. The higher levels represent the aft direction from the vessel.

TABLE 3.25. Measured radii for the *Aiviq* transiting at 8.8 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	< 10	< 10
170	< 10	10
160	44	67
150	280	420
140	1400	2000
130	4600	5500
120	9500	11,000

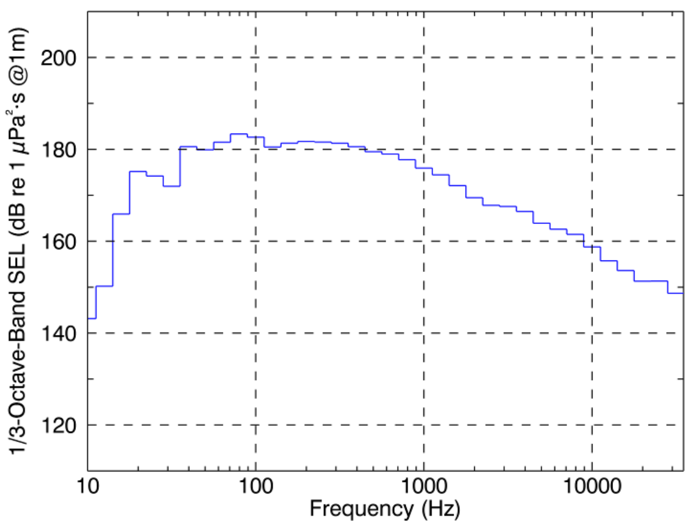


FIGURE 3.56. 1/3-octave band source levels for the *Aiviq* from data measured in the Beaufort Sea.

Arctic Seal

Figure 3.54 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.24 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.55).

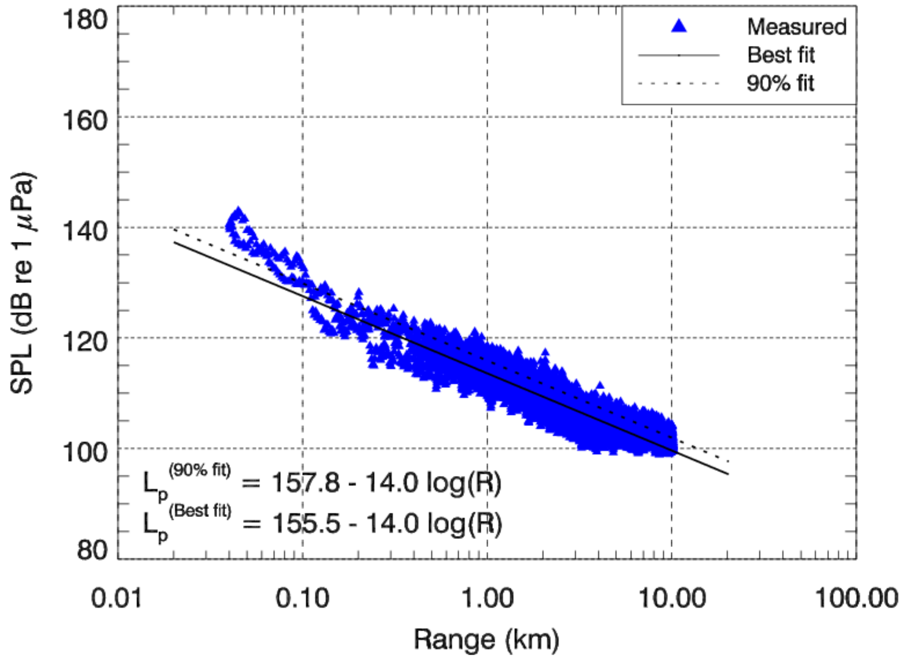


FIGURE 3.57. Vessel SPLs (rms) from AMAR A, B, and C for the *Arctic Seal* transiting at 9 kts in the Beaufort Sea.

TABLE 3.26. Measured radii for the *Arctic Seal* transiting at 9 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	0	0
170	0	0
160	< 10	< 10
150	< 10	< 10
140	13	19
130	67	98
120	350	510

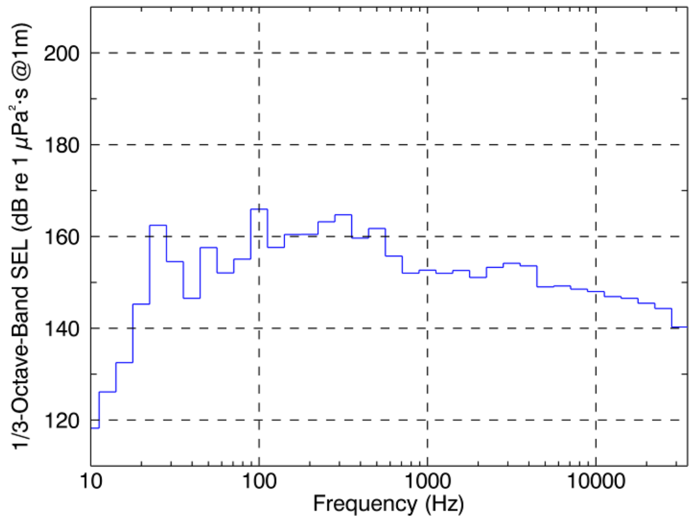


FIGURE 3.58. 1/3-octave band source levels for the *Arctic Seal* from data measured in the Beaufort Sea.

Lauren Foss (towing the Tuuq)

Figure 3.56 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.25 lists the ranges to SPL thresholds between 190 and 120 dB re 1 μPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.57).

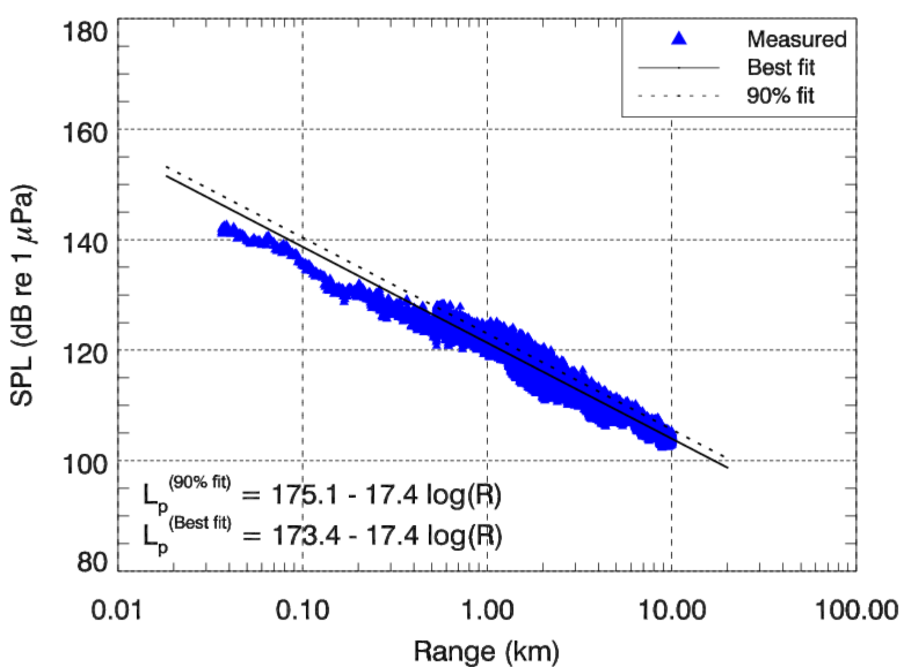


FIGURE 3.59. Vessel SPLs (rms) from AMAR A, B, and C for the *Lauren Foss* transiting at 6.5 kts in the Beaufort Sea while it was towing the *Tuuq*.

TABLE 3.27. Measured radii for the *Lauren Foss* transiting at 6.5 kts while it was towing the *Tuuq*, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius m (42 ft)
190	0	0
180	0	< 10
170	< 10	< 10
160	< 10	< 10
150	22	28
140	84	100
130	320	400
120	1200	1500

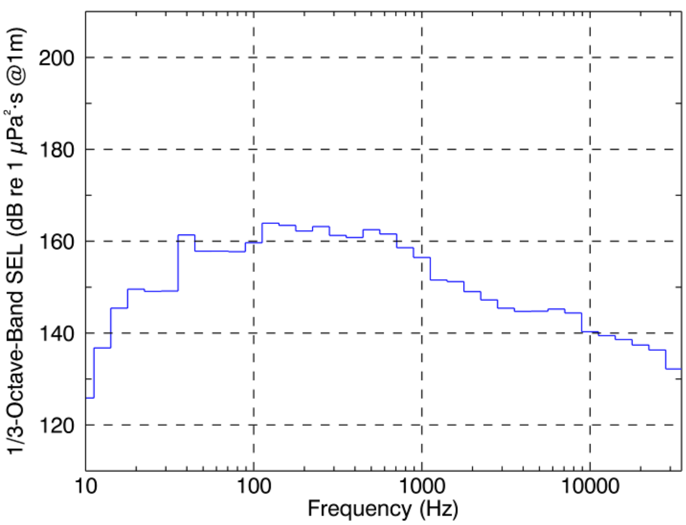


FIGURE 3.60. 1/3-octave band source levels for the *Lauren Foss* from data measured in the Beaufort Sea.

Nordica

Figure 3.58 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.26 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.59).

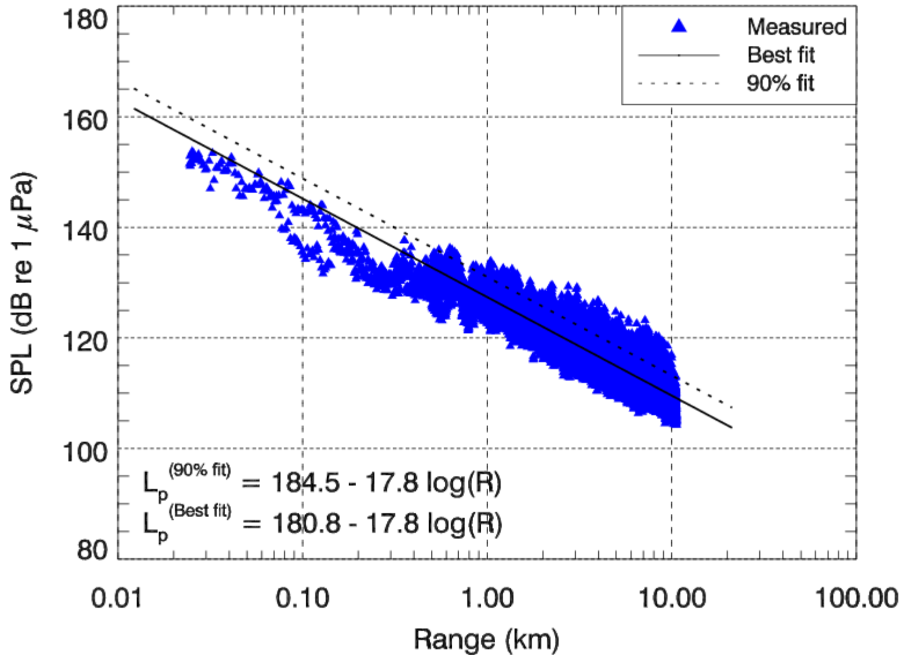


FIGURE 3.61. Vessel SPLs (rms) from AMAR A and C for the *Nordica* transiting at 9 kts in the Beaufort Sea. The sound levels are slightly higher on the vessel approach.

TABLE 3.28. Measured radii for the *Nordica* transiting at 9 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	< 10
180	< 10	< 10
170	< 10	< 10
160	15	24
150	54	86
140	200	310
130	710	1100
120	2600	4200

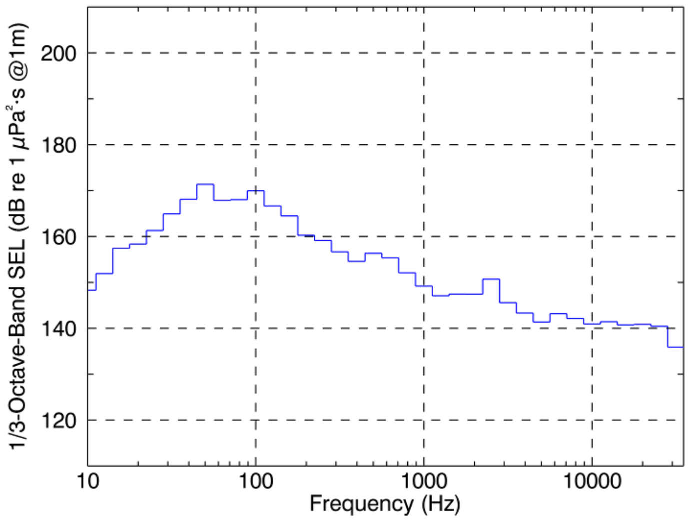


FIGURE 3.62. 1/3-octave band source levels for the *Nordica* from data measured in the Beaufort Sea.

Pt Oliktok

Figure 3.60 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.27 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.61).

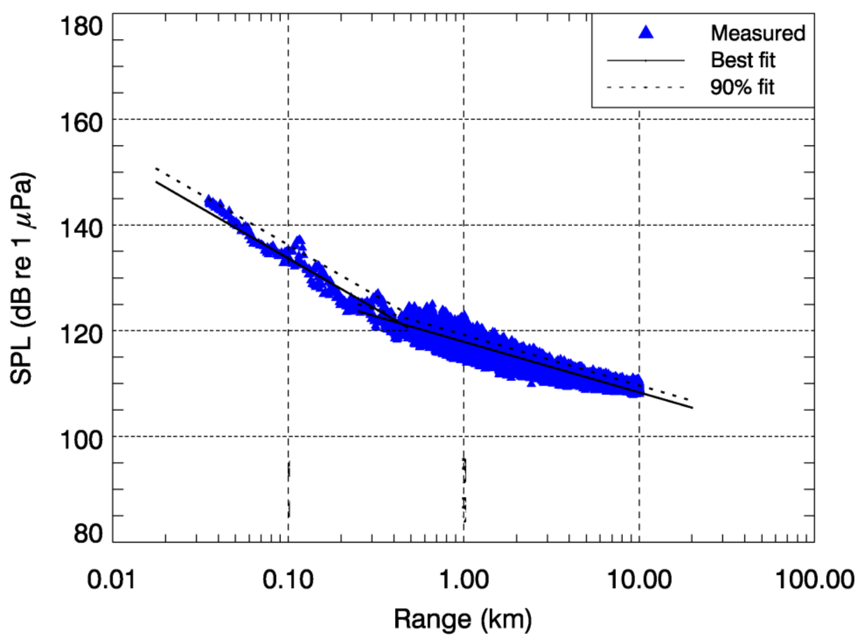


FIGURE 3.63. Vessel SPLs (rms) from AMAR A, B, and C for the *Pt Oliktok* transiting at 8.7 kts in the Beaufort Sea.

TABLE 3.29. Measured radii for the *Pt Oliktok* transiting at 8.7 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	0	< 10
170	< 10	< 10
160	< 10	< 10
150	14	19
140	47	64
130	160	210
120	610	830

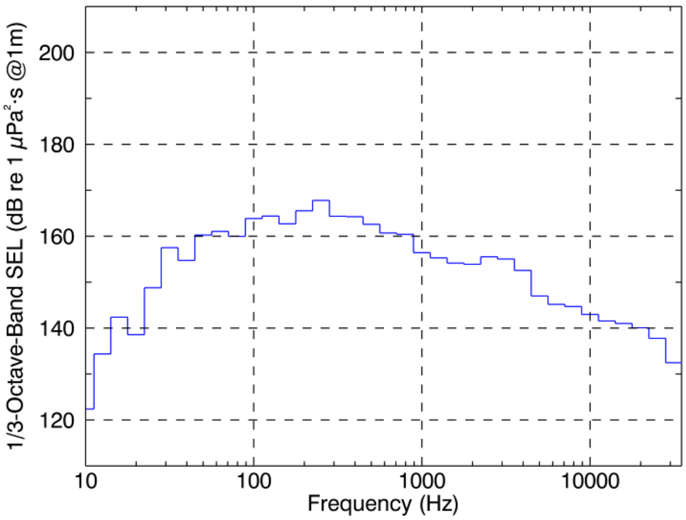


FIGURE 3.64. 1/3-octave band source levels for the *Pt Oliktok* from data measured in the Beaufort Sea.

Sisuaq

Figure 3.62 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.28 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.63).

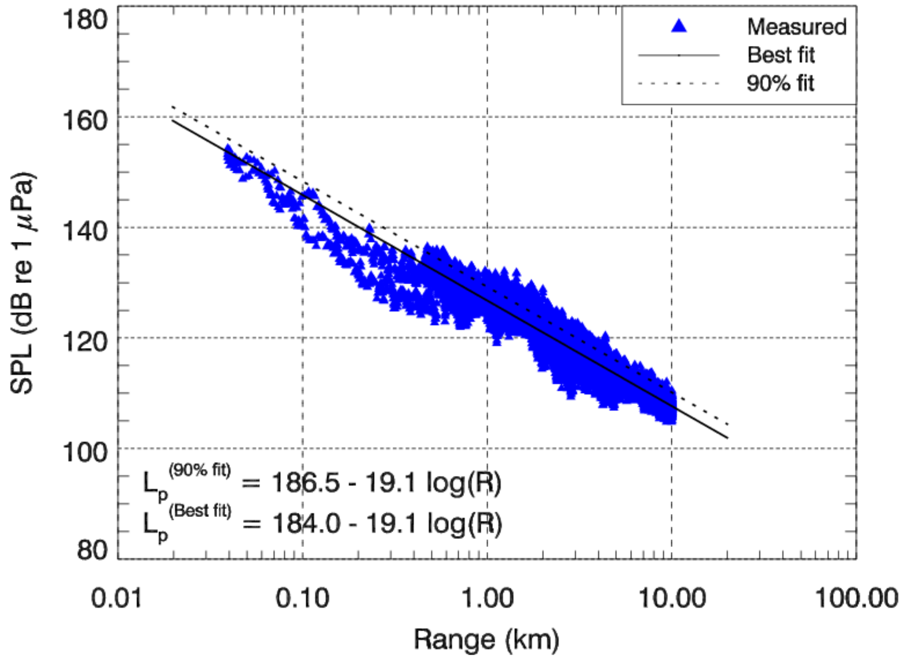


FIGURE 3.65. Vessel SPLs (rms) from AMAR A, B, and C for the *Sisuaq* transiting at 8.7 kts in the Beaufort Sea. The higher levels represent the forward direction from the vessel.

TABLE 3.30. Measured radii for the *Sisuaq* transiting at 8.7 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	< 10	< 10
180	< 10	< 10
170	< 10	< 10
160	18	25
150	61	82
140	200	270
130	680	910
120	2300	3000

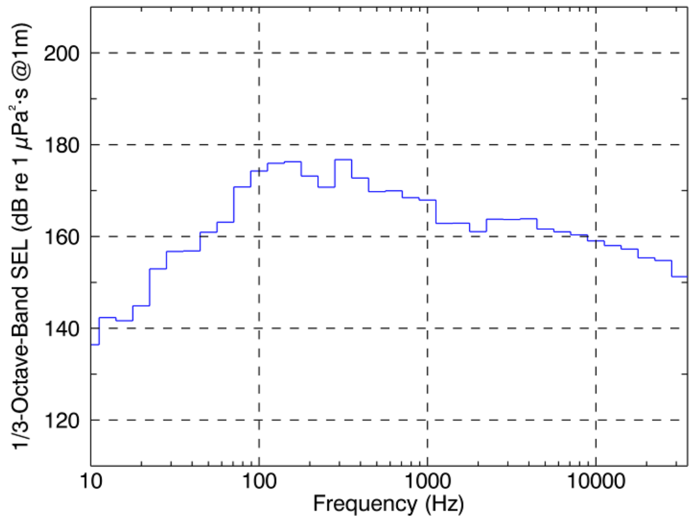


FIGURE 3.66. 1/3-octave band source levels for the *Sisuaq* from data measured in the Beaufort Sea.

Tor Viking II

Figure 3.64 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.29 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.65).

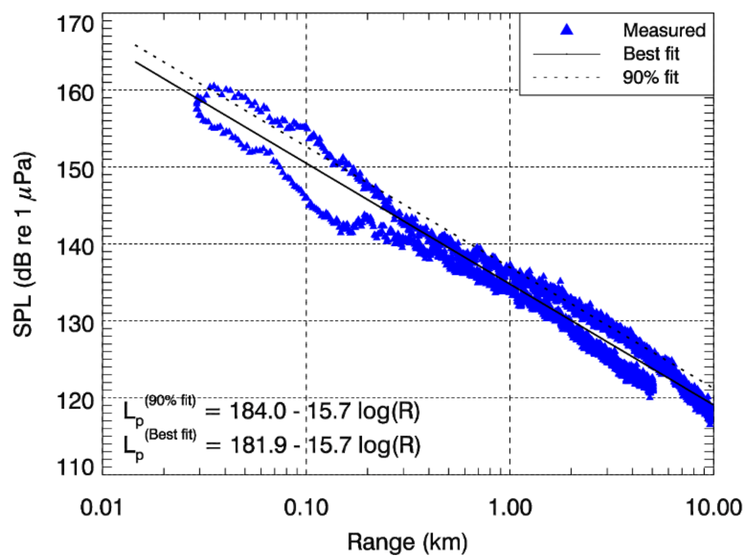


FIGURE 3.67. Vessel SPLs (rms) for the *Tor Viking II* transiting at 9.0 kts in the Beaufort Sea. At a given range, higher sound levels represent the aft direction from the vessel.

TABLE 3.31. Measured radii for the *Tor Viking II* transiting at 9.0 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	0	0
180	< 10	< 10
170	< 10	< 10
160	25	34
150	110	150
140	470	640
130	2000	2800
120	8700	12,000

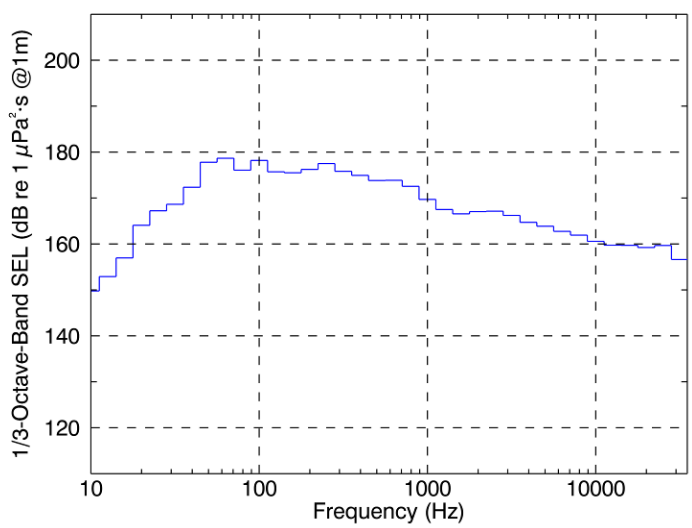


FIGURE 3.68. 1/3-octave band source levels for the *Tor Viking II* from data measured in the Beaufort Sea.

Warrior

Figure 3.66 shows vessel sound levels as a function of range as measured on each AMAR. Table 3.30 lists the ranges to SPL thresholds between 190 and 120 dB re 1 µPa based on the 90th-percentile and the best-fit lines to these data. Mean 1/3-octave band source levels were calculated from 10 s of data centered on the CPA (Figure 3.67).

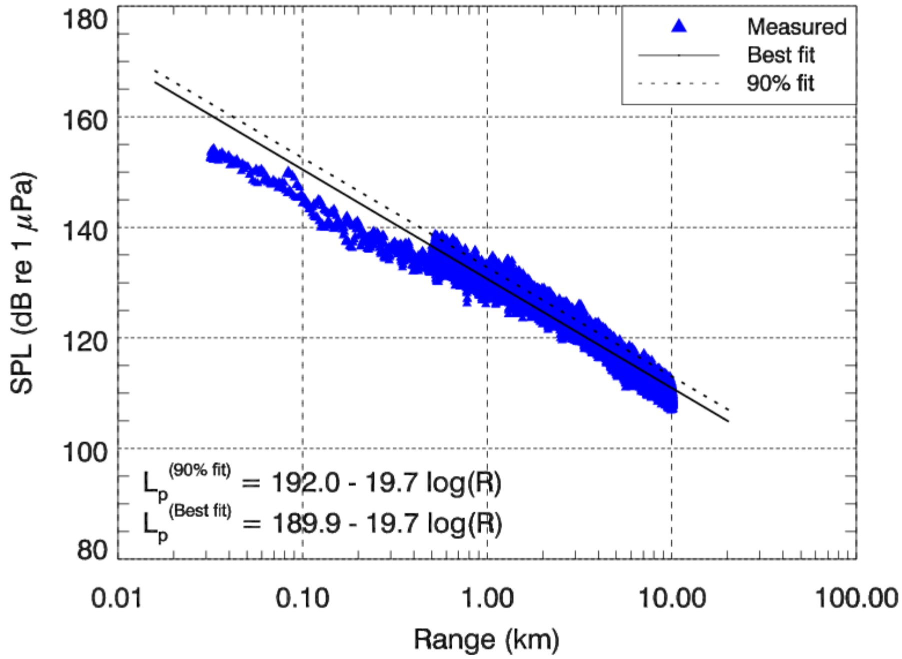


FIGURE 3.69. Vessel SPLs (rms) from AMAR A, B, and C for the *Warrior* transiting at 8.7 kts in the Beaufort Sea.

TABLE 3.32. Measured radii for the *Warrior* transiting at 8.7 kts, as determined from the rms SPL versus range data from the Beaufort Sea.

rms SPL Threshold (dB re 1 µPa)	Best-Fit Line Radius (m)	90th Percentile Radius (m)
190	< 10	< 10
180	< 10	< 10
170	10	13
160	33	42
150	110	130
140	340	430
130	1100	1400
120	3500	4400

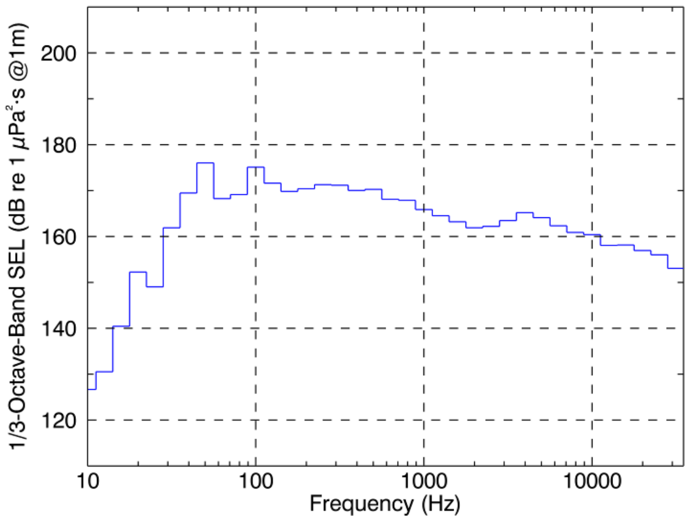


FIGURE 3.70. 1/3-octave band source levels for the *Warrior* from data measured in the Beaufort Sea.

Discussion

Vessel Directivity

The configuration of the AMARs for the support vessel SSC measurements allowed an examination of the directionality of the vessel sound levels. Table 3.31 compares the levels recorded at 500 and 1000 m (1640 and 3280 ft) in the fore, aft, and broadside directions for each prospect. The broadside sound levels were greater than those in the fore and aft directions in almost every case.

TABLE 3.33. Comparison of sound levels received at two ranges in the broadside, fore, and aft directions from the support vessel SSC measurements. Values shown are SPLs in dB re 1 µPa.

		500 m			1000 m		
Vessel	Speed	Broadside	Fore	Aft	Broadside	Fore	Aft
Burger-A Prospect, Chukchi Sea							
Affinity	9.0	–	119.7	126.3	120.6	115.7	120.9
Affinity	8.8	–	119.8	125.5	121.7	114.9	120.7
H Explorer	8.5	130.5	126.8	123.9	127.0	122.4	121.6
H Spirit	6.2	–	127.0	127.8	129.2	123.3	124.5
Nanuq	9.1	–	134.2	132.0	133.1	130.2	129.4
Nanuq	10.8	–	138.3	134.9	134.1	131.8	132.5
Nordica	12.1	–	132.8	125.8	132.8	128.5	123.1
Aiviq	3.4	–	144.0	142.4	141.0	138.9	136.5
Guardsman	9.4	137.9	134.8	133.9	133.0	130.0	125.3
Tor Viking II	9.0	–	134.1	132.7	132.5	129.6	124.3
Discoverer	9.0	–	137.3	122.3	131.4	137.5	120.9
Fennica	12.0	–	132.7	125.3	130.4	128.0	121.2
Fennica	8.0	–	125.4	126.5	124.8	119.8	119.4
Sivulliq-N Prospect, Beaufort Sea							
Affinity	9.0	130.3	130.9	129.8	126.3	126.8	126.0
Aiviq	8.8	147.8	145.1	143.6	143.6	140.5	140.5
Arctic Seal	9.0	118.2	119.7	115.3	114.4	114.4	111.6
Lauren Foss	6.5	126.8	125.0	123.8	122.7	120.4	120.2
Nordica	9.0	132.6	129.5	127.0	131.2	124.6	125.6
Pt Oliktok	8.7	123.8	123.3	119.5	120.1	117.7	115.4
Sisuaq	8.7	133.9	132.0	126.6	129.7	127.3	126.5
Warrior	8.7	136.4	133.1	132.7	132.2	128.8	129.7
Tor Viking II	9.0	–	137.8	140.2	–	134.0	136.8

Comparison with Pre-Season Model

In 2011 an acoustic model was applied to estimate the expected propagation range for sound levels during drilling operations at Burger and Sivulliq (Warner and Hannay 2011). The model scenarios considered drilling noise from the *Noble Discoverer* (based on measurements that JASCO collected in 2009) combined with noise from a support vessel, which was idling alongside the drill ship. Sound levels from these two sources were modeled at the Burger, Torpedo, and Sivulliq prospects. At frequencies below 200 Hz, the modeled sounds from drilling dominated the sounds of the support vessel idling nearby. The field measurements from 2012 indicated that when vessels were operating near the drill ship, they generally were not idle; rather, they were moving, thus generating considerable underwater sound levels relative to the drill ship. As such, the modeled scenario is most comparable to the 2012 measurements of drilling sounds in the absence of nearby vessels. The table below compares the modeled and measured results for each prospect site. The modeled ranges slightly underestimated those measured at Burger-A, but overestimated those measured at Sivulliq-N. This overestimation may be because of a discrepancy between the modeled and measured noise sources; source levels for the *Noble Discoverer* were applied to the Sivulliq model scenario, but the *Kulluk* was the source measured at Sivulliq-N.

TABLE 3.34 Comparison of measured range to 120 dB re 1 µPa with that from a 2011 model estimate.

	Burger-A		Sivulliq-N*	
Received Level (dB re 1 µPa)	2011 ModelEstimate (km)	2012 Measurement—Drilling 26 in hole (km)	2011 ModelEstimate (km)	2012 Measurement—Drilling 26 in hole (km)
140	0.071	0.10	0.112	0.03
130	0.26	0.39	0.427	0.15
120	1.31	1.5	2.2	0.66

* *Noble Discoverer* used as noise source in model, *Kulluk* was measured noise source.

Underwater Sound Levels from Industrial Activities in the Chukchi and Beaufort Seas

This section considers the sound levels reported in this chapter in the context of the industrial activities that have occurred in the Chukchi and Beaufort Seas over the past several years. Table 3.33 lists the specific programs for which acoustic measurements in the Chukchi and Beaufort Seas have been reported since 2006. All of the listed programs involved sounds from seismic airgun sources, which produced high amplitude, impulsive sounds that differ from the lower amplitude continuous sounds that characterize the noise from vessels and equipment used in drilling. Many of the programs also reported sounds from support vessels. Figure 3.68 shows the ranges to 120 dB re 1 µPa for every vessel SSC measurement reported since 2007, as well as for the vessel SSC measurements from this study. The ranges to 120 dB re 1 µPa from this study were within the bounds of those that have previously been reported, with the exception of one measurement of the *Aiviq* towing the *Kulluk*.

TABLE 3.35 Oil and gas exploration projects in the Chukchi and Beaufort project areas, from 2006 to 2011, which reported measurements of sound levels produced by their activities.

Project Operator and Year	Primary Survey Type	Location	Water Depths (m)	Airgun Array	Survey Vessel	Support Vessel	Sidescan/ Multibeam	Sub-bottom Profiler	Spark/ Boom/ Pulse	Reference
Shell Offshore Inc., 2006	3-D	Chukchi		X	X	X			X	Blackwell 2007
GX Technology 2006	2-D	Chukchi		X						Austin & Laurinolli 2007
ConocoPhillips Alaska, 2006	3-D	Chukchi		X	X					MacGillivray & Hannay 2007
Shell Offshore Inc., 2007	3-D, SH	Chukchi, Beaufort		X	X	X		X	X	Hannay, 2008
Eni and PGS, 2008	OBC	Beaufort	2-14	X	X	X				Warner et al. 2008
BP Alaska, 2008	OBC	Beaufort		X	X	X				Aerts et al. 2008
Shell Offshore Inc., 2008	3-D, SH	Chukchi, Beaufort	19-44	X	X	X		X	X	Hannay and Warner 2009
Shell Offshore Inc., 2009	SH	Chukchi	48, 41	X	X			X		Warner et al. 2010
Statoil, 2010	3-D	Chukchi	38-43	X						O'Neill et al. 2010
Shell Offshore Inc., 2010	SH,GT	Chukchi, Beaufort	46-51 15-38	 X	X X		X X	X X		Chorney et al. 2011
Statoil USA E&P Inc., 2011	SH, GT	Chukchi	37	X	X		X	X		Warner and McCrodan 2011

Notes:

2-D = 2-Dimensional seismic survey using airgun array sources.

3-D = 3-Dimensional seismic survey using airgun array sources.

OBC = Ocean Bottom Cable survey using airgun array sources.

SH = Shallow hazards or site clearance survey using small airgun arrays, sparkers or boomers or bubble pulsers.

GT = Geotechnical survey using sidescan, multibeam, single beam sonars.

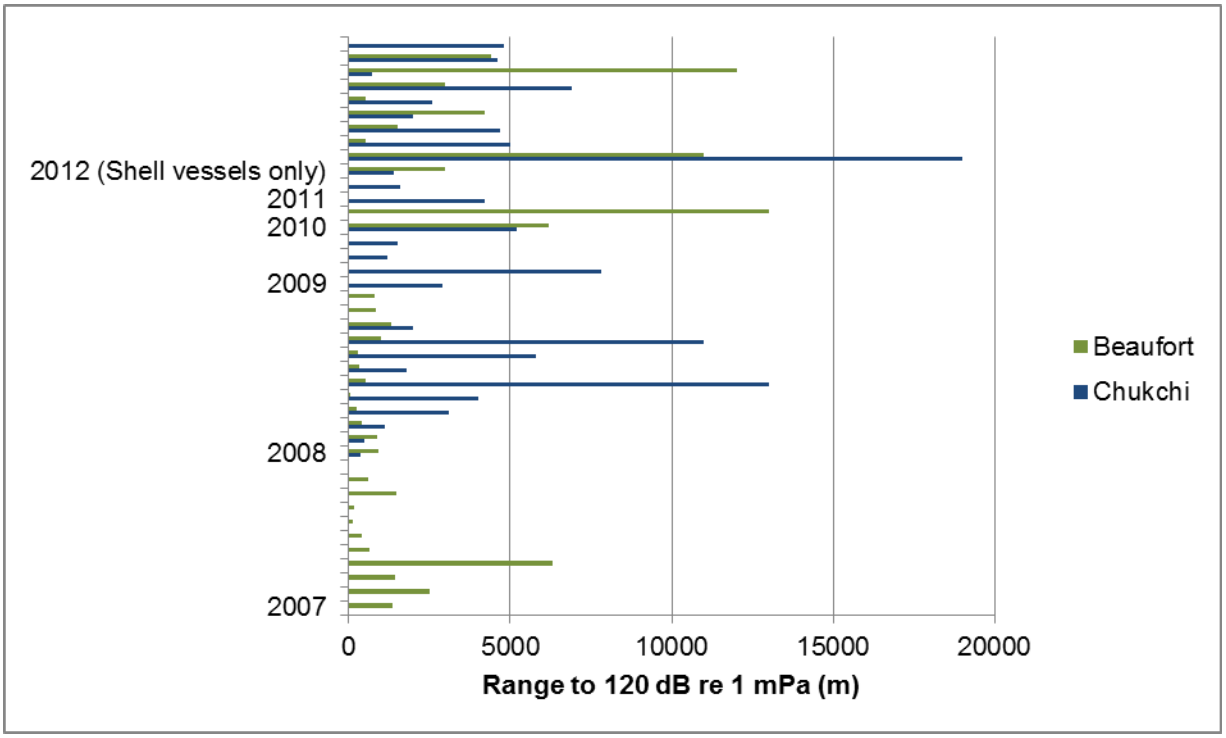


FIGURE 3.71 Ranges to 120 dB re 1 µPa from all vessel SSC measurements reported for programs in the Chukchi and Beaufort Seas since 2007.

Summary

This chapter presented results from an acoustic monitoring study that characterized sounds from vessels and equipment associated with Shell Exploration and Production Company's 2012 drilling programs in the Chukchi and Beaufort Seas. Distances to the sound level thresholds of 190, 180, 160, and 120 dB re 1 µPa are summarized below for each vessel and for each of the activities characterized in this report. The broadband (10 Hz–32 kHz) source level for drilling was calculated to be 181 dB re 1 µPa for the *Noble Discoverer* and 172 dB re 1 µPa for the *Kulluk*.

Burger-A Drill Site

TABLE 3.36. Sound level threshold distances for drilling operations at the Burger-A drill site. Distances were obtained from best-fit lines to averaged sound levels versus range for the respective activity.

Drill Site Activity	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Drilling 8.5 in pilot hole (*Tor Viking II* nearby)	< 10	< 10	22	13,000*
Drilling 17.5 in pilot hole (*Tor Viking II* nearby)	< 10	< 10	< 10	10,000*
Drilling 36 in pilot hole (*Tor Viking II* nearby)	< 10	< 10	30	25,000*
Drilling 26 in hole (no ancillary vessels)	< 10	< 10	< 10	1500
Drilling of MLC	< 10	20	130	8100
Ice management	< 10	< 10	60	9600*

* Extrapolated beyond measurement range.

TABLE 3.37. Sound level threshold distances for vessels operating at the Burger-A drill site. Distances were obtained from the 90th percentile fits to sound level versus range for the respective vessels.

Vessel Name	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Affinity–8.8 kts	0	0	< 10	1300
Affinity–9.0 kts	0	0	< 10	1400
Aiviq (towing the Kulluk)	< 10	< 10	110	19,000
Fennica–8.0 kts	0	< 10	11	2000
Fennica–12.0 kts	< 10	< 10	26	5000
Guardsman (towing the *Klamath*)	< 10	< 10	70	4700
Harvey Explorer	0	< 10	16	2000
Harvey Spirit	0	0	< 10	2600
Nanuq–9.1 kts	< 10	< 10	42	5200
Nanuq–10.8 kts	< 10	< 10	60	6900
Noble Discoverer (towed by *Tor Viking II*)	0	0	< 10	740
Nordica	< 10	< 10	40	4600
Tor Viking II (towing the *Noble Discoverer*)	< 10	< 10	25	4800

Sivulliq-N Drill Site

TABLE 3.38. Sound level threshold distances for drilling operations at the Sivulliq-N drill site. Distances were obtained from the best-fit lines to averaged sound level versus range for the respective activity.

Drill Site Activity	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Anchor laying	< 10	< 12	63–120	12,000–29,000
Drilling of pilot hole	< 10	< 10	< 10	660
Drilling of MLC	< 10	20	140	6200

TABLE 3.39. Sound level threshold distances for vessels operating at the Sivulliq-N prospect, from measurements made from 28 Sep to 2 Oct 2012. Distances were obtained from the 90th percentile fits to sound level versus range for the respective vessels.

Vessel Name	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Affinity	0	< 10	< 10	3000
Aiviq	0	< 10	67	11,000
Arctic Seal	0	0	< 10	510
Lauren Foss (towing the *Tuuq*)	0	< 10	< 10	1500
Nordica	< 10	< 10	24	4200
Pt Oliktok	0	< 10	< 10	830
Sisuaq	< 10	< 10	25	3000
Tor Viking II	0	< 10	30	12,000
Warrior	< 10	< 10	42	4400

A summary of key findings from this analysis are:

- Support vessels generated more noise than drillships actively drilling. In the absence of nearby support vessels, broadband drilling sounds decayed to 120 dB within 1500 m (4950 ft) in the Chukchi Sea and 660 m (2200 ft) in the Beaufort Sea while the pilot holes were drilled. When the *Tor Viking II* operated near the drillship *Noble Discoverer*, received sound levels of 120 dB persisted to ranges of 10 km or greater while pilot holes were drilled.
- Increased sound levels were recorded at each prospect while the mudline cellar was drilled compared to when the pilot holes were drilled. During mudline cellar drilling, sound levels of 120 dB extended to 8.1 km (26,000 ft) in the Chukchi Sea and 6.2 km (20,000 ft) in the Beaufort Sea. Spectral analysis showed that the sound from mudline cellar drilling was broadband in nature with dominant sound energy between 300 Hz and 3 kHz. The noise during mudline cellar drilling likely arose from the MLC bit grinding into the seafloor. In contrast, the sound generated during pilot hole drilling was very tonal in nature and arose from the rotating

machinery on the drillship; these tones were obscured by the broadband mudline cellar drilling sounds .

- While the support vessels transited the SSC track, sound levels received on the broadside were greater than those received in the forward and aft directions for almost every vessel.

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Glossary

1/3-octave band SEL

Frequency resolved sound exposure levels in non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave bands make up one octave. 1/3-octave bands become wider with increasing frequency.

attenuation

The acoustic energy loss due to absorption and scattering.

broadband sound level

The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measurement range.

broadside direction

Perpendicular to the travel direction of a source.

continuous sounds

Sounds that gradually vary in intensity with time, for example, sound from a transiting ship.

decibel

A logarithmic unit of the ratio of a quantity to a reference quantity of the same kind. Unit symbol: decibel (dB).

frequency

The rate of oscillation of a periodic function measured in units of cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. For example, 1 Hz = 1 cycle per second.

Global Positioning System (GPS)

A satellite based navigation system providing accurate worldwide location and time information.

hydrophone

An underwater sound pressure transducer. A passive electronic device for recording or listening to underwater sound.

noise

Unwanted sound that interferes with detecting other sounds.

omnidirectional hydrophone

A hydrophone that has a uniform directivity, i.e., measures sound equally in any direction.

power spectrum density

The acoustic signal power per unit frequency as measured at a single frequency. Unit: $\mu Pa^2/Hz$, or $\mu Pa^2 \cdot s$.

power spectrum density level

The decibel level ($10\log_{10}$) of the power spectrum density, usually presented in 1 Hz bins. Unit: dB re 1 $\mu Pa^2/Hz$.

pressure, acoustic

The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa).

pressure, hydrostatic

The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

received level (RL)

The sound pressure level measured at the receiver. Unit: dB re 1 μPa @ 1 m.

rms

root mean square.

rms sound pressure level (rms SPL)

The root-mean-square average of the instantaneous sound pressure (symbol is L_p) as measured over some specified time interval (symbol T). For continuous sound, the time interval is one second.

sound

A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound intensity

Sound energy flowing through a unit area perpendicular to the direction of propagation per unit time.

sound pressure level (SPL)

The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R1999). Unit: decibel (dB). Symbol: L_p.

For sound in water, the reference sound pressure is one micropascal (p_o = 1 μPa) and the unit for SPL is dB re 1 μPa:

$$L_P = 10\log_{10}\left(p^2/p_o^2\right) = 20\log_{10}\left(p/p_o\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level (rms SPL).

source level (SL)

The sound pressure level measured 1 metre from a point-like source that radiates the same total amount of sound power as the actual source. Unit: dB re 1 μPa @ 1 m.

spectrum

An acoustic signal represented in terms of its power (or energy) distribution versus frequency.

See also power spectrum density.

transmission loss (TL)

The decibel reduction in sound level that results from sound spreading away from an acoustic source, subject to the influence of the surrounding environment. Also referred to as propagation loss.

wavelength

Distance over which a wave completes one oscillation cycle. Unit: metre (m). Symbol: λ.

4. VESSEL-BASED MONITORING, MITIGATION, AND DATA ANALYSIS METHODS[1]

This chapter describes the marine mammal monitoring and mitigation measures implemented during Shell's exploratory drilling operations in the Chukchi and Beaufort seas during the 2012 open-water season. The required measures were detailed in the IHAs and LOAs issued to Shell by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), respectively. This chapter also describes the methods used to categorize and analyze the vessel-based monitoring data collected by observers and reported in the following chapters.

Monitoring Tasks

The main purposes of the marine mammal monitoring program were to ensure that the provisions of the IHAs and LOAs issued to Shell were satisfied, effects on marine mammals were minimized, and residual effects on animals were documented. Tasks specific to monitoring are listed below:

- use of dedicated Protected Species Observers (PSOs) aboard the drill rigs (*Discoverer* and *Kulluk*) and the support vessels to visually monitor the occurrence and behavior of marine mammals near the vessels and within the exclusion zones;
- use the visual monitoring data and observations as a basis for implementing the required mitigation measures;
- record (insofar as possible) the effects of exploratory drilling operations and the resulting sounds on marine mammals;
- estimate the number of marine mammals potentially exposed to low-level continuous sounds at specified levels from drilling and ice-management activities.

Safety and Potential Disturbance Radii

IHAs typically include provisions to minimize the possibility that marine mammals close to the sound source might be exposed to levels of sound high enough to cause short or long–term hearing loss or other physiological injury. Under current NMFS guidelines (e.g., NMFS 2001), "safety radii" for marine mammals around sound sources are customarily defined as the distances within which received sound levels (RSLs) are ≥180 decibels dB (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. The ≥180 and ≥190 dB (rms) guidelines were also employed by USFWS for the species under its jurisdiction (≥180 and ≥190 dB [rms] for walrus and polar bear, respectively) in the LOAs issued to Shell. Those safety radii are based on a cautionary assumption that other sounds at lower received levels will not injure these mammals or impair their hearing abilities, but that higher received levels might have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize the numbers of cetaceans and pinnipeds exposed to sound levels exceeding 180 and 190 dB (rms), respectively. Marine mammals exposed to pulsed sounds ≥160 dB (rms) or continuous sounds ≥120 dB (rms) are assumed by NMFS to be potentially subject to behavioral disturbance. Pulsed sounds from airguns used in zero-offset vertical seismic profiling (ZVSP) surveys of exploratory drilling wells were authorized in Shell's 2012 IHAs, however, no ZVSP surveys were conducted by Shell in the Arctic

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[1] By H.M. Patterson, L.N. Bisson, H.J. Reider, and C.M. Reiser (LGL).

during 2012. Therefore, the focus within this report is on continuous sounds produced during exploratory drilling operations, including ice-management activities in support of drilling.

Exploration Drilling Activities

Shell's IHA and LOA applications described the anticipated acoustic sources (or sources with comparable frequency and intensity) around the planned drilling and related support operations. Shell conducted sound source measurements of the drill rigs *Discoverer* and *Kulluk* in addition to support vessels. Sound source characterizations consisted of distances at which broadband received levels reached 190, 180, 170, 160, and 120 dB (rms) for vessel transit, drilling, and related support activities. The initial sound fields around the proposed drilling activities were based on sounds modeled from previous measurements of the *Kulluk* and *Discoverer*. Field measurements of underwater sounds during drilling activities as a function of distance and aspect were acquired during the beginning of drilling data acquisition (Warner et al. 2011) and are reported in Chapter 3 of this report. The 2012 pre-season (modeled) and measured sound propagation distances (radii) from drilling and related activities in the Chukchi and Beaufort seas are presented below (Tables 4.1 and 4.2, respectively). More extensive analysis of the field measurements was completed after the field season as described in Chapter 3 of this report.

Sounds from the *Discoverer* have not previously been measured in the Arctic. However, measurements of sounds produced by the *Discoverer* were made in the South China Sea in 2009 (Austin and Warner 2010). The results of those measurements were used to model the sound propagation from the *Discoverer* (including a nearby support vessel) at planned drilling locations in the Chukchi Sea. The measured radii to RSLs ≥120 dB (rms) from drilling and related support activities conducted in the Chukchi Sea during 2012 (Table 4.1) were used to assess vessel-based monitoring results reported in Chapter 5 during drilling and-ice management activities as prescribed in Shell's 2012 IHA issued by NMFS. Measurements of sound levels produced by drilling and ice-management activities were used to calculate the density-based exposure estimates of marine mammals presented in Chapter 5.

Sounds from the *Kulluk* have previously been measured in the Beaufort Sea (Greene 1987, Miles et al. 1987). The back-propagated source level estimated by Greene (1987) from these measurements was 185 dB re 1 µPa at 1 meter (m). Sound-attenuating equipment installed on the *Kulluk* prior to 2012 operations in the Beaufort Sea resulted in lower average source levels from this drill rig in the Beaufort Sea in 2012 compared to those that were measured and reported by Greene (1987; see Chapter 3 for detailed measurements and source levels). The measured radii to RSLs ≥120 dB (rms) from drilling and related support activities conducted in the Beaufort Sea during 2012 (Table 4.2) were used to assess the vessel-based monitoring results from drilling reported in Chapter 6, as prescribed by the IHA issued to Shell in 2012. Ice management did not occur in the Beaufort Sea in 2012 and therefore did not impact marine mammals in the area.

Anchor handling was not designated as an independent task in the NMFS IHAs issued to Shell that required separate measurement and consideration in relation to sounds produced during drilling activities. Anchor handling sounds were, however, measured in the Beaufort Sea and could be distinguished from other drilling-related activities. These sounds occurred over relatively short periods of time (several hours) across periods of several days within the drilling season. These measurements were not used in density-based exposure calculations because of the short durations over which they occurred and to maintain consistency with the NMFS IHAs issued to Shell. The time periods were noted in the PSO data, and sightings and potential reactions of marine mammals to anchor-handling activities during the longer period of several days. These data are reported in sections of Chapters 5 and 6 to gain a better understanding of the potential impacts of these operations.

TABLE 4.1. Measured distances (m) of received sound levels between 120 and 190 dB (rms) from drilling and related support activities during Shell's exploratory drilling program in the Chukchi Sea, Alaska, 2012.

Received Level dB (rms)	Drilling of 26-inch Pilot Hole	Drilling with Support Vessel in Dynamic Positioning	Mud-Line Cellar Drilling	Anchor Handling[a]	Ice Management
≥190	<10	<10	<10	-	<10
≥180	<10	<10	20	-	<10
≥170	<10	<10	40	-	20
≥160	<10	30	130	-	60
≥150	30	160	350	-	200
≥140	100	860	1000	-	730
≥130	390	4600	2800	-	2600
≥120	1500	25,000	8100	-	9600

[a] No measurements of anchor handling were analyzed during the 2012 season in the Chukchi Sea. Measurements of this activity from the Beaufort Sea (Table 4.2) were used in Chapter 5.

TABLE 4.2. Measured distances (m) of received sound levels between 120 and 190 dB (rms) from drilling and related support activities during Shell's exploratory drilling program in the Beaufort Sea, Alaska, 2012.

Received Level dB (rms)	Drilling of Pilot Hole	Drilling with Support Vessel in Dynamic Positioning[a]	Mud-Line Cellar Drilling	Anchor Handling	Ice Management[b]
≥190	<10	-	<10	<10	-
≥180	<10	-	20	<10	-
≥170	<10	-	60	14	-
≥160	<10	-	140	63	-
≥150	<10	-	360	290	-
≥140	30	-	930	1400	-
≥130	150	-	2390	6300	-
≥120	660	-	6200	29,000	-

[a] No measurements of sounds from drilling with a support vessel in dynamic positioning near the drill rig were analyzed for the Chukchi Sea. Measurements of this activity from the Beaufort Sea (Table 4.2) were used in Chapter 6.

[b] Shell did not not need to manage potentially hazardous ice floes in the Beaufort Sea during 2012.

Mitigation Measures as Implemented

The implementation of mitigation measures during Shell's 2012 exploratory drilling program in the Chukchi and Beaufort seas spanned all aspects of operations and was driven by several themes. Mitigation measures were centered on reducing potential impacts to marine mammals and subsistence activities from a wide range of vessel activities. Specifically, vessel activities related to transit, drilling, handling and setting of the anchors used to moor the drill rigs, and ice scouting and management activities all were mitigated by various actions requested by PSOs. Vessel-based PSOs also played a role in the routing of aircraft to minimize potential impacts on marine mammals, particularly for helicopters used to facilitate offshore crew changes. Potential impacts to local subsistence activities were mitigated by the timing and location of Shell's operations in the Chukchi Sea in accordance with the CAA, and also through communications from each vessel to the nearest communication center every six hours. Shell did not conduct ZVSP surveys at the Chukchi Sea drillsite in 2012, which precluded the establishment of 180 and 190 dB (rms) exclusion zones for marine mammals around the drill rigs as stipulated in Shell's Chukchi Sea IHA and LOA for periods with active airgun operations.

The most common forms of mitigation implemented by PSOs aboard vessels during 2012 were reductions in vessel speed and alterations of vessel headings during routine vessel operations. All efforts were made to maximize distance from marine mammals and avoid separating individuals from groups of marine mammals. Other mitigation measures implemented by PSOs aboard vessels included postponement of equipment deployments (e.g., hydrophone recorders) due to the presence of marine mammals in the deployment area. Vessel transit routes through the Chukchi Sea and within the drilling area were altered on numerous occasions as a result of PSOs from one vessel calling attention to large groups of walruses in water or hauled out on ice in specific areas. These areas were avoided whenever possible. Detailed mitigation measures and summaries are presented in Chapters 5 and 6 and in Appendix E.

Special Mitigation Measures During Ice Management

In addition to the standard mitigation measures set forth by IHAs and incidental-take LOAs, "take by harassment" LOAs were issued to Shell by the USFWS that authorized "intentional take" of polar bears and walruses (in the Chukchi Sea only) during ice-management activities to protect the safety of project personnel and vessels. Detailed instructions and protocols for ice-management activities, particularly in the Chukchi Sea as it related to walrus distribution, were prescribed in Shell's *Adaptive Approach to Ice Management and Walruses*. This plan was appended to Shell's USFWS "take-by-harassment" LOA for the Chukchi Sea. As noted above, no ice management occurred in the Beaufort Sea and only limited amounts of ice-management activities were conducted by Shell in the Chukchi Sea during discreet periods in 2012. Despite possession of "take-by-harassment" LOAs, there were no intentional takes of any marine mammals by Shell during 2012.

Ice scouting and management activities in the Chukchi Sea during 2012 involved significant communication between PSOs and vessel operators. These activities were restricted to periods with good visibility whenever possible to allow for large detection distances of marine mammals in the area prior to approaching or entering the main ice edge. Walruses hauled out on ice often were detected by PSOs using "Big Eye" binoculars aboard ice management vessels at distances between 5 and 8 km (3.1 and 5.0 mi). The location of these animals was communicated to vessel operators and shore-based project managers, and such distances from animals were maintained unless the ice was deemed potentially hazardous to the safety of the operation. Only small amounts of hazardous ice were managed in the Chukchi Sea drilling area between 31 Aug and 13 Sep, and no ice with marine mammals directly associated with it was managed or approached closer than was operationally necessary. All operational decisions related to ice scouting and management involved significant assessment of the distribution of marine mammals known to be in the area prior to any detailed instructions being delivered from Shell's shore-based management team in Anchorage to vessels. All operational instructions clearly prohibited vessel interactions with marine mammals on or near ice.

Marine Mammal Monitoring Methods

Marine mammal monitoring methods were designed to meet the requirements and objectives specified in the IHAs and LOAs. The main purposes of PSOs aboard the drill rigs and support vessels were as follows:

- Conduct visual watches for marine mammals to serve as the basis for implementation of mitigation measures for cetaceans, seals, walruses, and polar bears;
- Collect data of observations to estimate the numbers of marine mammals potentially exposed to low-level continuous sounds generated by drilling and ice-management activities; and
- Document any potential reactions of marine mammals to exploratory drilling and related support activities, and whether there was any possible effect on accessibility of marine mammals to subsistence hunters in Alaska.

Results of marine mammal monitoring in the Chukchi and Beaufort seas are presented in detail in Chapters 5 and 6. The visual monitoring methods that were implemented during Shell's 2012 exploratory drilling program were similar to those used during seismic and other geophysical marine surveys in 2006–2010. The standard visual observation methods utilized by PSOs aboard vessels are described below and in greater detail in Appendix E.

Vessel-based marine mammal monitoring and mitigation was conducted from the drill rigs and support vessels throughout operations in the Chukchi and Beaufort seas. Permit stipulations required that two PSOs be on watch aboard drill rigs and ice management vessels during all active drilling and ice management operations from nautical twilight-dawn to nautical twilight-dusk. As a conservative approach, at least one PSO maintained an active watch during periods of darkness when drilling or ice management was occurring, and an additional PSO was on-call during these periods. At least one PSO was on watch on the additional support vessels when the vessel was engaged in active operational activities and at other times whenever practicable. During daylight hours, scans were made with Fujinon 7×50 reticle binoculars and the unaided eye. During periods with excellent visibility, Fujinon 25×50 "Big-Eye" binoculars or Zeiss 20×60 image stabilized binoculars were used to monitor for distant marine mammals. PSOs frequently scanned areas around the vessel during periods of darkness using Generation 3 night vision devices (NVDs).

Changes to Monitoring Program Made based on NMFS's Expert Panel Recommendations

As part of the NMFS IHA application processes, an independent peer-review panel reviewed Shell's applications and provided comments and recommendations on the proposed marine mammal mitigation and monitoring plans. Recommendations were made for training procedures, field-observation techniques, data-recording procedures, and final reporting. A number of the recommendations made by the panel have been a part of similar monitoring programs in past years and were therefore already a part of the planned program in 2012 including:

- training of all observers, including Alaska Natives, together at the same time;
- instructing observers to identify animals as unknown/unidentified when appropriate rather than striving to identify a sighting to species without evidence of diagnostic features;
- sampling of the relative nearfield around operations was corrected for effort to provide the best possible estimates of marine mammals in safety and exposure zones;
- maximizing observers' time with their eyes on the water by utilizing a direct-entry, computer-software program designed specifically for data entry by PSOs aboard vessels (voice recorders also were used to record data to address this objective);

- training PSOs using visual aids (e.g., photos) to help them identify the species that they were likely to encounter in the conditions under which the animals would likely be seen;
- pairing new and experienced observers together during training and in the field to maximize understanding, mentorship opportunities, and consistency of data collection;
- documenting visibility conditions during observation periods;
- instructing observers to maximize time spent monitoring areas directly associated with operations and zones associated with implications for mitigation;
- stationing PSOs in the best possible positions for observing: the bridge, bridge wings, flying bridge, or stern (on drill rig or stationary vessel); and
- combining the use of “Big eye” binoculars, low power binoculars, and naked eye searches during watches to cover the greatest area allowable by weather conditions.

Data Analysis Methods

Categorization of Data

PSO *effort* is a systematic collection of observation records that captures the distance or amount of time spent with at least one observer 1.) actively searching for marine mammals, and 2.) documenting environmental conditions and vessel activities. For moving vessels, effort was quantified as the distance the vessel traveled while PSOs actively looked for marine mammals and recorded environmental and vessel activity data. For stationary vessels, effort was quantified as the number of hours during which PSOs actively looked for marine mammals and recorded data. The amount of effort was subdivided by various environmental or operational variables that may have influenced the ability of PSOs to detect marine mammals or the actual distribution of marine mammals in the area (e.g. Beaufort wind force, vessel activity). PSO effort was used to calculate marine mammal sighting rates in the following sections of this chapter.

Observer effort and marine mammal sightings were divided into several analysis categories related to environmental conditions and vessel activity. The categories were similar to those used during various other exploration activities conducted under IHAs in this region (e.g., Funk et al. 2008; Ireland et al. 2007a,b; Patterson et al. 2007; Reiser et al. 2010; Reiser et al. 2011). These categories are defined briefly below, with a more detailed description provided in Appendix E.

Species Groups

Results are presented separately by groups including cetaceans, pinnipeds (excluding walrus), Pacific walrus. and polar bear. Cetaceans and pinnipeds are treated separately due to expected differences in potential reactions to exploratory drilling and related support activities. Pacific walrus and polar bears are presented separately due to their management by USFWS.

Geographic Boundaries and Vessel Role

Data were collected during the entire cruise period for all vessels, including the transit between Dutch Harbor and the exploratory drilling areas. Data were first categorized by the geographic region and time period in which they were collected for reporting results in Chapters 5 and 6. Given the differences in marine mammal species composition, densities, etc. between the southern Chukchi Sea and the Burger prospect area in the northeastern Chukchi Sea, only marine mammal sightings and effort data from vessel activities north of Point Hope (68.34 °N) and west of Pt. Barrow (156.45 °W) were included in the Chukchi Sea study area (Fig. 4.1). The Chukchi Sea study area was designed to support more meaningful comparisons of data collected in the Chukchi Sea during drilling versus non-drilling periods. The

Beaufort Sea study area included data from vessels operating east of Pt. Barrow (156.45 °W) to the Canadian border (141 °W; Fig. 4.1).

Data were also categorized by the duties of the vessel on which the data were collected. A vessel was considered a "source" vessel if, at some point during the season, it engaged in activities other than general vessel operations (e.g., drilling, ice management; see "*Vessel Activity*", below). All data were further binned into periods when the vessel was moving versus stationary.

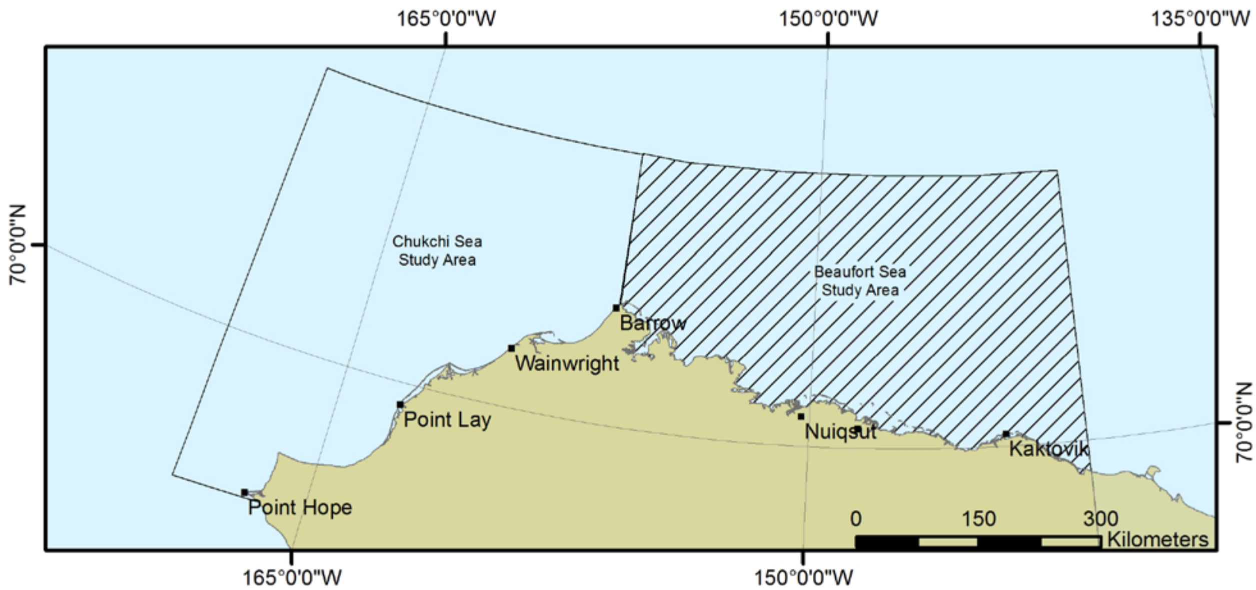

FIGURE 4.1. The Chukchi Sea and Beaufort Sea study area boundaries used to categorize vessel-based marine mammal sightings and effort data for analysis and presentation in Chapters 5 and 6, respectively.

Vessel Activity

Marine mammal sighting and observer effort data from all vessels were categorized into the following six bins based on activities and the relative amount of sound produced while the activity was being conducted: ***(1)*** pilot-hole drilling; ***(2)*** mud-line cellar drilling; ***(3)*** ice management; ***(4)*** anchor handling; ***(5)*** periods with no drilling, ice management, or anchor handling; and ***(6)*** a bin that encompasses either drilling or mud-line cellar activities concurrent with a stationary support vessel using dynamic-positioning (DP) technology within 1 km (0.6 mi) of the drill rig. Preliminary review of sound measurements of support vessels using dynamic positioning suggested that DP sounds masked those produced during drilling activities (see Chapter 3), thus the presence or absence of support vessels in dynamic positioning near an active drill rig warranted consideration in certain analyses. To be consistent with the vessel-based acoustic sources that were authorized for incidental take of cetaceans and seals by Shell's 2012 IHAs, only "*continuous drillship sounds during active drilling operations*" and "*vessel sounds generated during active ice management or icebreaking*" were considered when calculating exposure estimates to marine mammals.

Sighting Rate Calculations and Comparisons

Sighting rates (sightings/10 hr of observer effort from stationary vessels and sightings/1000 km or 621 mi of observer effort from moving vessels) are presented for all vessels within the analysis categories of Beaufort wind force (Bf), number of PSOs on watch, and by vessel activity status (specific to vessels which perform those activities). Sighting rates are presented independently by species groups including cetaceans, pinnipeds (excluding walrus), Pacific walrus, and polar bear.

Sighting rates have the potential to be biased by a number of different factors other than the variable being considered. In order to present meaningful and comparable sighting rates within and between categories, especially for purposes of considering the potential effects of vessel activity on the distribution and behavior of marine mammals, effort and sightings data were categorized by the relative quality of sighting/observing conditions (e.g. environmental conditions). The criteria were intended to exclude data from periods of observation effort when conditions would have made it difficult to detect marine mammals that were at the surface. If those data were to be included in analyses, important metrics like sightings rates and densities would be biased downward.

Criteria for Sighting Rate Data

Slightly different criteria were used for pinnipeds and cetaceans in order to account for assumed differences in their potential reactions to exploratory drilling and related support-vessel activities. Therefore, effort and sightings occurring under the following conditions were excluded when calculating sighting rates:

- periods 3 min to 1 h for pinnipeds and polar bears, or 2 h for cetaceans, after the cessation of vessel activities with a radius of received sound at the ≥120 dB (rms) isopleth of greater than 20 km (12.4 mi);
- periods when a moving vessel's speed was <3.7 km/h (2 kt);
- periods with seriously impaired visibility including:
  - all nighttime observations;
  - visibility distance was <3.5 km (2.2 mi);
  - Beaufort wind force (Bf) >5 (Bf >2 for "cryptic" cetaceans: minke whales, belugas, and porpoises; See Appendix F for Beaufort wind force definitions); and
  - >60º of severe glare in the forward 180° of a moving vessel's trackline.

This categorization system was designed primarily to allow identification of potential differences in behavior and distribution of marine mammals during periods with drilling or related support-vessel activity versus periods without any such activities.

The rate of recovery toward "normal" behavior and distributions during the post-exposure periods is uncertain. Marine mammal responses to seismic and other industrial sounds likely diminish with time after the cessation of the activity. The end of the post-exposure period was defined as a time long enough after cessation of vessel activity to ensure that any carry-over effects of exposure to sounds from the vessel activities would have waned to zero or near-zero. The reasoning behind these categories was explained in MacLean and Koski (2005) and Smultea et al. (2005), and is discussed in Appendix E.

Distribution and Behavior

Closest Point of Approach

The closest point of approach (CPA) of each sighting to the observer position was calculated in a GIS. The mean, standard deviation, and range of CPA distances to the observer were calculated within vessel-activity bins.

As with sighting rate calculations, the calculation of mean CPA distances and subsequent comparisons during different vessel activity states could be biased by including data from observation periods of poor visibility or when animals may have been affected by something other than sounds generated by drilling, ice management, or anchor handling activities. Therefore, only sightings that met the criteria for inclusion in the sighting rate calculations were used in the calculation of mean CPA distances to allow for meaningful comparisons between activities and vessel types.

Movement

Animal movements relative to the vessel were grouped into five categories: swim away, swim towards, neutral (e.g. parallel), none, or unknown. The observed movements of animals that fell into these categories were compared between activities and vessel types.

Initial Behavior

For each sighting, an initial behavior was recorded by the PSO. Animal behavior codes included: sink, thrash, fluke, dive, look, log, spyhop, swim, breach, lobtail, flipper slap, blow, bow ride, porpoise, raft, wake ride, unknown, walk, dead, and other. Activities, or a collection of behaviors that indicate an overall behavioral state, were also included as an initial behavior if PSOs clearly observed animals exhibiting these combinations of behaviors. Activity codes included: travel, surface active, surface active-travel, mill, feed, mate, and rest. The initial behaviors recorded for each sighting were summarized and compared between activities and vessel types.

Reaction Behavior

Animal reactions in response to the vessel presence or vessel activity were recorded during each sighting. Reaction behavior codes included: change in direction, increase or decrease in speed, look, splash, rush, bowride or wake ride, interactions with gear, and no reaction. The reaction behaviors of animals that fell into these categories were compared between activities and vessel types.

Estimating Numbers of Marine Mammals Potentially Affected

NMFS and USFWS practices in situations with intermittent impulsive sounds like seismic pulses has been to assume that "take by harassment" (Level B harassment) may occur if marine mammals are exposed to received sound levels exceeding 160 dB re 1 µPa rms (NMFS 2005, 2006; USFWS 2008). For continuous sounds, like those created by drilling and ice-management activities, Level B harassment is assumed to occur at received levels ≥120 dB re 1 µPa rms. When calculating the number of mammals potentially affected as described below, we used the measured ≥120 dB (rms) distances from sources shown in Tables 4.1 and 4.2.

Two methods were used to estimate the number of pinnipeds and cetaceans exposed to sound levels that may have caused disturbance or other effects. The methods were:

(A) estimates based on direct observations during drilling and related support-vessel activities; and

(B) estimates based on pinniped and cetacean densities utilized in Shell's 2012 IHA applications (Shell 2011a,b; Appendix E) multiplied by the area ensonified to ≥120 dB (rms) during drilling and ice-management activities. In the Beaufort Sea, bowhead whale densities from aerial survey data collected during the 2012 season were used to calculate density-based exposure estimates for this species.

Density-based exposure estimates were calculated for drilling and ice-management as prescribed by Shell's 2012 IHA and the subsequent authorization from NMFS of Level-B "takes" of cetaceans and seals from these activities. This method involved multiplying the following values:

- basal footprints of the areas ensonified by drilling and ice-management activities within each sea during Jul–Aug and Sep–Oct.

- expected densities of marine mammals from the best available data collected during the studies summarized in Chapters 5 and 6 and Appendix E.

This density-based exposure method is a modified version of the approach originally developed to estimate numbers of seals potentially affected by seismic surveys in the Alaskan Beaufort Sea conducted under previous IHAs (e.g., Harris et al. 2001; Funk et al. 2008; Ireland et al. 2007a,b; Patterson et al. 2007; Reiser et al. 2010; Reiser et al. 2011).

An alternative to the density-based exposure estimates described above was considered for bowhead whales during the fall migration period (Sep–Oct). The method is founded on estimates of the proportion of the population that would pass within the >120 dB (rms) zone on a given day during the migration while exploration drilling activities were occurring. Based on data in Richardson and Thomson (2002), the number of whales expected to pass each day was estimated as a proportion of the estimated 2012 bowhead whale population. The number of whales passing each day was based on the 10-day moving average presented by Richardson and Thomson (2002). This alternative to density-based estimates also was used to estimate exposures from drilling sounds to bowhead whales in Shell's 2012 Beaufort Sea IHA application (Shell 2011b; Appendix E). Like density-based estimates, this method also assumes that no whales avoided the area of drilling activities and thus probably overestimates the number of animals that would be exposed to drilling activities and sounds.

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5. CHUKCHI SEA VESSEL-BASED MARINE MAMMAL MONITORING RESULTS[1]

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes the visual observer effort from the project vessels during Shell's 2012 exploratory drilling operations in the Chukchi Sea, and does not include effort conducted during transit from Dutch Harbor to and from the survey area (south of Point Hope, Alaska and west of Barrow, Alaska). The survey period began when the first project vessel, the *Nordica*, entered the Chukchi Sea survey area on 23 Jul 2012 and ended when the last project vessels, the *Aiviq* and *Kulluk*, departed the area on 14 Nov 2012. With the exception of two hours on 10 Sep, the *Discoverer* did not begin drilling in the Chukchi Sea in 2012 until 23 Sep through 26 Oct 2012.

The project vessels traveled a total of ~65,140 km (40,476 mi) in the Chukchi Sea during the 2012 exploratory drilling season. The drill rig *Discoverer* traveled a total of ~1,186 km (737 mi). The drill rig was moored at the Burger-A drillsite for ~900 h from ~21 Sep to 28 Oct. The *Discoverer* was involved in drilling activities for ~387 h (42%) of the time on prospect, which included the construction of the MLC (See Chapter 2). The *Fennica* traveled a total of ~10,293 km (6396 mi). The *Tor Viking* traveled a total of ~7704 km 4787 mi). The *Aiviq* traveled a total of ~3964 km (2463 mi). The *Kulluk* traveled a total of ~1082 km (672 mi) through the Chukchi Sea on its way to and from its drilling location in the Beaufort Sea. The support vessels accounted for ~40,907 km (25,418 mi) of travel in the Chukchi Sea (see Chapter 2 for details about support vessels).

The *Discoverer*, *Fennica*, *Tor Viking*, *Aiviq* and *Kulluk* are classified as source vessels for the following vessel-based PSO monitoring results. Specifically, source vessels generated sounds during drilling, ice-management, or anchor-handling activities that were measured in the field (see Chapter 3) and used to calculate exposure estimates to marine mammals later in this chapter. All observation effort and marine mammal sightings data from these vessels were binned in the source-vessel category, which included transit and standby periods. All other vessels were classified as non-source. This vessel classification system also was created to allow for comparisons of data between different activity states and vessel types. The exception to this vessel classification system in the Chukchi Sea is for the drill rig *Kulluk*. The *Kulluk* only transited through the Chukchi Sea in 2012 without conducting the specific source-vessel activities defined above; however, these small amounts of data are included here with other source-vessel data for the sake of consistency.

Vessels other than those involved in Shell's operations seldom passed through the project area. Vessels involved in Shell's Beaufort Sea exploratory drilling operations transited through the Chukchi Sea and are included in these data. Each ship that was not participating in the project transited well away from exploratory drilling activities (>40 km (25 mi)) and PSOs observed no instances of harassment or disturbance to marine mammals due to their presence.

Observer Effort

PSO *effort* is a systematic collection of observation records that captures the distance or amount of time spent with at least one observer 1) actively searching for marine mammals, and 2) documenting environmental conditions and vessel activities. For moving vessels, effort was quantified as the distance

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[1] By L.N. Bisson, H.J. Reider, H.M. Patterson, M.L. Bourdon, and C.M. Reiser (LGL)

the vessel traveled while PSOs actively looked for marine mammals and recorded environmental and vessel activity data. For stationary vessels, effort was quantified as the number of hours during which PSOs actively looked for marine mammals and recorded data. The amount of effort was subdivided by various environmental or operational variables that may have influenced the ability of PSOs to detect marine mammals or the actual distribution of marine mammals in the area (e.g. Beaufort wind force, vessel activity). PSO effort was used to calculate marine mammal sighting rates in the following sections of this chapter.

PSOs aboard the project vessels in the Chukchi Sea were on watch for a total of ~45,428 km (~28,228 mi; 4691 h) while vessels were moving and ~5395 h while they were stationary (Fig. 5.1 and 5.2). During exploratory drilling activities PSOs were on watch during darkness for ~6095 km (~3787 mi) while vessels were moving and 1141 h while they were stationary. At least one observer was on watch during 100% (~185 h) of daylight during exploratory drilling activities and at least two observers were on watch for ~94% (~174 h) of daylight exploratory drilling activities. At least one observer was on watch during 100% (~202 h) of nighttime exploratory drilling operations and two observers were on watch for ~41% (~82 h) of nighttime exploratory drilling activities.

Observer Effort by Beaufort Wind Force

Observer effort from the project vessels occurred between Beaufort wind force (Bf) zero and Bf seven (Fig. 5.2). The greatest amount of observer effort while moving occurred during Bf three, which accounted for ~26% (11,717 km; 1177 h) of PSO effort aboard the project vessels (Fig. 5.3). The greatest amount of observer effort while stationary was ~26% (1424 h) also occurred during Bf 3 (Fig. 5.4). Overall, ~61% (27,590 km; 2814 h) of effort while moving and ~67% (3625 h) of effort while stationary occurred in Bf two, three, or four.

Observer Effort by Number of PSOs

On the project vessels, two PSOs were on watch during ~57% (19,211 km; 1835 h) of observation effort while moving and ~52% (2856 h) of observation effort while stationary (Fig. 5.5 and 5.6). PSOs were scheduled to maximize effort during daytime hours when optimum visibility conditions were likely to maximize monitoring and mitigation efforts. Due to regulatory requirements on source vessels two PSOs were on watch more frequently than one PSO.

Observer Effort by Vessel Activity

Exposure level takes into consideration the entire sound field of each individual vessel and surrounding vessels (see Chapter 4).

Most observer effort from the project vessels occurred during general vessel activities during both moving and stationary periods (Fig 5.7 and 5.8). General vessel activities included any vessel operation from source or non-source vessels other than anchor handling, drilling, and ice management activities. Approximately 73% (33,463 km; 3397 h) of total moving observer effort was during general vessel activities, and only ~26% (11,965 km; 1295 h) of moving observer effort was during anchor handling, drilling, and ice management activities. Approximately ~12% (5293 km; 546 h) of total moving observer effort was during anchor handling, ~11% (5105 km; 563 h) of total moving observer effort was during drilling activities, and ~3% (1567 km; 185 h) of total moving observer effort was during ice management activities. Sound exposure levels in the water around moving vessels were less than 120 dB (rms) during 98% (44,692 km; 4579 h) of observation effort and between 120 and 160 dB during the remaining ~2% (735 km; 66 h) of effort for both source and non-source vessels combined. Exposure level takes into consideration the entire sound field of each individual vessel and surrounding vessels (see Chapter 4).

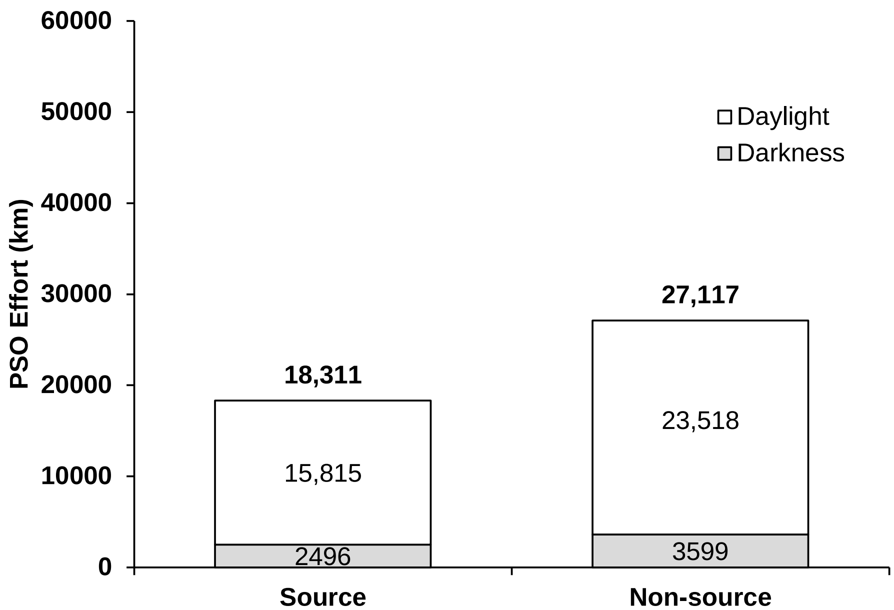

FIGURE 5.1. Total PSO moving observation effort (km) and PSO effort during daylight and darkness periods from project vessels during Shell's Chukchi exploratory drilling program, 2012.

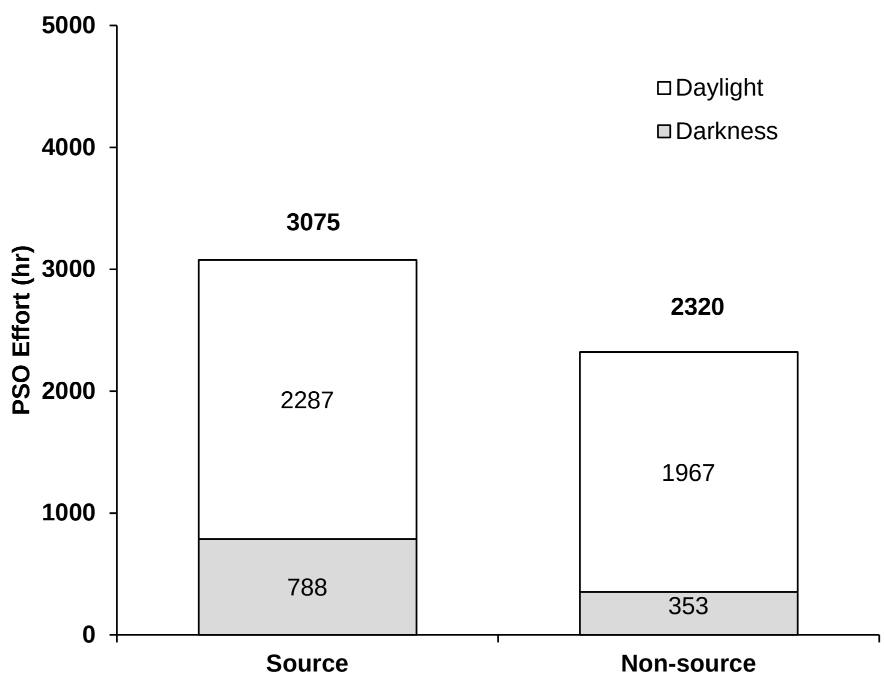

FIGURE 5.2. Total PSO stationary observation effort (h) and PSO effort during daylight and darkness periods from project vessels during Shell's Chukchi exploratory drilling program, 2012.

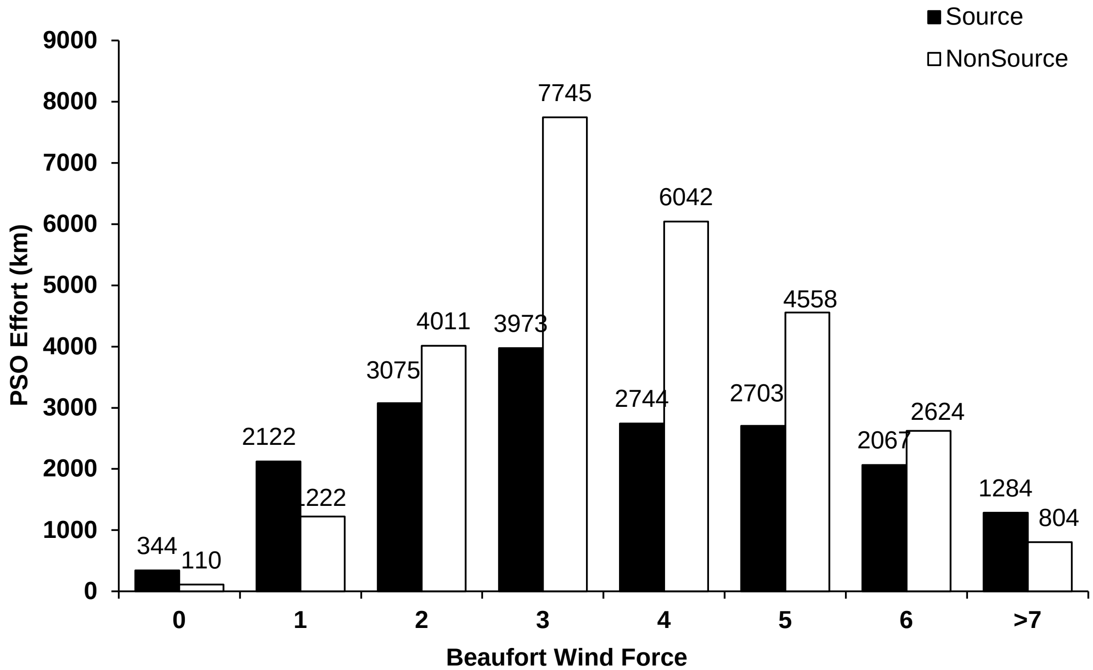

FIGURE 5.3.Total PSO observation effort (km) and PSO effort by Beaufort Wind Force from moving project vessels during Shell's exploratory drilling program in the Chukchi Sea, 2012.

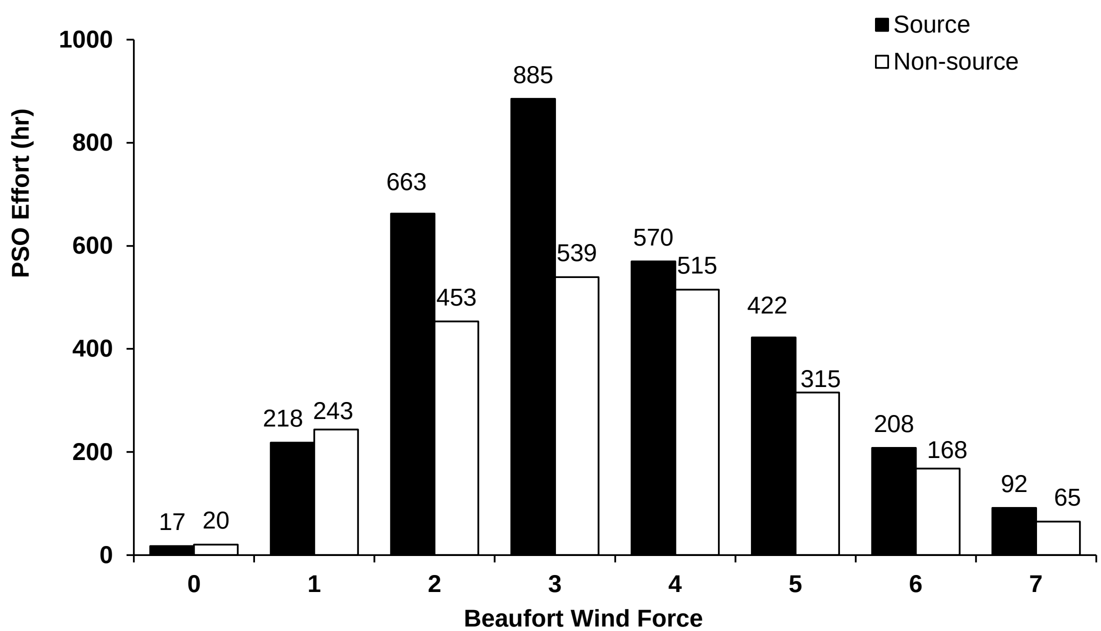

FIGURE 5.4.Total PSO observation effort (h) and PSO effort by Beaufort Wind Force from stationary project vessels during Shell's exploratory drilling program in the Chukchi Sea, 2012.

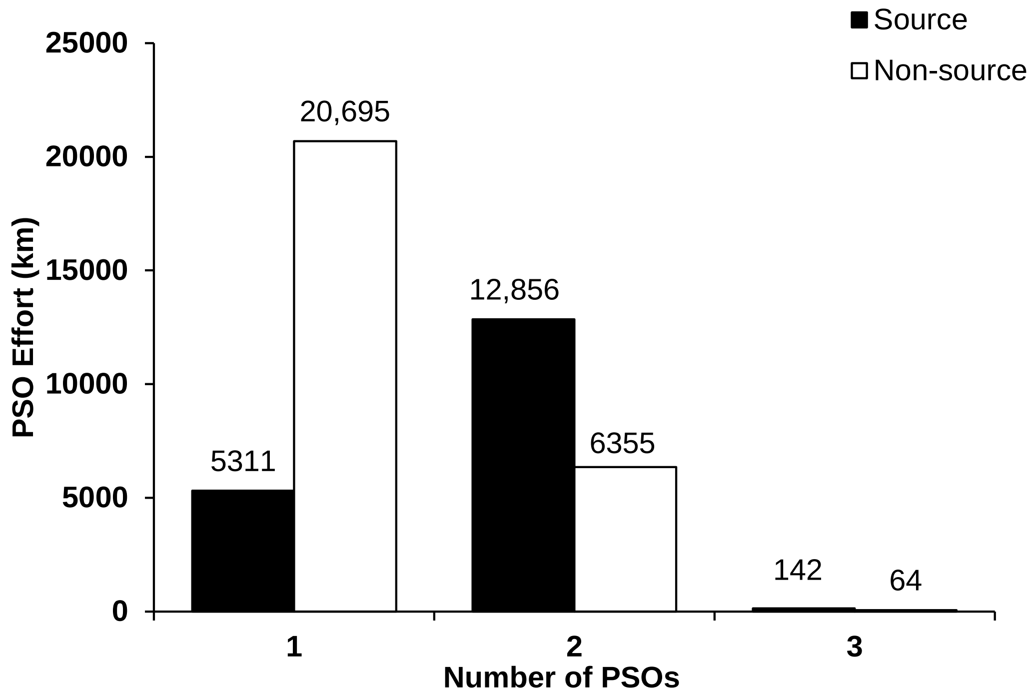

FIGURE 5.5. PSO observation effort (km) for moving periods by number of PSOs from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

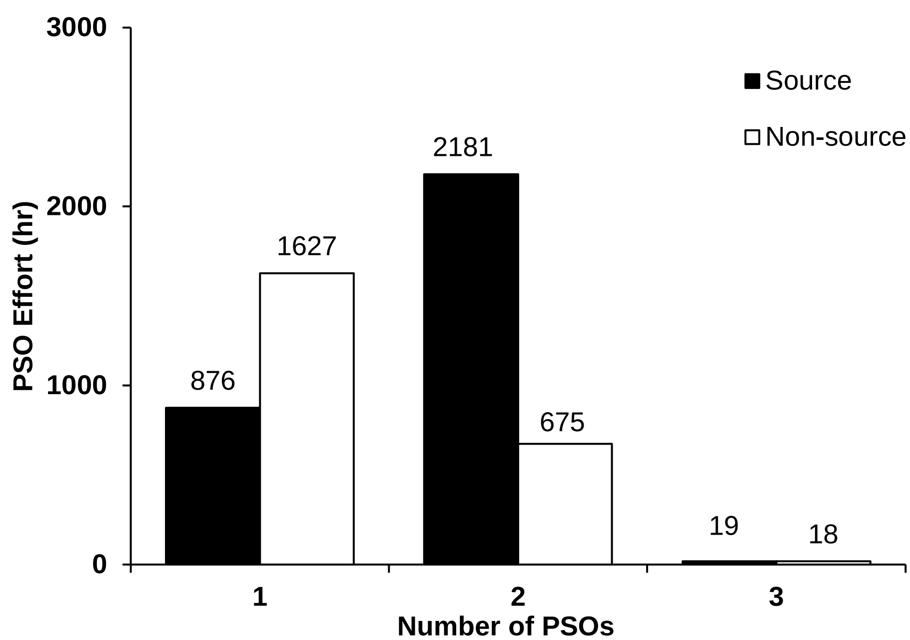

FIGURE 5.6. PSO observation effort (h) for stationary periods by number of PSOs from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

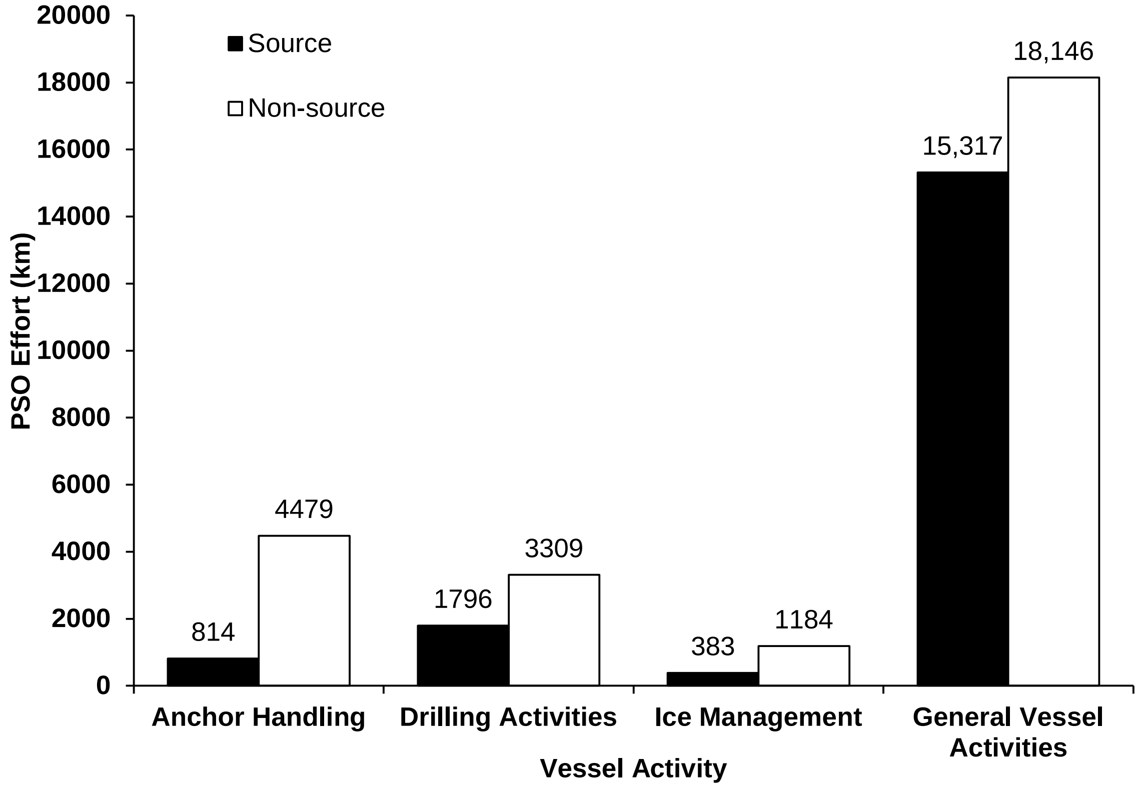

FIGURE 5.7. PSO observation effort (km) for moving periods by vessel activity from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

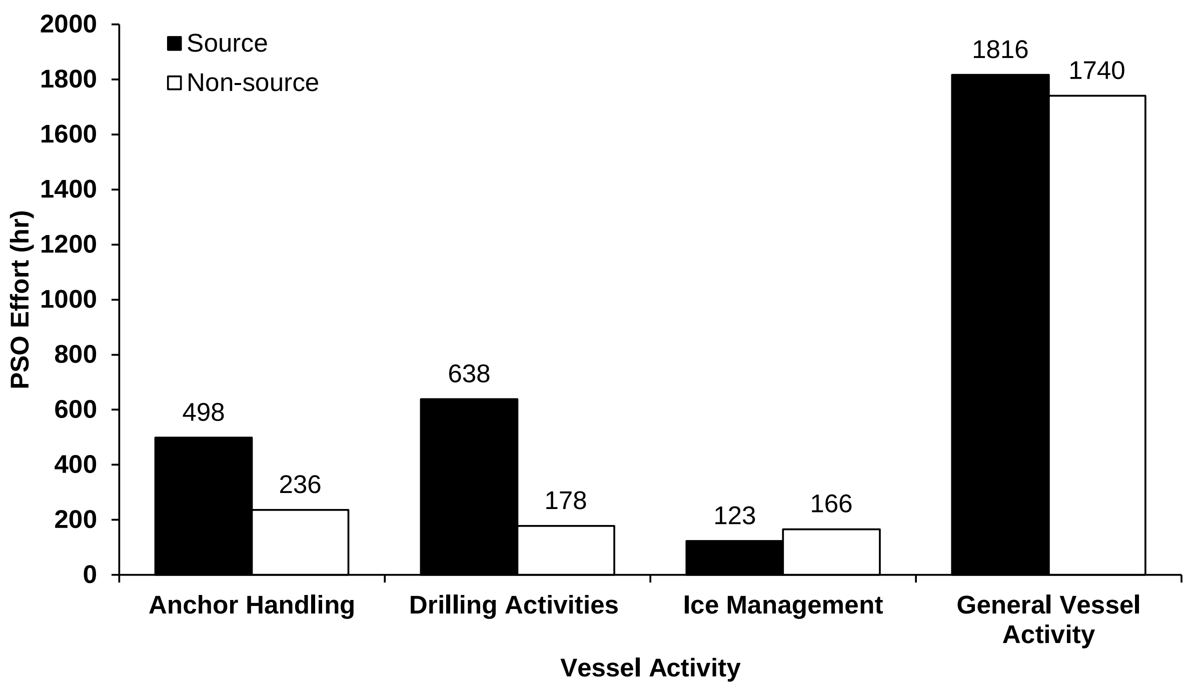

FIGURE 5.8. PSO observation effort (h) for stationary periods by vessel activity from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

General vessel activities comprised ~65% (3556 h) of total stationary observer effort; ~34% (1839 h) of moving observer effort was during anchor handling, drilling, and ice management activities. Anchor handling activities comprised ~13% (734 h) of total moving observer effort, drilling activities comprised of ~15% (816 h) of total moving observer effort, and the last ~5% (289 h) of total moving observer effort was during ice management activities. Sound exposure levels in the water around stationary vessels were less than 120 dB (rms) during 85% (4580 h) of observation effort, and greater than 120 dB (rms) during the remaining ~15% (815 h) of effort for both source and non-source vessels combined.

Marine Mammal Sightings

During the Shell exploratory drilling operations, PSOs observed a total of 1906 sightings of 11,304 marine mammals from the project vessels. Details of each marine mammal sighting observed in the survey area are available in Appendix G. Sighting rates from moving vessels are considered as sightings per 1000 km and from stationary vessels as sightings per 10 h. The sighting data below are presented for four groups: cetaceans, seals, Pacific walruses, and polar bears.

Cetacean Sightings

PSOs observed 581 sightings of 1179 cetaceans from the project vessels (Table 5.1). Approximately half of cetacean sightings could not be identified to species (~55%; Table 5.1). Diagnostic features for identifying cetaceans to species are oftentimes not easily observed from vessels. PSOs were instructed to identify animals based on clearly observed characteristics. Comments for unidentified cetaceans in many cases indicate probable species designations, such as characteristics consistent with gray or bowhead whales (e.g. large body). More whales were observed from moving vessels than stationary vessels.

TABLE 5.1. Total number of cetacean sightings (total number of individuals) from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

Species	Source Vessels	Non-source Vessels	Total: *Sightings (Individuals)*
Cetaceans			
Beluga whale	1 (2)	0 (0)	***1 (2)***
Bowhead whale	45 (107)	72 (212)	***117 (319)***
Dall's porpoise	0 (0)	1 (4)	***1 (4)***
Fin whale	0 (0)	1 (1)	***1 (1)***
Gray whale	41 (57)	87 (199)	***128 (256)***
Harbor porpoise	1 (6)	0 (0)	***1 (6)***
Humpback whale	0 (0)	2 (6)	***2 (6)***
Killer whale	0 (0)	2 (5)	***2 (5)***
Minke whale	3 (3)	7 (9)	***10 (12)***
Unidentified mysticete whale	77 (127)	89 (166)	***166 (293)***
Unidentified whale	32 (51)	120 (224)	***152 (275)***
Total Seals	***200*** **(353)**	***381*** **(826)**	***581 (1179)***

TABLE 5.2. Number of cetacean sightings (number of individuals) from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Moving			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Cetaceans				
Beluga whale	1 (2)	0 (0)	***1***	***(2)***
Bowhead whale	42 (103)	67 (205)	***109***	***(308)***
Dall's porpoise	0 (0)	1 (4)	***1***	***(4)***
Fin whale	0 (0)	1 (1)	***1***	***(1)***
Gray whale	29 (43)	63 (144)	***92***	***(187)***
Harbor porpoise	1 (6)	0 (0)	***1***	***(6)***
Humpback whale	0 (0)	2 (6)	***2***	***(6)***
Killer whale	0 (0)	2 (5)	***2***	***(5)***
Minke whale	2 (2)	4 (5)	***6***	***(7)***
Unidentified mysticete whale	58 (88)	69 (126)	***127***	***(214)***
Unidentified whale	21 (30)	103 (196)	***124***	***(226)***
Total Cetaceans	***154 (274)***	***312 (692)***	***466***	***(966)***

TABLE 5.3. Number of cetacean sightings (number of individuals) from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Stationary			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Cetaceans				
Bowhead whale	3 (4)	5 (7)	***8***	***(11)***
Gray whale	12 (14)	24 (55)	***36***	***(69)***
Minke whale	1 (1)	3 (4)	***4***	***(5)***
Unidentified mysticete whale	19 (39)	20 (40)	***39***	***(79)***
Unidentified whale	11 (21)	17 (28)	***28***	***(49)***
Total Cetaceans	***46 (79)***	***69 (134)***	***115***	***(213)***

Cetacean Sighting Rates

Cetacean sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 4 and Appendix C) and the sightings that occurred during those periods. Data that met these criteria are presented in Parts 2 and 3 of Appendix F.

Cetacean Sighting Rates by Beaufort Wind Force – Cetacean sighting rates tended to decrease with increased Bf wind force. Cetacean sighting rates were highest during Bf 2 for moving periods and Bf 1 for stationary periods (Fig 5.9 and 5.10). There is a weak downward trend which could have been influenced by effort hours in each category, although these results should be viewed with caution as there was very little effort in Bf 0 and a limited amount of effort in Bf 1

Cetacean Sighting Rates by Number of PSOs – Regulatory requirements mandated that source vessels, such as ice breakers and drill rigs, utilize two PSOs to monitor the water during daytime active operations. Non-source vessels typically utilized one PSO during monitoring to maximize effort when practicable. Two PSO on watch sighting rates for non-source vessels were similar to one PSO on watch sighting rates for non-source vessels for both moving and stationary periods (Fig 5.11 and 5.12). On watch sighting rates should be viewed with caution as they are closely linked to other variables affecting marine mammal detection, such as Bf wind force.

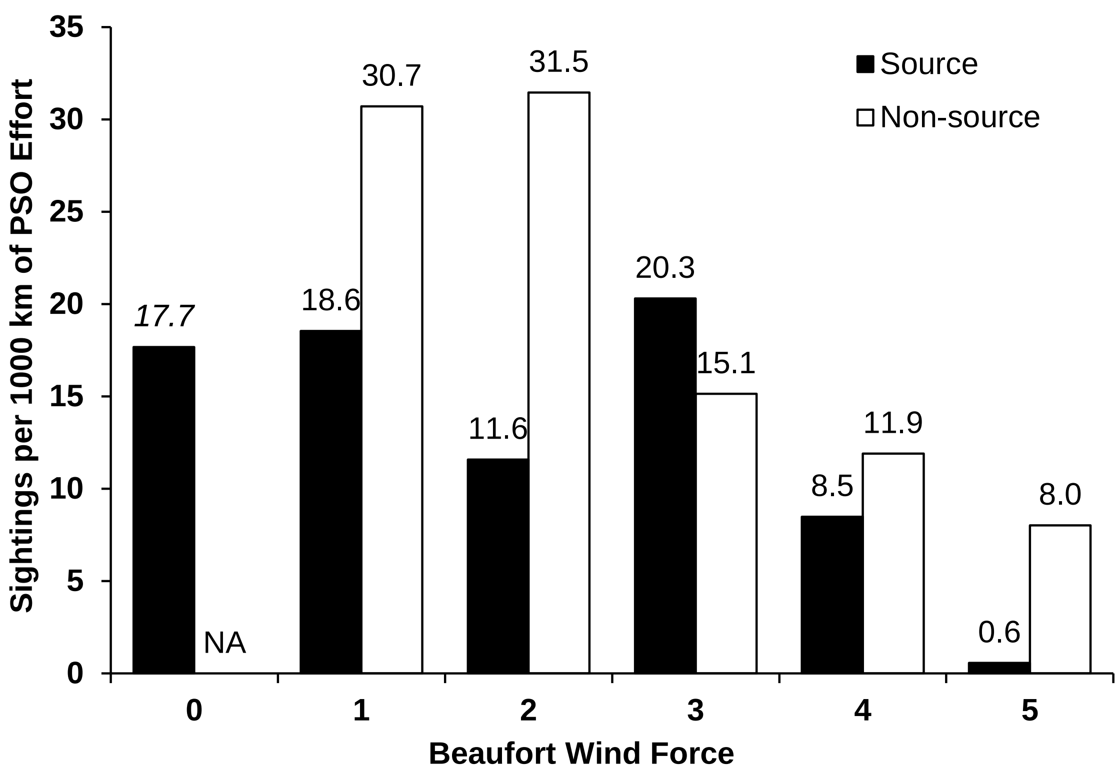

FIGURE 5.9. Cetacean sighting rates from moving vessels by Beaufort wind force during Chukchi Sea exploratory drilling operations, 2012. Note that < 250 km of observer effort occurred in Bf 0, which precluded meaningful inclusion. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

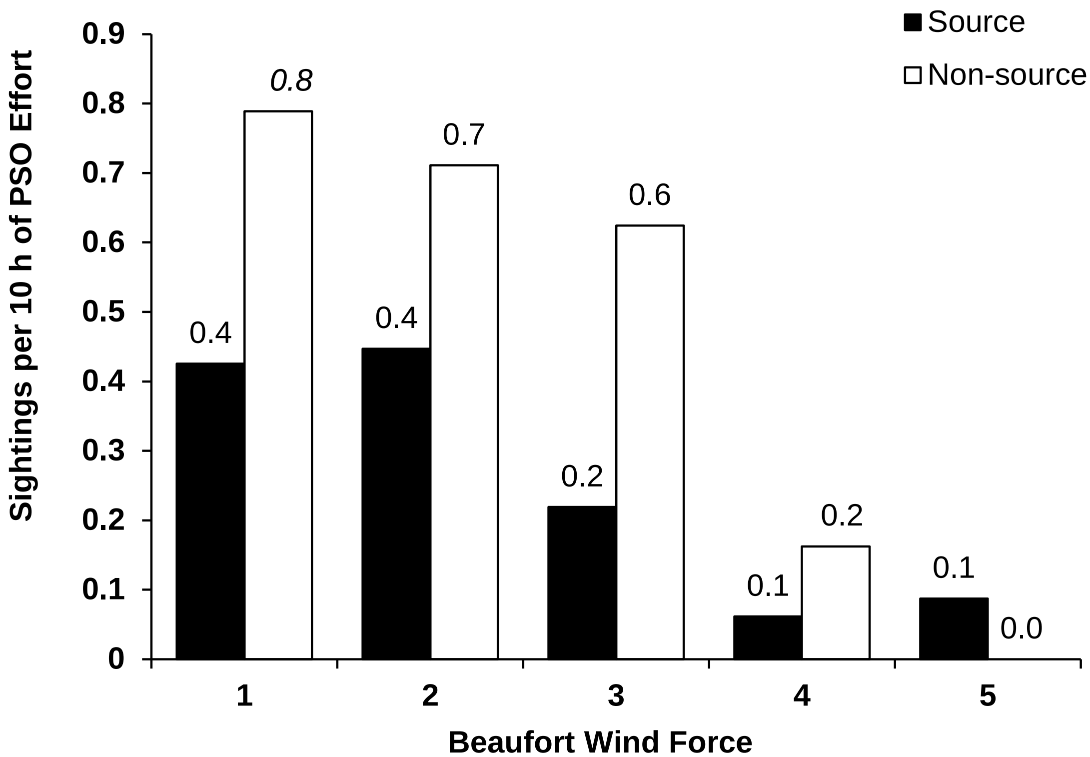

FIGURE 5.10. Cetacean sighting rates from stationary vessels by Beaufort wind force during Chukchi Sea exploratory drilling operations, 2012. Note that < 35 h of observer effort occurred in Bf 0, which precluded meaningful inclusion. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Cetacean Sighting Rates during Vessel Activity – Non-source vessels had higher sighting rates than source vessels for cetacean sightings rates during moving and stationary periods (Fig. 5.13 and 5.14). Limited effort occurred during ice management activities so those sighting rates should be viewed with caution (Fig. 5.13 and 5.14). Observers on stationary vessels had the highest rate of cetacean sightings during anchor handling activities (Fig. 5.14). Anchor handling was restricted to operational periods with low sea states. High cetacean sighting rates from source vessels during this activity likely were related to favorable conditions for detecting cetaceans.

Cetacean Sighting Rates by Received Sound Level –. PSO effort was not evenly distributed over received sound level bins (Fig 5.15 and 5.16). Factors which contributed to this uneven distribution include 1) sound pressure levels from activities such as drilling and ice management attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sounds at this level. During stationary and moving periods when animals would have been exposed to >120 dB (rms) and sufficient effort was recorded in these bins, one sighting was reported as exposed to bin 159-120 dB (rms) (Fig 5.16).

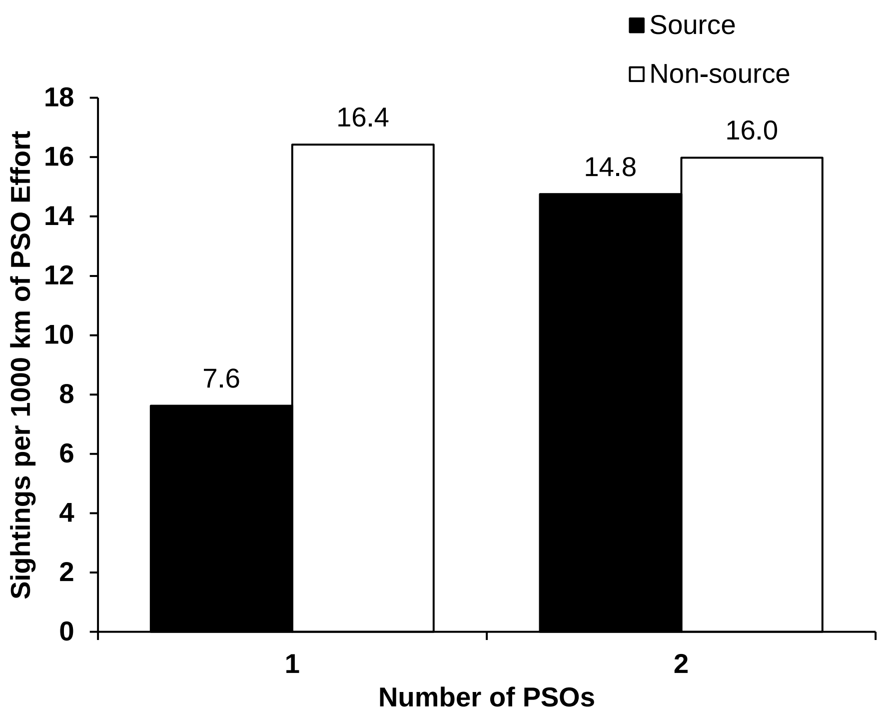

FIGURE 5.11. Cetacean sighting rates from moving vessels by number of PSOs on watch during Shell's Chukchi Sea exploratory drilling operations, 2012. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

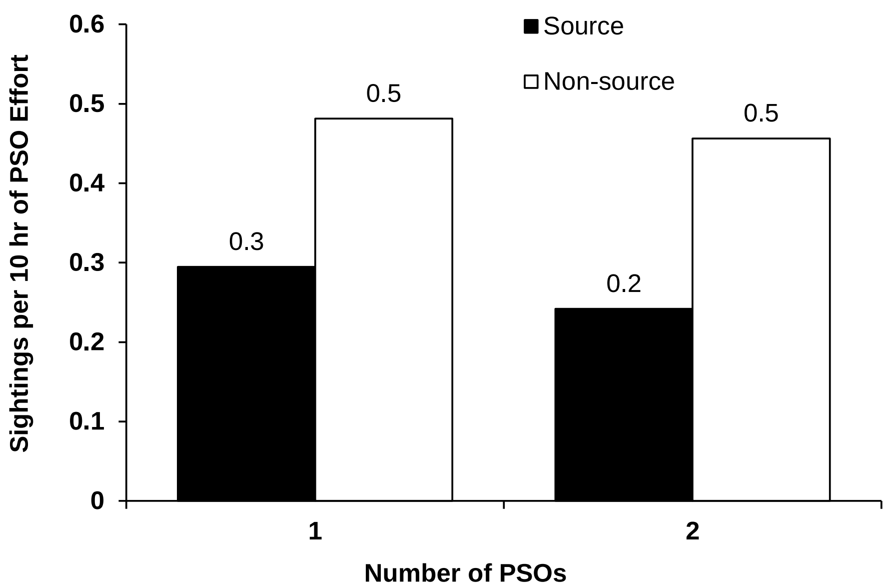

FIGURE 5.12. Cetacean sighting rates from stationary vessels by number of PSOs on watch during Shell's Chukchi Sea exploratory drilling operations, 2012. Note that < 35 h of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

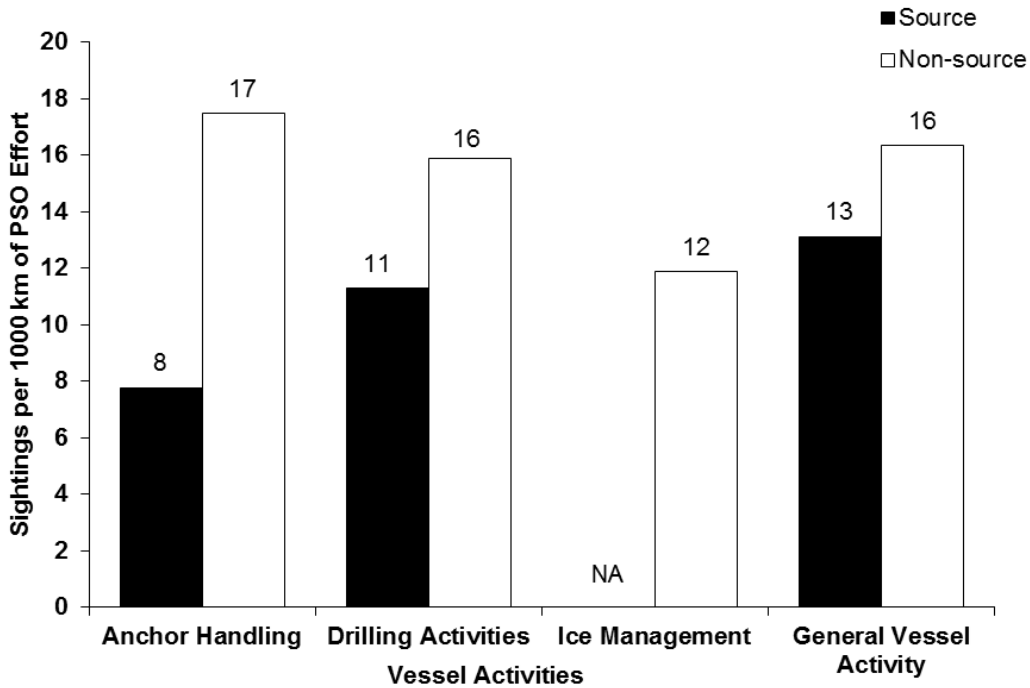

FIGURE 5.13. Cetacean sighting rates from moving vessels by vessel activity during Shell's Chukchi Sea exploratory drilling operations, 2012. Note that < 250 km of observer effort occurred during source ice management, which precluded meaningful inclusion.

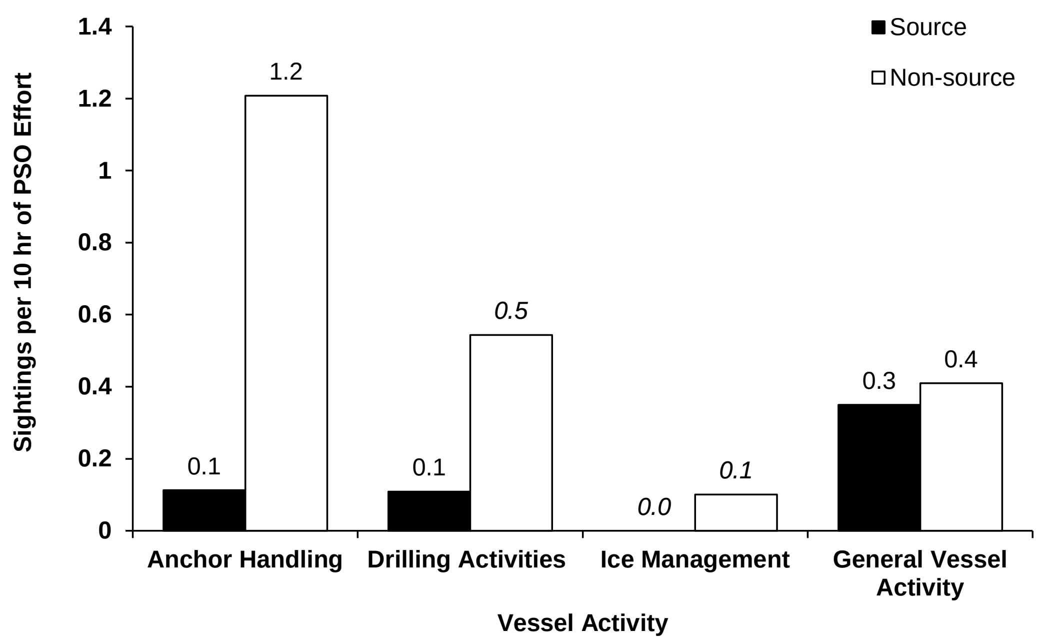

FIGURE 5.14. Cetacean sighting rates from stationary vessels by vessel activity during Shell's Chukchi Sea exploratory drilling operations, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

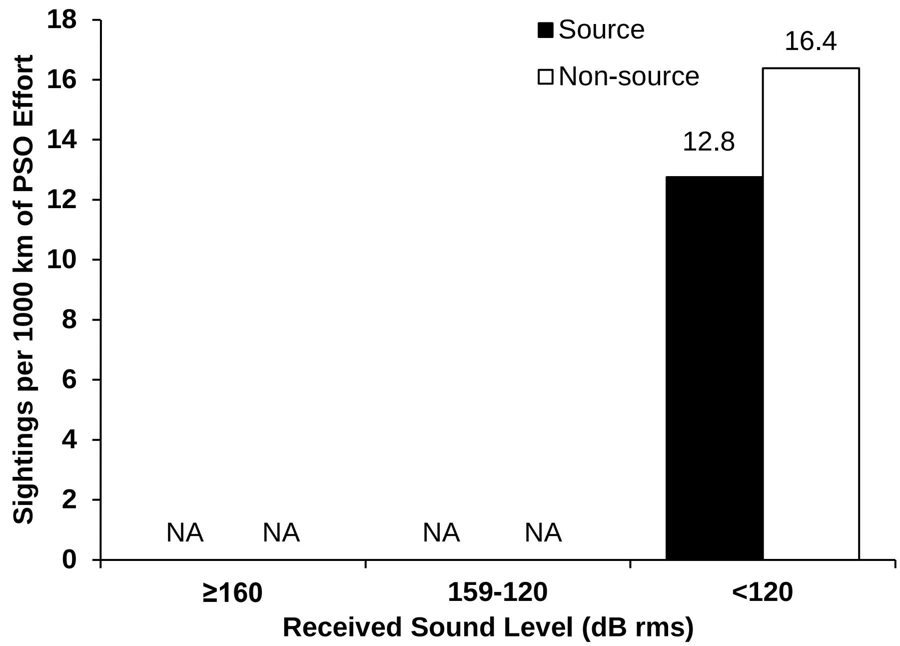

FIGURE 5.15. Cetacean sighting rates from moving vessels by received sound level for Shell's Chukchi Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

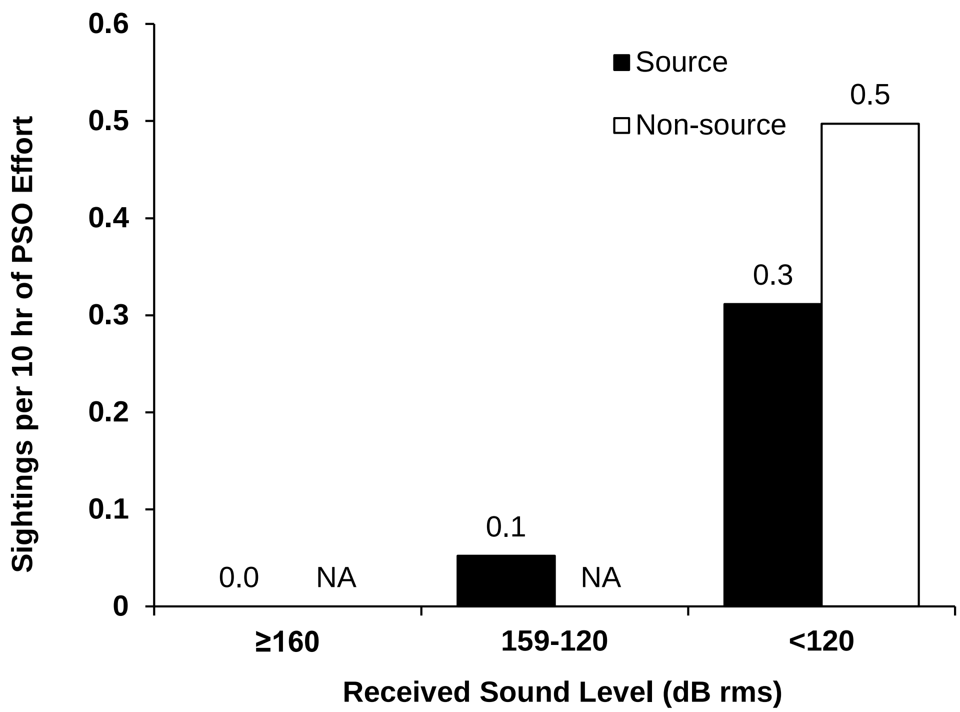

FIGURE 5.16. Cetacean sighting rates from stationary vessels by received sound level for Shell's Chukchi Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

Seal Sightings

There were 938 seal sightings of 1386 individuals by PSOs on the project vessels (Table 5.4). 291 of these sightings occurred while project vessels were moving, and 190 of the sightings occurred while vessels were stationary (Table 5.5 and 5.6). The majority of seal sightings could not be identified to species (68%; Table 5.4). Diagnostic features for identifying seals to species are oftentimes not observed from vessels since seal sightings tend to be brief in duration. PSOs were instructed to identify animals based on clearly observed characteristics.

Seal Sighting Rates

Seal sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect seals (See Chapter 4 and Appendix C) and the sightings that occurred during those periods.

Seal Sighting Rates by Beaufort Wind Force – Seal sighting rates from moving project vessels were greatest during periods of Bf one (Fig. 5.17). Seal sighting rates from stationary project vessels were also greatest during Bf one; however, there was limited observation effort for stationary non-source vessels during Bf one so the sighting rate should be viewed with some caution. As would be expected, most seal sightings from the project vessels occurred on days with lower average daily Beaufort wind force (Fig. 5.17). Observation effort during Bf 0 days is limited, so those sighting rates should be viewed with some caution.

Seal Sighting Rates by Number of PSOs – While the project vessels were moving, the seal sighting rates with two PSOs on watch were slightly higher than sighting rates with one PSO on watch. While project vessels were stationary, seal sighting rates with two PSOs on watch was approximately two times greater than with one PSO on watch.

TABLE 5.4. Total number of seal sightings (number of individuals) from the project vessels during Shell's exploratory drilling operations, 2012.

	Total			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Seals				
Bearded seal	54 (59)	95 (103)	***149***	***(162)***
Ringed seal	40 (41)	39 (44)	***79***	***(85)***
Spotted seal	51 (60)	17 (19)	***68***	***(79)***
Unidentified pinniped	18 (19)	37 (43)	***55***	***(62)***
Unidentified seal	318 (387)	269 (611)	***587***	***(998)***
Total Seals	***481 (566)***	***457 (820)***	***938***	***(1386)***

TABLE 5.5. Number of seal sightings (number of individuals) from the moving project vessels during Shell's exploratory drilling operations, 2012.

Species	Moving			
	Source Vessels	Non-source Vessels	*Sightings*	*(Individuals)*
Seals				
Bearded seal	28 (33)	40 (47)	***68***	***(80)***
Ringed seal	12 (12)	21 (21)	***33***	***(33)***
Spotted seal	28 (32)	11 (12)	***39***	***(44)***
Unidentified pinniped	11 (12)	31 (37)	***42***	***(49)***
Unidentified seal	212 (274)	224 (245)	***436***	***(519)***
Total Seals	***291 (363)***	***327 (362)***	***618***	***(725)***

TABLE 5.6. Number of seal sightings (number of individuals) from the stationary project vessels during Shell's exploratory drilling operations, 2012

Species	Stationary			
	Source Vessels	Non-source Vessels	*Sightings*	*(Individuals)*
Seals				
Bearded seal	26 (26)	55 (56)	***81***	***(83)***
Ringed seal	28 (29)	18 (23)	***46***	***(53)***
Spotted seal	23 (28)	6 (7)	***29***	***(35)***
Unidentified pinniped	7 (7)	6 (6)	***13***	***(13)***
Unidentified seal	106 (113)	45 (366)	***151***	***(479)***
Total Seals	***190 (203)***	***130 (458)***	***320***	***(661)***

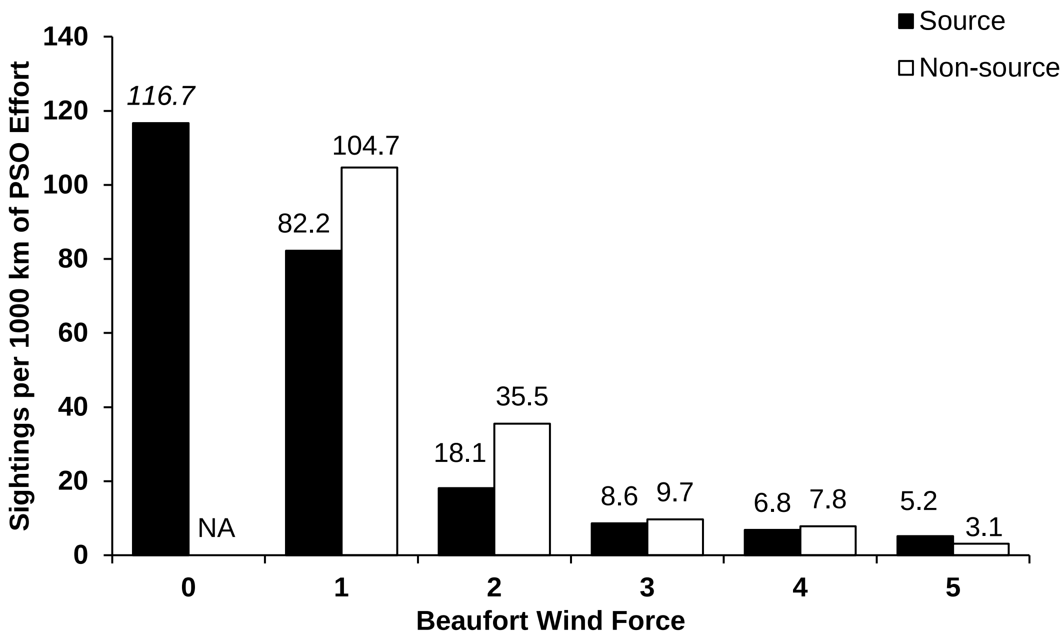

FIGURE 5.17. Seal sighting rates from moving vessels by Beaufort wind force during Chukchi Sea exploratory drilling operations, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

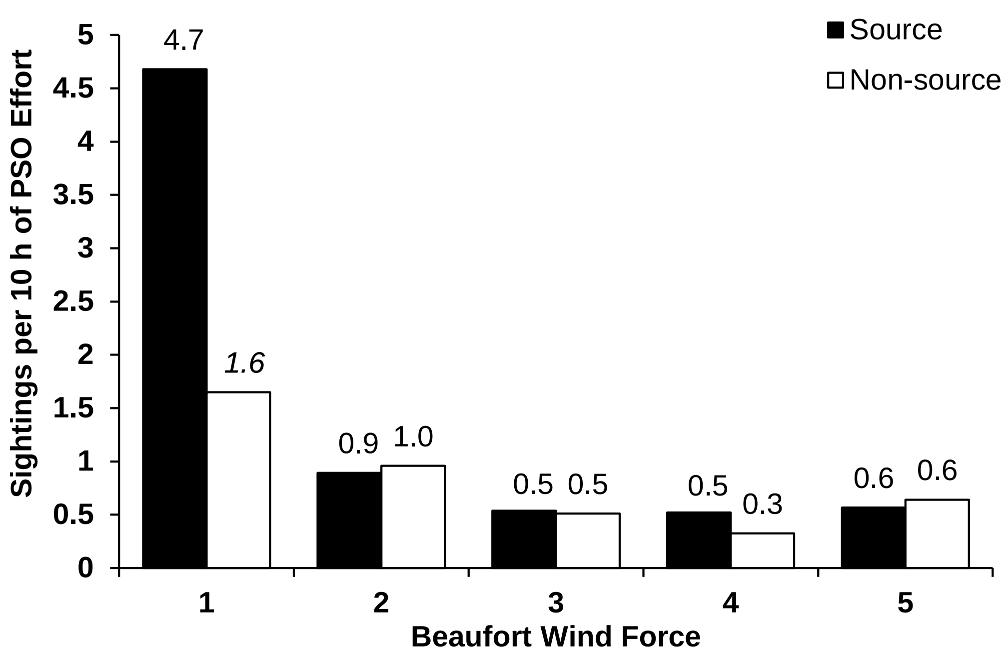

FIGURE 5.18. Seal sighting rates from stationary vessels by Beaufort wind force during Chukchi Sea exploratory drilling operations, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

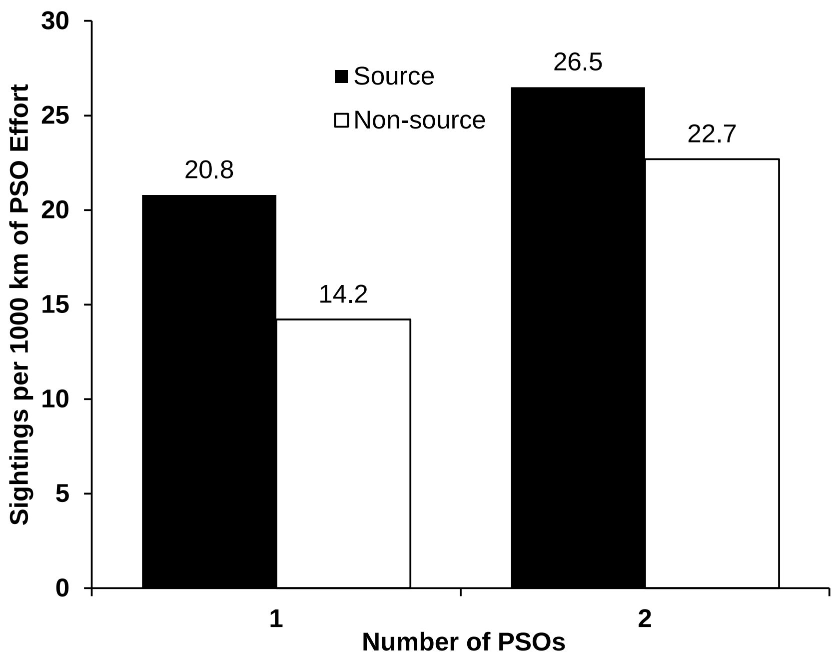

FIGURE 5.19. Seal sighting rates from moving vessels by number of PSOs on watch from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

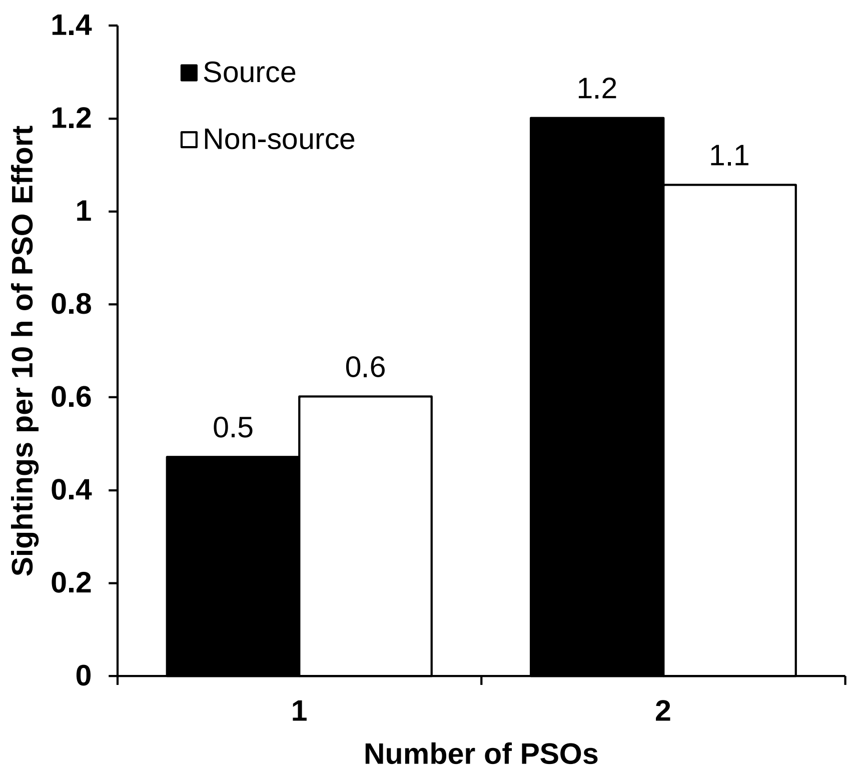

FIGURE 5.20. Seal sighting rates from stationary vessels by number of PSOs on watch from the project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

Seal Sighting Rates by Vessel Activity– Seal sighting rates were highest during moving periods when exposed to anchor handling (Fig. 5.21). Observers on stationary vessels observed the highest rate of seal sightings during general vessel activities (Fig. 5.22). Anchor handling was restricted to operational periods with low sea states. High seal sighting rates from source vessels during this activity likely were related to favorable conditions for detecting seals [and also the likelihood of two PSOs to be on watch during these periods on source vessels compared to only a single observer on non-source vessels (Fig. 5.19 and 5.20)].

Seal Sighting Rates by Received Sound Level – PSO effort was not evenly distributed over received sound level bins (Fig. 5.23 and 5.24). Factors which contributed to this uneven distribution include 1) sound pressure levels from activities such as drilling and ice management attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sounds at this level. During stationary and moving periods when animals would have been exposed to >120 dB (rms) and sufficient effort was recorded in these bins, few sightings were reported as exposed to >120 dB (rms).

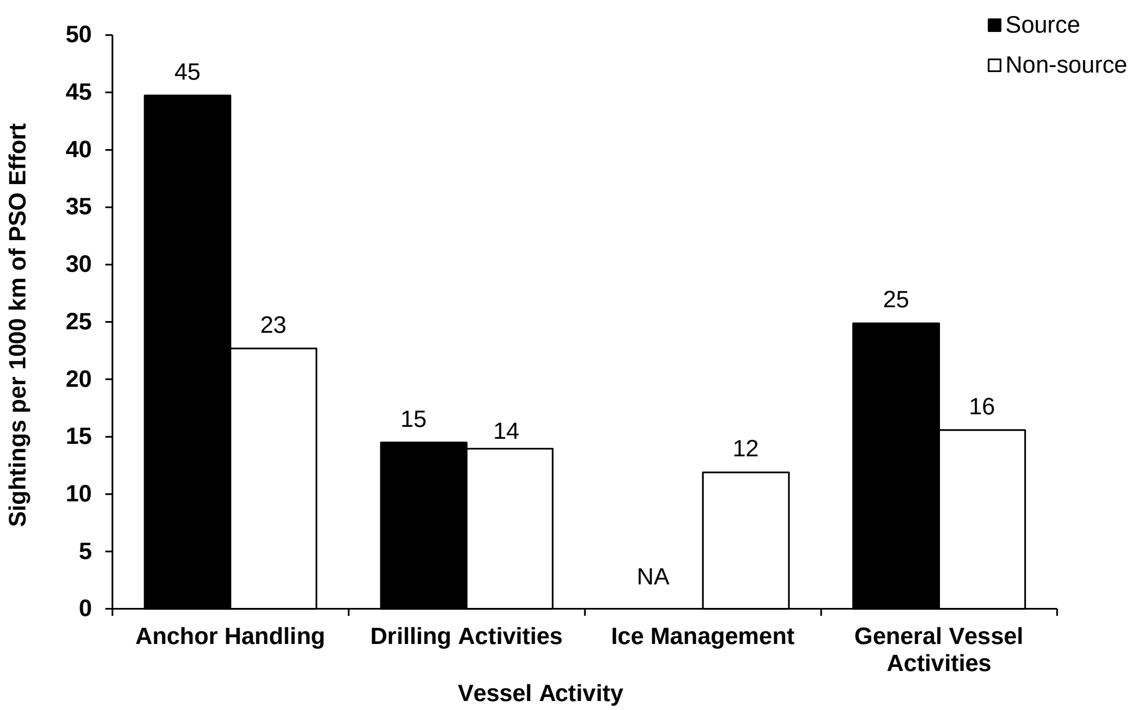

FIGURE 5.21. Seal sighting rates by vessel activity from the moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. A indicates that there was insufficient effort in the category to calculate a sighting rate.

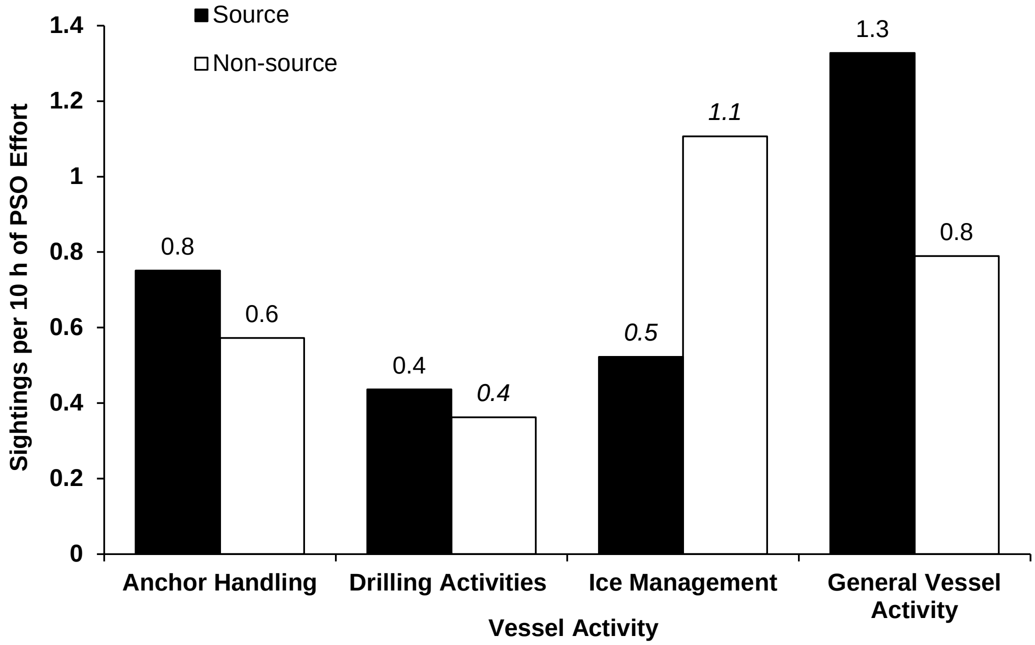

FIGURE 5.22. Seal sighting rates by vessel activity from the stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

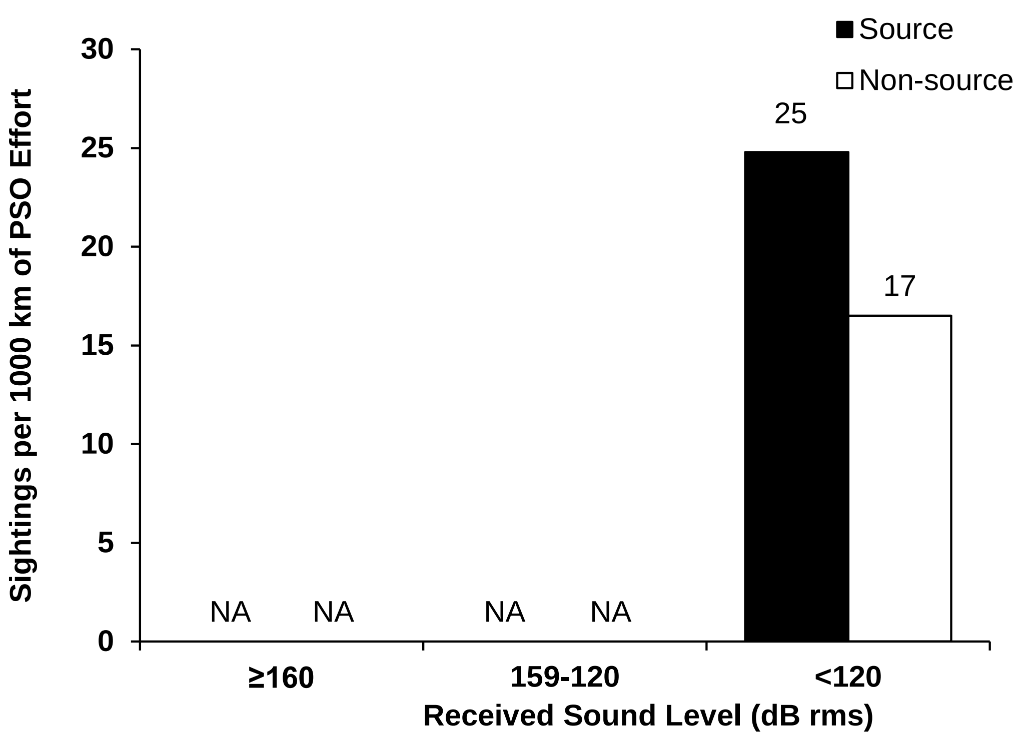

FIGURE 5.23. Seal sighting rates by received sound level moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

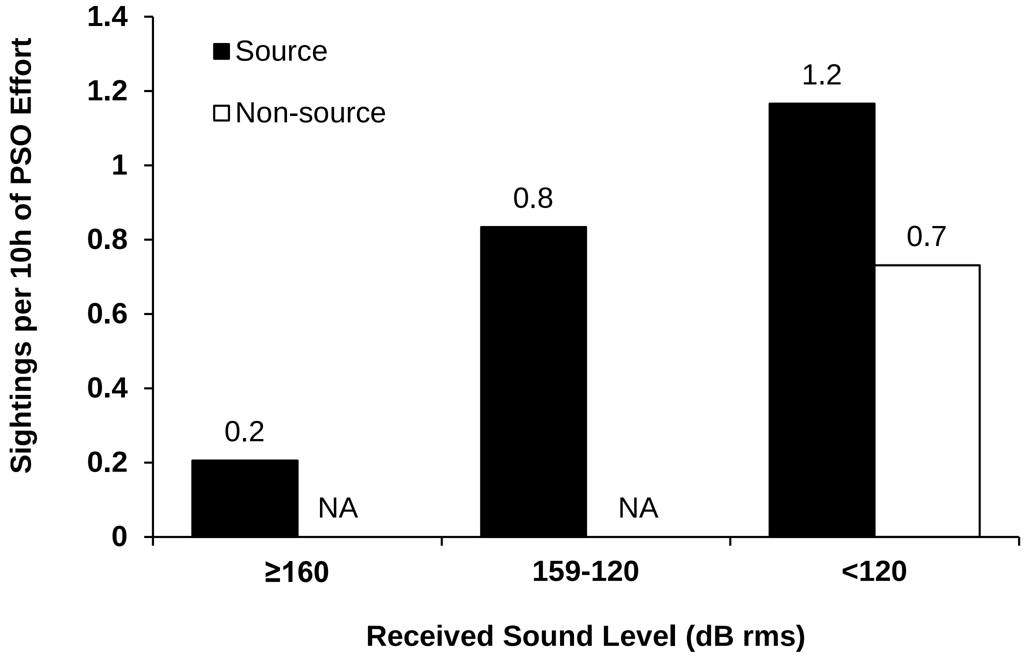

FIGURE 5.24. Seal sighting rates by received sound level from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

Pacific Walrus Sightings

There were 338 Pacific walrus sightings of 8678 individuals observed by PSOs on the project vessels (Table 5.7). There were 261 walrus sightings of 7306 individuals observed by PSOs on moving vessels and 77 walrus sightings of 1372 individuals observed by PSOs on stationary vessels (Table 5.8 and 5.9). The average group size was ~ 26 walrus for moving and stationary vessels combined.

Pacific Walrus Sighting Rates

Pacific walrus sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect walruses (See Chapter 4 and Appendix E) and the sightings that occurred during those periods.

TABLE 5.7. Total Number of Pacific Walrus sightings (number of individuals) from the project vessels during Shell's exploratory drilling operations, 2012.

	Total		
Species	**Source Vessels**	**Non-source Vessels**	***Sightings (Individuals)***
Pacific walrus	184 (6058)	154 (2620)	***338 (8678)***

TABLE 5.8. Number of Pacific Walrus sightings (number of individuals) from the moving project vessels during Shell's exploratory drilling operations, 2012.

	Moving			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Pacific walrus	128 (4928)	133 (2378)	***261***	***(7306)***

TABLE 5.9. Number of Pacific Walrus sightings (number of individuals) from the stationary project vessels during Shell's exploratory drilling operations, 2012.

	Stationary			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Pacific walrus	56 (1130)	21 (242)	***77***	***(1372)***

Pacific Walrus Sighting Rates by Beaufort Wind Force – Pacific walrus sighting rates from moving project vessels were greatest during Bf one, although the data showed no clear trend (Fig. 5.25). Pacific walrus sighting rates from stationary vessels were greatest during Bf one, although these results should be viewed with caution as there was very little effort for non-source vessels in Bf one (Fig. 5.26). ***Pacific Walrus Sighting Rates by Number of PSOs –*** Pacific Walrus sighting rates were somewhat greater between source and non-source vessels with one PSO on watch than two PSOs on watch during moving and stationary periods (Fig. 5.27).

Pacific Walrus Sighting Rates by Vessel Activity – Walrus sightings rates were highest during moving periods when exposed to anchor handling (Fig. 5.29). Observers on stationary vessels observed the highest rate of pacific walrus sightings during ice management activities, however limited effort occurred during ice management activities so those sighting rates should be viewed with caution (Fig. 5.30).

Walrus Sighting Rates by Received Sound Level – PSO effort was not evenly distributed over received sound level bins. Factors which contributed to this uneven distribution include 1) sound pressure levels from activities such as drilling and ice management attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sounds at this level. During moving periods received sound levels >120 dB (rms) lacked sufficient effort required for meaningful analysis. There was no clear trend in walrus sighting rates during stationary periods when compared across received sound level (dB rms), however sighting rates were highest when received sound levels were 159-120 dB (rms) (Fig. 5.32).

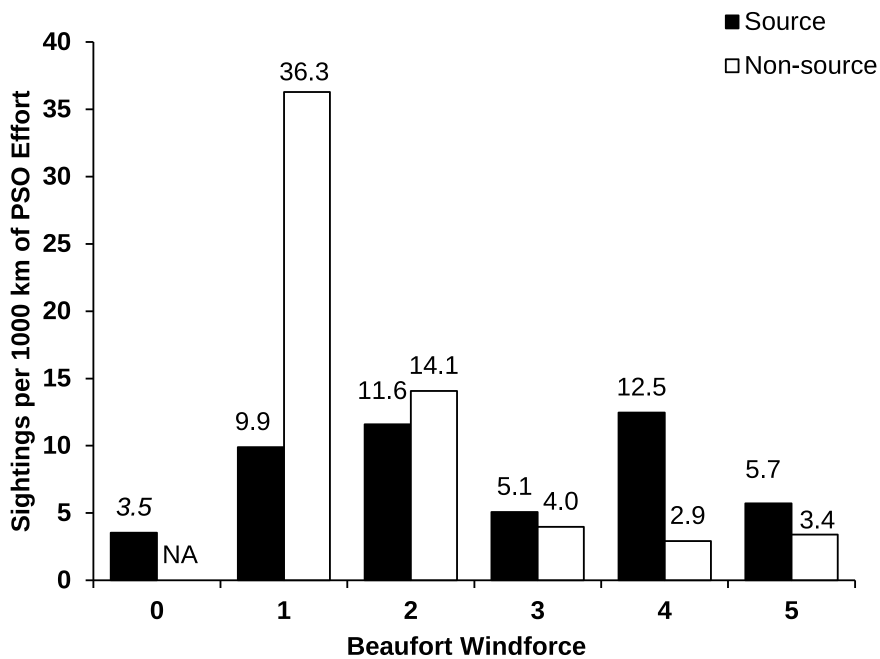

FIGURE 5.25. Walrus sighting rates by Beaufort wind force from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

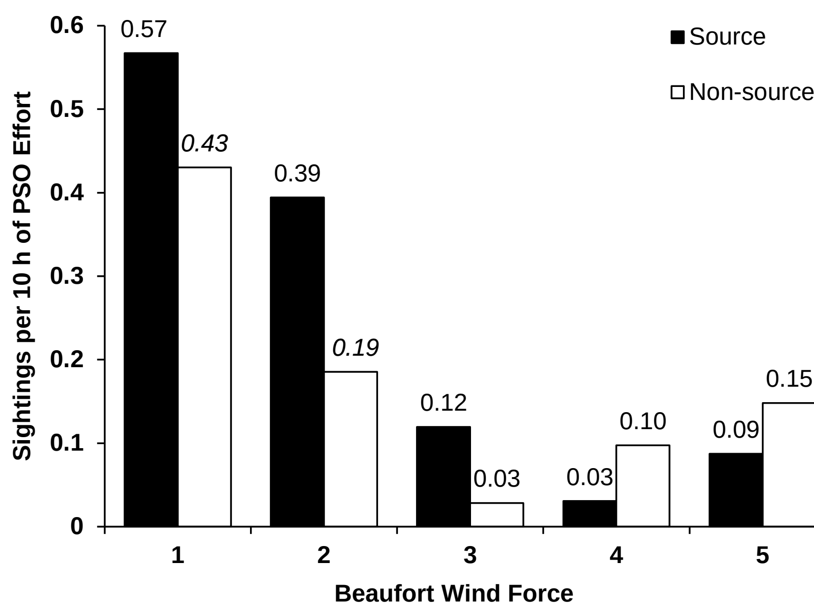

FIGURE 5.26. Walrus sighting rates by Beaufort wind force from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

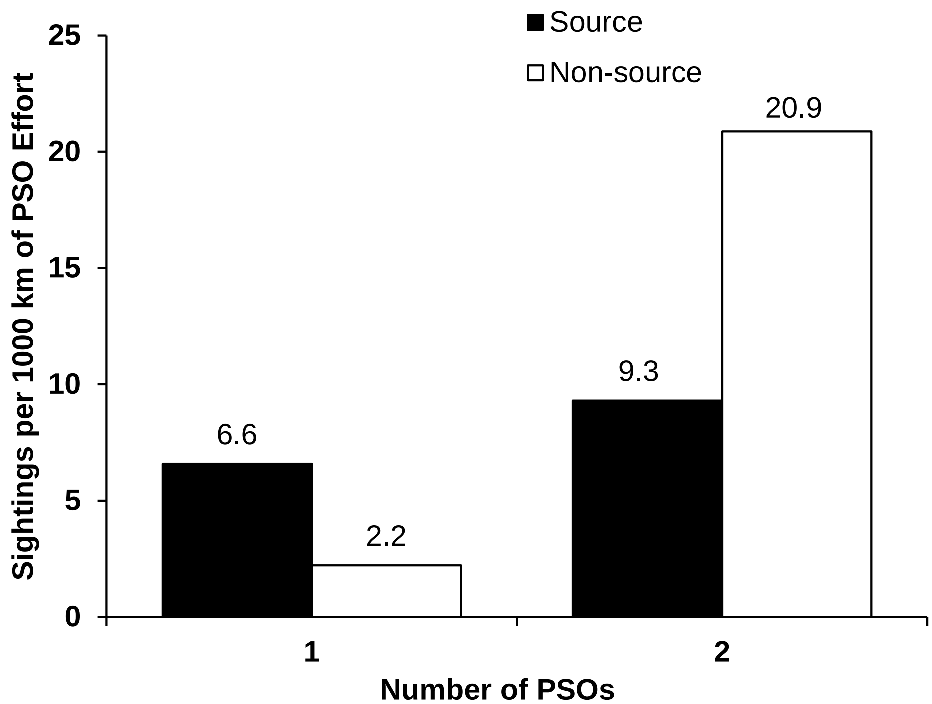

FIGURE 5.27. Walrus sighting rates by the number of PSOs from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

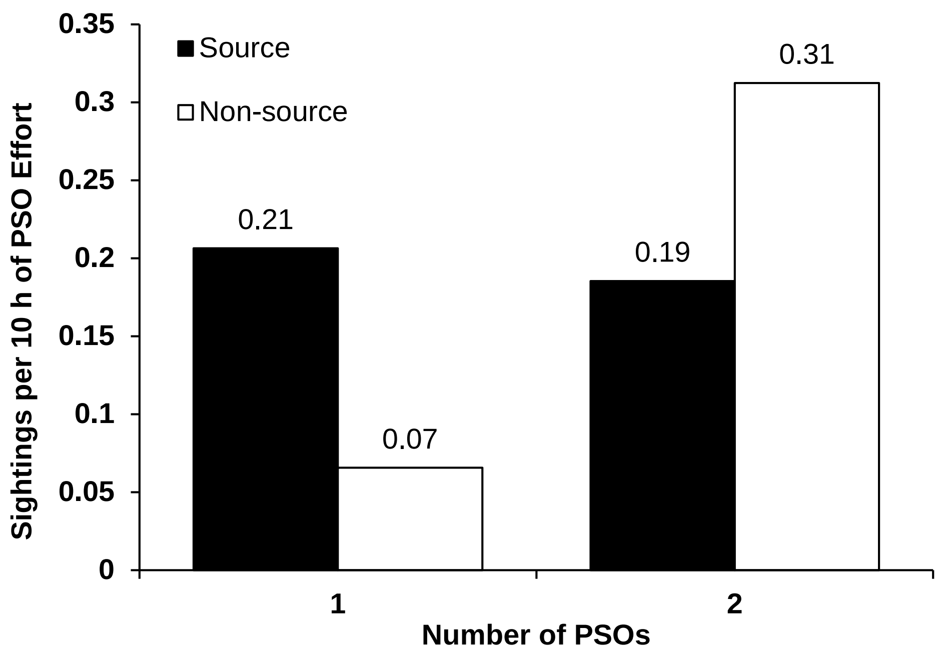

FIGURE 5.28. Seal sighting rates by the number of PSOs from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

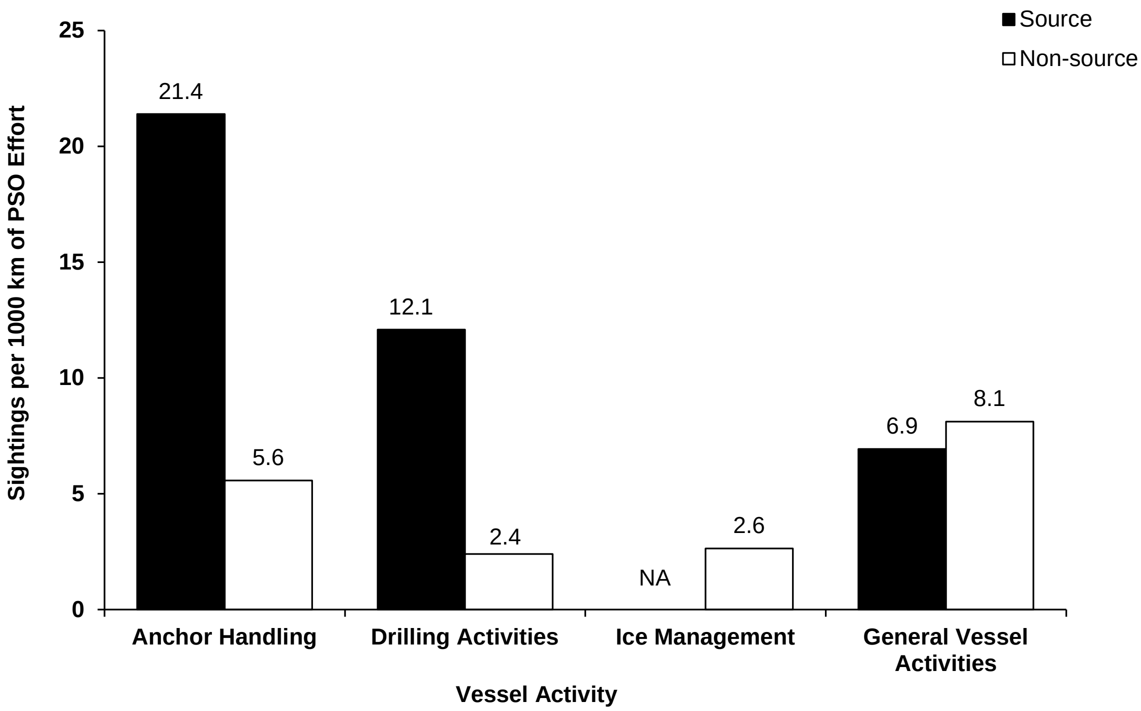

FIGURE 5.29. Walrus sighting rates by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

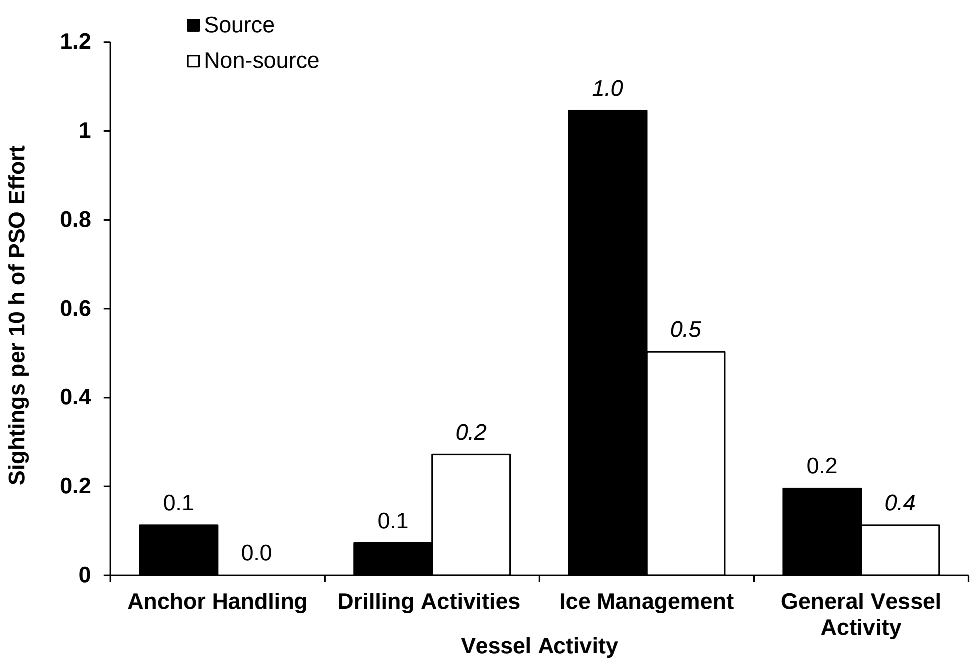

FIGURE 5.30. Walrus sighting rates by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

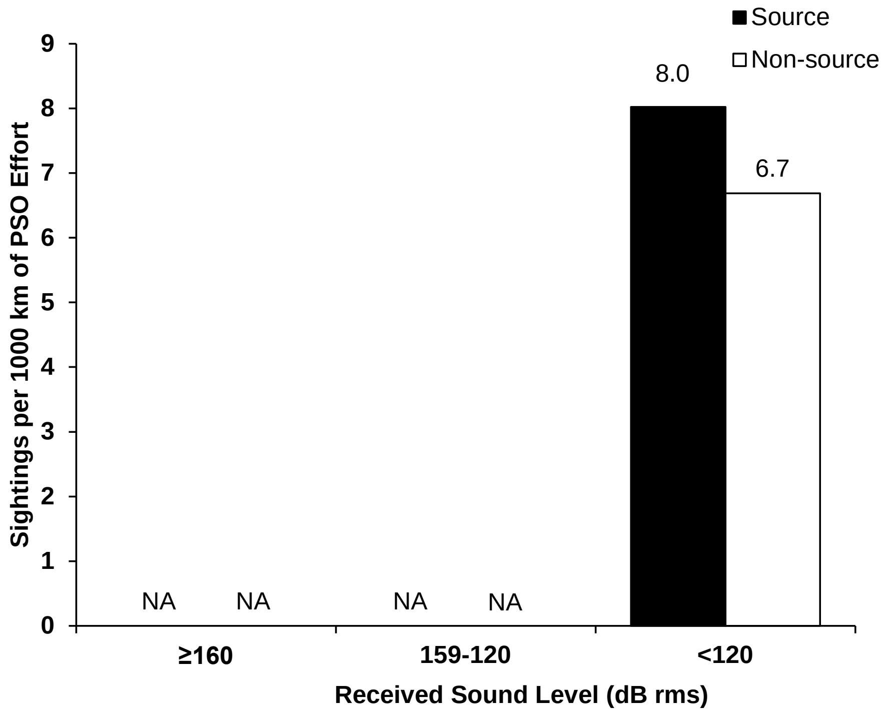

FIGURE 5.31. Walrus sighting rates by received sound level from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

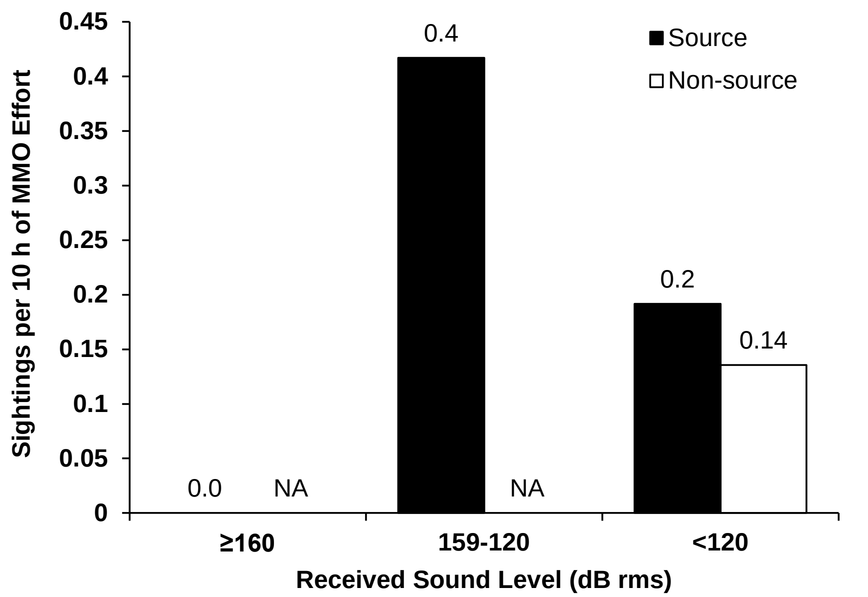

FIGURE 5.32. Walrus sighting rates by received sound level from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

Polar Bear Sightings

PSOs observed 49 sightings of 61 individual polar bears from the project vessels (Table 5.10). There were 24 polar bear sightings of 35 individuals recorded by PSOs on moving vessels and 25 polar bear sightings of 26 individuals observed by PSOs on stationary vessels (Table 5.11 and 5.12).

Polar Bear Sighting Rates

Polar bear sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect polar bears (See Chapter 4 and Appendix E) and the sightings that occurred during those periods.

Polar Bear Sighting Rates by Beaufort Wind Force – Polar bear sighting rates from moving project vessels were greatest during Bf two (Fig. 5.33). Polar bear sighting rates from stationary project vessels were greatest during Bf one and two, although insufficient effort was recorded during Bf one for meaningful comparison (Fig. 5.34).

Polar Bear Sighting Rates by Number of PSOs – Polar bear sighting rates were greater with two PSOs on watch than with one PSO on watch (Fig. 5.35 and 5.36). Only one polar bear sighting was observed with one PSO on watch during moving periods. Sighting rates were nearly four times higher with two PSOs on watch during stationary periods (Fig. 5.36).

Polar Bear Sighting Rates by Vessel Activity – Polar bear sightings rates were highest during moving periods when exposed to general vessel activities. Observers on stationary vessels had the highest rate of polar bear sightings during ice management activities, however limited effort occurred during ice management activities so those sighting rates should be viewed with caution.

TABLE 5.10. Total Number of Polar Bear sightings (number of individuals) from the project vessels during Shell's exploratory drilling operations, 2012.

	Total			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Polar Bear	33 (35)	16 (26)	***49***	***(61)***

TABLE 5.11. Number of Polar Bear sightings (number of individuals) from the moving project vessels during Shell's exploratory drilling operations, 2012.

	Moving			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Polar Bear	12 (13)	12 (22)	***24***	***(35)***

TABLE 5.12. Number of Polar Bear sightings (number of individuals) from the stationary project vessels during Shell's exploratory drilling operations, 2012.

	Stationary			
Species	**Source Vessels**	**Non-source Vessels**	***Sightings***	***(Individuals)***
Polar Bear	21 (22)	4 (4)	***25***	***(26)***

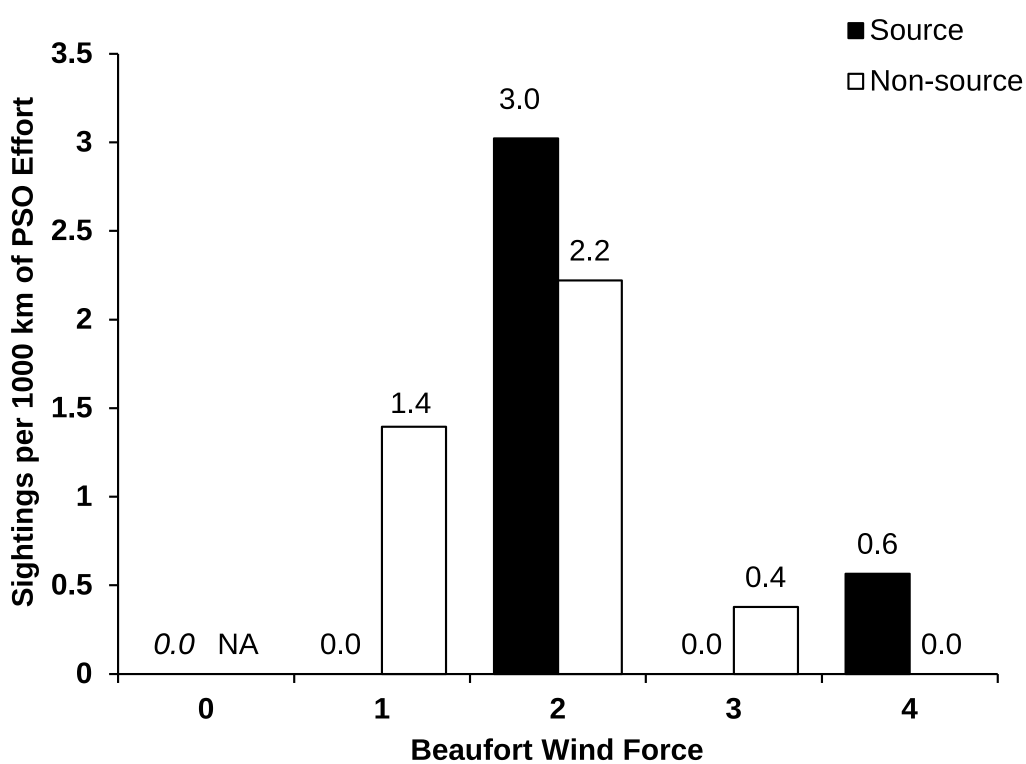

FIGURE 5.33. Polar bear sighting rates by Beaufort wind force from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

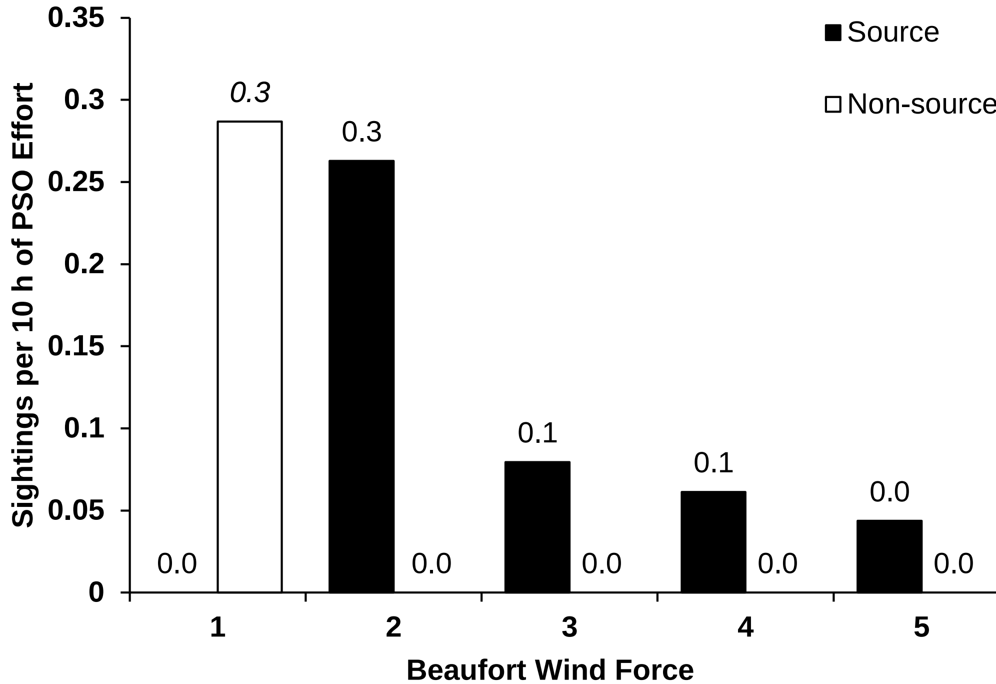

FIGURE 5.34. Polar bear sighting rates by Beaufort wind force from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

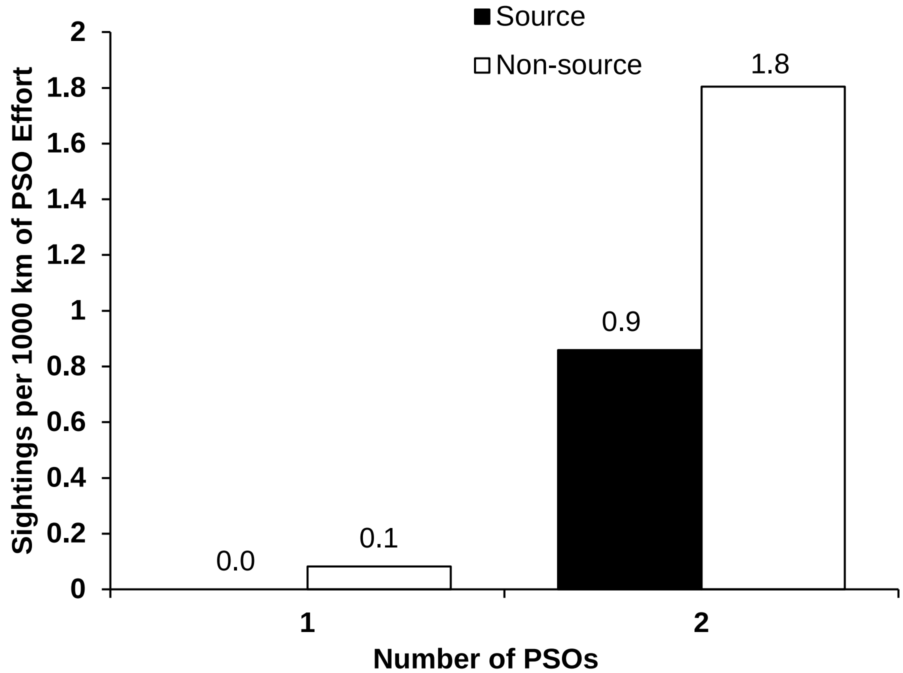

FIGURE 5.35. Polar bear sighting rates by the number of PSOs from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

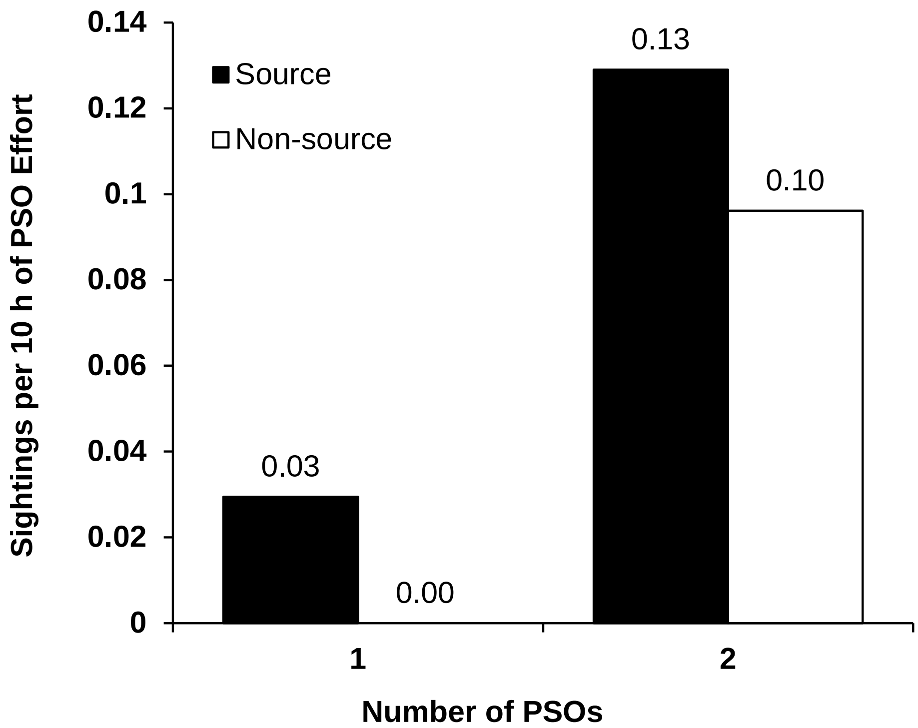

FIGURE 5.36. Polar bear sighting rates by the number of PSOs from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

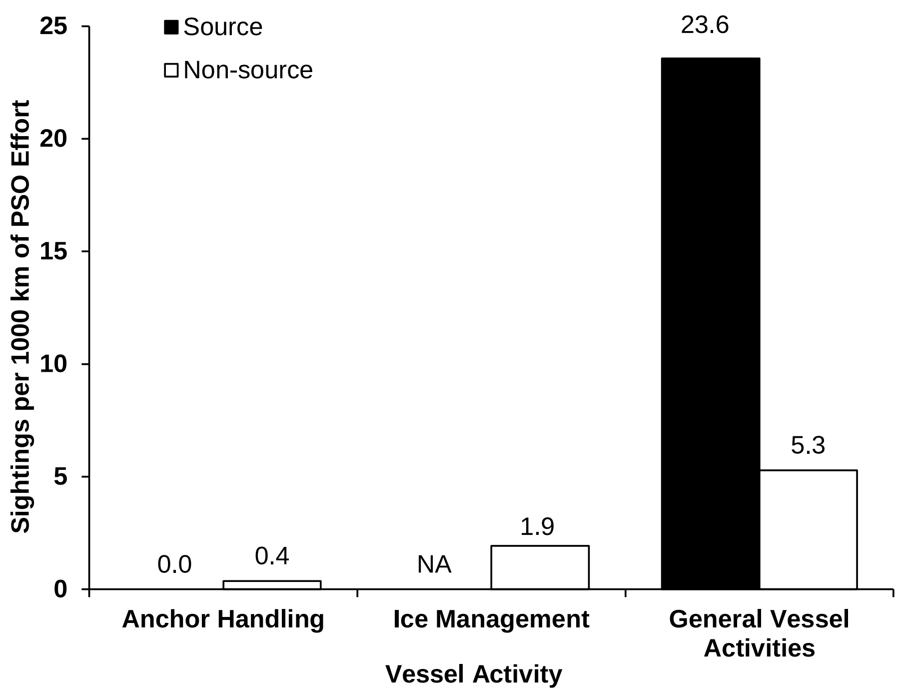

FIGURE 5.37. Polar bear sighting rates by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

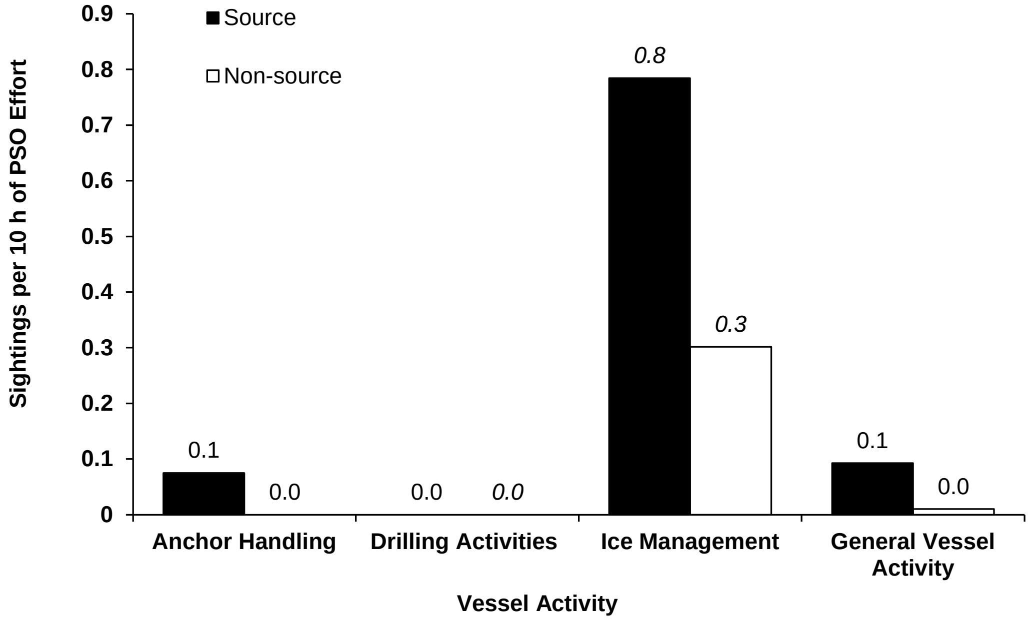

FIGURE 5.38. Polar bear sighting rates by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

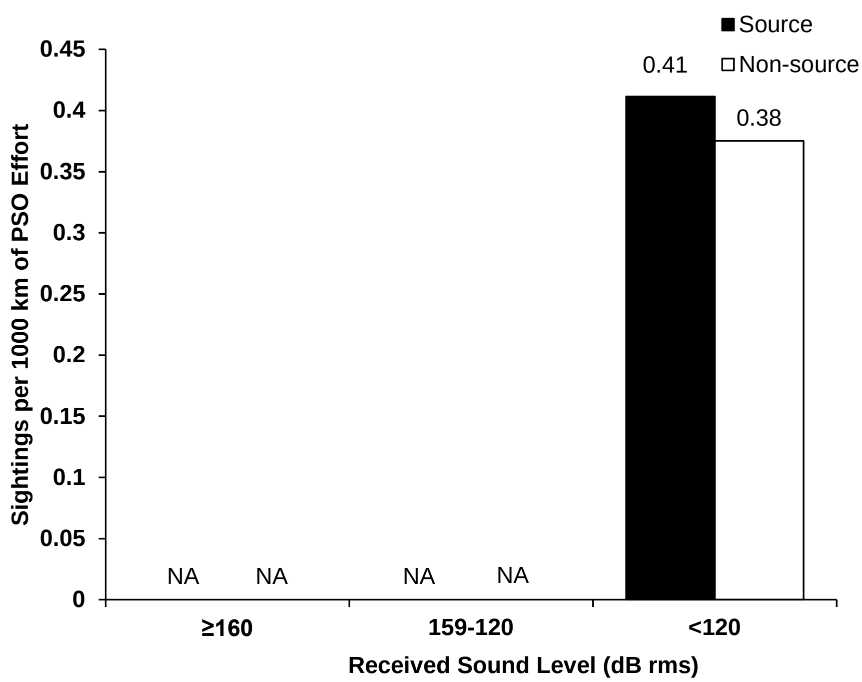

FIGURE 5.39. Polar bear sighting rates by received sound level from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

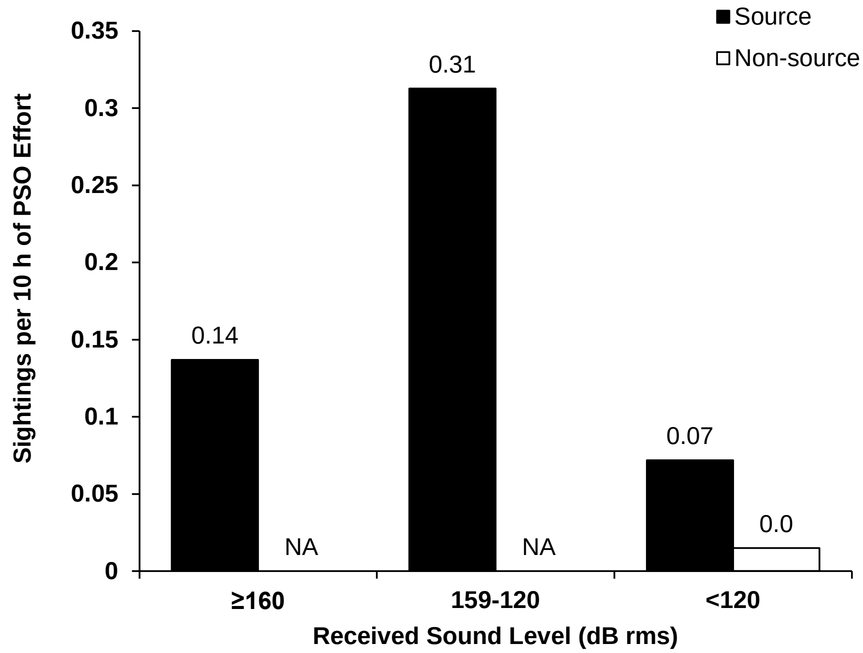

FIGURE 5.40. Polar bear sighting rates by received sound level from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

Distribution and Behavior of Marine Mammals

Marine mammal behaviors and reactions were difficult to observe because individuals and/or groups of animals typically spent most of their time below the water surface and could not be observed for extended periods, however data collected from stationary vessels, which typically allow observers sightings of extended duration, can offer a more accurate picture of surface behaviors than data collected from moving vessels. The PSOs' primary duty was to implement mitigation rather than collect extensive behavioral data. Relevant data collected include estimated closest observed point of approach (CPA), direction of movement relative to the vessel, initial behavior of the animal, and reaction of the animal to the vessel presence or activity.

Closest point of Approach

The mean CPA of cetaceans, seals, Pacific walruses, and polar bears were calculated using only sightings that occurred during periods of effort that met the criteria for reliable detection (see Chapter 4 and Appendix E).

Cetaceans

Cetacean sightings were recorded during moving and stationary vessel periods. Cetacean CPAs during moving vessel activity ranged from 30 to 10,000 m from the observer station (Table 5.13). The maximum allowable distance for sightings, 10,000 m, is based on the distance to the horizon from the height of an average observer on a vessel. There were six cetacean sightings which met or possibly exceeded 10,000 m; all were estimated distances of cetaceans seen on the horizon. There was little variation between CPAs from moving vessels during different vessel activities. During periods of stationary vessel activity cetacean CPAs ranged from 100 to 8000 m (Table 5.14).

TABLE 5.13. Comparison of mean cetacean CPA distances by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities.

Moving Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	2103	2082	50–10000	***51***
Drilling Activities	1526	1467	100–8500	***47***
Ice Management	2153	1199	875	***11***
General Vessel Activities	2002	2038	30–14400	***279***
Total	***1962***	***1966***	***30–14400***	***388***

[a] CPA=*Closest Point of Approach.*

TABLE 5.14. Comparison of mean cetacean CPA distances by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during stationary periods.

Stationary Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	3161	1892	212–7593	***22***
Drilling Activities	1816	1448	300–5128	***9***
Ice Management	875	--	875	***1***
General Vessel Activity	2818	2262	100–8000	***74***
Total	***2786***	***2140***	***100–8000***	***106***

[a] CPA=*Closest Point of Approach.*

Seals

The mean CPA for seals observed from moving project vessels was greater than the CPA for seals from stationary project vessels. Seals regularly approached stationary vessels such as the *Discoverer* and some seals maintained their close position for several days. CPAs ranged from 9 to 5031 m for moving vessels and 0 to 4500 m for stationary vessels (Table 5.15 and 5.16). The closest point of approach for all project vessels in the Chukchi Sea was a brief seal sighting in the moon pool of *Discoverer*, recorded as < 1 m distance from the vessel.

TABLE 5.15. Comparison of mean seal CPA distances by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

Moving Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	500	663	20–4000	***82***
Drilling Activities	225	358	20–2173	***47***
Ice Management	124	132	20–410	***10***
General Vessel Activities	404	553	9–5031	***340***
Total	***397***	***557***	***9–5031***	***479***

[a] CPA=*Closest Point of Approach.*

TABLE 5.16. Comparison of mean seal CPA distances by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during stationary periods.

Stationary Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	205	477	0–2500	***29***
Drilling Activities	143	131	20–400	**13**
Ice Management	154	159	10–600	***14***
General Vessel Activity	296	457	10–4500	***195***
Total	***270***	***438***	***0–4500***	***251***

[a] CPA=*Closest Point of Approach.*

Pacific Walruses

CPAs of Pacific walrus on ice and in water were considered separately because regulatory requirements were different for each of these situations as were their sightability by PSOs. Walruses were more easily detected on ice than in the water. Mean CPA for walruses observed from moving vessels was 4.9 times greater than the mean CPA for walruses observed in water (Table 5.17 and 5.18). Mean CPA for walruses observed from stationary vessels was 9.9 times greater than the mean CPA for walruses observed in water (Table 5.19 12nd 5.20). There was only one walrus in the water seen during ice management. The mean CPA for walruses on ice during ice management was 5440 m; ice management activities were primarily scouting and monitoring and vessels were instructed to maintain a distance of 800 m (0.5 mi) from walruses on ice.

The mean CPA for walruses observed in water from stationary vessels during drilling activities was 69 m (Table 5.19). The closest approach of a walrus to a project vessel in the Chukchi was a juvenile walrus which approached the *Tor Viking* and physically contacted the vessel many times, probably attempting to haul out on the vessel.

TABLE 5.17. Comparison of mean walrus CPA distances in water by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

Moving Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	599	503	50–1500	***22***
Drilling Activities	640	1052	15–3560	***11***
Ice Management	50	--	50–50	***1***
General Vessel Activities	742	786	30–5000	***119***
In Water Total	***710***	***770***	***15–5000***	***153***

[a] CPA=*Closest Point of Approach.*

TABLE 5.18. Comparison of mean walrus CPA distances on ice by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

Moving Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	4564	2535	1000–7000	***4***
Drilling Activities	3559	1151	2173–5000	***9***
Ice Management	5440	2434	3000–8000	***4***
General Vessel Activities	2927	1433	913–6480	***23***
On Ice Total	***3484***	***1754***	913–8000	***40***

[a] CPA=*Closest Point of Approach.*

TABLE 5.19. Comparison of mean Pacific walrus CPA distances in water by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during stationary periods.

Stationary Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	1188	583	775–1600	***2***
Drilling Activities	69	24	50–100	***4***
Ice Management	1125	1199	300–2500	***3***
General Vessel Activity	485	747	5–3256	***22***
Total	***539***	***769***	***5–3256***	***31***

[a] CPA=*Closest Point of Approach.*

TABLE 5.20. Comparison of mean Pacific walrus CPA distances on ice by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during stationary periods.

Stationary Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	7000	--	7000–7000	***1***
Drilling Activities	6264	--	6264–6264	***1***
Ice Management	5456	2240	2444–8268	***10***
General Vessel Activity	4487	2628	1943–10000	***8***
Total	***5186***	***2324***	***1943–10000***	***20***

[a] CPA=*Closest Point of Approach.*

Polar Bears

CPAs of polar bears on ice and in water were considered separately because regulatory requirements differ for each of these situations as does the sightability of polar bears by PSOs. As with Pacific walruses, polar bears were more easily detected on ice than in the water and vessels were requested to maintain an 800 m (0.5 mi) distance from polar bears on ice. Mean CPA for polar bears in water CPAs ranged from 50 to 1610 m for moving vessels and 0 to 1401 m for stationary vessels (Table 5.21 and 5.23). Polar Bears on ice was over 3 times farther for moving vessels and over 7 times farther for stationary vessels (Table 5.22 and 5.24) than it was for animals seen in the water. In several instances polar bears approached both moving and stationary vessels, and one polar bear (CPA of 0 m) touched the hull of the *Discoverer* with its forepaw.

TABLE 5.21. Comparison of mean polar bear CPA distances in water by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

Moving Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	1610	--	1610	***1***
Drilling Activities	--	--	--	**--**
Ice Management	50	--	50	***1***
General Vessel Activities	--	--	--	**--**
In Water Total	***830***	***1103***	***50–1610***	***2***

[a] CPA=*Closest Point of Approach.*

TABLE 5.22 Comparison of mean polar bear CPA distances in ice by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances for sightings exposed to all four vessel activities during moving periods.

Moving Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	--	--	--	--
Drilling Activities	--	--	--	--
Ice Management	3082	1863	993–6000	*7*
General Vessel Activities	3329	1955	200–5880	*7*
On Ice Total	***3206***	***1839***	***200–6000***	***14***

[a] CPA=*Closest Point of Approach.*

TABLE 5.23. Comparison of mean polar bear CPA distances in water by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances from all four vessel activities.

Stationary Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	150	212	0–300	*2*
Ice Management	400	495	50–750	*2*
General Vessel Activity	540	476	40–1401	*6*
Total	***434***	***429***	***0–1401***	***10***

[a] CPA=*Closest Point of Approach.*

TABLE 5.24. Comparison of mean polar bear CPA distances on ice by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012. The overall mean includes CPA distances from all four vessel activities.

Stationary Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Ice Management	2543	1961	493–5773	*7*
Anchor Handling	--	--	--	--
General Vessel Activity	4170	2790	1088–7000	*4*
Total	***3134***	***2306***	***493–7000***	***11***

[a] CPA=*Closest Point of Approach.*

Movement

Cetaceans

There were 581 cetacean sightings, 466 from moving vessels and 115 from stationary vessels (Table 5.1). The large distances at which most cetaceans were initially detected from vessels made it difficult to observe directions of movement, and predictably, the most common movements of cetaceans are neutral and unknown. Of cetacean sightings from moving vessels, ~44% of sightings had either no observed movement or neutral movement relative to the vessel and ~29% of movement was unknown (Table 5.25). Approximately 47% of cetacean sightings from stationary vessels had either no observed movement or neutral movement relative to the vessel and ~31% of movement was unknown (Table 5.26). Swim away was the next most common movement relative to the vessel with ~18% of sightings from moving vessels and ~16% of sightings from stationary vessels exhibiting this movement.

TABLE 5.25. Number of cetacean sightings within categories of movement relative to moving vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	37	1	11	2	13	***64***
Drilling Activities	29	--	9	5	13	***56***
Ice Management	5	1	1	3	3	***13***
General Vessel Activities	120	10	67	27	109	***333***
Total	***191***	***12***	***88***	***37***	***138***	***466***

TABLE 5.26. Number of cetacean sightings within categories of movement relative to stationary vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	8	--	5	--	9	***22***
Drilling Activities	4	--	--	1	4	***9***
Ice Management	2	--	--	--	--	***2***
General Vessel Activities	37	3	13	6	23	***82***
Total	***51***	***3***	***18***	***7***	***36***	***115***

Seals

There were 938 seal sightings, 618 sightings from moving vessels and 320 sightings from stationary vessels (Table 5.4) . The most commonly observed movements of seals relative to vessels were unknown, neutral, and swim away, for sightings from both moving and stationary vessels. Observers on moving vessels recorded ~35% unknown movement, ~28% neutral, and ~17% swim away (Table 5.27). Observers on stationary vessels recorded ~32% unknown movement, ~27% neutral, and ~19% swim away (Table 5.28).

TABLE 5.27. Number of seal sightings within categories of movement relative to vessels by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	27	3	16	6	43	***95***
Drilling Activities	16	2	12	6	17	***53***
Ice Management	3	7	3	1	2	***16***
General Vessel Activities	129	41	75	55	154	***454***
Total	***175***	***53***	***106***	***68***	***216***	***618***

TABLE 5.28. Number of seal sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	11	1	4	4	12	***32***
Drilling Activities	4	2	2	2	10	***20***
Ice Management	5	2	3	4	4	***18***
General Vessel Activities	66	24	53	31	76	***250***
Total	***86***	***29***	***62***	***41***	***102***	***320***

Pacific Walruses

Observers recorded 338 total sightings of Pacific walruses, 261 sightings from moving vessels and 77 sightings from stationary vessels in the Chukchi Sea (Table 5.7). The most common movements of walruses observed from moving vessels were neutral and swim away, at ~34% and ~32% of movement respectively (Table 5.29). The most common movements of walruses observed from stationary vessels were neutral (~29%) and none (~27%) (Table 5.30). However, many of the walrus sightings were of large groups (26 individuals per sighting on average) and these results should be viewed with caution due to difficulties inherent in ascribing a single movement to a large group of animals.

TABLE 5.29. Number of Pacific walrus sightings within categories of movement relative to vessels by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	13	5	3	4	5	***30***
Drilling Activities	8	2	17	3	2	***32***
Ice Management	1	4	--	--	--	***5***
General Vessel Activities	66	18	63	12	35	***194***
Total	***88***	***29***	***83***	***19***	***42***	***261***

TABLE 5.30. Number of Pacific walrus sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	6	2	1	--	1	***10***
Drilling Activities	2	2	1	2	3	***10***
Ice Management	1	9	1	2	--	***13***
General Vessel Activities	13	8	10	6	7	***44***
Total	***22***	***21***	***13***	***10***	***11***	***77***

Polar Bears

There was a total of 49 polar bear sightings recorded, 24 sightings from moving vessels and 25 sightings from stationary vessels (Table 5.10). The most common movement type observed from both moving and stationary vessels was "no observed movement" (Table 5.31 and 5.32). These sightings were primarily of resting polar bears on ice. The two records of a "swim towards" movement were recorded from moving vessels and involved the same individual polar bear approaching both the *Fennica* and *Tor Viking*. Both times the vessels were moving slowly away (>2 knots) and eventually outdistanced the swimming bear. One of the polar bear sightings exhibiting "swim towards" movement was recorded by the *Discoverer* and discussed previously as the polar bear which touched the vessel with its forepaw, and the other two bears approached the *Fennica* while it was in dynamic positioning. Pack ice was at least 10 km away in all instances of polar bears approaching project vessels in the Chukchi Sea.

TABLE 5.31. Number of polar bear sightings within categories of movement relative to vessels by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	1	--	--	--	--	***1***
Drilling Activities	--	--	--	--	--	***--***
Ice Management	1	10	1	2	1	***15***
General Vessel Activities	--	6	2	--	--	***8***
Total	***2***	***16***	***3***	***2***	***1***	***24***

TABLE 5.32. Number of polar bear sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Anchor Handling	1	1	1	1	--	***4***
Ice Management	3	8	--	--	--	***11***
General Vessel Activities	4	1	3	2	--	***10***
Total	***8***	***10***	***4***	***3***	***--***	***25***

Initial Behavior

Cetaceans

The large distances at which most cetaceans were initially detected from vessels make it difficult to observe specific behaviors compared to pinnipeds. "Blow" was the most frequently recorded initial behavior from moving and stationary vessels, comprising ~68% and ~66% of moving and stationary vessel records respectively (Table 5.33 and 5.34). Other initial behaviors were recorded in much smaller numbers. The five most common initial behaviors are shown in the tables below, however many other behaviors were observed during the season. Observers on moving vessels observed breach, feed, flipper slap, log, mill, surface active, surface active travel, porpoise, and unknown behaviors in addition to those shown below. Observers on stationary vessels observed cetaceans exhibit log, mill, surface active, and surface active travel in addition to the five behaviors below.

TABLE 5.33. Comparison of cetacean behaviors by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Blow**	**Dive**	**Fluke**	**Swim**	**Travel**	**Other**	***Totals***
Anchor Handling	44	1	2	5	6	6	***64***
Drilling Activities	41	4	3	2	3	3	***56***
Ice Management	9	1	0	0	0	3	***13***
General Vessel Activities	224	11	14	18	36	30	***333***
Total	***318***	***17***	***19***	***25***	***45***	***42***	***466***

TABLE 5.34. Comparison of cetacean behaviors by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Blow**	**Dive**	**Fluke**	**Swim**	**Travel**	**Other**	***Totals***
Anchor Handling	18	--	--	4	--	--	***22***
Drilling Activities	7	--	1	--	1	--	***9***
Ice Management	--	--	--	1	1	--	***2***
General Vessel Activities	52	4	2	12	6	6	***82***
Total	***77***	***4***	***3***	***17***	***8***	***6***	***115***

Seals

Seal sightings were brief in duration from moving vessels however while the *Discoverer* was moored it was approached by several individual seals that remained for several days. Although sighting duration may have differed between the two data collection techniques, "look" and "swim" were the most frequently recorded initial seal behaviors observed from both moving and stationary vessels (Table 5.35 and 5.36). "Look" comprised ~45% of seal behaviors observed from moving vessels and ~35% of seal behaviors from stationary vessels. "Swim" comprised ~16% of seal behaviors observed from moving vessels and ~18% of seal behaviors from stationary vessels. Observers on moving vessels observed flipper slap, log, mill, raft, sink, surface active travel, thrash, travel, and unknown seal behaviors in addition to those shown below. Observers on stationary vessels observed feed, flipper slap, log, mill, raft, spyhop, sink, surface active travel, thrash, travel, and unknown initial seal behaviors in addition to the five shown below.

Pacific Walruses

"Swim" and "Rest" were the most frequently recorded initial walrus behaviors (Table 5.37 and 5.38). The majority of walruses with the initial behavior of "rest" were observed on ice. Observers on moving vessels recorded "swim" as ~27% of initial behaviors and "rest" as ~19% of initial walrus behaviors (Table 5.37). Observers on stationary vessels recorded "rest" as ~28% of initial behaviors and "swim" as ~25% of initial walrus behaviors (Table 5.38). Observers on moving vessels also observed dive, log, mill, surface active, spyhop, thrash, and unknown walrus behaviors in addition to those shown below and these behaviors were included in the other column . Observers on stationary vessels observed log, mill, surface active, and surface active travel initial walrus behaviors in addition to the five shown below.

TABLE 5.35. Comparison of seal behaviors by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Dive**	**Look**	**Rest**	**Surface Active**	**Swim**	**Other**	***Totals***
Anchor Handling	10	60	2	1	6	16	***95***
Drilling Activities	7	28	1	0	6	11	***53***
Ice Management	0	7	2	0	6	1	***16***
General Vessel Activities	32	183	45	32	81	81	***454***
Total	***49***	***278***	***50***	***33***	***99***	***109***	***618***

TABLE 5.36. Comparison of seal behaviors by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Dive**	**Look**	**Rest**	**Surface Active**	**Swim**	**Other**	***Totals***
Anchor Handling	--	11	3	2	7	9	***32***
Drilling Activities	2	9	3	--	1	5	***20***
Ice Management	3	8	0	2	3	2	***18***
General Vessel Activities	15	86	37	29	46	37	***250***
Total	***20***	***114***	***43***	***33***	***57***	***53***	***320***

TABLE 5.37. Comparison of Pacific walrus behaviors by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Look**	**Rest**	**Surface Active Travel**	**Swim**	**Travel**	**Other**	***Totals***
Anchor Handling	7	6	4	3	6	4	***30***
Drilling Activities	6	7	1	7	7	4	***32***
Ice Management	0	4	0	1	0	0	***5***
General Vessel Activities	26	33	28	60	12	35	***194***
Total	***39***	***50***	***33***	***71***	***25***	***43***	***261***

TABLE 5.38. Comparison of Pacific walrus behaviors by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Dive**	**Look**	**Rest**	**Swim**	**Travel**	**Other**	***Totals***
Anchor Handling	--	1	1	1	1	6	***10***
Drilling Activities	1	5	1	2	--	1	***10***
Ice Management	--	--	10	1	--	2	***13***
General Vessel Activities	1	11	10	15	3	4	***44***
Total	***2***	***17***	***22***	***19***	***4***	***13***	***77***

Polar Bears

More polar bears on ice were observed from moving vessels and more polar bears in the water were observed from stationary vessels. "Rest" was the most frequent behavior of polar bears recorded from moving vessels (~42%) and "swim" was the most frequent behavior of polar bears recorded from stationary vessels (~36%) (Table 5.39 and 5.40). "Other" polar bear behaviors observed from moving vessels include mill and look. "Other" polar bear behaviors observed from stationary vessels include mill, surface active travel, and walk.

TABLE 5.39. Comparison of polar bear behaviors by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Feed**	**Rest**	**Surface Active Travel**	**Swim**	**Walk**	**Other**	***Totals***
Anchor Handling	--	--	1	--	--	--	***1***
Drilling Activities	--	--	--	--	--	--	***--***
Ice Management	--	7	--	3	4	1	***15***
General Vessel Activities	1	3	--	1	2	1	***8***
Total	***1***	***10***	***1***	***4***	***6***	***2***	***24***

TABLE 5.40. Comparison of polar bear behaviors by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Initial Behavior						
Vessel Activity	**Feed**	**Look**	**Rest**	**Swim**	**Travel**	**Other**	***Totals***
Anchor Handling	--	--	--	3	--	1	***4***
Ice Management	--	1	7	2	1	--	***11***
General Vessel Activities	1	1	--	4	1	3	***10***
Total	***1***	***2***	***7***	***9***	***2***	***4***	***25***

Reaction Behavior

Cetaceans

Cetaceans observed from moving and stationary vessels were most often recorded as having no reaction (~95% and ~97% respectively) (Table 5.41 and 5.42). Very few other cetacean reactions were observed.

TABLE 5.41. Comparison of cetacean reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction						
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Splash**	**None**	**Unknown**	***Totals***
Anchor Handling	--	--	--	--	63	1	***64***
Drilling Activities	3	1	--	--	52	--	***56***
Ice Management	--	--	--	--	11	2	***13***
General Vessel Activities	5	--	2	1	319	6	***333***
Total	***8***	***1***	***2***	***1***	***445***	***9***	***466***

TABLE 5.42. Comparison of cetacean reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction						
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	***Totals***
Anchor Handling	--	--	--	--	--	22	***22***
Drilling Activities	1	--	--	--	--	8	***9***
Ice Management	--	--	--	--	--	2	***2***
General Vessel Activities	1	--	--	--	1	80	***82***
Total	***2***	***--***	***--***	***--***	***1***	***112***	***115***

Seals

Seals sighted from moving vessels most often looked at the vessel (~42%), while the second most observed reaction was "no observable reaction" (~38%) (Table 5.43). The most often recorded reaction from stationary vessels was "no observable reaction" (~58) and the second most observed reaction was "look" (~38%) (Table 5.44). Other common reactions for both moving and stationary vessels included splash and change in direction.

Pacific Walruses

Walruses observed from the project vessels most frequently had no observable reaction both from moving and stationary vessels (~55%) (Table 5.45 and 5.46). The second-most commonly observed reaction from moving and stationary vessels was "look" (~25% and 39% respectively). Other reactions to the project vessels while it was underway included splash and change in direction. Two walrus sightings observed from stationary vessels had interactions with gear, both involved the previously mentioned juvenile walrus that contacted the vessel several times probably attempting to haul out.

TABLE 5.43. Comparison of seal reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction							
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	**Unknown**	***Totals***
Anchor Handling	1	1	48	--	8	36	1	***95***
Drilling Activities	2	4	25	--	2	19	1	***53***
Ice Management	1	--	8	--	--	6	1	***16***
General Vessel Activities	15	21	180	9	48	174	7	***454***
Total	***19***	***26***	***261***	***9***	***58***	***235***	***10***	***618***

TABLE 5.44. Comparison of seal reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction						
Vessel Activity	**Change Direction**	**Decrease Speed**	**Look**	**Rush**	**Splash**	**None**	***Totals***
Anchor Handling	--	--	18	--	2	12	***32***
Drilling Activities	--	--	10	--	2	8	***20***
Ice Management	--	--	4	--	0	14	***18***
General Vessel Activities	2	1	91	--	4 8	152	***250***
Total	***2***	***1***	***123***	***--***	***8***	***186***	***320***

TABLE 5.45. Comparison of walrus reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction							
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	**Unknown**	***Totals***
Anchor Handling	1	1	13	--	4	11	--	***30***
Drilling Activities	3	2	9	--	1	17	--	***32***
Ice Management	0	--	3	--	0	2	--	***5***
General Vessel Activities	22	7	40	1	6	114	4	***194***
Total	***26***	***10***	***65***	***1***	***11***	***144***	***4***	***261***

TABLE 5.46. Comparison of walrus reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction							
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	**Interaction with Gear**	***Totals***
Anchor Handling	--	--	8	--	--	2	--	***10***
Drilling Activities	--	--	6	--	2	2	--	***10***
Ice Management	--	--	1	--	--	12	--	***13***
General Vessel Activity	1	--	15	--	--	26	2	***44***
Total	***1***	***--***	***30***	***--***	***2***	***42***	***2***	***77***

Polar Bears

Polar bears observed from moving vessels most frequently reacted to the vessel by looking at it (~54%) or by showing no observable reaction (~38%) (Table 5.47). Polar bears observed from stationary vessels most frequently exhibited no observable reaction (~48%) and looking at the vessel (~36%) (Table 5.48). Other polar bear reactions observed from both moving and stationary vessels included change in direction and increase in speed.

TABLE 5.47. Comparison of polar bear reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012

	Reaction				
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**None**	***Totals***
Anchor Handling	--	--	--	1	***1***
Drilling Activities	--	--	--	--	***--***
Ice Management	--	1	9	4	***14***
General Vessel Activities	1	--	4	4	***9***
Total	***1***	***1***	***13***	***9***	***24***

TABLE 5.48. Comparison of polar bear reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Chukchi Sea, 2012.

	Reaction				
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**None**	***Totals***
Anchor Handling	1	--	2	1	***4***
Ice Management	--	1	2	8	***11***
General Vessel Activities	2	--	5	3	***10***
Total	***3***	***1***	***9***	***12***	***25***

Mitigation Measures Implemented

The implementation of mitigation measures during Shell's 2012 exploratory drilling program in the Chukchi Sea spanned all aspects of the operation and was driven by several themes. Mitigation measures were centered on reducing potential impacts to marine mammals and subsistence activities from a wide range of vessel activities and also from fixed-wing and rotary aircraft. Specifically in the Chukchi Sea, vessel activities related to transit, drilling, handling and setting of the anchors used to moor the *Discoverer*, and ice scouting and management activities all were mitigated by various actions requested by PSOs. Vessel-based PSOs also played a role in the routing of aircraft to minimize potential impacts on marine mammals, particularly for helicopters used to facilitate offshore crew changes. Potential impacts to local subsistence activities were mitigated by the timing and location of Shell's operations in the Chukchi Sea in accordance with the CAA, and also through communications from each vessel to the nearest communication center every six hours. Shell did not conduct ZVSP surveys at the Chukchi Sea drillsite in 2012, which precluded the establishment of 180 and 190 dB (rms) exclusion zones for marine mammals around the *Discoverer* as stipulated in Shell's Chukchi Sea IHA and LOA for periods with active airgun operations.

The most common forms of mitigation implemented by PSOs aboard vessels during 2012 in the Chukchi Sea were reductions in vessel speed and alterations of vessel headings during routine vessel operations (e.g., transit; Table 5.49). There were 109 instances when vessel speed was reduced for Pacific walruses observed in the water (as opposed to on ice) by PSOs, a stipulation specific to walruses per Shell's 2012 USFWS LOA for the Chukchi Sea. All efforts were made to maximize distance from marine mammals and avoid separating individuals from groups of marine mammals. Other mitigation measures implemented by PSOs aboard vessels included postponement of equipment deployments (e.g., hydrophone recorders) due to the presence of marine mammals in the deployment area. Vessel transit routes through the Chukchi Sea and within the drilling area were altered on numerous occasions as a result of PSOs from one vessel calling attention to large groups of walruses in water or hauled out on ice in a specific area. These areas were avoided whenever possible.

The re-routing of vessels around groups of marine mammals known to be present in specific areas of the Chukchi Sea exemplifies communication between PSOs on different vessels. Inter-vessel communication by PSOs was a standard practice throughout the exploratory drilling program to ensure awareness of the distribution of marine mammals across the entire project area. PSOs aboard ice-management vessels routinely communicated sightings of Pacific walruses to other vessels so they could be avoided during transits or during standby periods. Furthermore, sightings information was summarized at shore-based offices in Anchorage and routinely communicated to all vessel PSO crews to increase awareness of marine mammal distribution within the Chukchi Sea, particularly as distributions changed across the season.

TABLE 5.49. General mitigation measures implemented by vessel-based PSOs during Shell's exploratory drilling program in the Chukchi Sea, 2012.

Speed Reduction	**Course Alteration**	**Other Mitigation**	***Total***
182	73	26	***281***

Vessel-based PSOs also communicated sightings of marine mammals to shore-based command centers to inform helicopter operations associated with offshore crew changes. Flight plans were drafted that maximized onshore flight corridors to reduce aircraft activity over water, particularly in areas where marine mammals were known to be hauled out on ice. Vessels with helicopter decks served as the primary crew change platforms within the program. These vessels were moved away from the main ice edge during helicopter operations to minimize potential impacts on marine mammals using those areas, particularly Pacific walruses. On one occasion on 6 Aug, 30 walruses hauled out on ice entered the water as the search-and-rescue helicopter departed the *Nordica*. PSOs communicated the position of the walruses, which were ~2.5 km (1.6 mi) from the vessel, to pilots before the helicopter departed. Vessels with helicopter decks were moved to distances >7 km (4.3 mi) from known walruses-on-ice prior to helicopter flights to/from the vessel after 6 Aug, and there were no additional observations of walruses entering the water during helicopter operations in the Chukchi Sea for the duration of the 2012 program. See Chapter 7 for fixed-wing survey protocols in the Chukchi Sea, including minimum flight altitudes to reduce potential impacts to marine mammals.

Ice scouting and management activities in the Chukchi Sea during 2012 involved significant communication between PSOs and vessel operators. These activities were restricted to periods with good visibility whenever possible to allow for large detection distances of marine mammals in the area prior to approaching or entering the main ice edge. Walruses hauled out on ice often were detected by PSOs using “Big Eye” binoculars aboard ice management vessels at distances between 5 and 8 km (3.1 and 5.0 mi). The location of these animals was communicated to vessel operators and shore-based project managers, and such distances from animals were maintained unless the ice was deemed potentially hazardous to the safety of the operation. Only small amounts of hazardous ice were managed in the Chukchi Sea drilling area by the *Fennica* and *Tor Viking* between 31 Aug and 13 Sep, and no ice with marine mammals directly associated with it was managed or approached closer than was operationally necessary. All operational decisions related to ice scouting and management involved significant assessment of the distribution of marine mammals known to be in the area prior to any detailed instructions being delivered from Shell’s shore-based management team in Anchorage to vessels. All operational instructions clearly prohibited vessel interactions with marine mammals on or near ice. Shell was issued a “take-by-harassment” LOA from USFWS as a precautionary measure to protect the safety of the drilling operation if necessary; however, there were no intentional takes of any marine mammals during 2012.

Another form of vessel-based mitigation that was implemented during Shell’s 2012 exploratory drilling program in the Chukchi Sea was the common practice of vessels to spend standby periods in a stationary position. Vessel-hours totaled 14,381 for Shell’s 2012 Chukchi Sea fleet, and 50% of this total was comprised of periods when vessels were stationary. The maximization of periods when vessels were stationary likely reduced potential impacts on marine mammals from vessel movements.

As noted above, PSOs aboard each vessel contacted local communication centers located in coastal Chukchi Sea villages every six hours per the CAA. These routine communications were designed to avoid conflicts between local subsistence users and Shell’s operations. The CAA also established vessel blackout areas around Barrow for fall subsistence whaling activities. Shell vessels avoided this area until Barrow declared whaling was completed in mid Oct. Collectively, these actions mitigated potential effects to marine mammal subsistence activities from Shell’s activities. No conflicts were reported between Shell vessels and subsistence users in the Chukchi Sea during Shell’s 2012 exploratory drilling program.

Estimated Number of Marine Mammals Present and Potentially Affected

It is often difficult to estimate "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain; ***(2)*** The most appropriate criteria for take by harassment are uncertain and presumed to vary among different species, individuals within species, activities that the individuals are involved in, and the situations in which the animals are encountered; ***(3)*** The distance to which a received sound level (RSL) reaches a specific criterion such as 190, 180, 160, or 120 dB re 1 µPa (rms) is variable. The RSL depends on water depth, sound source depth, water-mass and bottom conditions, and - for directional sources - aspect (Chapter 3; see also Greene 1997, Greene et al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b); ***(4)*** The sounds received by marine mammals vary depending on the animals depth in the water, and will be considerably reduced for animals near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b) and even further reduced for animals that are out of the water on ice or land.

Marine mammal exposures to continuous sounds from drilling, ice-management, and anchor-handling activities in the Chukchi Sea were considered below in detail. Two methods were used to estimate the number of marine mammals exposed to continuous sounds from these activities in the Chukchi Sea strong enough that they might have caused a disturbance or other potential impacts. The procedures included estimates based on ***(A)*** the direct observations of marine mammals by PSOs during these operations, and ***(B)*** recent marine mammal density estimates for the Chukchi Sea as a function of the total area ensonified during drilling, ice-management, and anchor-handling activities in 2012. The actual number of individuals exposed to, and potentially impacted by, drilling or anchor-handling sounds likely was between the ranges of estimates provided in the following sections. Further details about the methods and limitations of these estimates are provided below.

Disturbance and Safety Criteria

Table 4.2 summarizes the estimated RSLs at various distances from the *Discoverer* while it was stationary and conducting various drilling activities, from ice-management activities, and from the *Aiviq* and *Tor Viking* during periods of anchor-handling related to mooring of the *Discoverer*. RSLs during drilling activities were considered for a variety of operations, including drilling of the pilot hole, excavation of the mudline cellar (MLC), and the additional influence of sounds introduced by a stationary vessel nearby in dynamic positioning (DP) mode. The NMFS required that distances to RSLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for cetaceans and seals respectively. The USFWS required that distances to RSLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for Pacific walruses and polar bears, respectively. Measurements of sounds produced by the *Discoverer* and nearby vessels in DP during drilling activities, ice-management, and anchor-handling activities indicated that sound levels at or above these thresholds were uncommon and, when these sound levels were generated, they did not propagate more than 10 to 20 m (33 to 66 ft) from the source (Table 4.2 and Chapter 3). Both agencies assume that disturbance to marine mammals from continuous sounds generated while conducting the above operations may occur at RSLs ≥120 dB (rms).

Estimates from Direct Observations during Drilling Activities

All sightings data from the *Discoverer* and nearby support vessels were included in the following exposure estimates based on direct observations, regardless of whether they met the data-analysis criteria described in Chapter 4. The number of animals actually sighted by observers within the various sound level distances during drilling activities likely provides a minimum estimate of the number potentially affected by the continuous sounds from these operations. Some animals may have moved away before coming within visual range of PSOs, and it was unlikely that PSOs were able to detect all of the marine mammals near the drillsite. During daylight, animals are missed if they are below the surface when the ship is nearby. Other animals, even if they surface near the vessel, are missed because of limited visibility (e.g. fog), glare, or other factors limiting sightability. Furthermore, marine mammals could not be seen effectively during periods of darkness, which increased as the operation progressed into late Sep. Nighttime observations were not required, however, at least one PSO aboard the *Discoverer* maintained an active watch during nighttime drilling operations and conducted monitoring using night vision devices.

Animals may also have avoided the area near the *Discoverer* while it was drilling (see Richardson et al. 1995). Within the measured ≥120 dB (rms) radii around the source, and perhaps farther away in the case of the more sensitive species and individuals, the distribution and behavior of pinnipeds and cetaceans may have been altered as a result of the *Discoverer's* drilling activities.

Cetaceans Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

With the exception of two hours on 10 Sep, the *Discoverer* did not begin drilling in the Chukchi Sea in 2012 until 23 Sep. This likely minimized potential exposures to cetaceans that utilize the Chukchi Sea earlier in the open-water season during the summer months, particularly gray whales that may have exited the area prior to late Sep. A total of 107 cetaceans (65 different sightings) were observed by PSOs aboard vessels in the Chukchi Sea during 2012 while the *Discoverer* was conducting drilling operations. All but two of these individual cetaceans, however, were recorded from distant support vessels in areas where RSLs from drilling activities were <120 dB (rms).

There was a single sighting of two unidentified mysticete whales observed by PSOs aboard the *Discoverer* on 7 Oct while it was excavating the mudline cellar. The two whales were approximately 1.6 km (1.0 mi) from the *Discoverer* at the time of the initial detection. The≥130 dB (rms) radius measured during excavation of the mudline cellar at Burger-A was 2.8 km (1.7 mi; Table 4.2 and Chapter 3). The ≥140 dB (rms) radius at this location was measured at 1.0 km (0.6 mi; Table 4.2 and Chapter 3). Based on these radii, it is likely that these two cetaceans were exposed to continuous drilling sounds between 130 and 140 dB (rms; Table 5.50). The whales were detected a second time nearly 40 minutes after the initial sighting at a distance of 2 km (1.2 mi).

Seals Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

A total of 396 seals (73 different sightings) were observed by PSOs aboard 10 different project vessels during periods when the *Discoverer* was conducting drilling activities. This total includes seal sightings from both moving and stationary vessels that were operating in the Burger area. Numerous seals from this total, however, were believed to be resightings of the same individuals recorded on multiple days. It was impossible to determine precisely how many seals represented sightings of new individuals or if they were resightings of seals that already had been observed and recorded in the area. It also is likely that numerous seals were recorded by PSOs aboard different vessels as vessels transited to and from the drillsite in support of operations. The total of 396 seals observed during drilling periods likely is greater than the actual number of distinct individuals observed due to double counting, however, this total of 396 seals is used here as a conservative estimate to avoid underestimation of exposures. It should be noted that 320 seals were recorded in a single sighting event by the PSO aboard the Arctic Seal on 23 Oct as the vessel transited near newly-formed ice in shallow areas of Peard Bay, far removed from the Burger prospect area.

The majority of these 396 seals, 369 or 93%, were recorded during periods when the pilot hole was being drilled. The remaining 26 seals were observed during excavation of the mudline cellar. The estimated radius to RSLs≥120 dB (rms) during excavation of the mudline cellar was 8.1 km (5.0 mi) compared to only 1.5 km (0.9 mi) during other drilling activities (e.g., pilot hole drilling; Table 4.2 and Chapter 3). The differences in these radii were considered when analyzing the estimated RSL to each seal to capture the specific acoustic footprint likely to have been present in the water at the time and location of each sighting. The vast majority of the 396 seals recorded during drilling activities in the Chukchi Sea in 2012, 386 or 97%, were observed in areas away from the drill site where they would not have been exposed to RSLs ≥120 dB (rms).

Only ten of the 396 seals observed during drilling activities in the Chukchi Sea in 2012 were observed at distances where RSLs were estimated to be ≥120 dB (rms; Table 5.50). Six of these 10 seals were observed while the pilot hole was being drilled and the remaining 4 were recorded during excavation of the mudline cellar. The 10 seals observed in areas where RSLs from drilling activities were ≥120 dB (rms) consisted of three ringed, two bearded, one spotted, and four unidentified seals.

Nine the 10 seals observed in areas where continuous sounds from drilling activities were ≥120 dB (rms) were recorded by PSOs aboard the *Discoverer*. Of these nine seals, two were observed in areas where RSLs were estimated to be ≥160 dB (rms; Table 5.50) and the remaining 7 seals were observed at distances from the drill rig where RSLs were estimated to be between 120 and 160 dB (rms). No seals were observed from any of the support vessels during drilling activities in areas where RSLs were estimated to be ≥160 dB (rms).

Pacific Walruses Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

Forty-two sightings of 574 Pacific walruses were recorded while drilling activities were occurring in the Chukchi Sea during 2012. As was the case with cetaceans and seals, not all of these animals were observed in areas where RSLs from drilling activities were ≥120 dB (rms). Thirty-eight sightings of 94 walruses were observed during drilling activities but outside the ≥120 dB (rms) radii for these activities.

The remaining 480 walruses observed during drilling activities in the Chukchi Sea in 2012 were in areas where RSLs in the water were estimated to be ≥120 dB (rms), however, 474 of these individuals (99%) were hauled out on ice and likely would not have been exposed to levels of sound comparable to those in the water. The remaining six walruses observed during drilling periods, two of which were recorded from the Discoverer and four from the Tor Viking, were in the water where estimated RSLs were ≥120 but <160 dB (rms; Table 5.50).

Polar Bears Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

With the exception of two hours on 10 Sep, the *Discoverer* did not begin drilling in the Chukchi Sea in 2012 until 23 Sep. There were no polar bears observed during the brief period of drilling on 10 Sep, and the last vessel-based polar bear sighting in the Chukchi Sea in 2012 was recorded on 22 Sep. Therefore, no polar bears were observed in areas with RSLs ≥120 dB (rms) from Shell's 2012 Chukchi Sea drilling activities (Table 5.50).

Estimates from Direct Observations during Ice-management Activities

All sightings data from the ice-management vessels *Fennica* and *Tor Viking* as well as the drill rig *Discoverer* and nearby support vessels were included in the following exposure estimates based on direct observations, regardless of whether they met the data-analysis criteria described in Chapter 4. Instances when ice-management vessels actually made contact with ice, including pushing or breaking, were uncommon and isolated. The following assessment, however, considers broader time periods when vessels were maneuvering through ice and assessing the potential need for management of specific floes that posed a potential safety hazard to the drilling operation (Fig. 2.4). This approach has been taken to avoid underestimation of exposures to marine mammals observed during brief, isolated periods when ice truly was being managed. The following section may actually overestimate exposures from ice management in some cases depending on the precise location of a marine mammal at the actual moment when an ice floe was actively managed. Ice management occurred in discrete periods in the Chukchi Sea from 31 Aug through 13 Sep.

TABLE 5.50. Number of marine mammals observed in areas with estimated RSLs of ≥120 and ≥160 dB (rms) during active drilling periods in the Chukchi Sea, 2012.

Species or Species Group	Number of Individuals and Exposure Level in dB re 1µPa (rms)	
	≥120	≥160
Cetaceans	2	0
Seals	10	2
Pacific Walruses*	480	0
Polar Bears	0	0

*474 of the 480 walruses observed in areas with RSLs in the water ≥120 dB (rms) were hauled out on ice and would not have been exposed to the same RSLs as those in the water

<u>Cetaceans Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)</u>

A total of 27 cetaceans were observed by PSOs aboard five different vessels in the Chukchi Sea in 2012 while ice-management activities were being conducted. Twenty-four of these 27 cetaceans were observed by support vessels in areas that were far-removed from where ice management occurred. These 24 cetaceans would not have been exposed to RSLs ≥120 dB (rms).

Only 3 of the 72 cetaceans observed during ice-management activities were recorded in areas where estimated RSLs were ≥120 dB (rms; Table 5.51). All three were identified as bowhead whales by PSOs aboard the *Fennica* on 13 Sep. The *Fennica* did not conduct ice-management activities on 13 Sep but the Tor Viking was in the area conducting limited amounts of ice management at the Burger-A drillsite. The whales were recorded at distances of 0.98, 1.5, and 4.0 km (0.61, 0.93, and 2.5 mi) from the *Fennica*, respectively. All of the whales, however, were between 9.6 and 2.6 km (6.0 and 1.6 mi) from the *Tor Viking*, which corresponded to estimated RSLs from ice management of between 120 and 130 dB (rms; Table 4.2).

<u>Seals Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)</u>

Similar to the distribution of cetacean sightings with respect to RSL during ice-management activities, 24 of the 34 seals observed in the Chukchi Sea in 2012 during these periods were in areas outside the ≥120 dB (rms). The remaining 10 seals were observ ed in areas where RSLs from ice management would have been ≥120 dB (rms), however, three of these seals were hauled out on ice and would likely not have been exposed to RSLs from ice-management comparable to those in the water at that location (Table 5.51). The seven seals observed in the water where estimated RSLs from ice management were ≥120 dB (rms) consisted of two bearded, two spotted, and three unidentified seals. Two of these seals, a bearded seal recorded from the *Fennica* and a spotted seal observed by *Tor Viking* PSOs, were 50 m (164 ft) from the vessel where estimated RSLs from ice management would have been between 160 and 170 dB (rms; Tables 4.2 and 5.51).

<u>Pacific Walruses Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)</u>

The breakdown of walrus sightings observed during periods when ice-management activities were occurring in the Chukchi Sea in 2012 was similar to seals and cetaceans in that most individuals either were recorded outside the ≥120 dB (rms) radius or they were hauled out on ice. A total of 985 walruses were observed during periods of ice management, although 656 of these were recorded in areas where they would not have been exposed to RSLs ≥120 dB (rms) from this activity.

The remaining 329 walruses recorded during 2012 ice-management activities in the Chukchi Sea were within the ≥120 dB (rms) isopleth (Table 5.51). At least 250 of these, however, were hauled out on ice and likely would not have been exposed to levels of sound comparable to those in the water. The remaining ~79 walruses were observed in water within the ≥120 dB (rms) radius and likely would have been exposed to these RSLs from ice-management activities. No walruses were observed in areas where RSLs from ice management were estimated to be ≥160 dB (rms; Table 5.51).

<u>Polar Bears Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)</u>

A total of 30 polar bears were observed during periods of ice management in the Chukchi Sea during 2012 (Table 5.50). It is particularly difficult to estimate the number of unique individuals as opposed to multiple resightings of the same bears by different vessels over the span of several days. All 30 bears were recorded by PSOs aboard the *Fennica*, *Nordica*, and *Tor Viking* on 12, 13, and 14 Sep (16, 8, and 6 bears on each day, respectively). Comments from sightings indicate numerous instances when PSOs suspected specific bears were being observed repeatedly both from their own vessel and from the other vessels that were nearby. The following assessment considers the 30 bears as distinct individuals to avoid underestimation of exposures, but this total almost certainly overestimates the number of bears present in the area during isolated periods of ice management. No ice was managed that was directly associated with polar bears, and all efforts were made to maintain a distance of at least 0.8 km (0.5 mi) from all bears.

Six polar bears were observed in areas outside the ≥120 dB (rms) radius estimated for ice-management sounds, and another 19 bears were observed hauled out on ice within the ≥120 dB (rms) radius. It is unlikely that these 25 bears were exposed to continuous RSLs ≥120 dB (rms) from ice management. Two polar bears were observed in the water where RSLs from ice-management activities were between 120 and 160 dB (rms) and the remaining three bears were observed in areas with estimated RSLs ≥160 dB (rms; Table 5.51). Although three polar bears were observed within the ≥160 dB (rms) radius, this exposure-level classification is the result of conservatively categorizing broad periods of time as ice management rather than only the discrete, isolated moments when ice actively was being managed. It does not indicate that these three bears were within 60 m (197 ft; the ≥160 dB [rms] isopleths for ice management; Table 4.2) of the vessel as ice was actively being managed.

Estimates from Direct Observations during Anchor-handling Activities

All sightings data from the anchor-handling vessels *Aiviq* and *Tor Viking* as well as the drill rig *Discoverer* and nearby support vessels were included in the following exposure estimates based on direct observations, regardless of whether they met the data-analysis criteria described in Chapter 4. Specifically, anchor-handling for the purpose of this assessment refers to activities and sounds associated with deploying, setting, connecting, and disconnecting the eight anchors used to moor the *Discoverer* in place at the Burger-A drillsite during 2012 (Fig 2.4).

Measurements of anchor-handling activities at the Burger-A drillsite were not available at the time of this report, however, analysis of sounds from this activity at the Sivulliq drillsite in the Beaufort Sea in

2012 were available. The ≥120 dB (rms) RSL radius from anchor-handling activities in the Beaufort Sea has been incorporated here as the best available data for assessment of potential exposures to animals from this activity in the Chukchi Sea in 2012 (29 km or 18 mi; Table 4.2). As with the other assessments above, the total numbers of marine mammals observed during anchor-handling activities and reported below are conservative estimates that do not account for animals that were potentially double-counted to avoid underestimation of exposures.

TABLE 5.51. Number of marine mammals observed in areas with estimated RSLs of≥120 and ≥160 dB (rms) during periods of ice management in the Chukchi Sea, 2012.

Species or Species Group	Number of Individuals and Exposure Level in dB re 1µPa (rms)	
	≥120	≥160
Cetaceans	3	0
Seals*	10	2
Pacific Walruses*	329	0
Polar Bears*	24	3

*3 of the 10 seals, 250 of the 329 walruses, and 19 of the 24 polar bears observed in areas with RSLs in the water ≥120 dB (rms) were hauled out on ice and would not have been exposed to the same RSLs as those in the water

Cetaceans Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

A total of 179 cetaceans (93 different sightings) were observed by PSOs aboard seven different vessels in the Chukchi Sea in 2012 while anchor-handling activities were being conducted. None of these, however, were observed from the *Tor Viking* or *Aiviq* during periods of anchor handling. As a result, none of the 179 cetaceans observed in the Chukchi Sea in 2012 during anchor-handling activities were in areas where estimated RSLs were ≥120 dB (rms; Table 5.52).

Seals Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

PSOs recorded 1386 seals from Shell vessels in the Chukchi Sea in 2012 during periods when anchor handling was occurring. Similar to the case for cetacean sightings during anchor handling, the majority of seals were observed by PSOs aboard distant support vessels that were not directly involved in anchor-handling activities. As a result, 1351 of the 1386 seals recorded during anchor-handling activities were >29 km (18 mi; the 120 dB [rms] threshold radius for anchor handling) from the actual operations and, therefore, would not have been exposed to RSLs of ≥120 dB (rms).

The remaining 35 of the 1386 seals recorded during anchor-handling activities were observed in areas where RSLs from anchor handling were estimated to be≥12 0 dB (rms), and six of these seals were in areas where estimated RSLs were ≥ 160 dB (rms; Table 5.52). The 40 seals observed in areas where estimated RSLs from anchor handling were ≥ 120 dB (rms) consisted of seven ringed, seven bearded, four spotted, 16 unidentified seals, and a single unidentified pinniped. Three of these unidentified seals were observed on ice and would not have been exposed to the same RSLs from anchor handling compared to sound levels in the water.

Pacific Walruses Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

There were 3536 walruses (54 sightings) observed in the Chukchi Sea in 2012 from four different vessels during periods when anchor-handling activities were occurring. No walruses were observed from the *Tor Viking* or *Aiviq* while these vessels were handling anchors, which occurred almost exclusively in open-water conditions as opposed to areas with sea ice and concentrations of walruses. The majority of the walruses observed from other vessels during anchor handling, 3070 or 87%, were observed in areas removed from the activity where RSLs were <120 dB (rms). The remaining 466 walruses were observed in areas where estimated RSLs from anchor handling were ≥ 120 dB but <160 dB (rms; Table 5.52). Ninety one of these 466 walruses were observed on ice and would not have been exposed to the same sound levels from anchor handling compared to levels in the water at the same location.

Polar Bears Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

A total of five polar bears (five different sightings) were observed from support vessels during periods when the *Aiviq* and *Tor Viking* were conducting anchor-handling activities in the Chukchi Sea during 2012. Three of these individuals were in areas outside the ≥120 dB (rms) isopleth and they would not have been exposed to those levels of sound from anchor handling. The remaining two polar bears were observed swimming in the water in areas where estimated RSLs from anchor-handling activities were between 120 and 130 dB (rms; Table 5.52).

TABLE 5.52. Number of marine mammals observed in areas with estimated RSLs of ≥120 and ≥160 dB (rms) during periods with anchor-handling activities in the Chukchi Sea, 2012.

Species or Species Group	Number of Individuals and Exposure Level in dB re 1μPa (rms)	
	≥120	≥160
Cetaceans	0	0
Seals*	40	6
Pacific Walruses*	466	0
Polar Bears	2	0

*3 of the 40 seals and 91 of the 466 walruses observed in areas with RSLs in the water ≥120 dB (rms) were hauled out on ice and would not have been exposed to the same RSLs as those in the water

Estimates Extrapolated from Density

The number of marine mammals visually detected by PSOs likely underestimated the actual numbers of animals that were present for reasons described above. Marine mammal density estimates for the Chukchi Sea were used to correct for animals that may have been present but not detected by observers. This section presents estimates of the exposure of marine mammals to RSLs ≥120 dB (rms) from Shell's drilling and ice-management activities conducted during 2012 as prescribed by Shell's 2012 NMFS IHA. Additional analyses of sightings and exposure data that include a broader range of sound-generating activities that occurred during discreet time periods and the corresponding exposure estimates are ongoing, and results will be presented in detail in the 2012 Comprehensive Report.

The densities used for the following exposure estimates (Table 5.53) included the cetacean and seal density estimates used in Shell's 2012 Chukchi Sea IHA application (Shell 2011), and polar bear (Evans et al. 2003) and walrus (Brueggeman et al. 1990) densities from aerial surveys in the vicinity of the Burger prospect area. The densities of marine mammals were then multiplied by the area of water ensonified (i.e., exposed to sounds produced during drilling and ice-management operations; Table 5.54) to estimate the number of individual marine mammals likely to have been exposed to continuous received sound levels (RSLs) ≥120 dB (rms) from these operations assuming that there was no avoidance of these sounds or activities by the animals (see Chapter 4 and Appendix C for details).

Marine mammal densities near the drilling and ice-management operations are likely to vary by season and habitat, particularly with the presence or absence of sea ice. Expected densities are provided below for Jul–Aug and Sep–Oct seasonal periods, and for open-water (i.e., nearshore) and ice-margin areas (Table 5.53). Density-based exposure estimates during Shell's 2012 exploratory drilling program in the Chukchi Sea were calculated separately by seasonal period and also with consideration of the proportions of ensonified areas that were within or outside of areas containing sea ice. As expected, sea-ice concentrations in the Burger prospect area during 2012 varied considerably within each seasonal period.

Variation in sea-ice cover within the project area was accounted for in the following ways when calculating density-based exposure estimates from drilling and ice-management activities. No drilling activities occurred during Jul–Aug at Burger, and only limited amounts of ice management occurred within this period on 31 Aug. To reflect these early-season ice conditions and the associated ice-management activities that occurred prior to the commencement of drilling, ice-margin densities were applied to 100% of the areas ensonified with RSLs ≥120 dB (rms) for exposure estimates in Jul–Aug.

Ice cover persisted within the project area into the Sep–Oct period, and isolated ice-management activities were conducted at or near Burger (within 10 km or 6 mi) until 13 Sep. Shell did not conduct ice-management activities in the Chukchi Sea after 13 Sep, and all subsequent drilling activities occurred in open-water conditions through the end of Oct. To reflect the proportion of these activities that occurred in ice-covered versus open-water conditions during Sep–Oct, density-based exposure estimates were calculated by applying ice-margin densities to 25% of the areas ensonified with RSLs ≥120 dB (rms) from ice management and drilling activities and open-water densities to the remaining 75% of areas ensonified by ice management and drilling activities. This stratified-density approach is consistent with the methodology used in Shell's IHA application to estimate exposures to marine mammals (Shell 2011).

The following density-based exposure estimates assume that all mammals present were well below the surface where they would have been exposed to RSLs at various distances as reported in Chapter 3 and summarized in Table 4.2. Some pinnipeds, cetaceans, and polar bears in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Additionally, some marine mammals may have stayed away from sound-sources through an avoidance response. Finally, and as noted in the above sections, many of the animals observed during ice-management activities were hauled out on ice, particularly pinnipeds and polar bears (Table 5.51). Marine mammals on ice would not have been exposed to RSLs from drilling or ice-management activities that were comparable to those in the water at the same location.

TABLE 5.53. Estimated marine mammal densities in the Chukchi Sea used to calculate density-based exposure estimates from Shell's 2012 exploratory drilling program.

Species	Jul - Aug* Open-Water Density (# / km^2)	Jul - Aug* Ice-Margin Density (# / km^2)	Sep - Oct** Open-Water Density (# / km^2)	Sep - Oct** Ice-Margin Density (# / km^2)
Odontocetes				
Monodontidae				
Beluga	NA	0.0040	0.0015	0.0060
Narwhal	NA	0.0000	0.0000	0.0000
Delphinidae				
Killer whale	NA	0.0001	0.0001	0.0001
Phocoenidae				
Harbor porpoise	NA	0.0011	0.0007	0.0007
Mysticetes				
Bowhead whale	NA	0.0013	0.0219	0.0438
Fin whale	NA	0.0001	0.0001	0.0001
Gray whale	NA	0.0258	0.0080	0.0080
Humpback whale	NA	0.0001	0.0001	0.0001
Minke whale	NA	0.0001	0.0001	0.0001
Pinnipeds				
Bearded seal	NA	0.0142	0.0107	0.0142
Ribbon seal	NA	0.0005	0.0005	0.0005
Ringed seal	NA	0.4891	0.2458	0.3277
Spotted seal	NA	0.0098	0.0049	0.0065
Pacific walrus	NA	0.6169	0.0010	0.6169
Marine Fissiped				
Polar Bear	NA	0.0068	0.0001	0.0068

*Operations considered for density-based exposure estimates in Jul-Aug occurred exclusively in areas with ice cover. Therefore, open-water densities were not used for exposure estimates from this period.

**Operations considered for density-based exposure estimates in Sep-Oct occurred in ice ~25% of the time and in open-water conditions during the remaining 75%. Therefore, ice-margin densities were applied to 25% of the areas ensonified by these activities and open-water densities were applied to the remaining 75% of ensonified areas.

TABLE 5.54. Estimated areas (km^2) ensonified to≥120 and ≥160 dB (rms) from drilling and ice-management activities during Shell's 2012 exploratory drilling program in the Chukchi Sea.

Seasonal Period	Level of ensonification in dB re1µPa (rms) and area ensonified in km^2: ≥120	≥160
Jul-Aug	441	2
Sep-Oct	843	13

Cetaceans

Table 5.55 shows the estimated numbers of cetaceans that may have been exposed to sounds from drilling and ice-management activities at received levels ≥120 dB (rms) based on the density estimates in Table 5.53 and the ensonified areas in Table 5.54. Half of the estimated 47 cetaceans exposed to RSLs ≥120 dB (rms) in the Chukchi Sea during 2012 drilling and ice-management activities would have been bowhead whales in Sep–Oct (Table 5.55). This was the result of higher bowhead whale densities in the Chukchi Sea during Sep–Oct compared to Jul–Aug (Table 5.53), and larger areas ensonified to ≥120 dB (rms) during Sep–Oct compared to Jul–Aug (Table 5.54). The only drilling or ice-management activity conducted by Shell in the Chukchi Sea during Jul–Aug 2012 was a minimal amount of ice management on 31 Aug. All of the remaining 2012 ice-management and drilling activities occurred in Sep–Oct. Gray whales made up the majority of the remaining cetacean exposure estimates followed by beluga whales and smaller numbers of other species (Table 5.55).

Seals

The total number of seals estimated to have been exposed to continuous sounds ≥120 dB (rms) from drilling and ice-management activities in the Chukchi Sea during 2012 was 466 (Table 5.55). The majority of these would have been ringed seals during Sep–Oct given higher estimated densities for ringed seals compared to other seal species in the Chukchi Sea (Table 5.53) and larger ensonified areas from drilling and ice management during this period compared to Jul–Aug (Table 5.54). The only drilling or ice-management activities conducted by Shell in the Chukchi Sea during Jul–Aug 2012 was a minimal amount of ice management on 31 Aug. All of the remaining 2012 ice-management and drilling activities occurred in Sep–Oct. The remaining seal exposure estimates were comprised of relatively small numbers of bearded and spotted seals (Table 5.55).

Pacific Walruses

The total number of Pacific walruses estimated to have been exposed to continuous sounds ≥120 dB (rms) from drilling and ice-management activities in the Chukchi Sea during 2012 was comparable to the density-based exposure estimates for seals (Table 5.55). The majority of these estimated exposures to walruses would have occurred during Sep–Oct given that all drilling and the vast majority of ice-management activities conducted by Shell in the Chukchi Sea during 2012 occurred after Aug. As noted above, many of the walruses observed during periods concurrent with drilling and ice-management activities were hauled out on ice as opposed to in the water (Tables 5.50 and 5.51). Animals on ice would not have been exposed to RSLs from drilling or ice management comparable to those in the water at the same location, but these are included in the numbers of exposed animals since density estimates from Bruggeman et al. 1990 included animals hauled out on ice. Therefore this likely is an over estimate of actual exposures at these sound levels.

Polar Bears

The density-based exposure estimates of RSLs ≥120 dB (rms) to polar bears from drilling and ice-management activities conducted by Shell in the Chukchi Sea during 2012 are shown in Table 5.55 and result in the exposure of only about four polar bears through the season. As with other marine mammals, animals on ice would not have been exposed to RSLs from these activities that were comparable to those in the water.

TABLE 5.55. Estimated numbers of individual marine mammals exposed to continuous sound levels ≥120 dB (rms) from drilling and ice-management activities during Shell's 2012 exploratory drilling program in the Chukchi Sea. Estimates were calculated by multiplying the marine mammal densities in Table 5.53 by the area ensonified to ≥120 dB (rms) from Table 5.54 and rounding to the nearest whole number.

	Estimated No. Individuals		
Species	**Jul-Aug**	**Sep-Oct**	***Estimated Totals***
Cetaceans			
Beluga	2	2	***4***
Narwhal	0	0	***0***
Killer whale	0	0	***0***
Harbor porpoise	0	1	***1***
Bowhead whale	1	23	***24***
Fin whale	0	0	***0***
Gray whale	11	7	***18***
Humpback whale	0	0	***0***
Minke whale	0	0	***0***
Total Cetaceans	***14***	***33***	***47***
Seals			
Bearded seal	6	10	***16***
Ribbon seal	0	1	***1***
Ringed seal	216	224	***440***
Spotted seal	4	5	***9***
Total Seals	***226***	***240***	***466***
Pacific Walrus	***272***	***131***	***403***
Polar Bear	***3***	***1***	***4***

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6. BEAUFORT SEA VESSEL BASED MARINE MAMMAL MONITORING RESULTS[1]

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes the visual observer effort from the vessels that operated in the Beaufort Sea during Shell's 2012 exploratory drilling operations in the Beaufort Sea (west of Barrow, Alaska). The fleet included the conical drilling unit (CDU) *Kulluk* and its support vessels: *Affinity*, *Aiviq*, *Arctic Seal*, *Fennica*, *Lauren Foss*, *Nanuq*, *Nordica*, *Pt. Oliktok*, *Sisuaq*, *Tor Viking*, and *Warrior*. This chapter does not include effort conducted during transit from Dutch Harbor to and from the survey area (through the Chukchi Sea).

The project vessels traveled a total of ~38,618 km (23,996 mi) in the Beaufort Sea during the 2012 exploratory drilling season. Between 15 and 25 Aug, anchor laying activities occurred in the area of the wellsite in preparation for the arrival of the *Kulluk*. After 25 Aug, no Shell vessels were present in the Beaufort Sea until 8 Sep 2012 (AKDT), when support vessels returned to the Beaufort to await completion of subsistence activities. General vessel activities took place throughout the first and second operational periods and drilling activities, including mud-line cellar construction, took place between 13 and 17 Oct, as well as 21, 22, and 24 Oct. A total of ~831 hours of anchor handling and ~731 hours of drilling activities, including construction of the mud-line cellar, took place in the Beaufort Sea during the 2012 open water season. No ice management took place in the Beaufort Sea during the 2012 season. On 9 Nov, the last Shell vessels departed the Beaufort when the *Aiviq* entered the Chukchi Sea with the *Kulluk* under tow. Vessels other than those involved in Shell's operations seldom passed through the project area. Each ship that was not participating in the project transited well away from survey activities (>15 km) and PSOs observed no instances of harassment or disturbance to marine mammals due to their presence.

The *Kulluk*, *Tor Viking*, and *Aiviq* are classified as source vessels for the following vessel-based PSO monitoring results. Specifically, source vessels generated sounds during drilling, ice-management, or anchor-handling activities that were measured in the field (see Chapter 3) and used to calculate exposure estimates to marine mammals later in this chapter. All observation effort and marine mammal sightings data from these vessels were binned in the source-vessel category, which included transit and standby periods. All other vessels were classified as non-source. This vessel classification system also was created to allow for comparisons of data between different activity states and vessel types. For more information on data analysis methods, please see Chapter 4 of this report.

Observer Effort

PSO effort is a systematic collection of observation records that captures the distance or amount of time spent with at least one observer 1.) actively searching for marine mammals, and 2.) documenting environmental conditions and vessel activities. For moving vessels, effort was quantified as the distance the vessel traveled while PSOs actively looked for marine mammals and recorded environmental and vessel activity data. For stationary vessels, effort was quantified as the number of hours during which PSOs actively looked for marine mammals and recorded data. The amount of effort was subdivided by various environmental or operational variables that may have influenced the ability of PSOs to detect

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[1] By H.M. Patterson, L.N. Bisson, H.J. Reider, M.L. Bourdon, and C.M. Reiser (LGL)

marine mammals or the actual distribution of marine mammals in the area (e.g. Beaufort wind force, vessel activity). PSO effort was used to calculate marine mammal sighting rates in the following sections of this chapter.

PSOs aboard moving vessels were on watch for a total of ~28,733 km (17,958 mi; ~3383 h) (Figure 6.1). Of the ~7167 km (4790 mi; ~1039 h) of observations from source vessels, ~1795 km (1122 mi; ~296 h) were in darkness and ~5372 km (3358 mi; ~743 h) were during daylight hours (Figure 6.1). PSOs aboard non-source vessels conducted observations over ~3956 km (2473 mi; ~443 h) during darkness and ~17,610 km (11,006 mi; ~1901 h) in daylight, for a total of ~21,565 km (13478 mi; ~2345 h) (Figure 6.1). While vessels were stationary, a total of ~4362 h of observations were conducted (Figure 6.2). From source vessels, PSOs were on watch for ~1443 h, ~569 h of which were in darkness and ~874 h of which were in daylight (Figure 6.2). Of the ~2919 h of observations conducted by PSOs on non-source vessels, ~545 h were during darkness and ~2375 h were during daylight hours (Figure 6.2). At least one observer was on watch on all vessels during 100% of daylight hours regardless of vessel activity. During all darkness hours (night time), at least one PSO remained on duty on the *Kulluk*. This PSO did not conduct systematic watches the entire darkness period, but did perform periodic scans of the waters around the *Kulluk* with night vision devices.

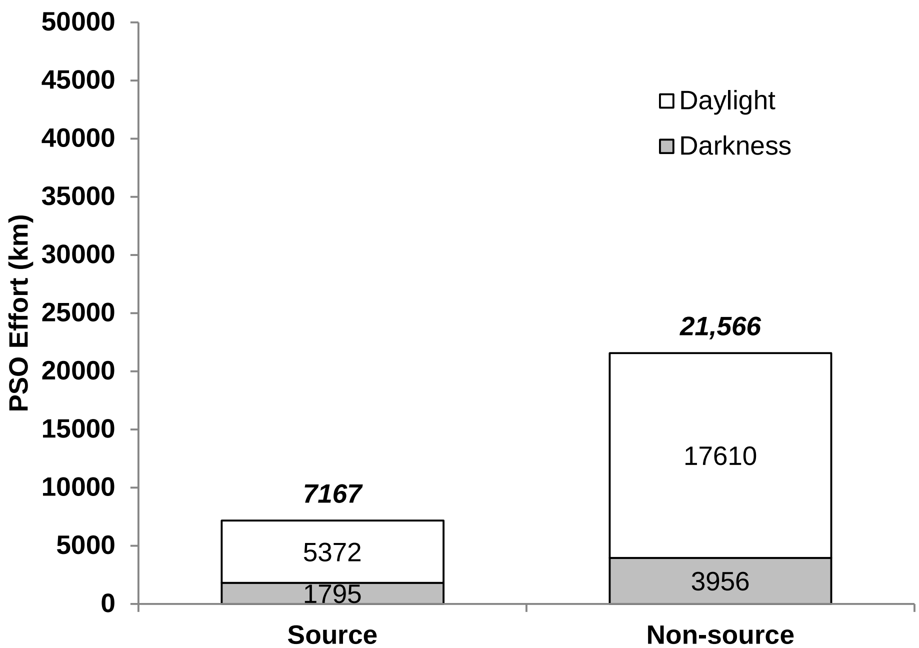

FIGURE 6.1. Total PSO observation effort (km) during daylight and darkness periods from moving project vessels during Shell's exploratory drilling program in the Beaufort Sea, 2012.

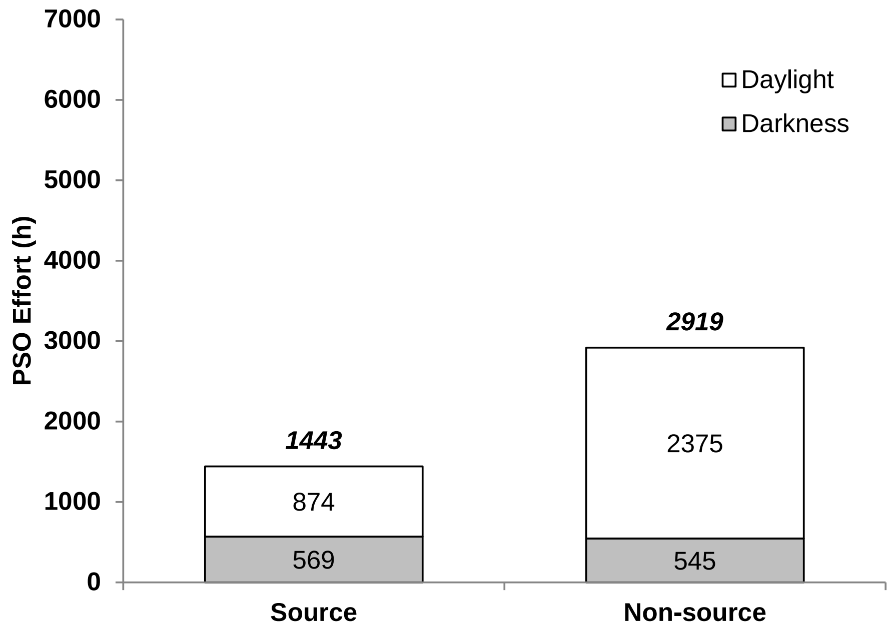

FIGURE 6.2. Total PSO observation effort (h) during daylight and darkness periods from stationary project vessels during Shell's exploratory drilling program in the Beaufort Sea, 2012.

Observer Effort by Beaufort Wind Force

Observer effort from moving vessels occurred between Beaufort wind force (Bf) one and Bf seven (Figures 6.3 and 6.4). For both source and non-source vessels, the greatest amount of observer effort while moving occurred during Bf three, which accounted for ~28% (5874 km) of PSO effort. The greatest amount of observer effort while both source (~31%; 446 h) and non-source (~26%; 770 h) vessels were stationary (~28%; 1216 h) occurred during Bf three. For both moving and stationary vessels, ~70% of effort occurred in Bf two through four and ~81% of effort occurred in Bf two through five.

Observer Effort by Number of PSOs

On moving source vessels, two or more PSOs were on watch during ~54% (3875 km; ~596 h) of observation effort (Fig. 6.5). While non-source vessels were moving, at least two PSOs were on watch for ~31% (676 km; ~659 h) of observation effort. Two or more PSOs were on watch during 61% (886 h) of observation effort from stationary source vessels and ~40% (1153 h) of observation effort from stationary non-source vessels. PSOs were scheduled to maximize effort during mid-day hours, when optimum visibility conditions were likely to maximize monitoring and mitigation efforts, and during anchor handling and drilling activities, when monitoring and mitigation needs were highest.

Observer Effort by Vessel Activity

Most observer effort from moving source (~82%; 5872 km; 809 h) and non-source (~75%; 16,105 km; 1786 h) vessels occurred during general vessel activities (Fig. 6.7). Drilling activities, including construction of the mud-line cellar, were in progress nearby during ~13% (949 km; 159 h) of observer effort from moving source vessels and ~8% (1172 km; 176 h) of observer effort from moving non-source vessels. Observation during anchor handling accounted for ~5% (346 km; 71 h) of effort from moving source vessels and ~17% (3689 km; 383 h) of effort from moving non-source vessels.

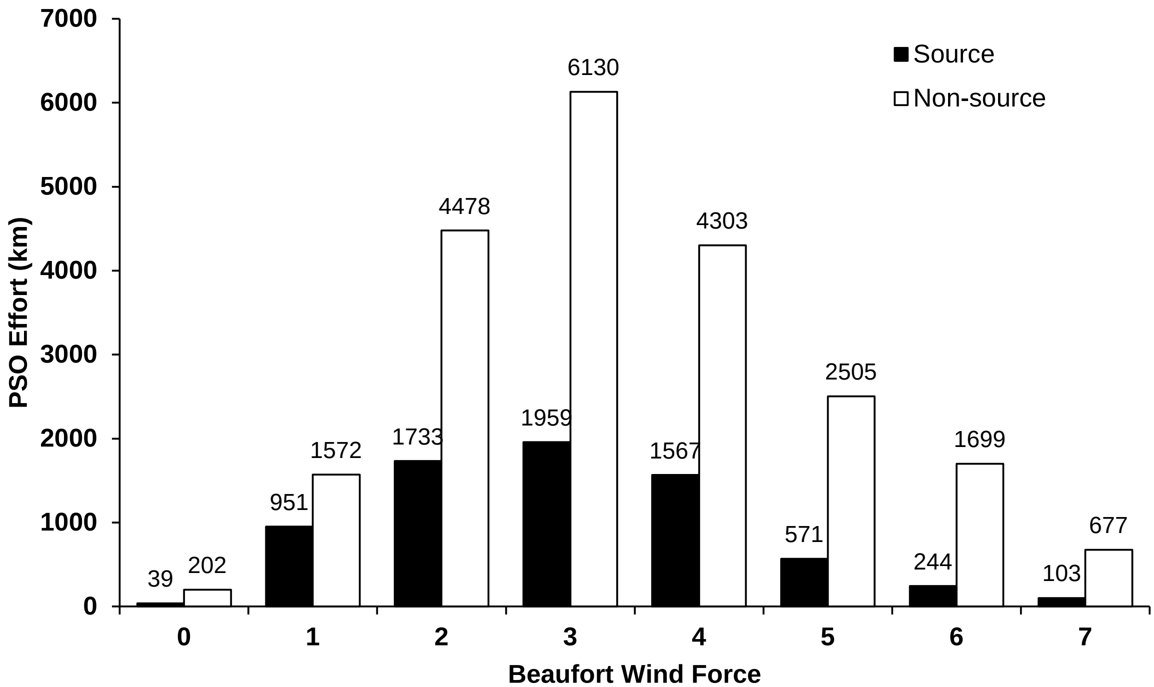

FIGURE 6.3. Total PSO observation effort (km) from moving project vessels in each Beaufort wind force category during Shell's exploratory drilling program in the Beaufort Sea, 2012.

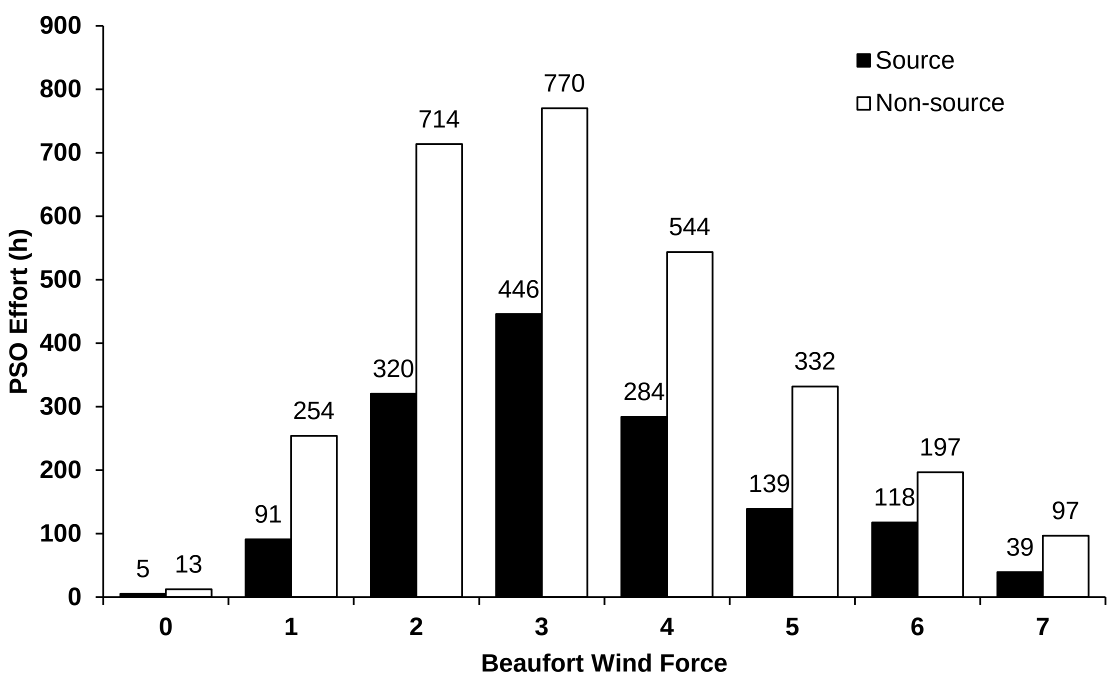

FIGURE 6.4. Total PSO observation effort (h) from stationary project vessels in each Beaufort wind force category during Shell's exploratory drilling program in the Beaufort Sea, 2012.

For stationary source vessels, ~64% (920 h) of observation effort occurred during general vessel activities, ~18% (260 h, 264 h) during each of anchor handling and drilling activities (Fig. 6.8). The percentages of observer effort during general vessel activities, anchor handling, and drilling activities aboard non-source vessels were ~65% (1881 h), ~20%, (571 h) and ~15% (467 h) respectively.

Exposure level takes into consideration the entire sound field of each individual vessel and surrounding vessels (see Chapter 4). Sound exposure levels in the water around moving vessels for both source and non-source vessels were less than 120 dB (rms) during ~98% (7024 km; 997 h; 21,127 km; 2291 h) of observation effort and between 120 and 160 dB during the remaining ~2% (143 km; 42h; 438 km; 54 h) of effort. For source vessels, ~70% (999 h) of stationary effort was conducted when the received sound level was less than 120 dB (rms), ~15% (219 h) occurred while the received sound level was between 120 and 160 dB (rms) and the remaining ~15% (213 h) of effort occurred at exposure levels of greater than 160 dB (rms). The received sound levels during observer effort from non-source vessels was less than 120 dB (rms) ~94% (2722 h) of the time and between 120 and 160 dB (rms) during the remainder of effort (171 h).

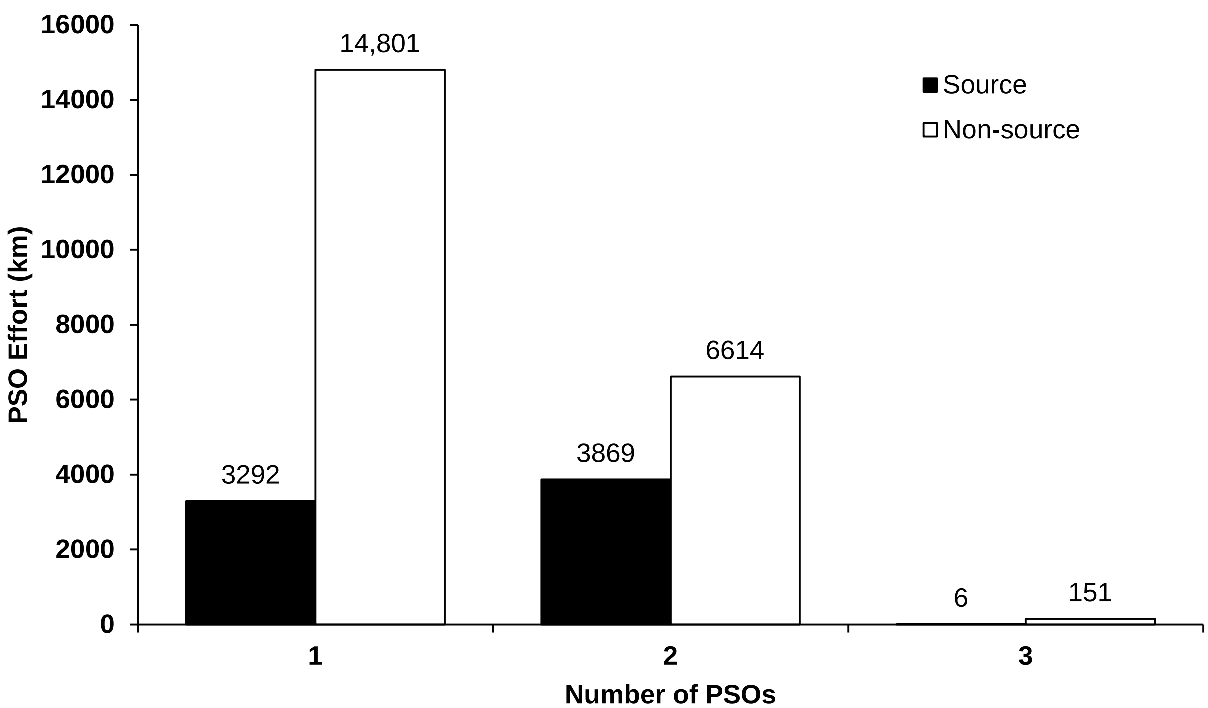

FIGURE 6.5. Total PSO observation effort (h) from moving project vessels showing number of PSOs on watch during Shell's exploratory drilling program in the Beaufort Sea, 2012.

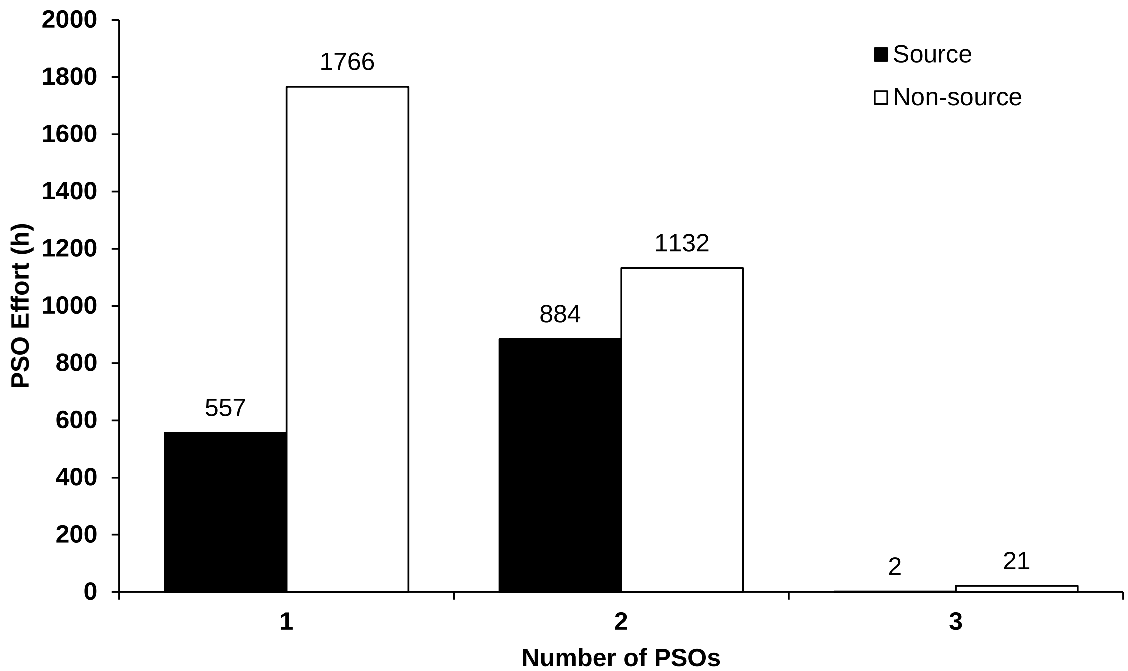

FIGURE 6.6. Total PSO observation effort (h) from moving project vessels showing number of PSOs on watch during Shell's exploratory drilling program in the Beaufort Sea, 2012.

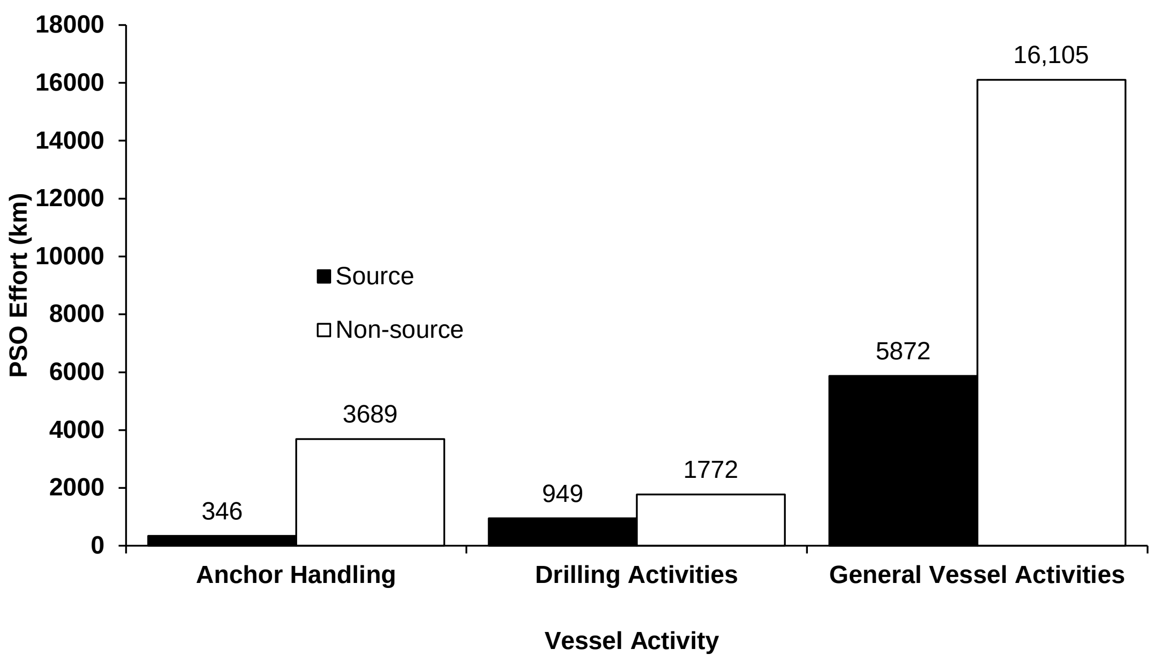

FIGURE 6.7. Total PSO observation effort (km) from moving project vessels for each vessel activity category during Shell's exploratory drilling program in the Beaufort Sea, 2012.

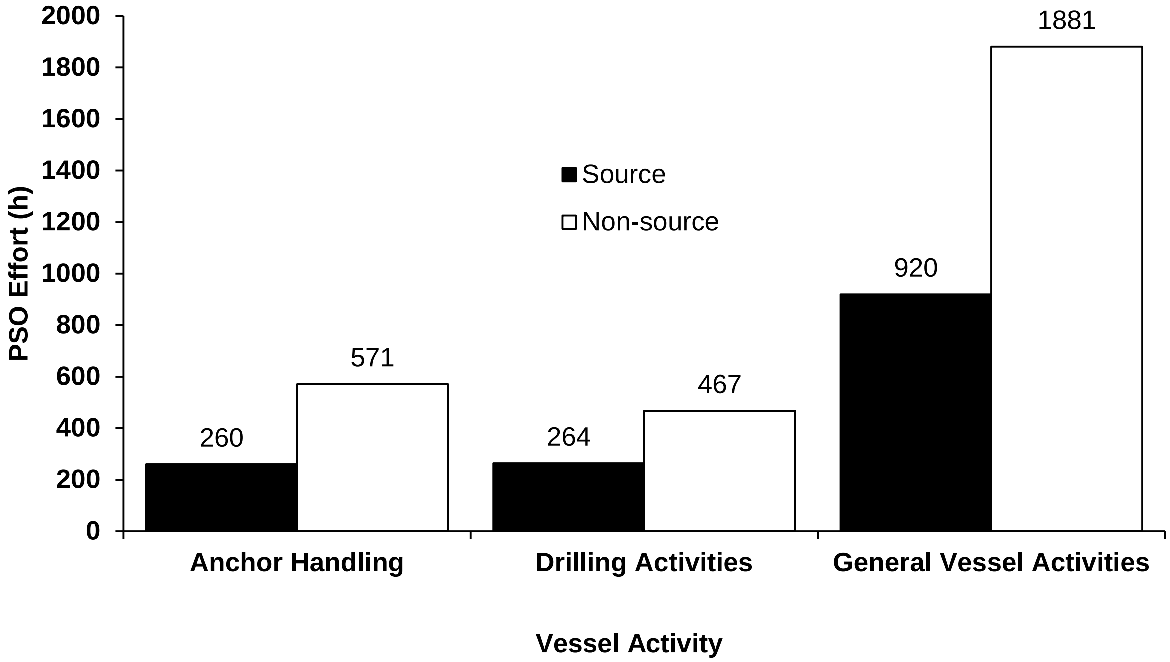

FIGURE 6.8. Total PSO observation effort (h) from moving project vessels for each vessel activity category during Shell's exploratory drilling program, 2012.

Marine Mammal Sightings

During the Shell exploratory drilling operations in the Beaufort Sea, PSOs observed a total of 1906 sightings of 11,304 marine mammals from the project vessels. Details of each marine mammal sighting observed in the survey area are available in Appendix G. Sighting rates from moving vessels are considered as sightings per 1000 km and from stationary vessels as sightings per 10 hr. The sighting data below are presented for four groups: cetaceans, seals, Pacific walruses, and polar bears.

Cetacean Sightings

PSOs recorded 160 sightings of 295 cetaceans from the project vessels (Table 6.1). Most cetacean sightings were recorded from moving vessels (~79%; Tables 6.2 and 6.3). Over half of cetacean sightings could not be identified to species (~61%; Table 6.1). Diagnostic features for identifying cetaceans to species are oftentimes not observed from vessels. PSOs were encouraged to identify animals based only on observed characteristics. Comments for many unidentified cetaceans indicated what the species designations probably were, such as characteristics consistent with bowhead whales, (e.g. dark body).

TABLE 6.1. Total number of cetacean sightings (total number of individuals) from the project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Species	Total		
	Source Vessels	**Non-source Vessels**	**Total**
Beluga whale	0 (0)	1 (13)	1 (13)
Bowhead whale	26 (46)	29 (61)	55 (107)
Gray whale	3 (4)	2 (2)	5 (6)
Minke whale	0 (0)	1 (1)	1 (1)
Unidentified mysticete whale	21 (49)	37 (58)	58 (107)
Unidentified whale	5 (5)	35 (56)	40 (61)
Total Cetaceans	***55 (104)***	***105 (191)***	***160 (295)***

TABLE 6.2. Number of cetacean sightings (number of individuals) from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Species	Moving		
	Source Vessels	**Non-source Vessels**	**Total**
Beluga whale	0 (0)	1 (13)	1 (13)
Bowhead whale	19 (38)	26 (58)	45 (96)
Gray whale	3 (4)	1 (1)	4 (5)
Minke whale	0 (0)	1 (1)	1 (1)
Unidentified mysticete whale	17 (45)	29 (43)	46 (88)
Unidentified whale	4(4)	25(41)	29(45)
Total Cetaceans	***43 (91)***	***83 (157)***	***126 (248)***

TABLE 6.3. Number of cetacean sightings (number of individuals) from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Species	Stationary		
	Source Vessels	Non-source Vessels	Total
Bowhead whale	7 (8)	3 (3)	10 (11)
Gray whale	0 (0)	1 (1)	1 (1)
Unidentified mysticete whale	4 (4)	8 (15)	12 (19)
Unidentified whale	1 (1)	10 (15)	11 (16)
Total Cetaceans	***12 (13)***	***22 (34)***	***34 (47)***

Cetacean Sighting Rates

Cetacean sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 4 and Appendix E) and the sightings that occurred during those periods. Data that met these criteria are presented in Parts 2 and 3 of Appendix F.

Cetacean Sighting Rates by Beaufort Wind Force – There was no clear trend in cetacean sighting rates when compared across Bf wind force level. Cetacean sighting rates were highest during Bf 3 for moving periods and Bf 1 for stationary periods (Fig 6.9 and 6.10). These results should be viewed with caution as there was very little effort in Bf 0 and a limited amount of effort in Bf 1.

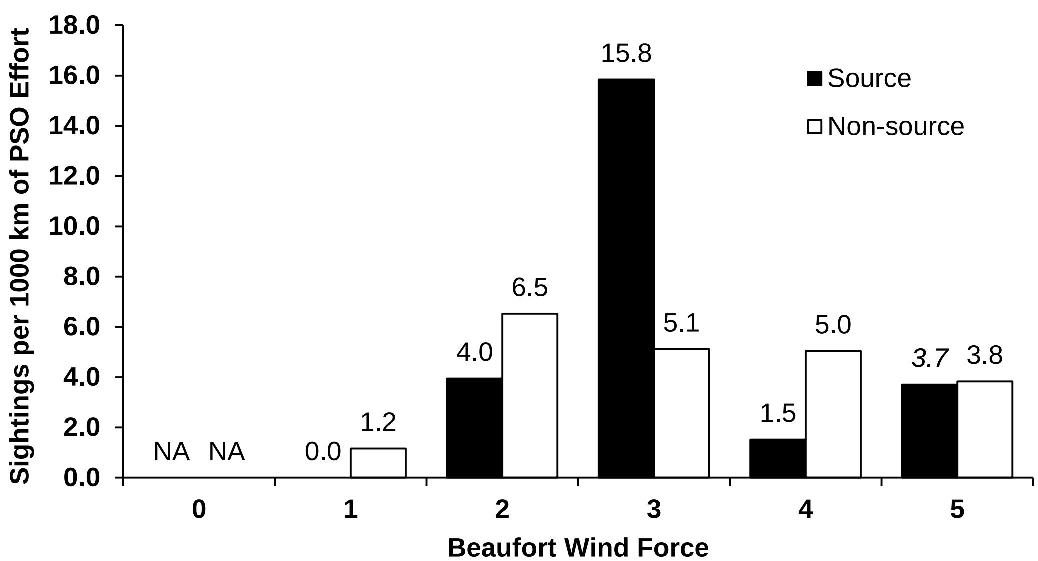

FIGURE 6.9. Cetacean sighting rates from moving vessels by Beaufort wind force during Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

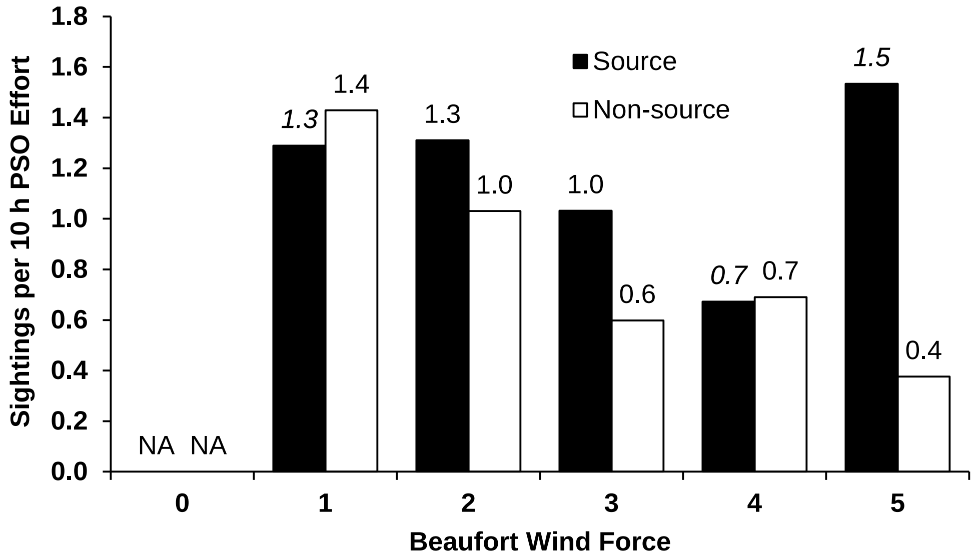

FIGURE 6.10. Cetacean sighting rates from stationary vessels by Beaufort wind force during Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Cetacean Sighting Rates by Number of PSOs – Regulatory requirements mandated that source vessels, such as ice breakers and drill rigs, utilize two PSOs to monitor the water during daytime active operations. Non-source vessels typically utilized one PSO during monitoring to maximize effort when practicable. Two PSO sighting rates for source vessels were similar to one PSO sighting rates for moving periods, however sighting rates for non-source vessels decreased with 2 PSOs on watch for moving periods. Two PSO sighting rates for non-source vessels were similar to one PSO sighting rates for non-source vessels during stationary periods, however sighting rates for source vessels were higher with one PSO for stationary periods (Fig 6.11 and 6.12). These sighting rates should be viewed with caution as they are closely linked to other variables affecting marine mammal detection, such as Bf wind force.

Cetacean Sighting Rates during Vessel Activity– Observers on moving vessels had the highest rate of cetacean sightings during general vessel activities (Fig. 6.13). Observers on stationary vessels had the highest rate of cetacean sightings during anchor handling activities (Fig. 6.14). Anchor handling was restricted to operational periods with low sea states. High cetacean sighting rates from source vessels during this activity likely were related to favorable conditions for detecting cetaceans. Sighting rates were lowest during drilling activities from both moving and stationary vessels. Limited moving effort from source vessels occurred during drilling activities since the primary source vessels were stationary during these activities so those sighting rates should be viewed with some caution.

Cetacean Sighting Rates by Received Sound Level –During stationary and moving periods received sound levels ≥160 dB (rms) either lacked effort required for meaningful analysis or no sightings exposed to ≥160 dB (rms) were reported. PSO effort was not evenly distributed over received sound level bins. Factors which contributed to this uneven distribution include 1) sound pressure levels from activities such as drilling and ice management attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sounds at this level.

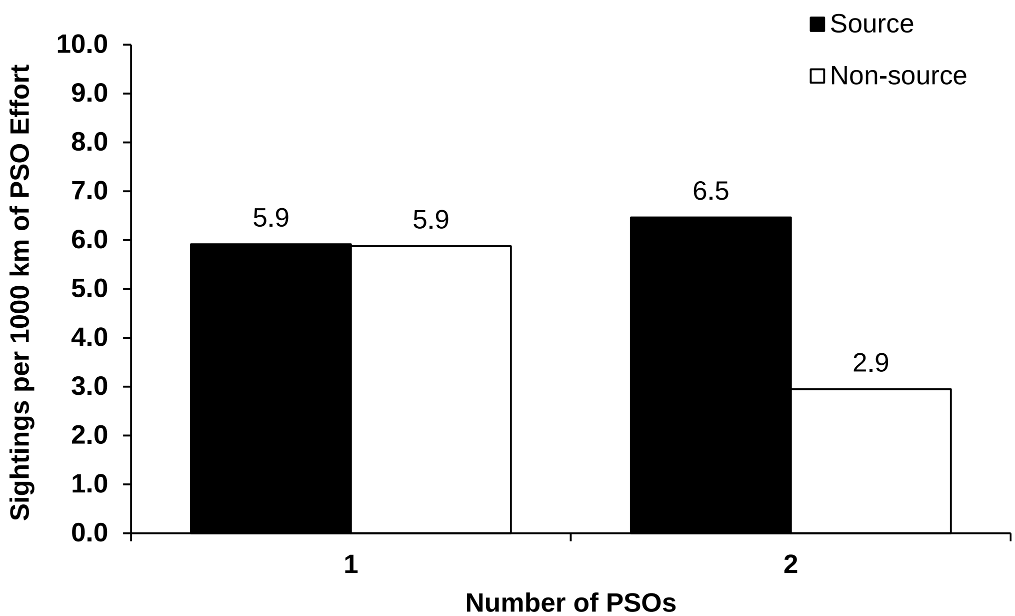

FIGURE 6.11. Cetacean sighting rates from moving vessels by number of PSOs on watch during Shell's Beaufort Sea exploratory drilling operations, 2012. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

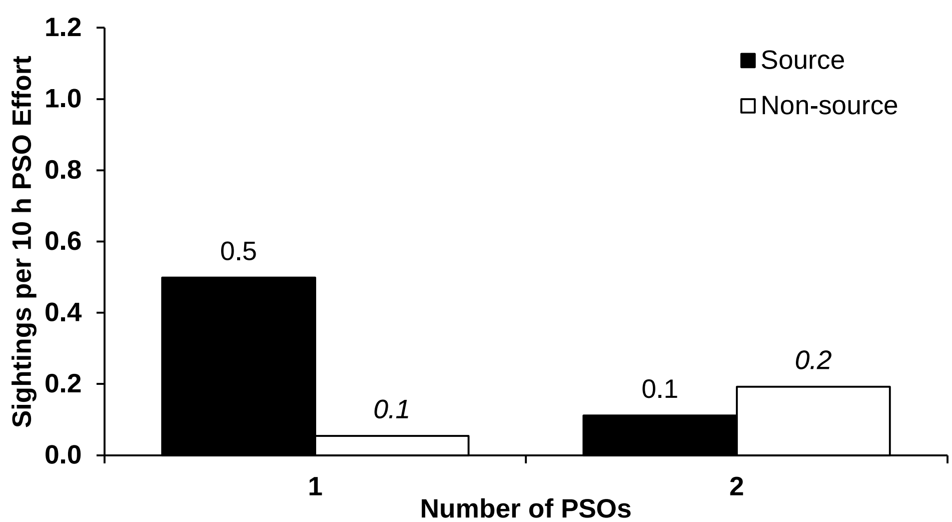

FIGURE 6.12. Cetacean sighting rates from stationary vessels by number of PSOs on watch during Shell's Beaufort Sea exploratory drilling operations, 2012. Note that < 35 h of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

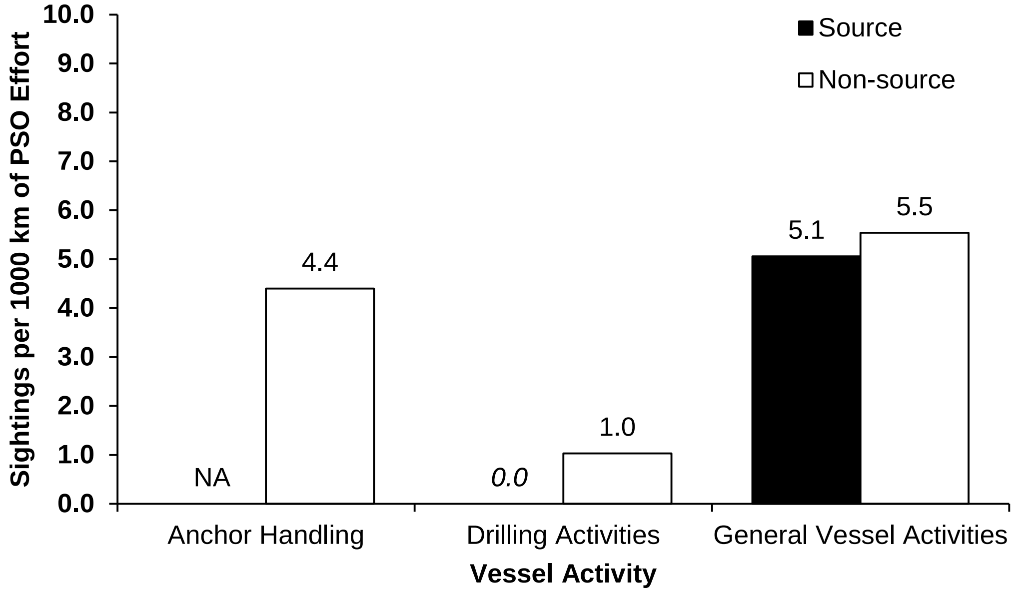

FIGURE 6.13. Cetacean sighting rates from moving vessels during vessel activity during Shell's Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

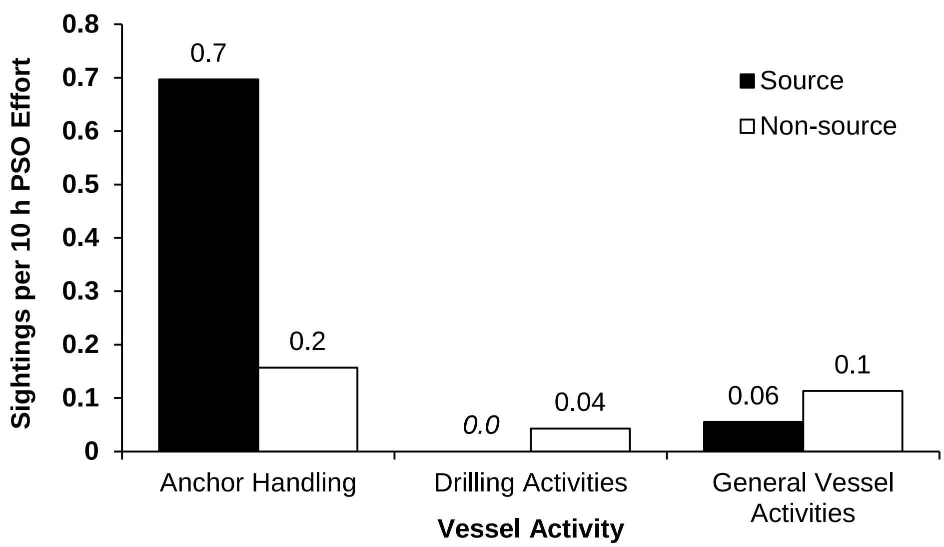

FIGURE 6.14. Cetacean sighting rates from stationary vessels during vessel activity during Shell's Beaufort Sea exploratory drilling operations, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

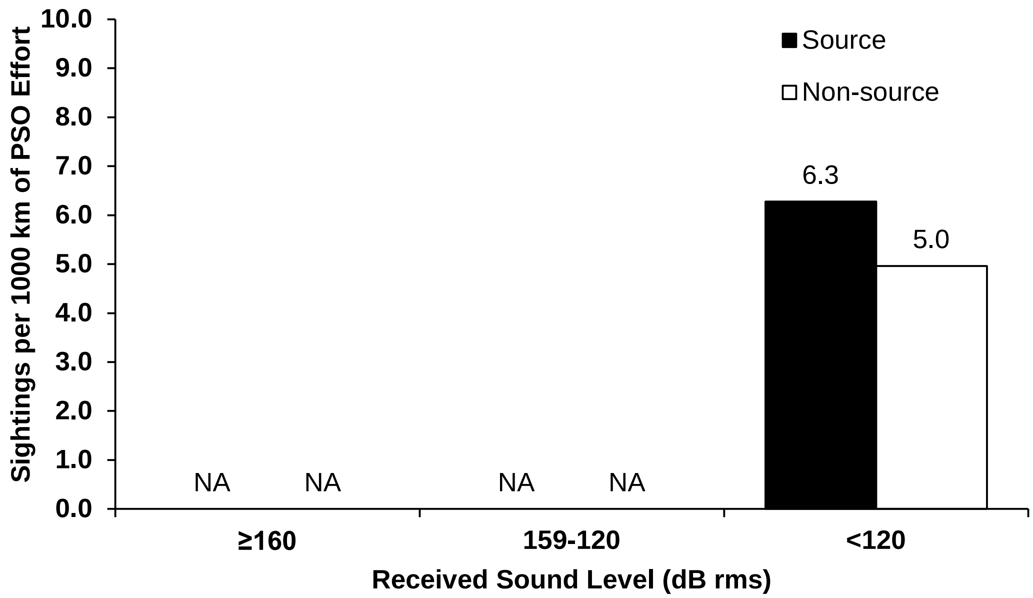

FIGURE 6. 15 Cetacean sighting rates from moving vessels by received sound level for Shell's Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

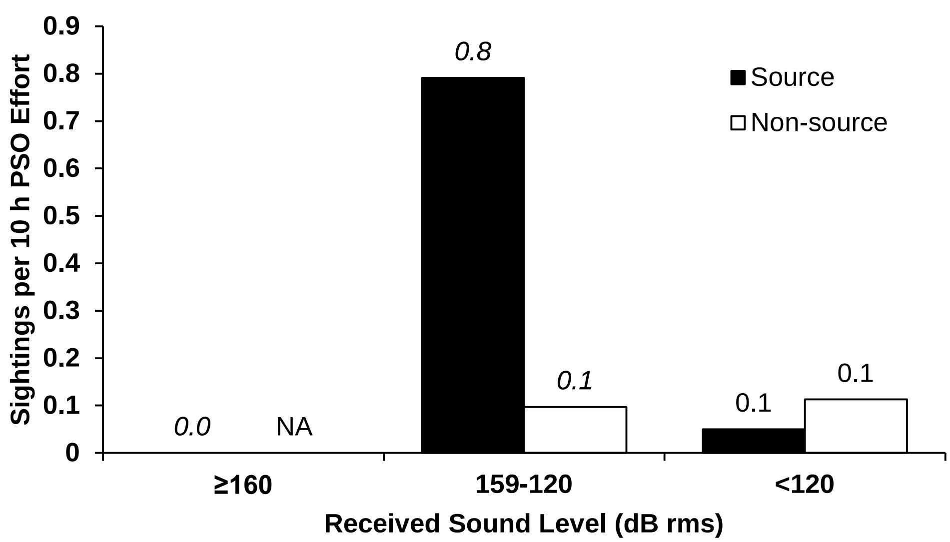

FIGURE 6.16. Cetacean sighting rates from stationary vessels by received sound level for Shell's Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Seal Sightings

There were 593 seal sightings of 878 individuals by PSOs on the project vessels (Table 6.4). 274 of these sightings occurred while project vessels were moving, and 319 of the sightings occurred while vessels were stationary (Table 6.5 and 6.6). Approximately half of seal sightings could not be identified to species (~52%; Table 6.4). Clearly observed diagnostic features for identifying seals to species are oftentimes not observed from vessels since seal sightings tend to be brief in duration. PSOs were instructed to identify animals to species only when distinguishing characteristics were clearly observed.

TABLE 6.4. Total number of seal sightings (number of individuals) from the project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Species	Total		
	Source Vessels	**Non-source Vessels**	**Total**
Bearded seal	47 (47)	30 (31)	77 (78)
Ringed seal	103 (213)	47 (58)	150 (271)
Spotted seal	7 (7)	52 (56)	59 (63)
Unidentified pinniped	4 (6)	8 (11)	12 (17)
Unidentified seal	96 (157)	199 (292)	295 (449)
Total Seals	***257 (430)***	***336 (448)***	***593 (878)***

TABLE 6.5. Number of seal sightings (number of individuals) from the moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Species	Moving		
	Source Vessels	**Non-source Vessels**	**Total**
Bearded seal	11 (11)	15 (15)	26 (26)
Ringed seal	13 (20)	16 (22)	29 (42)
Spotted seal	4 (4)	17 (20)	21 (24)
Unidentified pinniped	4 (6)	7 (10)	11 (16)
Unidentified seal	64 (118)	123 (211)	187 (329)
Total Seals	***96 (159)***	***178 (278)***	***274 (437)***

TABLE 6.6. Number of seal sightings (number of individuals) from the stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012

Species	Stationary		
	Source Vessels	Non-source Vessels	Total
Bearded seal	36 (36)	15 (16)	51 (52)
Ringed seal	90 (193)	31 (36)	121 (229)
Spotted seal	3 (3)	35 (36)	38 (39)
Unidentified pinniped	0 (0)	1 (1)	1 (1)
Unidentified seal	32 (39)	76 (81)	108 (120)
Total Seals	***161 (271)***	***158 (170)***	***319 (441)***

<u>*Seal Sighting Rates*</u>

Seal sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect seals (See Chapter 4 and Appendix E) and the sightings that occurred during those periods.

Seal Sighting Rates by Beaufort Wind Force – Seal sighting rates from moving project vessels were greatest during periods of Bf one and show a clear downward trend with increasing Bf wind force levels (Fig. 6.17). Seal sighting rates from stationary vessels show no clear trend, however observation effort from source vessels during stationary periods during Bf 0,1,4, and 5 days are limited, so those sighting rates should be viewed with some caution.

Seal Sighting Rates by Number of PSOs – Seal sighting rates with two PSOs on watch were higher than sighting rates with one PSO on watch for all project vessels.

Seal Sighting Rates during Vessel Activity –. Moving vessels during general vessel activities experienced higher seal sighting rates during moving periods (Fig. 6.21). Seal sighting rates from stationary vessels showed no clear trend across different vessel activities (Fig. 6.22).

Seal Sighting Rates by Received Sound Level – During moving periods, received sound levels≥120 dB (rms) lacked sufficient effort required for meaningful analysis. PSO effort was not evenly distributed over received sound level bins. Factors which contributed to this uneven distribution include 1) sound pressure levels from activities such as drilling activities and ice management attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sound at greater levels. Results from stationary periods of received sound levels ≥120 dB (rms) should be viewed with caution due to lack of sufficient effort, however sighting rates were highest during drilling activities (Fig. 6.24).

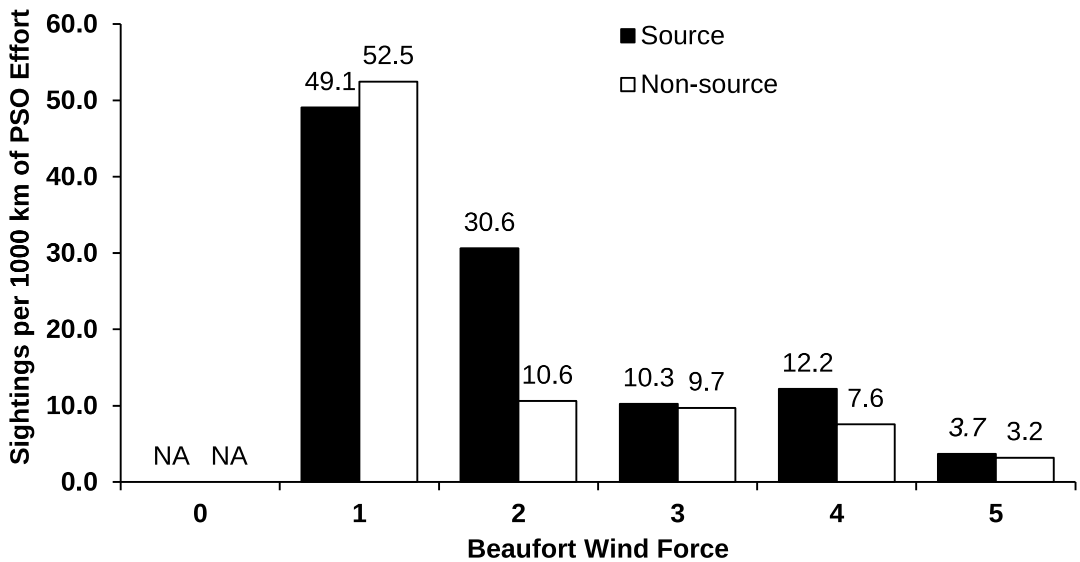

FIGURE 6.17. Seal sighting rates from moving vessels by Beaufort wind force during Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

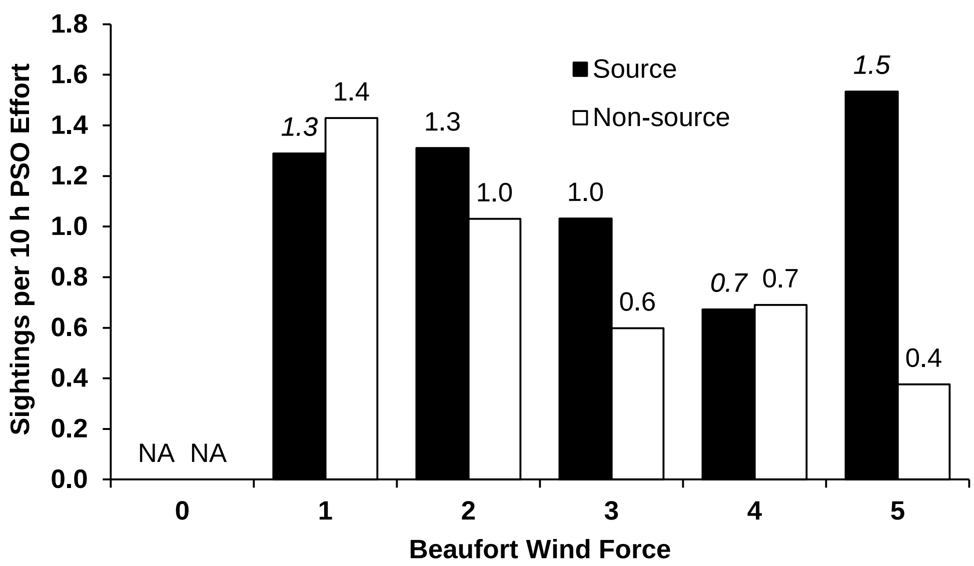

FIGURE 6.18. Seal sighting rates from stationary vessels by Beaufort wind force during Beaufort Sea exploratory drilling operations, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

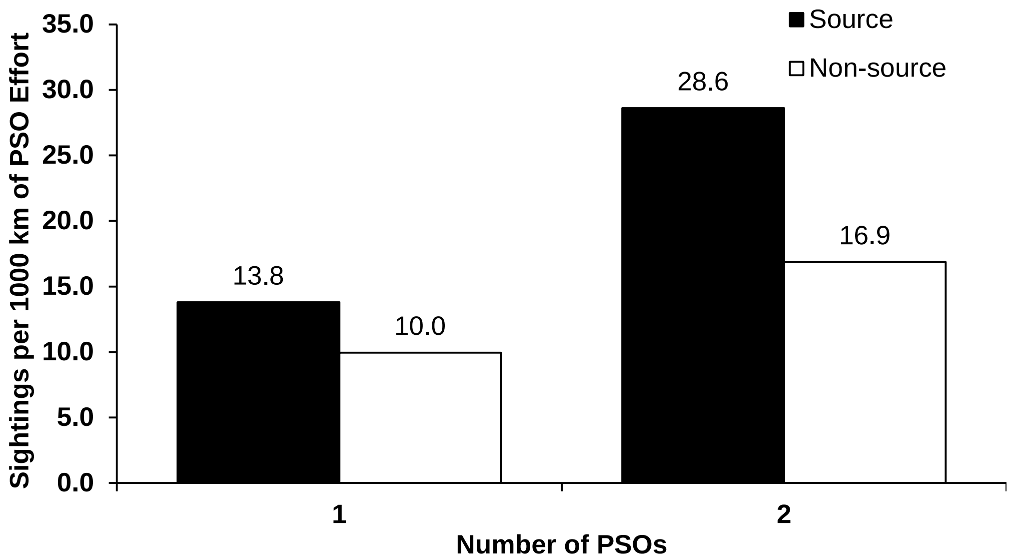

FIGURE 6.19. Seal sighting rates from moving vessels by number of PSOs on watch from the project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

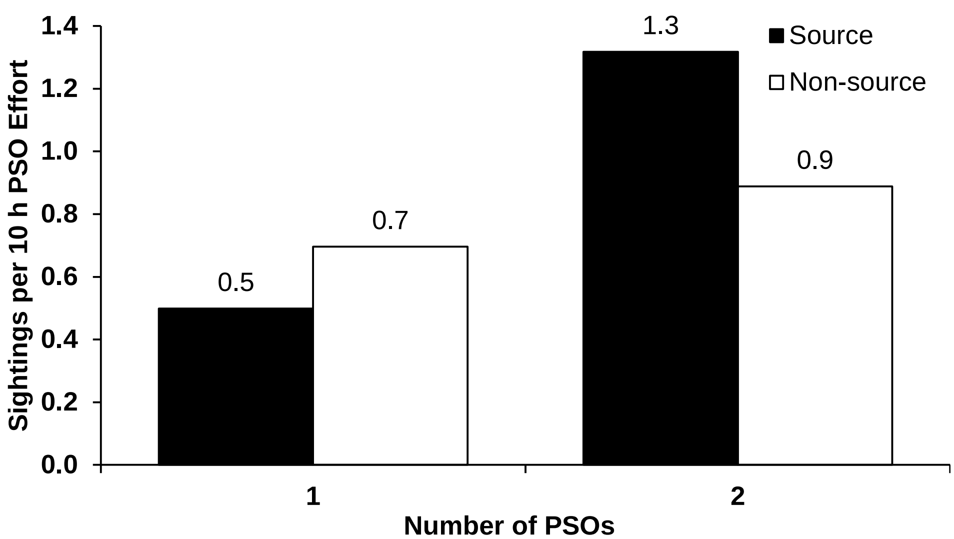

FIGURE 6.20. Seal sighting rates from stationary vessels by number of PSOs on watch from the project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Note that < 35 h of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

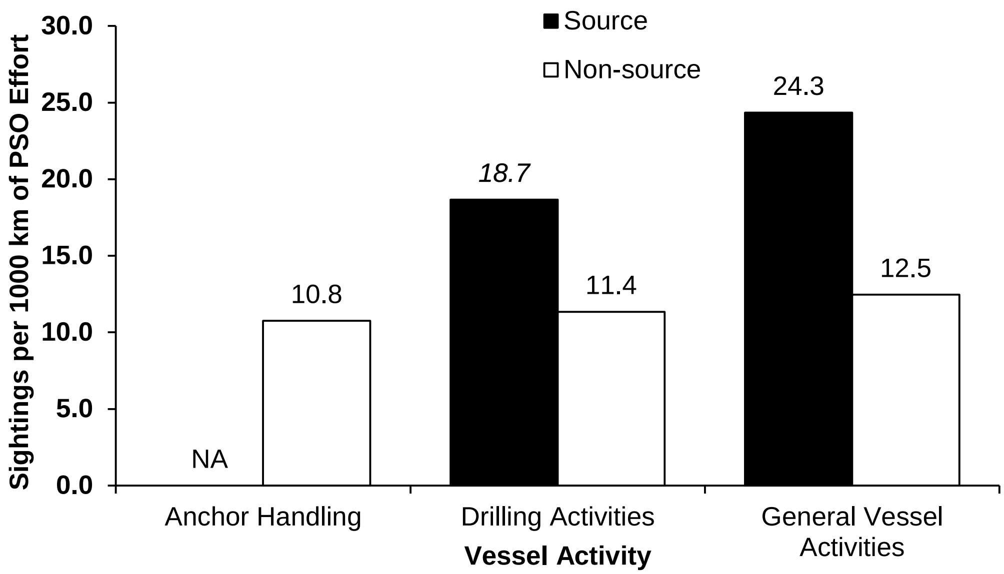

FIGURE 6.21. Seal sighting rates during vessel activity from the moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

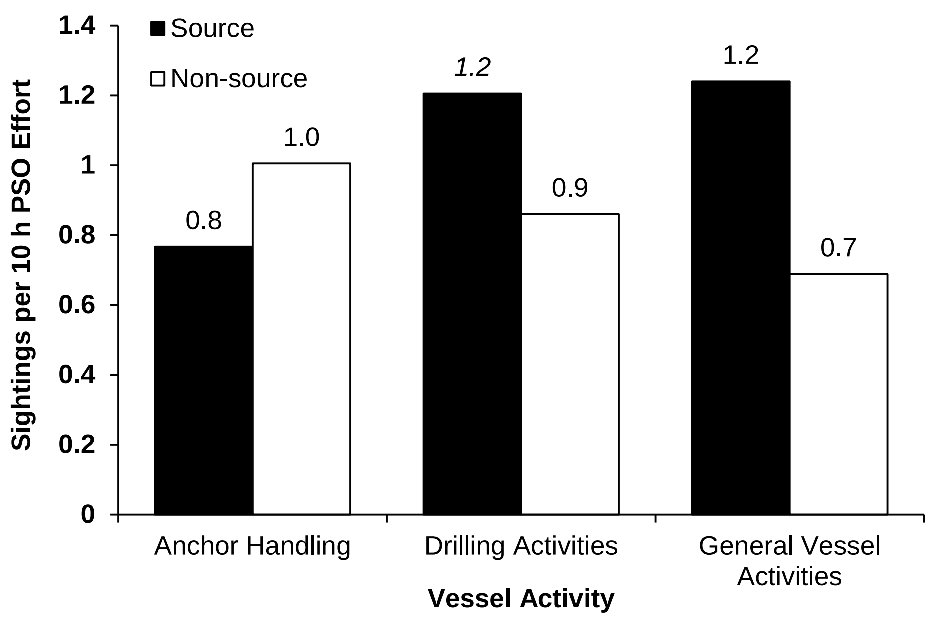

FIGURE 6.22. Seal sighting rates during vessel activity from the stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

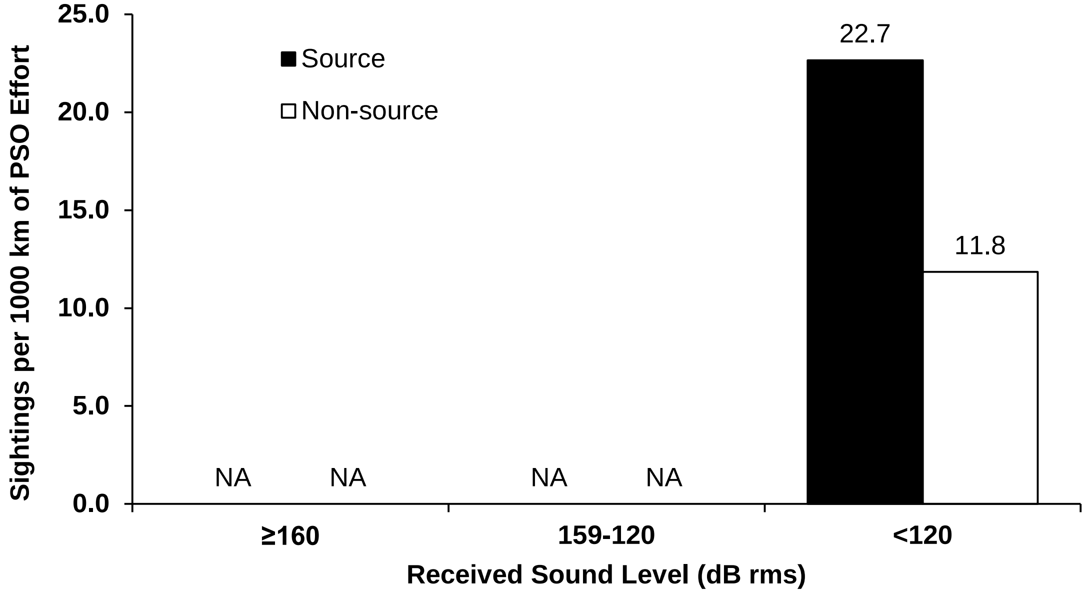

FIGURE 6.23. Seal sighting rates from moving project vessels by received sound level during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

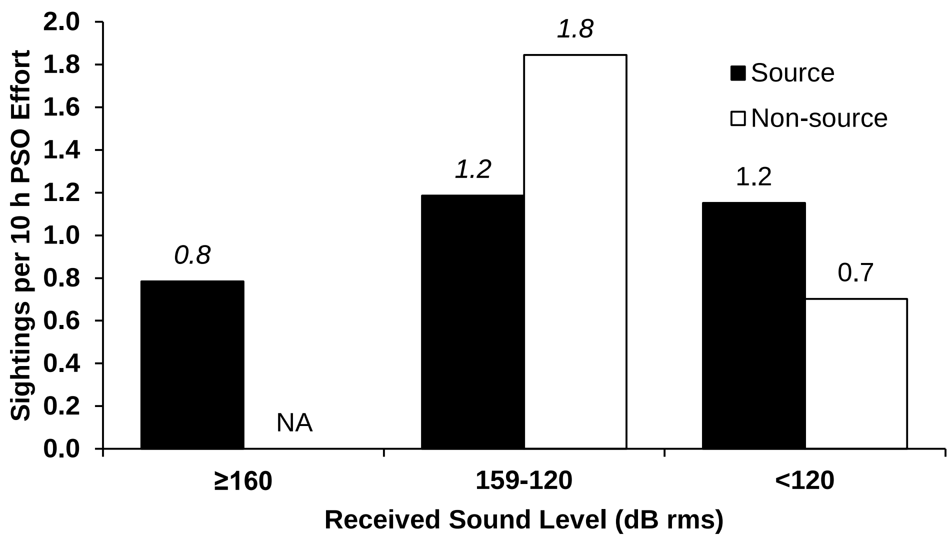

FIGURE 6.24. Seal sighting rates from stationary project vessels by received sound level during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Pacific Walrus Sightings

There were 9 Pacific walrus sightings of 18 individuals by PSOs on the project vessels (Table 6.7). There were 9 walrus sightings of 18 individuals observed by moving vessels and 5 walrus sightings of 6 individuals observed by stationary vessels (Table 6.8 and 6.9).

TABLE 6.7. Total number of Pacific Walrus sightings (number of individuals) from the project vessels during Shell's exploratory drilling operations, 2012.

	Total		
Species	**Source Vessels**	**Non-source Vessels**	**Total**
Pacific walrus	11 (21)	3 (3)	14 (24)

TABLE 6.8. Number of Pacific Walrus sightings (number of individuals) from moving project vessels during Shell's exploratory drilling operations, 2012.

	Moving		
Species	**Source Vessels**	**Non-source Vessels**	**Total**
Pacific walrus	9 (18)	0 (0)	9 (18)

TABLE 6.9. Number of Pacific Walrus sightings (number of individuals) from stationary project vessels during Shell's exploratory drilling operations, 2012.

	Stationary		
Species	**Source Vessels**	**Non-source Vessels**	**Total**
Pacific walrus	2 (3)	3 (3)	5 (6)

<u>*Pacific Walrus Sighting Rates*</u>

Pacific walrus sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect walruses (See Chapter 4 and Appendix E) and the sightings that occurred during those periods.

Pacific Walrus Sighting Rates by Beaufort Wind Force – Pacific walrus sighting rates from moving source vessels showed a clear downward trend as Bf wind force levels increased (Fig. 6.25). Pacific walrus sighting rates from stationary vessels were greatest during Bf one (Fig. 6.26).

Pacific Walrus Sighting Rates by Number of PSOs – Pacific Walrus sighting rates were somewhat greater for source and non-source vessels with two PSOs on watch than one PSO on watch during both moving and stationary periods (Fig. 6.27). No walruses were observed from moving non-source vessels or from stationary vessels with one PSO on watch (Fig. 6.27 and 6.28).

Pacific Walrus Sighting Rates during Vessel Activity – Walrus sighting rates were highest for both moving and stationary periods during general vessel activities (Fig. 6.29 and 6.30).

Walrus Sighting Rates by Received Sound Level – During moving periods, received sound levels>120 dB (rms) lacked sufficient effort required for meaningful analysis. Observers on stationary source vessels observed the highest rate of Pacific walrus sightings while received sound levels were 159-120 dB (rms; Fig. 6.32), however PSO effort was not evenly distributed over received sound level bins. Factors which contributed to this uneven distribution included 1) sound pressure levels from activities such as drilling and ice management attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sound at greater levels.

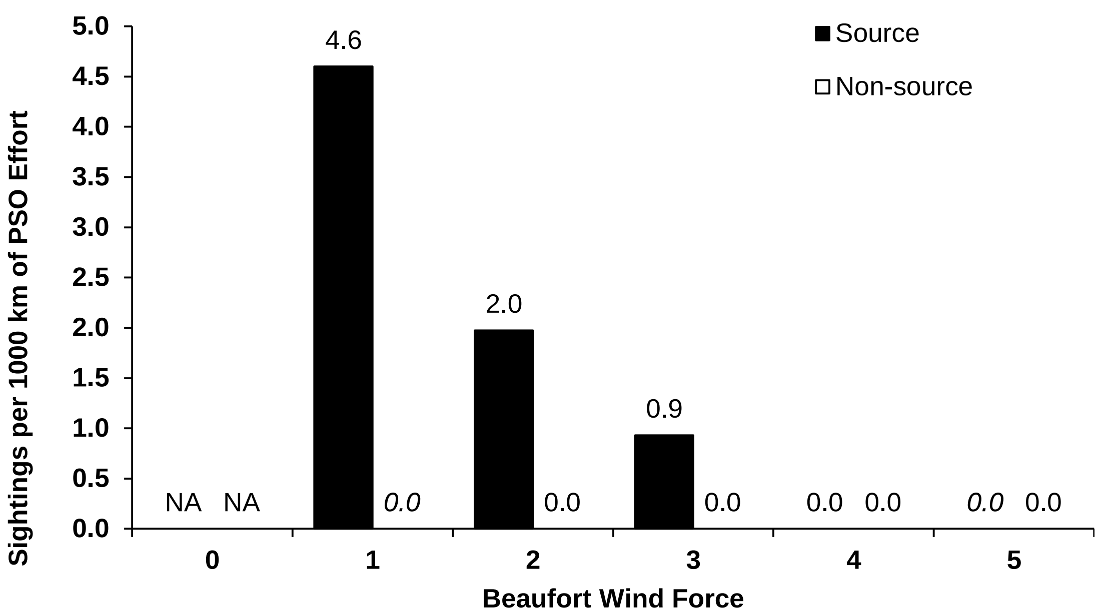

FIGURE 6.25. Walrus sighting rates by Beaufort wind force from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

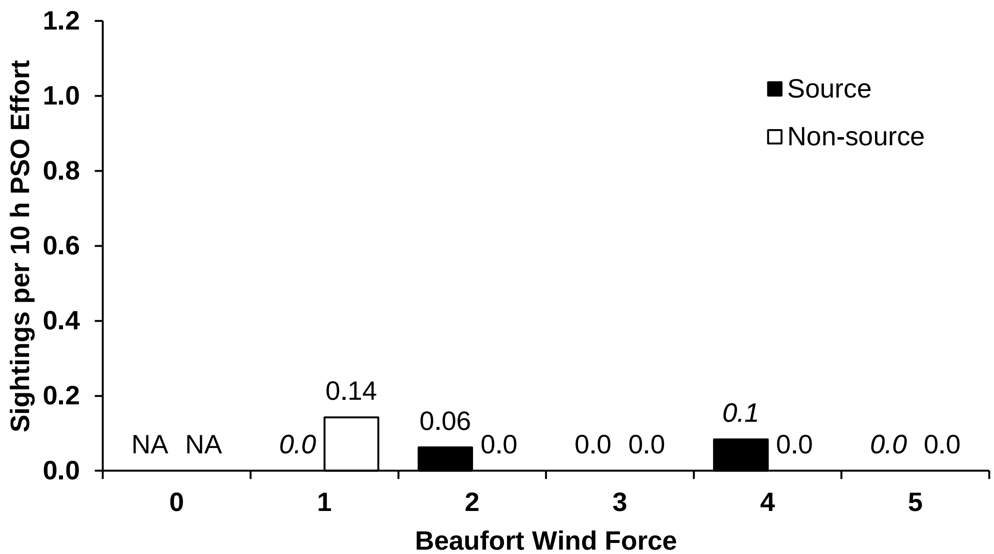

FIGURE 6.26. Walrus sighting rates by Beaufort wind force from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

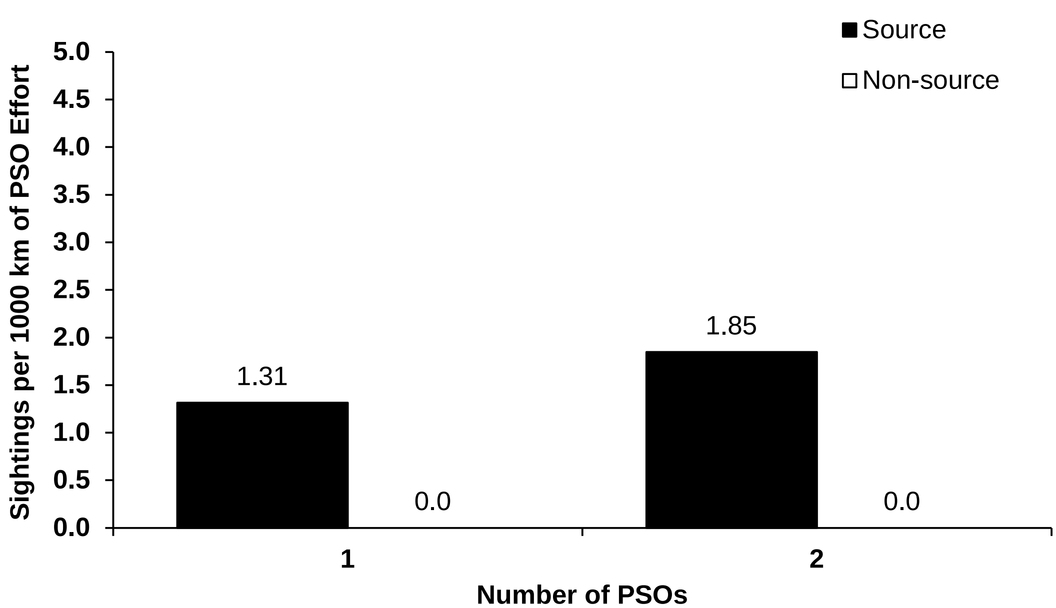

FIGURE 6.27. Walrus sighting rates by the number of PSOs from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

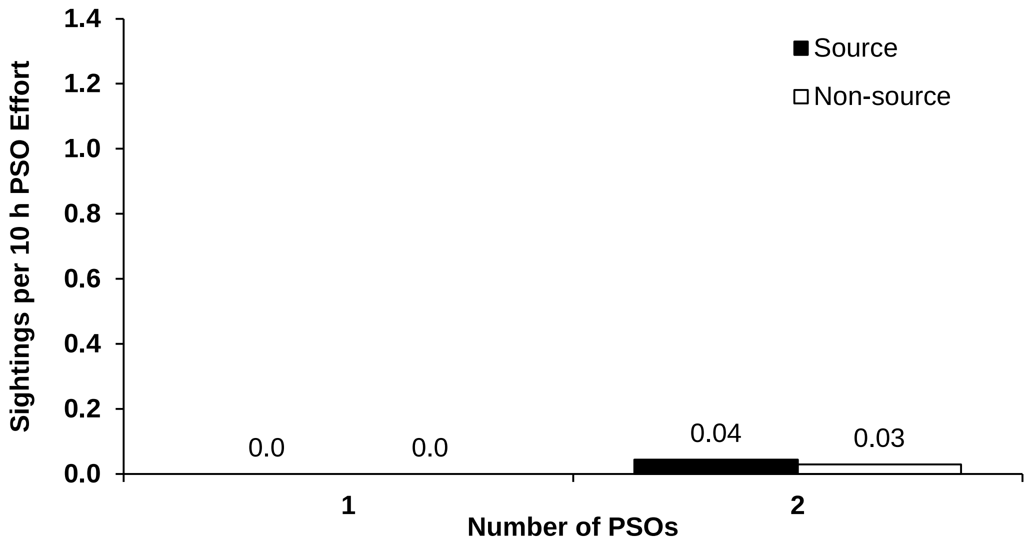

FIGURE 6.28. Walrus sighting rates by the number of PSOs from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Note that < 35 h of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

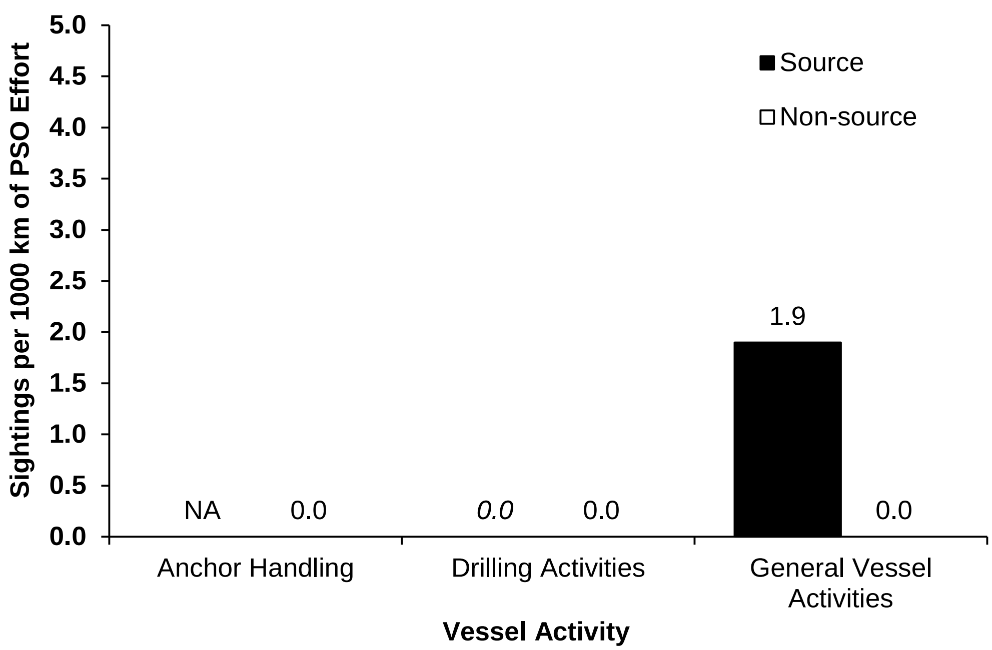

FIGURE 6.29. Walrus sighting rates by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

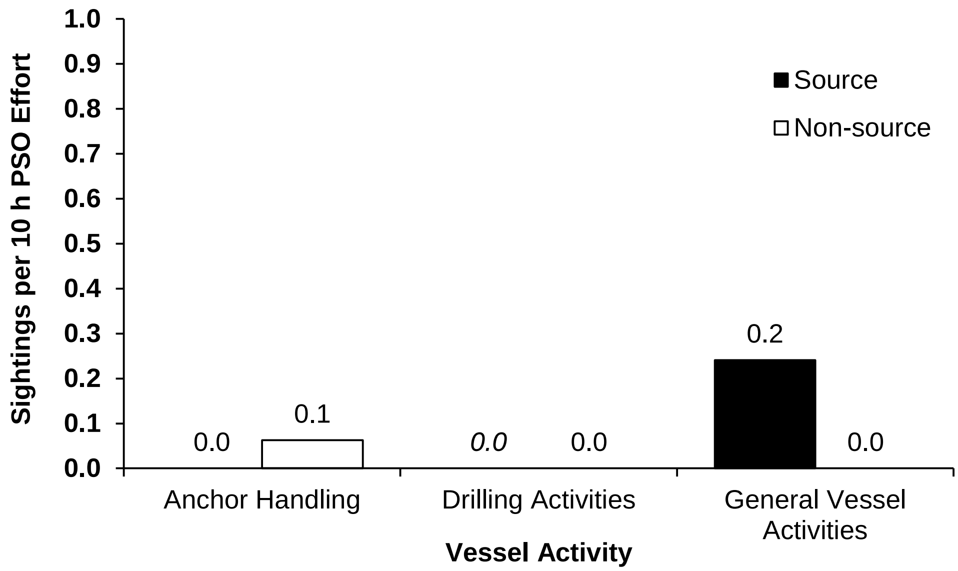

FIGURE 6.30. Walrus sighting rates by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

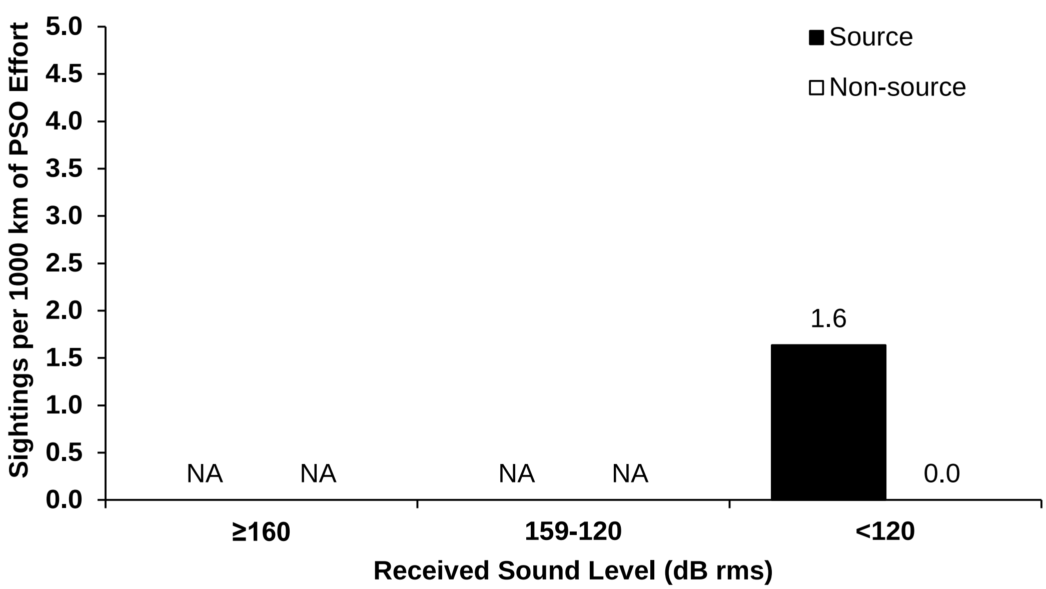

FIGURE 6.31. Walrus sighting rates by received sound level from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

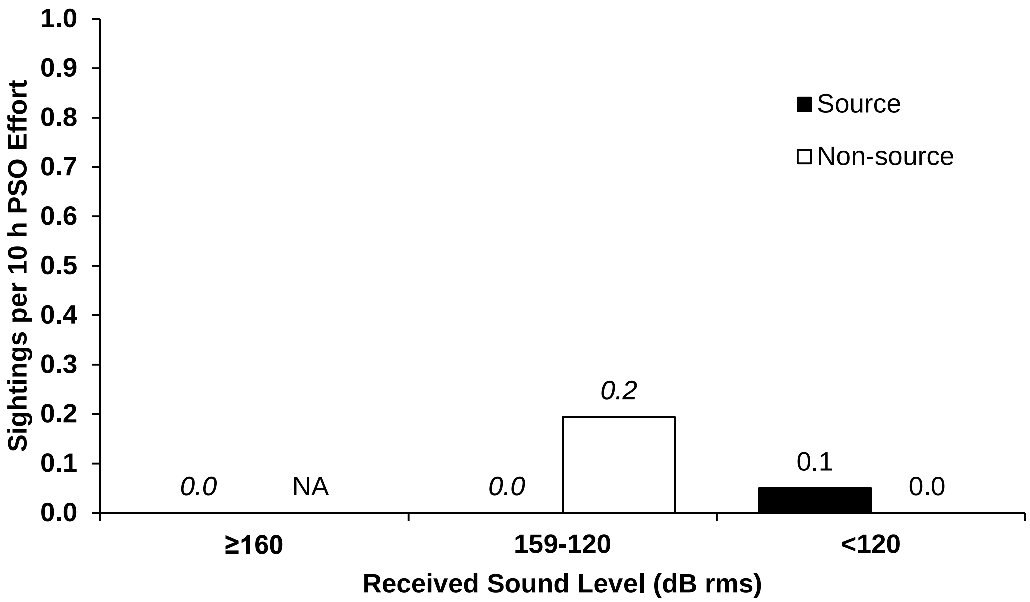

FIGURE 6.32. Walrus sighting rates by received sound level from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Polar Bear Sightings

There were 29 polar bear sightings of 104 individuals by PSOs on the project vessels (Table 6.10). There were 13 polar bear sightings of 39 individuals recorded by PSOs on moving vessels and 16 polar bear sightings of 65 individuals recorded by PSOs on stationary vessels (Table 6.11 and 6.12).

TABLE 6.10. Total number of polar bear sightings (number of individuals) from the project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Species	Total: Source Vessels	Total: Non-source Vessels	Sightings (Individuals)
Polar Bear	2 (4)	27 (100)	***29 (104)***

TABLE 6.11. Number of polar bear sightings (number of individuals) from moving project vessels during Shell's exploratory drilling operations, 2012.

	Moving		
Species	**Source Vessels**	**Non-Source Vessels**	**Sightings (Individuals)**
Polar bear	2 (4)	11 (35)	***13 (39)***

TABLE 6.12. Number of polar bear sightings (number of individuals) from stationary project vessels during Shell's exploratory drilling operations, 2012.

	Stationary		
Species	**Source Vessels**	**Non-Source Vessels**	**Sightings (Individuals)**
Polar bear	0 (0)	16 (65)	***16 (65)***

Polar Bear Sighting Rates

Polar bear sighting rates were calculated using only the periods of effort that met the criteria for being able to reliably detect polar bears (See Chapter 4 and Appendix E) and the sightings that occurred during those periods.

Polar Bear Sighting Rates by Beaufort Wind Force – Polar bear sighting rates from moving project vessels were greatest during Bf two (Fig. 6.33). Polar bear sighting rates from stationary project vessels were greatest during Bf three, although there was no clear trend across Bf wind force levels (Fig. 6.34).

Polar Bear Sighting Rates by Number of PSOs – Polar bear sighting rates were greater with two PSOs on watch than with one PSO on watch during moving periods (Fig. 6.35). Polar bear sighting rates during stationary periods were slightly higher with one PSO on watch than with two PSOs on watch (Fig. 6.36).

Polar Bear Sighting Rates during Vessel Activity – Polar bear sighting rates were highest from non-source moving vessels during drilling activities and highest from moving source vessels during general vessel activities (Fig. 6.37). Sighting rates were marginally higher from stationary vessels during general vessel activities (Fig. 6.38) than from either anchor handling or drilling activities.

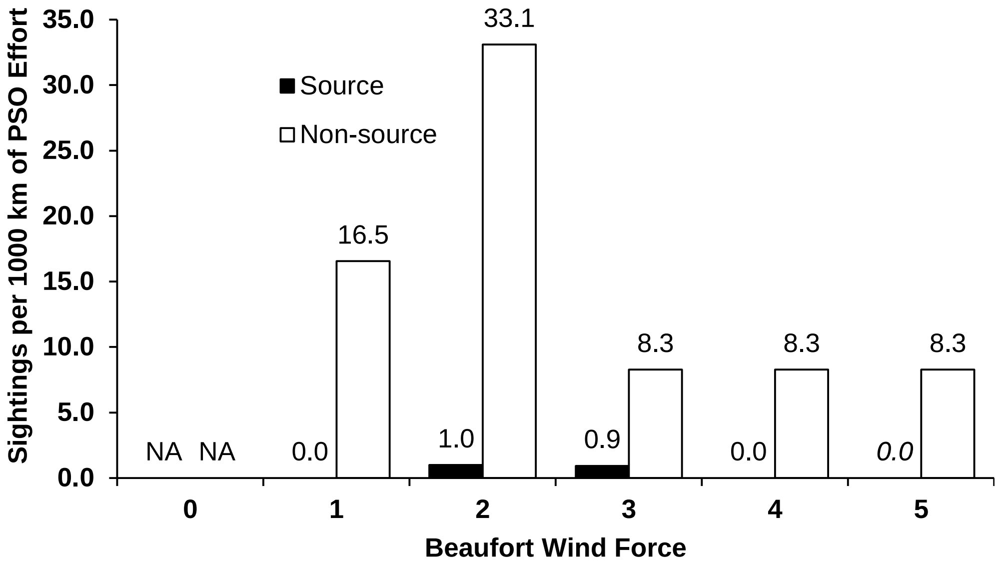

FIGURE 6.33. Polar bear sighting rates by Beaufort wind force from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

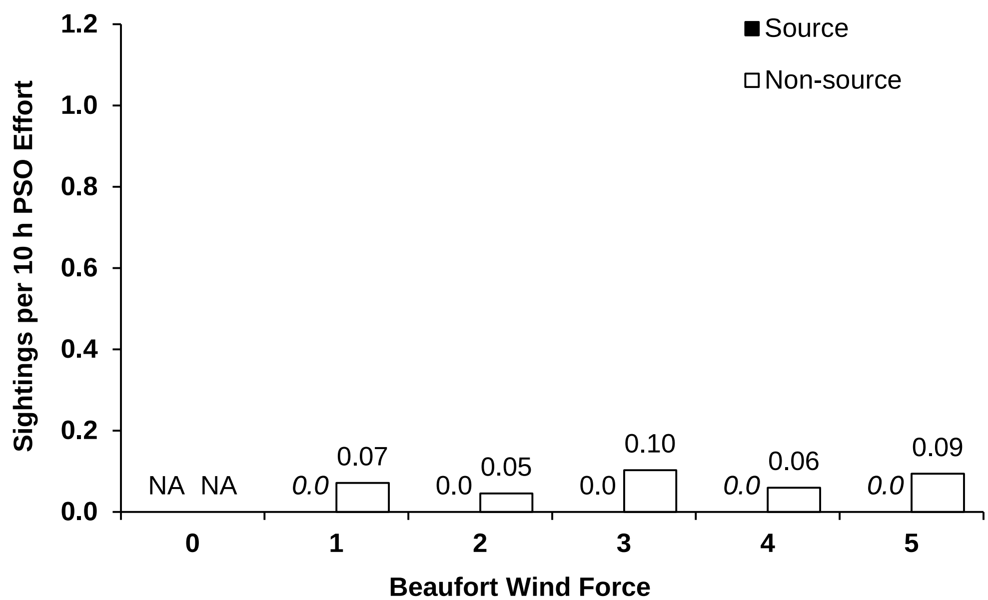

FIGURE 6.34. Polar bear sighting rates by Beaufort wind force from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

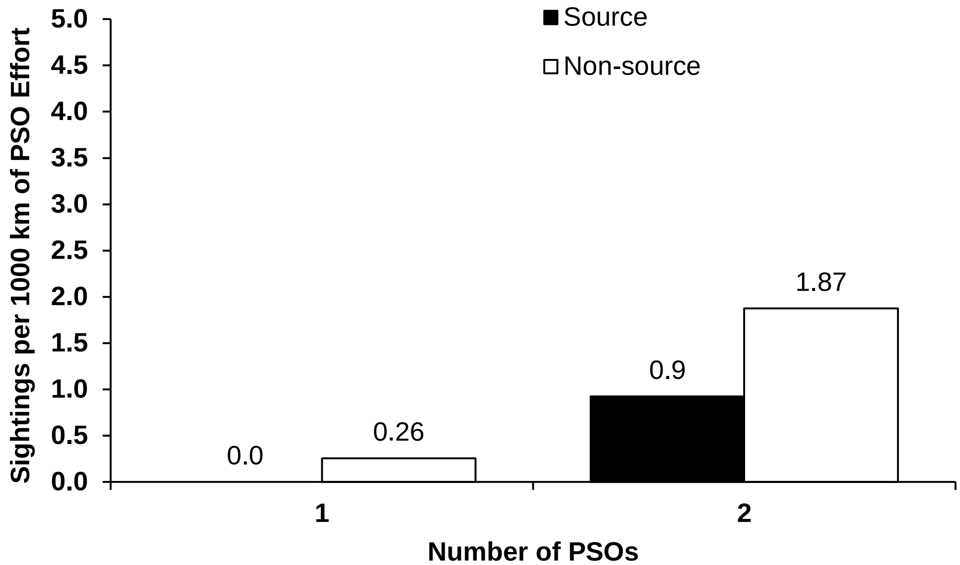

FIGURE 6.35. Polar bear sighting rates by the number of PSOs from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

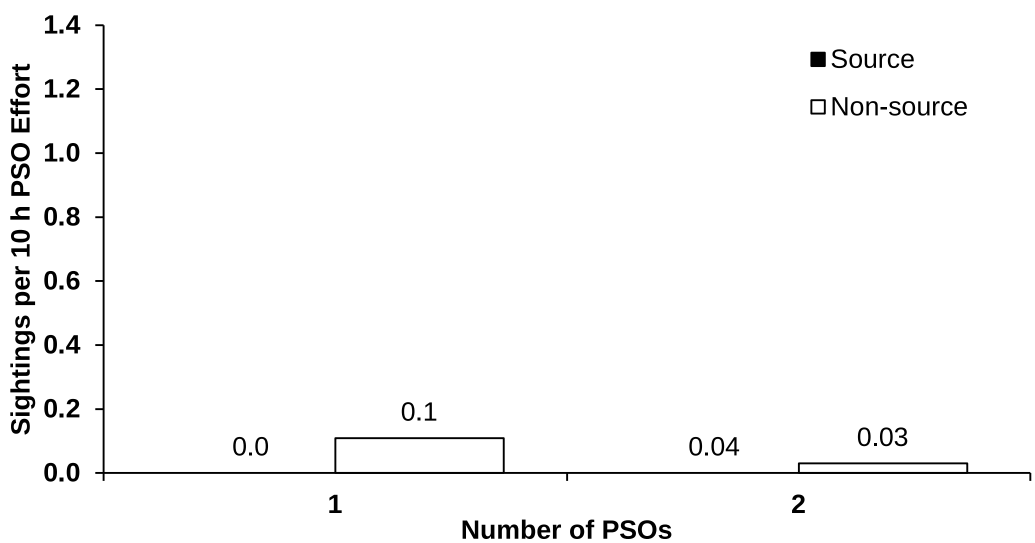

FIGURE 6.36. Polar bear sighting rates by the number of PSOs from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Note that < 35 h of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

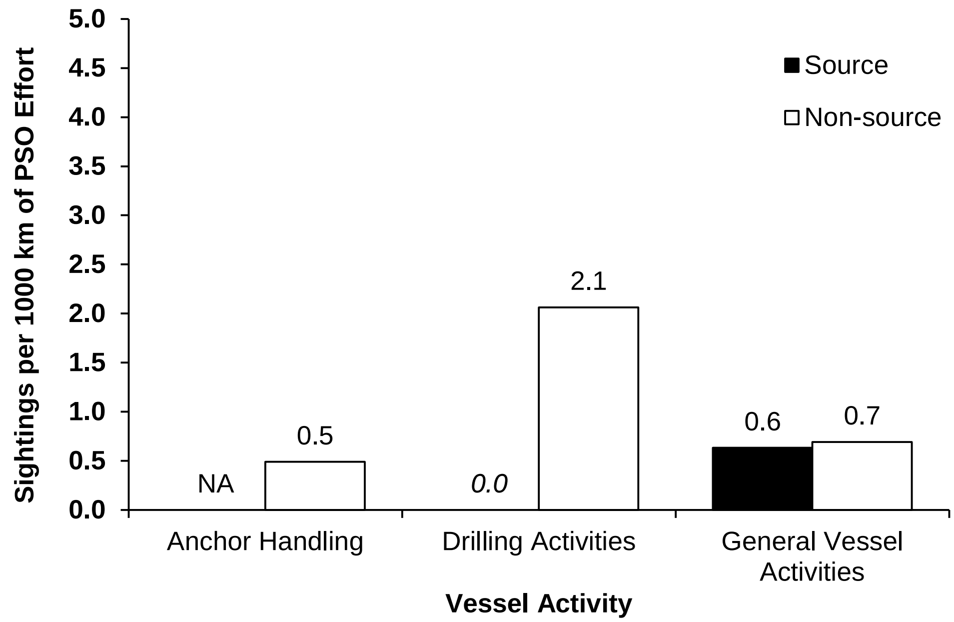

FIGURE 6.37. Polar bear sighting rates by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

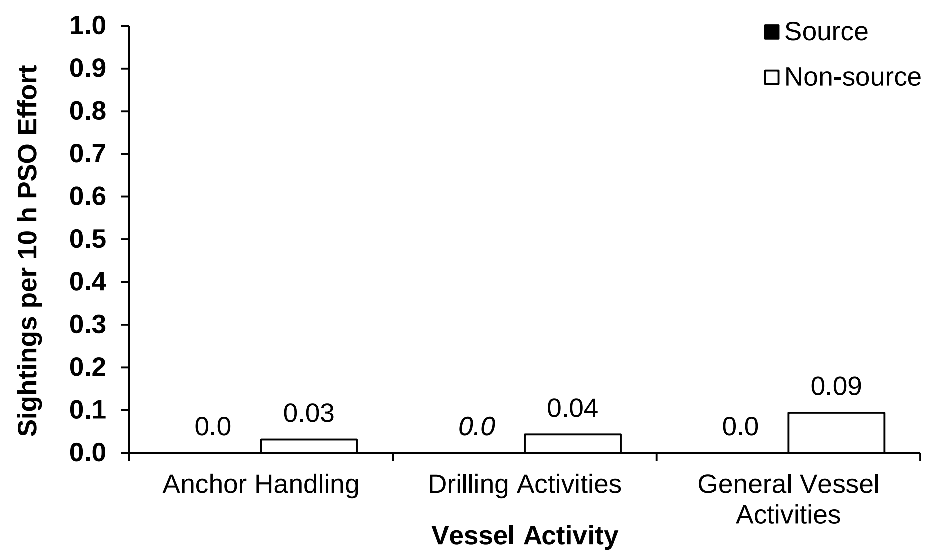

FIGURE 6.38. Polar bear sighting rates by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Polar Bear Rates by Received Sound Level – During moving periods received sound levels >120 dB (rms) lacked sufficient effort required for meaningful analysis. PSO effort was not evenly distributed over received sound level bins. Factors which contributed to this uneven distribution included 1) sound pressure levels from activities such as drilling attenuated to less than 160 dB over relatively short distances (see Chapter 3), 2) support vessels staged far from drill rigs as part of Shell's air quality permit, and 3) source vessels had short operational windows for activities that produced sounds of higher levels.

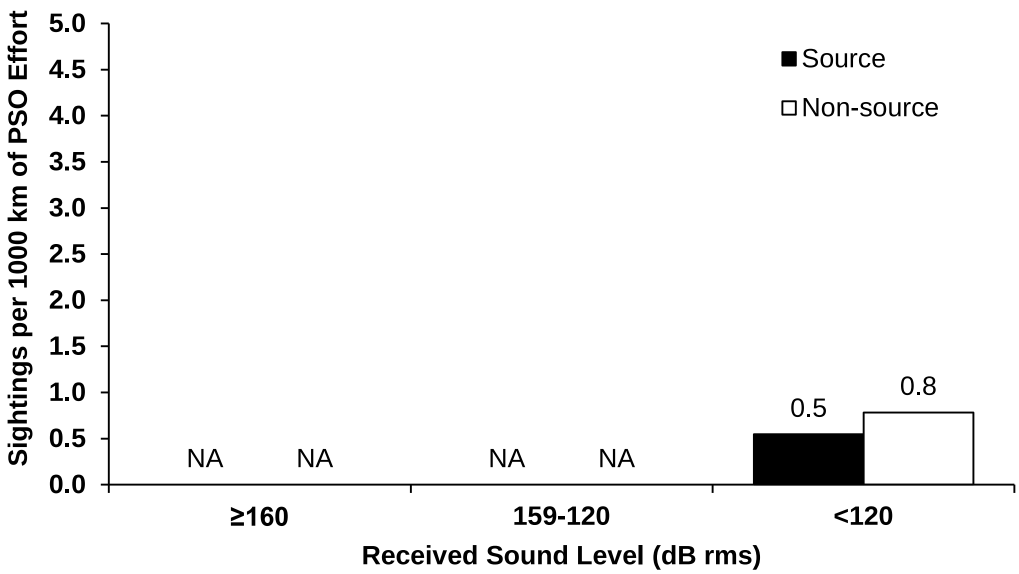

FIGURE 6.39. Polar bear sighting rates by received sound level from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate.

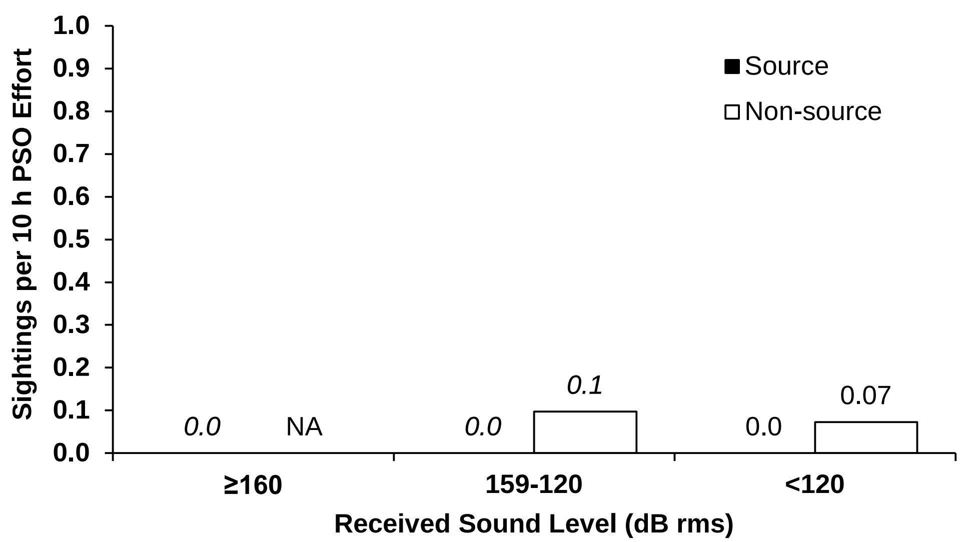

FIGURE 6.40. Polar bear sighting rates by received sound level from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. NA indicates that there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to a limited amount of observation effort having occurred within the category.

Distribution and Behavior of Marine Mammals

Marine mammal behaviors and reactions were difficult to observe because individuals and/or groups of animals typically spent most of their time below the water surface and could not be observed for extended periods. However, data collected from stationary vessels can offer a reasonably accurate picture of surface behaviors. The PSOs' primary duty was to implement mitigation rather than collect extensive behavioral data. Relevant data collected include estimated closest observed point of approach (CPA), direction of movement relative to the vessel, initial behavior of the animal, and reaction of the animal to the vessel presence or activity.

Closest Point of Approach

The mean CPA of cetaceans, seals, Pacific walruses, and polar bears were calculated using only sightings that occurred during periods of effort that met the criteria for reliable detection (see Chapter 4 and Appendix E).

Cetaceans

During most vessel activities, few cetacean sightings occurred during periods of effort that met the criteria for being able to reliably detect cetaceans, and the majority of those occurred while the vessel was moving (Tables 6.13 and 6.14). As such a meaningful comparison of the mean closest points of approach (CPAs) between vessel activity periods is not possible. The mean CPA of the cetaceans observed from moving vessels in good visibility conditions during periods of general vessel activity was 2250 m (2453 yd). Cetaceans were observed as close as 200 m (219 yd) and as far as 5128 m (5590 yd). The sighting with the 200 m (219 yd) CPA was of a single bowhead whale that surfaced numerous times near the *Pt. Oliktok* while it was in slow transit.

TABLE 6.13. Comparison of mean cetacean CPA distances by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings during all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	2065	949	200–3599	***16***
Drilling Activities	3000	--	3000	***1***
General Vessel Activities	2250	1347	300–5128	***64***
Total	***2223***	***1269***	***200–5128***	**81**

[a] CPA=*Closest Point of Approach.*

TABLE 6.14. Comparison of mean cetacean CPA distances by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings exposed to all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	4424	1787	2430–9371	***15***
Drilling Activities	5128	--	5128	***1***
General Vessel Activities	2574	2342	200–9000	***14***
Total	***3584***	***2223***	***200–9371***	***30***

[a] CPA=*Closest Point of Approach.*

Seals

The mean closest point of approach (CPA) for seals observed from moving vessels appeared to be higher than the closest CPA for seals observed from stationary vessels during periods of general vessel activity (Tables 6.15 and 6.16). The sample size of sightings during periods of drilling and anchor handling was very limited and so no meaningful comparison can be made of seal CPAs during different vessel activities (Table 6.15).

TABLE 6.15. Comparison of mean seal CPA distances by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings during all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	196	264	20-1281	***22***
Drilling Activities	177	221	20-800	***17***
General Vessel Activities	598	807	4-3771	***185***
Total	528	1237	***4-3771***	***224***

[a] CPA=*Closest Point of Approach.*

TABLE 6.16. Comparison of mean seal CPA distances by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings during all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	143	187	10–100	***43***
Drilling Activities	90	102	5–426	***30***
General Vessel Activities	132	239	2–1997	***118***
Total	***128***	***212***	***2–1997***	***191***

[a] CPA=*Closest Point of Approach.*

Pacific Walrus

To satisfy reporting requirements, CPA distances for Pacific walrus on ice and in water are considered separately. No Pacific walrus on ice were observed by PSOs on stationary vessels. The total number of Pacific walrus sightings that met the necessary criteria was ten, and none of these sightings occurred during drilling activities (Tables 6.17 through 6.19). Of the sightings that met the analysis criteria, six sightings were made from moving vessels and involved eight individual animals hauled out on ice and five individual animals swimming in the water. Four sightings were made from stationary vessels and involved five animals swimming in the water. The CPA distances of Pacific walrus were between 75 and 2000 m (82 and 2180 yd).

TABLE 6.17. Comparison of mean Pacific walrus CPA distances in water by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings during all vessel activities.

Vessel Activity	Mean CPA[a] (m)		s.d.		Range (m)		*n*
Anchor Handling	--	**--**	--	**--**	--	**--**	***--***
Drilling Activities	--	**--**	--	**--**	--	**--**	***--***
General Vessel Activities	313		165		100–500		***4***
In Water Total	***313***		***165***		***100–500***		***4***

[a] CPA=*Closest Point of Approach.*

TABLE 6.18. Comparison of mean Pacific walrus CPA distances on ice by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings during all vessel activities during stationary periods.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	557	504	200–913	***2***
Drilling Activities	--	--	--	***--***
General Vessel Activities	397	230	75–400	***2***
In Water Total	***397***	***369***	***75–913***	***4***

[a] CPA=*Closest Point of Approach.*

TABLE 6.19. Comparison of mean Pacific walrus CPA distances in water by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012. The overall mean includes CPA distances for sightings during all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	557	504	200–913	***2***
Drilling Activities	--	--	--	--
General Vessel Activities	397	230	75–400	***2***
In Water Total	***397***	***369***	***75–913***	***4***

[a] CPA=*Closest Point of Approach.*

Polar Bears

As with Pacific walrus, CPA distances for polar bears on ice or land and in water are considered separately, however this was unnecessary for sightings from moving vessels as no animals were sighted in the water. A total of 28 polar bear sightings met these criteria; however this total includes sightings from both moving and stationary vessels and includes polar bears in the water and on ice or land (Tables 6.20 through 6.22). The lack of sightings in any one vessel category precludes meaningful comparison of polar bear CPA distances. All of the sightings of polar bears in water involved single individuals, group sizes of polar bears on ice or land ranged from five to nearly twenty animals feeding on a whale carcass.

TABLE 6.20. Comparison of mean polar bear CPA distances on ice or land by vessel activity from moving project vessels during Shell's exploratory drilling operations, 2012. The overall mean includes CPA distances from all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	1500	--	1500	***1***
Drilling Activities	2411	298	2200–2622	***2***
General Vessel Activities	2347	1441	1000–5000	***8***
On Ice Total	***2282***	***1237***	***1000–5000***	***11***

[a] CPA=*Closest Point of Approach.*

TABLE 6.21. Comparison of mean polar bear CPA distances in water by vessel activity from stationary project vessels during Shell's exploratory drilling operations, 2012. The overall mean includes CPA distances from all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	200	--	200	***1***
Drilling Activities	--	--	--	--
General Vessel Activities	475	634	25–1200	***8***
In Water Total	***406***	***536***	***25–1200***	***9***

[a] CPA=*Closest Point of Approach.*

TABLE 6.22. Comparison of mean polar bear CPA distances on ice or land by vessel activity from stationary project vessels during Shell's exploratory drilling operations, 2012. The overall mean includes CPA distances from all vessel activities.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Anchor Handling	--	--	--	--
Drilling Activities	2500	--	2500	***1***
General Vessel Activities	1271	377	900–2500	***7***
On Ice Total	***1425***	***557***	***900–2500***	***8***

[a] CPA=*Closest Point of Approach.*

Movement

Cetaceans

During periods when vessels were under way, the movement of cetaceans was frequently not discernible (Table 6.23). For nine of 27 sightings during anchor handling and 21 of 98 sightings during general vessel operations, cetaceans swam away from the vessel. Cetacean swimming direction was neutral to moving vessel location in 6 of the 27 sightings during anchor handling, 27 of the 98 sightings during general vessel activities, and during the sole sighting during drilling activities. In six of the sightings during general vessel activities, cetaceans swam towards the vessel.

A total of 34 cetacean sightings occurred while vessels were stationary – 15 during anchor handling, one during drilling activities, and 18 during general vessel activities (Table 6.24). Swimming direction tended to be neutral, unknown, or away from the vessel. Cetaceans swam towards vessels on one occasion during each of anchor handling and general vessel activities. On one occasion during anchor handling, the cetacean was milling and not swimming in any direction.

TABLE 6.23. Number of cetacean sightings within categories of movement relative to vessels during periods of moving vessel activity during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	6	--	9	--	12	***27***
Drilling Activities	1	--	--	--	--	***1***
General Vessel Activities	27	--	21	6	44	***98***
Total	***34***	***--***	***30***	***6***	***56***	***126***

TABLE 6.24. Number of cetacean sightings within categories of movement relative to vessels during periods of stationary vessel activity during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	6	1	4	1	3	***15***
Drilling Activities	1	0	0	0	0	***1***
General Vessel Activities	8	0	4	1	5	***18***
Total	***15***	***1***	***8***	***2***	***8***	***34***

Seals

There were 274 sightings of seals from moving vessels and 321 sightings of seals from stationary vessels during the 2012 season (Tables 6.25 and 6.26). During general vessel operations, the three most frequently observed swimming directions were unknown, neutral to, or away from the vessel. Relatively few sightings occurred during anchor handling and drilling activities and so it is not possible to draw meaningful conclusions about differences in seal swimming direction during different activities.

TABLE 6.25. Number of seal sightings within categories of movement relative to vessels by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	13	1	8	4	5	***31***
Drilling Activities	5	--	8	2	7	***22***
General Vessel Activities	51	44	44	15	67	***221***
Total	***69***	***45***	***60***	***21***	***79***	***274***

TABLE 6.26. Number of seal sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	11	6	19	2	20	***58***
Drilling Activities	16	6	7	10	19	***58***
General Vessel Activities	47	24	37	25	72	***205***
Total	***74***	***36***	***63***	***37***	***111***	***321***

Pacific Walrus

Pacific walrus were observed swimming away from or neutral to moving vessels (Table 6.27). On two occasions, the direction of travel could not be determined. All sightings from moving vessels occurred during general vessel operations. During anchor handling activities, two walrus sightings were made by PSOs on stationary vessels (Table 6.28). On one occasion, the animals swam away and on the other occasion their direction of travel was unclear. During general vessel activities, two sightings occurred in which animals swam away from a stationary vessel and, on one occasion, the animals swam toward the vessel.

TABLE 6.27. Number of Pacific walrus sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	--	--	--	--	--	***--***
Drilling Activities	--	--	--	--	--	***--***
General Vessel Activities	4	--	3	--	2	***9***
Total	***4***	***--***	***3***	***--***	***2***	***9***

TABLE 6.28. Number of Pacific walrus sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	0	0	1	0	1	***2***
Drilling Activities	0	0	0	0	0	***0***
General Vessel Activities	0	0	2	1	0	***3***
Total	***0***	***0***	***3***	***1***	***1***	***5***

Polar Bears

Polar bears were seen from moving vessels during each of the major vessel activities (Table 6.29). For the sightings during anchor handling and drilling activities, the direction of travel of the bears could not be determined. One polar bear swam away from a stationary vessel during anchor handling (Table 6.30). During general vessel operations, the only direction of travel that was not observed from either moving or stationary vessels was swimming or walking toward the vessel.

TABLE 6.29. Number of polar bear sightings within categories of movement relative to vessels by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	--	--	--	--	1	***1***
Drilling Activities	--	--	--	--	2	***2***
General Vessel Activities	1	5	2	--	2	***10***
Total	***1***	***5***	***2***	***--***	***5***	***13***

TABLE 6.30. Number of polar bear sightings within categories of movement relative to vessels by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Movement Relative to Vessel					
	Neutral	None	Swim Away	Swim Towards	Unknown	*Totals*
Anchor Handling	0	0	1	0	0	***1***
Drilling Activities	0	0	0	0	1	***1***
General Vessel Activities	7	2	4	0	1	***14***
Total	***7***	***2***	***5***	***0***	***2***	***16***

Behavior

Cetaceans

From both moving and stationary vessels, the most frequently observed initial behavior of cetaceans was "blow" (Figures 6.31 and 6.32); this was the first observed behavior for 91% of sightings from moving vessels and 74% of sightings from stationary vessels. As cetaceans tended to be located from a distance, it was impossible for PSOs to determine a behavior other than "blow" for most cetacean sightings. Other initial behaviors observed were "swim", "travel", "breach", "surface active", and "feed".

TABLE 6.31. Number of cetacean sightings within categories of animal behavior observed by PSOs on moving vessels during each vessel activity of Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Initial Behavior					
	Blow	Breach	Fluke	Swim	Other	*Totals*
Anchor Handling	25	0	0	2	0	***27***
Drilling Activities	0	0	0	1	0	***1***
General Vessel Activities	91	1	2	1	3	***98***
Total	***116***	***1***	***2***	***4***	***3***	***126***

TABLE 6.32. Number of cetacean sightings within categories of animal behavior observed by PSOs on stationary vessels during each vessel activity of Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Initial Behavior					
	Blow	Feed	Surface Active	Swim	Travel	*Totals*
Anchor Handling	14	0	0	0	1	***15***
Drilling Activities	1	0	0	0	0	***1***
General Vessel Activities	10	1	2	3	2	***18***
Total	***25***	***1***	***2***	***3***	***3***	***34***

Seals

The initial behaviors of seals observed from both moving and stationary vessels varied considerably (Tables 6.33 and 6.34). The most commonly observed initial behaviors were "look", "swim", and "dive". "Rest" was the first observed behavior in 18% of encounters observed from moving vessels, as opposed to 4% of encounters observed from stationary vessels. Several behaviors, including "log", "mill", "surface active", "porpoise", "thrash", "travel", "sink", and "feed", were observed infrequently and included in Tables 6.x and 6.x as "other".

TABLE 6.33. Number of seal sightings within categories of animal behavior observed by PSOs on moving vessels during each vessel activity of Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Initial Behavior					
	Dive	Look	Rest	Swim	Other	*Totals*
Anchor Handling	7	14	1	5	4	***31***
Drilling Activities	2	10	1	8	1	***22***
General Vessel Activities	17	79	46	51	28	***221***
Total	***26***	***103***	***48***	***64***	***33***	***274***

TABLE 6.34. Number of seal sightings within categories of animal behavior observed by PSOs on stationary vessels during each vessel activity of Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Initial Behavior					
	Dive	Look	Rest	Swim	Other	*Totals*
Anchor Handling	17	21	4	9	7	***58***
Drilling Activities	19	18	2	6	13	***58***
General Vessel Activities	32	78	7	47	41	***205***
Total	***68***	***117***	***13***	***62***	***61***	***321***

Pacific Walrus

A total of 14 Pacific walrus sightings were documented, nine from moving vessels and five from stationary vessels (Tables 6.35 and 6.36). The observed initial behaviors were “dive”, “rest”, and “swim”, all of which occurred during general vessel operations. Only two sightings occurred during anchor handling, in each case the first recorded behavior was “dive”. No sightings of Pacific walrus occurred during drilling activities.

TABLE 6.35. Number of Pacific walrus sightings within categories of animal behavior observed by PSOs on moving vessels during each vessel activity of Shell’s exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Initial Behavior					
	Dive	**Look**	**Rest**	**Swim**	**Other**	***Totals***
Anchor Handling	--	--	--	--	--	**--**
Drilling Activities	--	--	--	--	--	**--**
General Vessel Activities	3	--	2	4	--	***9***
Total	***3***	***--***	***2***	***4***	***--***	***9***

TABLE 6.36. Number of Pacific walrus sightings within categories of animal behavior observed by PSOs on stationary vessels during each vessel activity of Shell’s exploratory drilling operations, 2012.

Vessel Activity	Initial Behavior					
	Dive	**Look**	**Rest**	**Swim**	**Other**	***Totals***
Anchor Handling	2	--	--	--	--	***2***
Drilling Activities	--	--	--	--	--	**--**
General Vessel Activities	--	--	--	3	0	***3***
Total	***2***	***--***	***--***	***3***	***--***	***5***

Polar Bears

Of the 29 sightings of polar bears, the most frequently observed initial behaviors were “walk”, “swim”, and “rest” (Figures 6.37 and 6.38). Polar bears looked at a stationary vessel on two occasions. There were two sightings for which “feed” was the first documented behavior, this involved of group of approximately 20 animals observed feeding on a whale carcass on two consecutive days.

TABLE 6.37. Number of polar bear sightings within categories of animal behavior observed by PSOs on moving vessels during each vessel activity of Shell's exploratory drilling operations, 2012.

Vessel Activity	Initial Behavior					
	Feed	Look	Rest	Swim	Walk	*Totals*
Anchor Handling	--	--	--	--	1	***1***
Drilling Activities	1	--	1	--	--	***2***
General Vessel Activities	--	--	1	--	9	***10***
Total	***1***	***--***	***2***	***--***	***10***	***13***

TABLE 6.38. Number of polar bear sightings within categories of animal behavior observed by PSOs on stationary vessels during each vessel activity for Shell's exploratory drilling operations, 2012.

Vessel Activity	Initial Behavior					
	Feed	Look	Rest	Swim	Walk	*Totals*
Anchor Handling	--	--	--	1	--	***1***
Drilling Activities	--	--	--	--	1	***1***
General Vessel Activities	1	2	3	3	5	***14***
Total	***1***	***2***	***3***	***4***	***6***	***16***

Reaction Behavior

Cetaceans

Only one cetacean was observed to exhibit a discernible reaction to a vessel during the 2012 season, it changed direction to move away from a transiting vessel (Tables 6.39 and 6.40).

TABLE 6.39. Number of cetacean reactions to the vessel by vessel activity from the moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	--	--	--	--	23	4	***27***
Drilling Activities	--	--	--	--	--	1	--	***1***
General Vessel Activities	1	--	--	--	--	95	2	***98***
Total	***1***	***--***	***--***	***--***	***--***	***119***	***6***	***126***

TABLE 6.40. Number of cetacean reactions to the vessel by vessel activity from the stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	--	--	--	--	15	--	***15***
Drilling Activities	--	--	--	--	--	1	--	***1***
General Vessel Activities	--	--	--	--	--	18	--	***18***
Total	**--**	**--**	**--**	**--**	**--**	***34***	**--**	***34***

Seals

Seals exhibited no discernible reaction behavior in 43% of sightings from moving vessels and 63% of sightings from stationary vessels (Tables 6.41 and 6.42). The most frequently observed reaction behavior was looking at the vessel, which occurred during 42% of sightings from moving vessels and 35% of sightings from stationary vessels. Splashing occurred during 7% of sightings from moving vessels. On one occasion, a seal was seen touching the vessel *Sisuaq* and appeared to attempt to haul out on the vessel, but stopped after approximately ten seconds and swam away.

TABLE 6.41. Number of seal reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	3	10	--	5	13	--	***31***
Drilling Activities	--	--	11	--	1	10	--	***22***
General Vessel Activities	4	9	94	3	14	96	1	***221***
Total	***4***	***12***	***115***	***3***	***20***	***119***	***1***	***274***

TABLE 6.42. Number of seal reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Look	Rush	Splash	Interaction With Gear	None	Unknown	*Totals*
Anchor Handling	--	13	--	--	--	45	--	***58***
Drilling Activities	1	18	--	--	--	37	--	***56***
General Vessel Activities	2	80	3	1	1	119	1	***207***
Total	***3***	***111***	***3***	***1***	***1***	***201***	***1***	***321***

Pacific Walrus

In seven of nine instances of Pacific walrus sightings from moving vessels, the animals exhibited no discernible reaction to the vessel (Table 6.43). On one occasion the animal increased its swimming speed, and on the remaining occasion the animal looked at the vessel. During two of five sightings from stationary vessels, no reaction behavior was recorded (Table 6.44). Animals looked at the vessel during the one sighting that occurred while anchor handling was in progress. One animal changed direction and another rushed at the vessel while general vessel activities were under way.

TABLE 6.43. Number of Pacific walrus reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	--	--	--	--	--	--	--
Drilling Activities	--	--	--	--	--	--	--	--
General Vessel Activities	--	1	1	--	--	7	--	***9***
Total	***--***	***1***	***1***	***--***	***--***	***7***	***--***	***9***

TABLE 6.44. Number of Pacific walrus reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	--	1	--	--	1	--	***2***
Drilling Activities	--	--	--	--	--	--	--	***0***
General Vessel Activities	1	--	--	1	--	1	--	***3***
Total	***1***	***0***	***1***	***1***	***0***	***2***	***0***	***5***

Polar Bears

Polar bears reacted to moving vessels by looking at them on three occasions, but for all other sightings, no observable reaction was recorded (Table 6.45). A similar proportion of sightings from stationary vessels involved animals looking at the vessel, but no other discernible reactions were observed (Table 6.46).

TABLE 6.45. Number of polar bear reactions to the vessel by vessel activity from moving project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	--	--	--	--	1	--	***1***
Drilling Activities	--	--	--	--	--	2	--	***2***
General Vessel Activities	--	--	3	--	--	7	--	***10***
Total	***--***	***--***	***3***	***--***	***--***	***10***	***--***	***13***

TABLE 6.46. Number of polar bear reactions to the vessel by vessel activity from stationary project vessels during Shell's exploratory drilling operations in the Beaufort Sea, 2012.

Vessel Activity	Reaction							
	Change Direction	Increase Speed	Look	Rush	Splash	None	Unknown	*Totals*
Anchor Handling	--	--	1	--	--	--	--	***1***
Drilling Activities	--	--	--	--	--	1	--	***1***
General Vessel Activities	--	--	3	--	--	10	--	***13***
Total	***--***	***--***	***4***	***--***	***--***	***11***	***--***	***15***

Mitigation Measures Implemented

The implementation of mitigation measures during Shell's 2012 exploratory drilling program in the Beaufort Sea spanned all aspects of the operation and was driven by several themes. Mitigation measures were centered on reducing potential impacts to marine mammals and subsistence activities from a wide range of vessel activities and also from fixed-wing and rotary aircraft. Specifically in the Beaufort Sea, vessel activities related to transit, drilling, handling and setting of the anchors used to moor the *Kulluk*, and scouting for hazardous sea ice all were mitigated by various actions requested by PSOs. Vessel-based PSOs also played a role in the routing of aircraft to minimize potential impacts on marine mammals, particularly for helicopters used to facilitate offshore crew changes. Potential impacts to local subsistence activities were mitigated by the timing and location of Shell's operations in the Beaufort Sea in accordance with the CAA, and also through communications from each vessel to the nearest communication center every six hours. Shell did not conduct ZVSP surveys at the Beaufort Sea drillsite in 2012, which precluded the establishment of 180 and 190 dB (rms) exclusion zones for marine mammals around the *Kulluk* as stipulated in Shell's Beaufort Sea IHA and LOA for periods with active airgun operations.

The most common forms of mitigation implemented by PSOs aboard vessels during 2012 in the Beaufort Sea were reductions in vessel speed and alterations of vessel headings during routine vessel operations (e.g., transit; Table 6.47). Vessel speed was never greater than 9 kt (10.4 mph) for any project vessel in the Beaufort Sea per Shell's 2012 exploration plan and IHA. All efforts were made to maximize distance from marine mammals and avoid separating individuals from groups of marine mammals. Other mitigation measures implemented by PSOs aboard vessels included postponement of equipment deployments (e.g., hydrophone recorders) due to the presence of marine mammals in the deployment area. In one instance on 13 Oct, towing operations were halted when a polar bear in the water approached the *Lauren Foss*, *Sisuaq*, and *Arctic Seal*. The bear departed the area after approximately 30 min and towing operations were resumed after PSOs aboard each vessel confirmed no further evidence of the animal in the area.

The polar bear mitigation event above exemplifies communication between PSOs on different vessels. Inter-vessel communication by PSOs was a standard practice throughout the exploratory drilling program to ensure awareness of the distribution of marine mammals across the entire project area. The PSO aboard the *Arctic Seal* routinely communicated sightings of polar bears on Beaufort Sea barrier islands to other vessels so they could be avoided during transits. Furthermore, sightings information was summarized at shore-based offices in Anchorage and routinely communicated to all vessel PSO crews to increase awareness of marine mammal distribution within the Beaufort Sea, particularly as distributions changed across the season.

TABLE 6.47. General mitigation measures implemented by vessel-based PSOs during Shell's exploratory drilling program in the Beaufort Sea, 2012.

Speed Reduction	Course Alteration	Other Mitigation	*Total*
16	11	7	***34***

Vessel-based PSOs also communicated sightings of marine mammals to shore-based command centers to inform helicopter operations associated with offshore crew changes. Flight plans were drafted that maximized onshore flight corridors to reduce aircraft activity over water, particularly in areas where marine mammals were known to be hauled out on ice. Vessels with helicopter decks served as the primary crew change platforms within the program. These vessels were moved away from the main ice edge during helicopter operations to minimize potential impacts on marine mammals using those areas, although these scenarios were limited to Aug prior to the ice edge receding well offshore of operations where it remained the vast majority of the season. See Chapter 8 for fixed-wing survey protocols in the Beaufort Sea, including minimum flight altitudes to reduce potential impacts to marine mammals.

Another form of vessel-based mitigation that was implemented during Shell's 2012 exploratory drilling program in the Beaufort Sea was the common practice of vessels to spend standby periods in a stationary position. Vessel-hours totaled 11,737 for Shell's 2012 Beaufort Sea fleet, and 57% of this total was comprised of periods when vessels were stationary. The maximization of periods when vessels were stationary likely reduced potential impacts on marine mammals from vessel movements.

As noted above, PSOs aboard each vessel contacted local communication centers in Barrow, Deadhorse, or Kaktovik every six hours per the CAA. These routine communications were designed to avoid conflicts between local subsistence users and Shell's operations. The CAA also established vessel blackout areas in the Beaufort Sea beginning 25 Aug until the completion of whaling activities by villagers from Nuiqsut (Cross Island) and Kaktovik. All Shell vessels departed the Beaufort Sea on 25 Aug after laying anchors at the Sivulliq drillsite in preparation for anchoring the *Kulluk* later in the season. Several vessels returned to the Beaufort Sea on 8 Sep and staged in a standby location to await the completion of whaling activities. Collectively, these actions mitigated potential effects to marine mammal subsistence activities from Shell's activities. No conflicts were reported between Shell vessels and subsistence users in the Beaufort Sea during Shell's 2012 exploratory drilling program.

Estimated Number of Marine Mammals Present and Potentially Affected

It is often difficult to estimate "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain; ***(2)*** The most appropriate criteria for take by harassment are uncertain and presumed to vary among different species, individuals within species, activities that the individuals are involved in, and the situations in which the animals are encountered; ***(3)*** The distance to which a received sound level (RSL) reaches a specific criterion such as 190, 180, 160, or 120 dB re 1 µPa (rms) is variable. The RSL depends on water depth, sound source depth, water-mass and bottom conditions, and - for directional sources - aspect (Chapter 3; see also Greene 1997, Greene et al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b); ***(4)*** The sounds received by marine mammals vary depending on the animals depth in the water, and will be considerably reduced for animals near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b) and even further reduced for animals that are out of the water on ice or land.

Marine mammal exposures to continuous sounds from drilling and anchor-handling activities in the Beaufort Sea were considered below in detail. There was no management of hazardous ice floes in the Beaufort Sea comparable to that which occurred briefly in the Chukchi Sea during 2012 operations (see Chapters 2 and 7). Two methods were used to estimate the number of marine mammals exposed to continuous sounds from drilling and anchor-handling activities in the Beaufort Sea strong enough that they might have caused a disturbance or other potential impacts. The procedures included estimates based on ***(A)*** the direct observations of marine mammals by PSOs during these operations, and ***(B)*** recent marine mammal densities in the Beaufort Sea as a function of the total area ensonified during drilling and anchor-handling activities in 2012. The actual number of individuals exposed to, and potentially impacted by, drilling or anchor-handling sounds likely was between the ranges of estimates provided in the following sections. Further details about the methods and limitations of these estimates are provided below.

Disturbance and Safety Criteria

Table 4.2 summarizes the estimated RSLs at various distances from the *Kulluk* while it was stationary and conducting various drilling activities, and also from the *Aiviq* during anchor-handling activities related to mooring of the *Kulluk*. RSLs during drilling activities were considered for a variety of operations, including drilling of the pilot hole, excavation of the mudline cellar (MLC), and the additional influence of sounds introduced by a stationary vessel nearby in dynamic positioning (DP) mode. The NMFS required that distances to RSLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for cetaceans and seals respectively. The USFWS required that distances to RSLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for Pacific walruses and polar bears, respectively. Measurements of sounds produced by the *Kulluk* and nearby vessels in DP during drilling activities, and of the *Aiviq* during anchor-handling activities, indicated that sound levels at or above these thresholds were uncommon and, when these sound levels were generated, they did not propagate more than 10 to 20 m (33 to 66 ft) from the source (Table 4.2 and Chapter 3). Both agencies assume that disturbance to marine mammals from continuous sounds generated while conducting the above operations may occur at RSLs ≥120 dB (rms).

Estimates from Direct Observations during Drilling Activities

All sightings data from the *Kulluk* and nearby support vessels were included in the following exposure estimates based on direct observations, regardless of whether they met the data-analysis criteria described in Chapter 4. The number of animals actually sighted by observers within the various sound level distances during drilling activities likely provides a minimum estimate of the number potentially affected by the continuous sounds from these operations. Some animals may have moved away before coming within visual range of PSOs, and it was unlikely that PSOs were able to detect all of the marine mammals near the drillsite. During daylight, animals are missed if they are below the surface when the ship is nearby. Other animals, even if they surface near the vessel, are missed because of limited visibility (e.g. fog), glare, or other factors limiting sightability. Furthermore, marine mammals could not be seen effectively during periods of darkness, which increased as the operation progressed into late Sep. Nighttime observations were not required, however, at least one PSO aboard the *Kulluk* maintained an active watch during nighttime drilling operations and conducted monitoring using night vision devices.

Animals may also have avoided the area near the *Kulluk* while it was drilling (see Richardson et al. 1995). Within the measured ≥120 dB (rms) radii around the source and perhaps farther away in the case of the more sensitive species and individuals, the distribution and behavior of pinnipeds and cetaceans may have been altered as a result of the *Kulluk's* drilling activities.

Cetaceans Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

The *Kulluk* did not begin drilling in the Beaufort Sea in 2012 until 3 Oct, presumably well after the majority of bowhead whales had passed through the Alaskan Beaufort Sea during their annual fall migration into the Chukchi and Bering seas, though some bowheads are seen well into Nov. There were no cetaceans observed by PSOs aboard the *Kulluk* while it was conducting drilling activities at the Sivulliq drillsite in 2012. A total of two sightings (four individuals) of unidentified mysticete whales were recorded by *Nordica* PSOs while the *Kulluk* was conducting drilling activities at Sivulliq in late Oct. Specifically, the mudline cellar was being excavated by the *Kulluk* during each of these cetacean sightings. No other cetaceans were observed from Shell's vessels during active drilling operations in the Beaufort Sea in 2012. Comments entered by PSOs for each of these sightings noted dark bodies that supported identification as bowhead whales, however, diagnostic features were not observed and identification to species could not be confirmed.

The first of the cetaceans observed from the *Nordica* while the *Kulluk* was excavating the mudline cellar was of a single, black whale. The *Nordica* was approximately 5 km (3.1 mi) from the drill rig at the time of the sighting, and the whale itself was greater than 6.15 km (3.82 mi) from the *Kulluk*, or the distance to the ≥120 dB (rms) threshold measured during excavation of the mudline cellar at Si vulliq-N (Table 4.2 and Chapter 3). Therefore, this individual whale was unlikely to have been exposed to RSLs ≥120 dB (rms).

The second cetacean sighting recorded from the *Nordica* while the *Kulluk* was excavating the mudline cellar was of three individuals, all of which were classified as adults. The *Nordica* was stationary and approximately 8 km (5 mi) from the drill rig, and the animals were approximately 5 km (3.1 mi) from the drill rig. The ≥120 dB (rms) radius measured during excavation of the mudline cellar at Sivulliq-N was 6.15 km (3.82 mi; Table 4.2 and Chapter 3). The ≥130 dB (rms) radius at this location was measured at 2.39 km (1.49 mi; Table 4.2 and Chapter 3). Based on these radii, it is likely that these three cetaceans were exposed to RSLs between 120 and 130 dB (rms; Table 6.48).

Seals Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

A total of 123 seals (80 different sightings) were observed by PSOs aboard eight different project vessels during periods when the *Kulluk* was conducting drilling activities. This total includes seal sightings from both moving and stationary vessels that were operating in the Sivulliq area. Numerous seals from this total, however, were confirmed to be resightings of the same individuals recorded on multiple days across the drilling period. *Kulluk* PSOs catalogued the distinct markings on the pelages of at least six different seals (four ringed and two bearded seals) that were observed in the vicinity of the drill rig over the period of multiple days. It was impossible to determine precisely how many seals represented sightings of new individuals or if they were resightings of seals that already had been observed and recorded in the drilling area. It also is likely that several of these seals were recorded by PSOs aboard different vessels as vessels transited to and from the drillsite in support of operations. The total of 123 seals observed during drilling periods undoubtedly is greater than the actual number of distinct individuals observed due to double counting, however, this total of 123 seals is used here as a conservative estimate to avoid underestimation of exposures.

The majority of these 123 seals, 103 or 84%, were recorded during periods when the pilot hole was being drilled. The remaining 20 seals were observed during excavation of the mudline cellar. The estimated radius to RSLs≥120 dB (rms) during excavation of the mudline cellar was 6.15 km (3.82 mi) compared to only 660 m (2165 ft) during other drilling activities (e.g., pilot hole drilling; Table 4.2 and Chapter 3). The differences in these radii were considered when analyzing the estimated RSL to each seal to capture the specific acoustic footprint likely to have been present in the water at the time and location of each sighting. Not all of the 123 seals recorded during drilling activities in the Beaufort Sea in 2012 were observed in areas where RSLs were estimated to be ≥120 dB (rms).

Eighty one of the 123 seals observed during drilling activities in the Beaufort Sea in 2012 were observed at distances where RSLs were estimated to be ≥120 dB (rms; Table 6.48). Sixty nine of these 81 seals were observed while the pilot hole was being drilled and the remaining 12 were recorded during excavation of the mudline cellar. The 81 seals observed in areas where RSLs from drilling activities were ≥120 dB (rms) consisted of 58 ringed, 12 bearded, one spotted, and 10 unidentified seals.

The vast majority of the 81 seals observed in areas where continuous sounds from drilling activities were ≥120 dB (rms) were recorded by PSOs aboard the *Kulluk* (*n=68* or 84%). Of these 68 seals, 41 were observed in areas where RSLs were estimated to be ≥160 dB (rms; Table 6.48) and the remaining 27 seals were observed at distances from the drill rig where RSLs were estimated to be between 120 and 160 dB (rms). No seals were observed from any of the support vessels during drilling activities in areas where RSLs were estimated to be ≥160 dB (rms).

Pacific Walruses Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

There were no Pacific walruses observed while drilling activities were occurring in the Beaufort Sea during 2012. A total of 24 walruses (14 different sightings) were observed from Shell vessels in the Beaufort Sea during 2012, however, all of these sightings occurred prior to the commencement of drilling activities by the *Kulluk* on 3 Oct, and none of them would have been exposed to RSLs of ≥120 dB (rms) from these activities (Table 6.48).

Polar Bears Potentially Exposed to Received Sound Levels ≥120 dB re 1 µPa (rms)

A total of 15 polar bears (three different sightings) were observed from support vessels during periods when the Kulluk was conducting drilling activities in the Beaufort Sea during 2012. All of these polar bears were observed on Cross Island, and none of them would have been exposed to RSLs of ≥120 dB (rms) from drilling activities at the Sivulliq-N drillsite (Table 6.48).

TABLE 6.48. Number of marine mammals observed in areas with estimated RSLs of ≥120 and ≥160 dB (rms) during active drilling periods in the Beaufort Sea, 2012.

Species or Species Group	Number of Individuals and Exposure Level in dB re 1μPa (rms)	
	≥120	≥160
Cetaceans	3	0
Seals	81	41
Pacific Walruses	0	0
Polar Bears	0	0

Estimates from Direct Observations during Anchor-handling Activities

All sightings data from the anchor-handling vessel *Aiviq* as well as the drill rig *Kulluk* and nearby support vessels were included in the following exposure estimates based on direct observations, regardless of whether they met the data-analysis criteria described in Chapter 4. Specifically, anchor-handling for the purpose of this assessment refers to activities and sounds associated with deploying, setting, connecting, and disconnecting the 12 anchors used to moor the *Kulluk* in place at the Sivulliq-N drillsite during 2012 (Fig 2.6).

As noted above, the number of animals actually sighted by observers within the various sound level distances during these activities provides a minimum estimate of the number potentially affected by the continuous sounds from these operations. Some animals may have moved away before coming within visual range of PSOs, and it was unlikely that PSOs were able to detect all of the marine mammals near anchor locations. Conversely, and also as discussed directly above under *Seals*, individuals likely were double counted by PSOs on different vessels and also on subsequent days if they remained in the operational area. The total numbers of marine mammals observed during anchor-handling activities and reported below are conservative estimates that do not account for animals that were potentially double-counted in order to avoid underestimation of exposures.

Cetaceans Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

A total of 72 cetaceans (42 different sightings) were observed by PSOs aboard seven different vessels in the Beaufort Sea in 2012 while anchor-handling activities were being conducted. The estimated radius to RSLs of ≥120 dB (rms) for anchor handling at the Sivulliq-N drillsite was 29 km (18 mi). Despite the relatively large size of this radius compared to threshold RSL radii from drilling sounds (Table 4.2), only11 of the 72 cetaceans observed during anchor-handling activities were recorded in areas where estimated RSLs were ≥120 dB (rms; Table 6.49). The remaining 61 cetaceans, or 85%, were recorded from distant support vessels that were not directly involved in anchor-handling activities. These 61 of the 72 cetaceans were recorded at distances >29 km (18 mi) from anchor-handling activities and would not have been exposed to continuous sounds of ≥120 dB (rms).

The 11 cetaceans observed during anchor-handling activities in areas where RSLs were estimated to be ≥120 dB (rms) consisted of eight bowhead whales, two unidentified mysticete whales, and a single unidentified whale. All of these whales except one were observed from the *Aiviq*, the primary anchor-handling vessel in the Beaufort Sea that often operated without other vessels nearby. The exception was a single unidentified mysticete whale that was recorded from the *Kulluk* while the Aiviq was handling anchors. Ten of the 11 cetaceans exposed to RSLs of ≥120 dB (rms) from anchor-handling activities were recorded at distances between the threshold RSL radii of ≥130 and ≥140 dB (rms; 6.3 and 1.4 km, or

3.9 and 0.87 mi, respectively; Table 4.2). All 10 of these cetaceans were observed from the *Aiviq* and would have been exposed to between 130 and 140 dB (rms) from anchor-handling activities. The single unidentified mysticete whale observed from the *Kulluk* during anchor-handling activities was recorded at a distance of 9.4 km (5.8 mi), which would have corresponded to a RSL of between 120 and 130 dB (rms) based on estimated radii for anchor handling (Table 4.2 and Chapter 3).

Seals Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

PSOs recorded 102 seals (91 different sightings) from Shell vessels in the Beaufort Sea in 2012 during periods when anchor handling was occurring. As was the case for cetacean sightings during anchor handling, the majority of seals were observed by PSOs aboard distant support vessels that were not directly involved in anchor-handling activities. As a result, 62 of the 102 seals recorded during anchor-handling activities were >29 km (18 mi; the 120 dB [rms] threshold radius for anchor handling) from the actual operations and, therefore, would not have been exposed to RSLs of ≥120 dB (rms). The remaining 40 of the 102 seals recorded during anchor handling activities were observed in areas where RSLs from anchor handling were estimated to be ≥120 but <160 dB (rms; Table 6.49). The 40 seals observed in areas where estimated RSLs from anchor handling were between 120 and 160 dB (rms) consisted of 12 ringed, four bearded, one spotted, and 23 unidentified seals.

Pacific Walruses Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

There were two individual walruses observed in the Beaufort Sea in 2012 during periods when anchor-handling activities were occurring, each of which was recorded from the *Aiviq* on 19 Aug. A juvenile walrus was observed at a distance of 200 m (656 ft) from the vessel, and an hour later PSOs recorded an adult 913 m (2995 ft) from the vessel. Both of these walruses would have been exposed to continuous RSLs of ≥120 but <160 dB (rms) from anchor-handling activities. Specifically, these detection distances correspond to estimated RSLs between 150 and 160 dB (rms) for the juvenile and between 140 and 150 dB (rms) for the adult (Tables 6.49 and 4.2).

Polar Bears Potentially Exposed to Received Sound Levels ≥120 dB re 1 μPa (rms)

A total of 10 polar bears (two different sightings) were observed from support vessels during periods when the *Aiviq* was conducting anchor-handling activities in the Beaufort Sea during 2012. A single sighting of nine individuals on Cross Island was recorded by the PSO aboard the Arctic Seal on 22 Sep. None of these nine individuals would have been exposed to RSLs of ≥120 dB (rms) from anchor-handling activities. The remaining polar bear observed during periods of anchor handling was swimming approximately 200 m (656 ft) from the *Nordica*. The bear was ~8 km (5 mi) away from the *Aiviq* at the time of the sighting, which corresponded to estimated RSLs in the water of ≥120 but <130 dB (rms; Tables 6.49 and 4.2)

TABLE 6.49. Number of marine mammals observed in areas with estimated RSLs of ≥120 and ≥160 dB (rms) during periods with anchor-handling activities in the Beaufort Sea, 2012.

Species or Species Group	Number of Individuals and Exposure Level in dB re 1μPa (rms)	
	≥120	≥160
Cetaceans	11	0
Seals	40	0
Pacific Walruses	2	0
Polar Bears	1	0

Estimates Extrapolated from Density

The number of marine mammals visually detected by PSOs likely underestimated the actual numbers of animals that were present for reasons described above. Marine mammal density estimates for the Beaufort Sea were used to correct for animals that may have been present but not detected by observers. This section presents estimates of the exposure of marine mammals to RSLs ≥120 dB (rms) from Shell's drilling activities conducted during 2012 as prescribed by Shell's 2012 NMFS IHA. Ice management activities also create sounds that could impact marine mammals, however no ice management occurred in the Beaufort Sea in 2012 and is thus not included in these exposure estimates. Additional analyses of sightings and exposure data that include a broader range of sound-generating activities that occurred during discreet time periods and the corresponding exposure estimates are ongoing, and results will be presented in detail in the 2012 Comprehensive Report.

The densities used for the following exposure estimates (Table 6.50) included the cetacean and seal density estimates used in Shell's 2012 Chukchi Sea IHA application (Shell 2011), bowhead whale density estimates from Shell's 2012 Beaufort Sea aerial surveys of the Sivulliq area (Chapter 8), and polar bear density estimates from recent, comparable surveys in the drilling area (Reiser et al. 2011). Pacific walruses are uncommon in the Beaufort Sea. Minimal density values were assigned to Pacific walrus, similar to those for ribbon seal, which also is uncommon in the Beaufort Sea. The densities of marine mammals were then multiplied by the area of water ensonified during drilling activities (i.e., exposed to sounds produced during drilling; Table 6.51) to estimate the number of individual marine mammals that potentially would have been exposed to continuous received sound levels (RSLs) ≥120 dB (rms) from drilling operations (see Chapter 4 and Appendix E for details). Estimates from the 2012 aerial survey program probably represent the closest approximation to actual densities during drilling. Exposure estimates using densities from the IHA application assume that no animals avoided the area due to sounds or activities and probably represents an over estimate of the number of animals exposed to the drilling sounds and activities.

Marine mammal densities near an Arctic drilling operation are likely to vary by season. Seasonal variability in marine mammal densities during Jul–Aug compared to Sep–Oct were considered in Shell's 2012 Beaufort Sea IHA application when estimating exposures to marine mammals from sounds produced by drilling (Shell 2011). In 2012, however, Shell did not conduct drilling operations in the Beaufort Sea until early Oct, which precluded the calculation of exposure estimates based on marine mammal densities from the Jul–Aug period (Table 6.50).

The presence or absence of ice also is likely to affect marine mammal densities in the Beaufort Sea. Expected densities are provided below for open-water (i.e., nearshore) and ice-margin areas during Sep–Oct (Table 6.50). Sea-ice concentrations in the Sivulliq prospect area varied considerably during exploratory drilling operations in Oct. Drilling activities were conducted for approximately four weeks. The first three weeks of drilling occurred in open-water, which was followed by the formation of new and young ice in the drilling area during the final week of drilling operations. To reflect the proportion of drilling that occurred in open-water conditions compared to within ice, density-based exposure estimates were calculated by applying open-water densities to 75% of the areas ensonified with RSLs ≥120 dB (rms) from drilling, and ice-margin densities were applied to the remaining 25% of ensonified areas. This stratified-density approach is consistent with the methodology used in Shell's IHA application to estimate exposures to marine mammals (Shell 2011).

The following density-based exposure estimates assume that all mammals present were well below the surface where they would have been exposed to RSLs at various distances as reported in Chapter 3 and summarized in Table 4.2. Some pinnipeds, cetaceans, and polar bears in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Additionally, some marine mammals may have stayed away from sound-sources through an avoidance response. Finally, some marine mammals may have been hauled out on ice during the latter stages of 2012 drilling operations in the Beaufort Sea, particularly seals and polar bears. Marine mammals on ice would not have been exposed to RSLs from drilling or ice-management activities that were comparable to those in the water at the same location.

An Alternative Method for Exposure Estimates to Migrating Bowhead Whales

An alternative to the density-based exposure estimates described above was considered for bowhead whales during the fall migration period (Sep–Oct). The method is founded on estimates of the proportion of the population that would pass within the >120 dB (rms) zone on a given day during the migration while exploration drilling activities were occurring. Based on data in Richardson and Thomson (2002), the number of whales expected to pass each day was estimated as a proportion of the estimated 2012 bowhead whale population. The number of whales passing each day was based on the 10-day moving average presented by Richardson and Thomson (2002). This alternative to density-based estimates also was used to estimate exposures from drilling sounds to bowhead whales in Shell's 2012 Beaufort Sea IHA application (Shell 2011; see Chapter 4 and Appendix E for details). Like density-based estimates, this method also assumes that no whales avoided the area of drilling activities and thus probably overestimates the number of animals that would be exposed to drilling activities and sounds.

Cetaceans

Nine bowhead whales and a single beluga whale may have been exposed to sounds from exploratory drilling in the Beaufort Sea in 2012 at received levels ≥120 dB (rms; Table 6.52) based on the density estimates in Table 6.50 and the ensonified areas in Table 6.51. The low density-based exposure estimates from 2012 drilling sounds for cetaceans were the result of several factors. These factors included the absence of drilling prior to Oct and relatively small source levels and relatively short propagation distances to the ≥120 dB (rms) isopleths measured during drilling activities (Table 4.2 and Chapter 3).

As noted above, an alternative to density-based estimates was considered for estimating exposures of continuous drilling sounds ≥120 dB (rms) to bowhead whales during the fall migration period. Estimating the number of westward migrating bowhead whales that would have passed through the area ensonified to sound levels ≥120 dB (rms) from drilling each day results in a total of 277 bowhead whales. Similar to density-based methods, and as mentioned above, this estimate assumes no avoidance of drilling activities by bowhead whales.

Seals

The total number of seals estimated to have been exposed to continuous sounds ≥120 dB (rms) from Beaufort Sea exploratory drilling activities in Oct 2012 was 43 (Table 6.52). Forty of these would have been ringed seals with much smaller numbers of bearded and spotted seals based on expected densities in the area.

Pacific walruses and Polar Bears

Less than a single Pacific walrus or polar bear would have been exposed to RSLs ≥120 dB (rms) from drilling activities in the Beaufort Sea during Oct 2012 (Table 6.52). The primary reason for these minimal estimates is the combination of relatively low density values for these species compared to other species in the Beaufort Sea during the period of drilling activity (Table 6.50) and a relatively small area that was ensonified to ≥120 dB (rms) by the drilling activities (Table 6.51).

TABLE 6.50. Estimated marine mammal densities in the Beaufort Sea used to calculate density-based exposure estimates from Shell's 2012 exploratory drilling program.

	Jul - Aug*		Sep - Oct**	
Species	**Open-Water Density (# / km^2)**	**Ice-Margin Density (# / km^2)**	**Open-Water Density (# / km^2)**	**Ice-Margin Density (# / km^2)**
Odontocetes				
Monodontidae				
Beluga	NA	NA	0.0030	0.0120
Narwhal	NA	NA	0.0000	0.0000
Phocoenidae				
Harbor porpoise	NA	NA	0.0001	0.0000
Mysticetes				
Gray whale	NA	NA	0.0001	0.0000
Bowhead Whale	NA	NA	0.0700	0.0700
Pinnipeds				
Bearded seal	NA	NA	0.0181	0.0128
Ribbon seal	NA	NA	0.0001	0.0001
Ringed seal	NA	NA	0.3547	0.2510
Spotted seal	NA	NA	0.0037	0.0001
Pacific walrus	NA	NA	0.0001	0.0001
Marine Fissiped				
Polar Bear	NA	NA	0.0001	0.0005

*All drilling activities occurred in Oct, which precluded density-based exposure estimates for Jul-Aug

**Drilling operations considered for density-based exposure estimates in Sep-Oct occurred in open water ~75% of the time and in new-ice conditions during the final 25% of the season. Therefore, open-water densities were applied to 75% of the areas ensonified by drilling activities, and open-water densities were applied to the remaining 25% of ensonified areas.

TABLE 6.51. Estimated areas (km^2) ensonified to ≥120 and ≥160 dB (rms) from drilling activities during Shell's 2012 exploratory drilling program in the Beaufort Sea.

	Level of ensonification in dB re1µPa (rms) and area ensonified in km^2	
Seasonal Period	**≥120**	**≥160**
Jul-Aug*	NA	NA
Sep-Oct	123	0

*All drilling occurred in Oct, thus no areas were ensonified from this activity during Jul-Aug

TABLE 6.52. Estimated numbers of individual marine mammals exposed to continuous sound levels ≥120 dB (rms) from drilling activities during Shell's 2012 exploratory drilling program in the Chukchi Sea. Estimates were calculated by multiplying the marine mammal densities in Table 6.50 by the area ensonified to ≥120 dB (rms) from Table 6.51 and rounding to the nearest whole number.

	Estimated No. Individuals		
Species	**Jul-Aug***	**Sep-Oct**	***Estimated Totals***
Cetaceans			
Beluga	0	1	***1***
Narwhal	0	0	***0***
Harbor porpoise	0	0	***0***
Gray whale	0	0	***0***
Bowhead Whale	0	9	***9***
Total Cetaceans	***0***	***10***	***10***
Seals			
Bearded seal	0	2	***2***
Ribbon seal	0	0	***0***
Ringed seal	0	40	***40***
Spotted seal	0	1	***1***
Total Seals	***0***	***43***	***43***
Pacific walrus	***0***	***0***	***0***
Polar Bear	***0***	***0***	***0***

*All drilling occurred in Oct, thus no marine mammals were exposed to this activity in Jul-Aug

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7. CHUKCHI SEA AERIAL SURVEYS[1]

Introduction

Prior to 2006, aerial surveys of marine mammals during the open–water season in the Chukchi Sea had not been conducted since the 1980s and early 1990s. Distribution and abundance of marine mammal species may have changed since those surveys (George et al. 2004; Rugh 2004). Potential changes may have occurred due to differences in available habitat related to global warming, such as changing ice conditions (Tynan and DeMaster 1997; Johannessen et al. 1999; Ferguson et al. 2001; Stirling and Parkinson 2006; Treacy et al. 2006; Moore and Huntington 2008). In 2006, aerial surveys of marine mammals over the nearshore waters of the Chukchi Sea were conducted as part of an industry–funded Joint Monitoring Program (JMP) by Shell Offshore Inc. (SOI), ConocoPhillips Alaska Inc. (CPAI), and GX Technology (GXT). The objective of the surveys was to gather information on current marine mammal distribution and abundance in the eastern Chukchi Sea (Thomas et al. 2007). Aerial surveys over the same area were continued in 2007, 2008, 2010 and 2012 by SOI (with support from other industry operators) to supplement the 2006 data, identify annual variation in marine mammal distribution and relative abundance and to assess potential effects of industry seismic acquisition programs. The surveys focused on beluga, bowhead and gray whales, although other marine mammals were recorded when observed. Sightings of pinnipeds were obtained during the surveys and pinniped distribution and sighting–rate data are presented, but flight altitude and speed limited the ability of observers to collect consistent and reliable data on those species.

There is also a need to collect information on the distribution and numbers of marine mammals in offshore areas. Some animals are attracted to or avoid vessels so aerial platforms are one method of collecting unbiased data. Flying far from shore during open-water periods puts people's lives at risk and Shell and LGL wish to use alternative methodologies to obtain data on marine mammal distribution, densities and abundance. Unmanned Aerial Systems (UAS) are potentially a good alternative to manned aerial surveys but studies have not been conducted that compare data obtained from UAS to those obtained by PSOs (Protected Species Observers) in manned aircraft. During the 2012 field season Shell collected data using sensors that are likely to be used in UAS in the future (DSLR and video cameras) on the aircraft that was conducting manned aerial surveys in the Alaskan Beaufort Sea and nearshore areas of the Chukchi Sea. They also conducted photographic surveys around their drilling operation in the offshore Chukchi Sea using these same sensors with only the pilots on board the aircraft.

The eastern Chukchi Sea stock of beluga whales was estimated to contain ~3,710 individuals in 1991 (based on 1989–1991 aerial surveys), and the population size is considered stable (Allen and Angliss 2012) but estimates may be soon available from surveys conducted during early summer 2012. During Jun–Jul the Chukchi Sea stock of beluga whales is typically found in nearshore waters and in lagoons along the Alaskan Chukchi Sea coast. The coastal villages, most notably Pt. Lay, conduct subsistence hunts for beluga whales during this period. By Aug, most Chukchi Sea beluga whales have moved into the northern Chukchi Sea, the Arctic Ocean, or into the Beaufort Sea, where they spend the rest of the summer (Suydam et al. 2001; NMFS 2006). They return to the eastern Chukchi Sea during their fall migration in Oct (NMFS 2006). The much larger Beaufort Sea stock of beluga whales (39,258; Allen and Angliss 2012) also migrates through the eastern Chukchi Sea during their spring (Apr–early Jun) and fall (Oct) migrations.

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1 By Tannis Thomas and Marc Bourdon (LGL)

The Bering/Chukchi/Beaufort Sea (BCB) stock of bowhead whales was estimated to contain about 10,545 animals as of 2001, with lower and upper 95% confidence bounds of 8200 and 13,500 animals (Zeh and Punt 2005). Between 1978 and 2001 this bowhead population was estimated to have increased ~ 3.4% per year (95% confidence interval 1.7 to 5.0%). Aerial photographs used in a capture-recapture analysis provided another sampling of the bowhead population in 2004, with an estimate of 12,631 whales (95% CI: 7,900 to 19,700) (Koski et al. 2010). The annual subsistence harvest (landed animals) by Natives from Alaska, Russia, and Canada averaged 39.6 whales during 2005 through 2009 (Allen and Angliss 2012). If a 3.4% annual rate of increase continued after 2001, the 2012 population size would be ~16,500 bowhead whales based on the 2004 population estimate of (Koski et al. 2010).

In spring (Apr to mid–Jun), bowhead whales migrate north from the Bering Sea through the open leads in the Chukchi Sea along the west coast of Alaska. They continue across the Alaskan Beaufort Sea and into the Canadian Beaufort Sea and Amundsen Gulf, arriving there in May and Jun (Quakenbush et al. 2010b). Although most bowheads appear to migrate to the Canadian Beaufort Sea for the summer, small numbers may summer in the northeastern Chukchi Sea (Moore 1992; Quakenbush et al. 2011). Some of those summering in the Chukchi may not migrate to the Beaufort; in spring 2010, one tagged whale migrated west to the Chukchi Peninsula, not east to the Canadian Beaufort with the other tagged whales (Quakenbush et al. 2011). However, a few tagged whales seen in the Chukchi Sea during summer returned to the Chukchi Sea in late spring to early summer after spending a brief period in the polynya at the mouth of Amundsen Gulf (Quakenbush et al. 2011).

In fall, most bowhead whales migrate west through the central Alaskan Beaufort Sea during Sep and Oct and they frequently stop near Barrow to feed (Landino et al. 1994; Okkonen et al. 2011). After reaching Barrow, some whales are thought to migrate southwest from Barrow (Moore 1993) while others migrate westward or northwest from Barrow, before heading south along the Chukotka coast. The latter migration route seems to be the principal route based on tracks of satellite–tagged bowheads in fall (Mate et al. 2000; Quakenbush et al. 2007; 2009; 2010a,b; 2011). Moore et al. (1995) observed bowhead whales along the Chukotka Coast during opportunistic mammal/seabird surveys in the Chukchi Sea in fall 1992 and 1993, and satellite–tagged bowheads spent an average of 59 days, probably feeding (Schell et al. 1989; Thomson et al. 2002; Lee et al. 2005), along the Chukotka coast during fall before migrating into the Bering Sea wintering area in December to early January (Quakenbush et al. 2010a, b).

The Eastern North Pacific stock of gray whales had peak abundance estimates in 1987–88 (Allen and Angliss 2012), but the population was reduced following high mortality events in 1999 and 2000 (Gulland et al. 2005). Since then estimates for the Eastern North Pacific stock have been lower and relatively stable with estimates of 16,369 for 2000–2001, 16,033 for 2001–2002 and 19,126 for 2006–2007 (Allen and Angliss 2012). Rugh et al. (2005) estimated the carrying capacity (K) to be 26,290 (CV=0.059) animals for this stock of gray whales.

During the 1980s, some of this stock migrated to the Chukchi Sea to feed, arriving in mid–Jun (Braham 1984; Moore et al. 1986; Moore 2000), but in recent years, several tens of gray whales have been seen near Barrow by early Jun (W. Koski survey data from 2003 and 2004). Some gray whales continue east into the Beaufort Sea (Reeves et al. 2002; Allen and Angliss 2012), but most remain in the Chukchi Sea until Sep–Oct, when they migrate south to wintering areas in northern Mexico and southern California (Moore et al. 1986). Recent evidence from acoustical data suggest that some gray whales may overwinter in the Barrow area (Stafford et al. 2007) but this would only be possible if there was persistent open water throughout the winter because gray whales cannot break through ice to breath.

Alaskan Natives from several villages along the east coast of the Chukchi Sea hunt marine mammals during the summer, and there is concern that offshore oil and gas development activities may negatively impact their ability to harvest marine mammals. Of particular concern for summer activities are potential impacts on the early summer beluga harvest at Point Lay, the fall bowhead harvest at Barrow, and on proposed fall bowhead harvests at Point Hope and Wainwright. Native hunters at Point Hope and Wainwright have traditionally hunted bowheads in the spring, when the whales pass through leads relatively close to shore, but these villagers have not traditionally hunted bowheads during the fall, although one bowhead was harvested in late October 2011 (Suydam et al. 2012). Members of the coastal communities also hunt seals and walruses for subsistence purposes.

Objectives

The objectives of the 2012 aerial surveys were to collect data on the current distribution and relative abundance of marine mammals in nearshore areas of the eastern Chukchi Sea during the open–water season and their distribution and abundance relative to an offshore drilling program conducted by Shell Offshore Inc at their Burger Prospect.

Methods

New to Shell's overflight program, the aircraft was outfitted with camera ports to support installation of high-definition photographic and video-monitoring equipment used concurrently with PSO observations on flights in the nearshore Chukchi Sea and also the Beaufort Sea. Also new to the overflight program, aerial photographic surveys using these cameras and high-definition video were flown by a pilot and co-pilot without PSOs aboard over the Burger Prospect Area in the Chukchi Sea, identified from here on in as the offshore surveys.

Aerial surveys for marine mammals were conducted in the Alaskan Chukchi Sea from 14 Aug through 27 Oct 2012. A total of 23 surveys were attempted in 2012, 5 in the nearshore survey area and 18 in the offshore survey area.

Survey Area

Aerial surveys in 2012 were located at two sites in the Alaskan Chukchi Sea: nearshore area (Fig. 7.1) and offshore area (Fig. 7.2). The survey effort over the offshore area was performed in conjunction with Shell drilling operations. No drilling or seismic activity occurred in the nearshore area during the open-water season of 2012, and hence aerial survey effort was a secondary priority in the nearshore area and so, was more limited than in the offshore area. The results of the nearshore area surveys are presented here, despite their limited data acquisition, because of the geographic proximity to the drilling activity, and they provide comparative information with previous year’s surveys.

Nearshore Survey

Within this survey area, two series of systematic transects were flown. The “sawtooth” surveys provided broad–scale coverage of the entire survey area. The “coastline” surveys provided additional opportunities to detect marine mammals in nearshore areas, where most subsistence hunting occurs. The “sawtooth” survey grid flown in 2012 nominally consisted of 22 transect lines (total length ~1015 km or ~631 mi) in a sawtooth pattern (Fig. 7.1). The survey pattern was developed in consultation with scientists from the National Marine Fisheries Service (NMFS) and the North Slope Borough (NSB). Survey transects were determined by placing transect start/end points every 55 km (34 mi) along the offshore boundary of the survey area and at points along the shore midway between the offshore points. The transect line start/end points were shifted along both the coast and the offshore boundary for each survey based upon a randomized starting point. Overall, distance did not vary substantially among surveys. The shorter "coastline" survey (total length ~560 km or 348 mi) was flown either on the return trip to Barrow after completion of the sawtooth survey, or while en route to the southwestern end of the survey area on days when the sawtooth portion of the survey began near Point Hope. The coastline survey was designed to document the distribution of beluga and gray whales in coastal areas, but was not designed to calculate abundance estimates. Another objective of the coastal surveys was to document walrus haulouts and numbers of animals using those sites. This design permitted completion of the survey in two days.

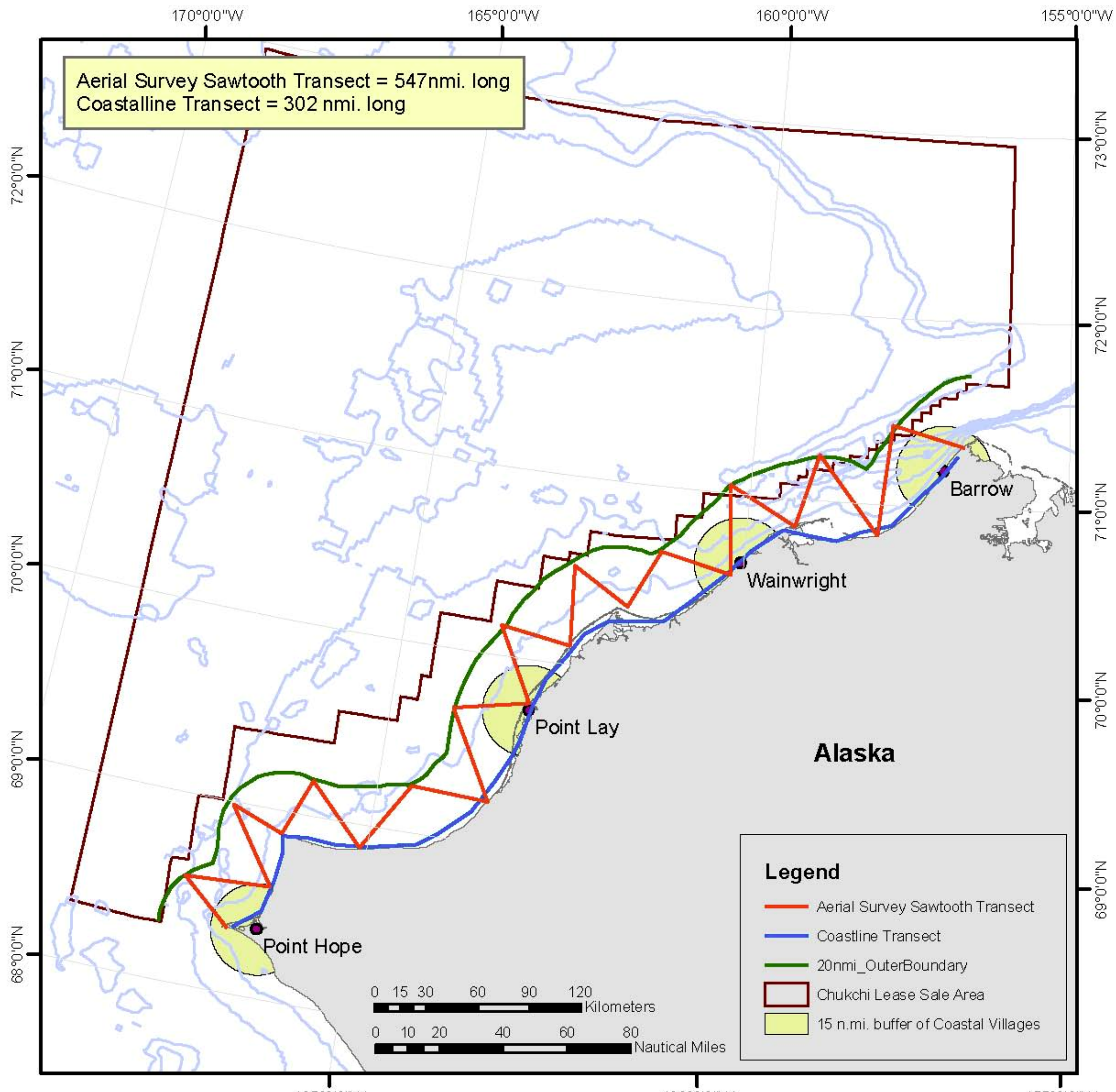

FIGURE 7.1. Nearshore aerial survey transect locations and general survey patterns for the eastern Chukchi Sea, summer and fall 2012.

Offshore Survey

The offshore survey grid was designed to cover a circular area with a radius of 40 km around the drillship as shown in (Fig. 7.2). Transects were spaced 7.2 km apart which allowed even coverage of the survey area during a single flight if weather conditions permitted completion of a survey. A random starting point was selected for each survey and the evenly spaced lines were shifted NE or SW along the perimeter of the circular survey area based on the start point. The total length of survey lines was approximately 1200 km and the exact length depended on the location of the randomly selected start point.

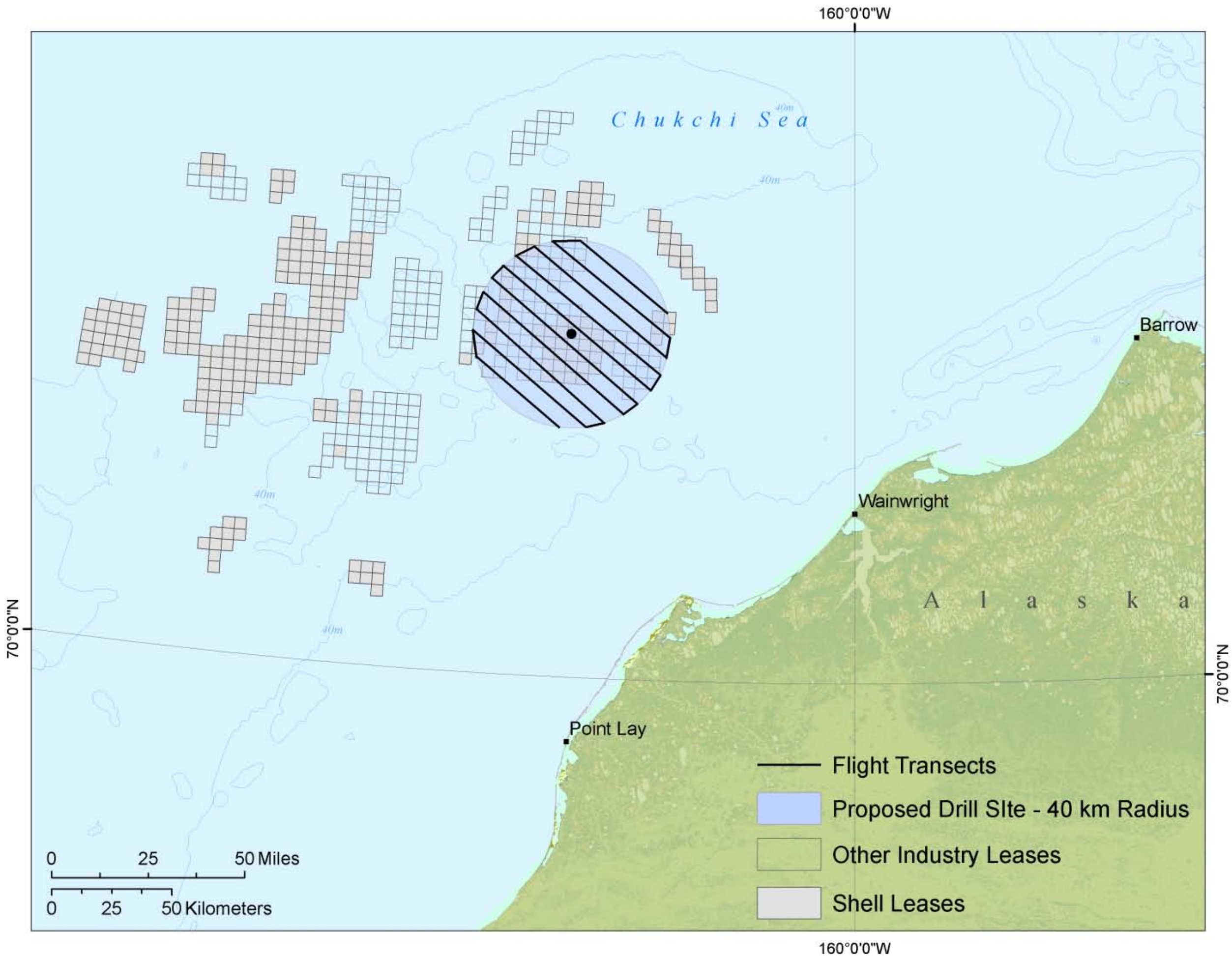

FIGURE 7.2. Offshore aerial photographic survey transect locations and general survey pattern for the eastern Chukchi Sea, summer and fall 2012.

Survey Procedures

From 14 Aug through 27 Oct 2012, aerial surveys were flown in a Twin Otter aircraft operated by Bald Mountain Air Services, Alaska. This twin–engine high–wing aircraft was specially modified for survey work. The special features included an auxiliary fuel tank for long-range flights, multiple GPS navigation systems, bubble windows at all observer positions, 110 V AC power for survey equipment, and a camera port in the belly of the aircraft for the camera equipment.

The surveys of the offshore area around the drillship took precedence over the nearshore survey. When weather did not permit surveying offshore but did permit flying in the nearshore area the nearshore survey was conducted. Fuel capacity of the Twin Otter aircraft allowed completion of the offshore survey, but precluded completion of the nearshore survey without refueling. If the nearshore survey could not be completed in one day, the survey was finished within the next two days if weather permitted.

Surveys were conducted at altitudes of 305 to 457 m (1000–1500 ft) above sea level (ASL) and a groundspeed of 222 km/h (138 m/h). An altitude of 457 m ASL (1500 ft) was maintained in the Ledyard Bay spectacled eider critical habitat area, as required by BOEM. This critical habitat area extended from Icy Cape to Cape Lisburne. The preferred altitude outside the critical habitat area was 305 m ASL (1000 ft), but some surveys were conducted at higher altitudes during periods when there was concern about potential aircraft disturbance to whaling activities at Barrow, Wainwright, Point Lay and Point Hope. "No–fly" zones around coastal villages or other hunting areas established during communications with village representatives were in place during hunting seasons. For example, in 2012 transects 1 and 2 were not surveyed during Barrow whaling to avoid the potential aircraft disturbance to whaling. These procedures were implemented to provide as much coverage of the survey area as possible while minimizing the potential for aircraft disturbance to whales in the whaling area.

Data Recording Procedures

A laptop computer using PSO Tracker software was used to record waypoints throughout the PSO flights. The electronics system consisted of a portable computer, Bluetooth GPS unit, and PSO Tracker data–logging software. A portable GPS unit (Garmin GPSmap 76CSx) was set to automatically recorded time and aircraft position (latitude and longitude) at 2–s intervals throughout the flights. In addition to the automated flight–track recording, locations were recorded through keystrokes initiated by the computer operator at various times, including when marine mammals were sighted by one of the observers, at transect starts and ends, at the ends of 2–minute time periods, and when other observations or comments were recorded.

The two primary observers recorded the time, sightability (subjectively classified as excellent, good, moderately impaired, seriously impaired, or impossible), sea conditions (Beaufort wind force), ice and slush cover (in 100ths) and sun glare (none, up to 10% glare, 10–30% glare, >30% and <70% glare, and >70% glare) onto digital recorders at the end of each 2–minute (~7.4 km or 4.6 mi) period. In 2012, an ice observer was present and recorded percent ice concentration, percent slush concentration, ice type, primary stages of development, secondary stages of development, percent primary partial concentrations, and percent secondary partial concentrations onto digital recorders at the end of each 2–minute period. The PSO Tracker software automatically logged the time and position of the aircraft when any type of data were entered into the computer by PSOs.

For each whale sighting, the observer notified the computer operator of the species and number seen and then dictated details of the sighting into a portable digital recorder, including the species, number, size/age/sex class when determinable, activity, heading, swimming speed category, sighting cue, inclinometer angle (taken when the animal's location was 90° to the side of the aircraft track), and altitude. In conjunction with aircraft altitude, inclinometer readings allowed calculation of lateral distances of whales from the transect line. Non–transect (incidental) sightings were identified as being recorded along "Connect" segments (between transect lines) and "Search" segments (seen while circling). For pinnipeds and polar bears, only the species, and numbers were routinely dictated. In addition to recording sighting data on the digital recorder, time and position of the sighting were recorded in the PSO Tracker software as waypoints. The whale sighting information entered into the software in real time was cross–checked against the recorded dictation after each survey to correct any data entry errors.

Sensor Data Collecton

Data Recording

The aircraft had two still cameras and a video camera recording throughout the flights. The still cameras were Nikon D800 digital single lens reflex cameras (DSLR) with a 21 mm Zeiss lens pointed at 25 degrees from vertical so that they covered an area out to 670 m from the center line and had an overlap of 85 m either side of the center line. One pixel on the water was ~6 cm at the center line and 33 cm at the outer edge of the frame. For a brief time at the start of the field season the cameras were pointed at 33 degrees from vertical so that they covered an area out to 1029 m from the center line and had an overlap of 40 m either side of the center line. For the latter setting, one pixel on the water was ~6 cm at the center line and 68 cm at the outer edge of the frame. The angle of 33 degrees was changed to 25 degrees latter in the season to allow for adequate overlap of images so sightings would not be missed on the centerline. In comparison, the Effective Strip Width (ESW) during 2006-2010 manned aerial surveys has been 857-1498 m for bowheads and 350-703 m for belugas. A Canon HD XF100 video camera was mounted vertically to cover a 300 m swath either side of the center line. One pixel on the water was 25 cm.

The cameras were linked to a lap-top computer and Global Positioning System (GPS) that added the time, position, and camera settings to the properties file associated with each image. Data was stored on the hard drives of the lap-tops connected to the cameras during the flight and backed up onto 3.5" SATA drives after the aircraft returned to its base in Barrow.

Review of Imagery

The digital images were initially reviewed in a manner that will permit direct comparisons to data collected during manned aerial surveys and that would permit timely reporting of marine mammals recorded digitally to permitting agencies. On days when PSOs were not flying, images from the two DSLR cameras were reviewed, sightings and environmental conditions were recorded onto digital recorders, and recorded data were coded into a digital database in the same way as data from manned aerial surveys. PSOs viewed the imagery on 2560×1600 monitors hooked up to dedicated desktops. The screen resolution of the monitor was only about one ninth of the resolution of the DSLR imagery, but in theory, this resolution is as good as or better than is obtained by observers looking out of bubble windows, particularly toward the edges of the outer viewing area. PSOs recorded sightings and environmental conditions for a one-hour block of time to reduce fatigue issues and to mimic an observation shift on the aircraft. Images were viewed as a slide show where each image remains on the screen for ~4 sec; because there is 50% overlap in each of the still images, this means that the area being examined is in view for 8 seconds. The photo imagery data presented in this report are from only the quick review of photographs. A comparison of the quick review of the nearshore surveys to the PSO sightings is presented but the most meaningful comparison is the PSO observations to the detailed photo review. The photo data from the nearshore surveys is currently undergoing detailed review that will be used in conjunction with the quick review described above and the PSO sightings to do a comparative analysis of all three reviews.

The HD video imagery is being analyzed so it is not included in this report. It covered the inner 300 m on either side of the aircraft and hence is not directly comparable to observations by PSOs because they direct their effort to 100-1100 m from the trackline to improve detection efficiency. The primary function of the video is to compare sightings recorded from the video to sightings from the DSLR camera images because some people believe that full motion video will permit detection of animals that will not be seen in the still imagery because motion is one of the cues to detection of marine mammals. The video will also provide full-time monitoring of the track-line and those sightings can later be added to the PSO sightings database to provide a fully corrected value of the detection bias $f_d(0)$, which has not been available during past surveys.

Analyses of Aerial Survey Data

On-Transect Sightings and Effort

Environmental factors such as sea conditions, low clouds, and glare can affect an observer's ability to see marine mammals during aerial surveys and they bias results if not accounted for during analysis. To minimize bias, environmental data were used to classify sightings and effort as "on–transect" or "other" for quantitative analyses. Sightings and effort were considered on–transect when the following criteria were met: the animal was sighted while the aircraft was flying a pre–established transect, Beaufort wind force was 4 or less (winds 20–30 km/h; 11–16 kts), glare covered 30% or less of the viewing field, and overall sightability was described as excellent to moderately impaired. Survey effort and sightings data that did not meet these criteria were excluded (off-transect) from analyses. Effort was measured in kilometers for the nearshore surveys and in hours for the offshore surveys. We will calculate effort in kilometers for the offshore surveys in the comprehensive report. Pinnipeds were only visible during optimal sightability conditions and were difficult to identify to species; therefore, no in–depth analyses of pinniped data will be conducted. Sightings of animals hauled out on land are not included in data analyses.

Mapping

Maps were prepared to show the locations of cetacean and pinniped sightings. Each sighting symbol on the maps represents a sighting of one or more individuals. All sightings including on-transect, off-transect and incidentals are shown in the maps. Sightings from the two ice surveys flown at the beginning of the season, which were technically not in the survey area as described above and therefore not included in the summary tables, are also shown in the distribution maps.

Results

Nearshore Surveys

Cetaceans

Survey Effort

Aerial surveys were flown from 23 Aug through 26 Oct 2012 along 3490 km (2168 mi) of nearshore transects and 82% of this effort met the data–analysis criteria for inclusion in quantitative analyses. Table 7.1 summarizes the surveys of the nearshore area showing aerial survey effort and whale sightings for each aerial survey with on-transect data. Appendix Table K.1 summarizes the aerial survey effort and whale sightings for each survey with all data including on-transect, off-transect and incidental sightings. Appendix K contains daily aerial survey maps showing the nearshore transects surveyed each day and the whale sightings in 2012 (Figs. K.1–K.7).

Total or partial aerial survey coverage of the nearshore was obtained on 5 surveys (during 6 days). Adequate coverage (>250 km) of the survey area was obtained on 4 surveys. This limited coverage was due to the nearshore surveys being secondary priority to the offshore surveys. There were also two ice reconnaissance surveys flown at the start of the season, but they were not in the nearshore survey area and thus are not included in the survey effort numbers.

Sightings

Seventeen cetacean sightings of an estimated 22 individuals were recorded during nearshore surveys within the Chukchi Sea (Table 7.1). Bowhead whales were sighted on two nearshore surveys, and all sightings were of single animals. Gray whales were also sighted on two nearshore surveys, and their group sizes varied from 1 to 3 with a mean group size of 1.3. A group of three killer whales was sighted on one nearshore survey.

TABLE 7.1. Summary of nearshore aerial survey effort (km) and numbers of cetacean sightings (numbers of individuals) in the Alaskan Chukchi Sea, 2012.

Date in 2012	Survey No.	On-transect Effort	Gray Whale	Bowhead Whale	Killer Whale	Unknown Whale
23-Aug	1	1011	9 (12)	0	1 (3)	0
15-Sep	2	311	0	0	0	1 (1)
26-Sep	3	226	1 (1)	1 (1)	0	0
28-Sep	4	816	0	4 (4)	0	0
24-26 Oct	5	523	0	0	0	0
Total		2887	10 (13)	5 (5)	1 (3)	1 (1)

Distribution

Bowhead whales were found in the northern portion of the survey area, with all sightings occurring north of Wainwright (Fig. 7.3) and in the latter half of the field season. Gray whales were sighted throughout the survey area during the field season, with most sightings occurring in the northern half of the study area (Fig. 7.3). Beluga whales were not sighted on the nearshore surveys, but they were seen on an ice survey north-east of Barrow at the start of the season (Fig. 7.3). The group of killer whales was sighted on the coastline survey just north of Point Lay.

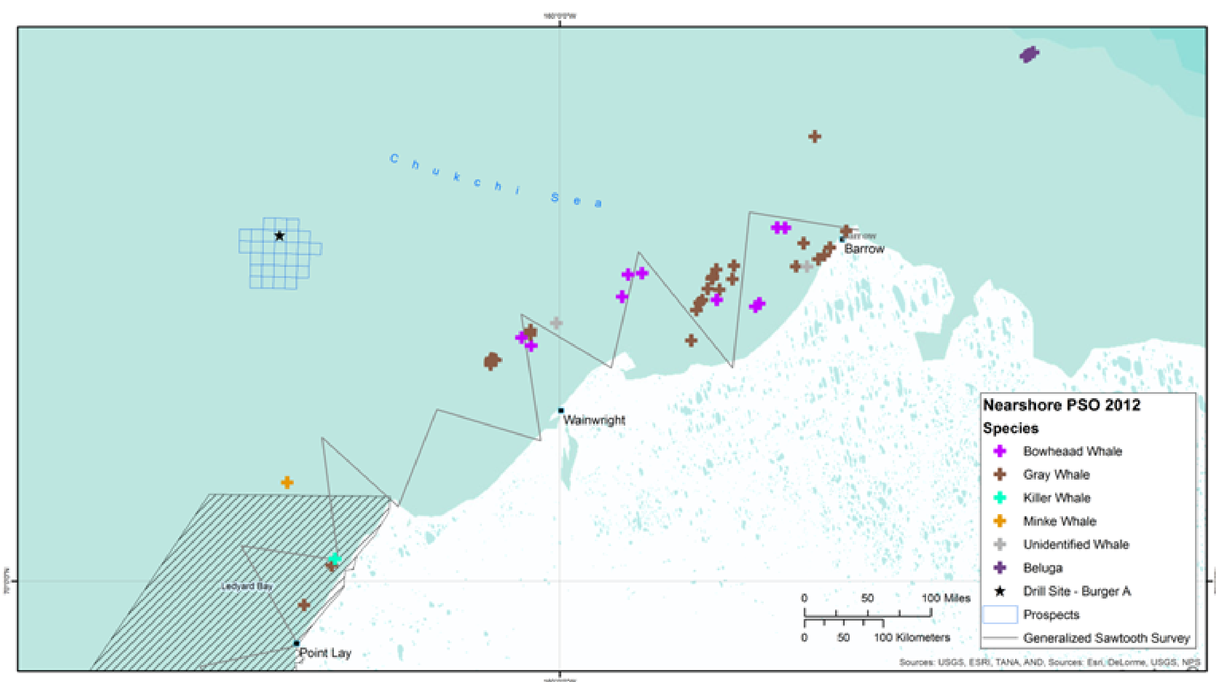

FIGURE 7.3. Locations of cetacean sightings during aerial surveys in the nearshore Chukchi Sea during Aug to Oct 2012. All sightings are shown on this map including on–transect, off-transect, incidental and sightings from the two ice surveys.

Pinnipeds

Survey Effort

Table 7.2 summarizes the surveys of the nearshore area showing aerial survey effort and pinniped sightings for each aerial survey with on-transect data. Appendix Table K.2 summarizes the aerial survey effort and pinniped sightings for each survey with all data including on-transect, off-transect and incidental sightings. Appendix K contains daily aerial survey maps showing the nearshore transects surveyed each day and the pinniped sightings in 2012 (Figs. K.1–K.7).

Total or partial aerial survey coverage of the nearshore was obtained on 5 surveys (during 6 days) in 2012. Adequate coverage (>250 km) of the survey area was obtained on 1 survey.

Sightings

In total, 61 pinniped sightings of an estimated 73 individual pinnipeds were recorded during nearshore surveys within the Chukchi Sea (Table 7.2). Because ribbon, ringed and spotted seals were difficult to distinguish during aerial surveys at 305 m (1000 ft) most seals of these species are classified as unknown seals. The most commonly recorded pinniped species were unknown seals.

One sighting of two walrus was made during nearshore surveys (Table 7.2). Bearded seals were sighted during two nearshore surveys and they were sighted as single animals in all cases except one sighting of two animals. Sightings of ringed and unknown seals were recorded on three nearshore surveys and their group sizes varied from 1 to 3 with a mean group size of 1.3.

TABLE 7.2. Summary of nearshore aerial survey effort (km) and number of pinniped sightings (number of individuals) in the Alaskan Chukchi Sea, 2012.

Date in 2012	Survey No.	On-transect Effort	Walrus	Bearded Seal	Ringed Seal	Unknown Seal	Unknown Pinniped
23-Aug	1	801	0	14 (15)	1 (1)	27 (36)	0
15-Sep	2	243	1 (2)	11 (11)	0	4 (4)	1 (1)
26-Sep	3	0	0	0	0	0	0
28-Sep	4	0	0	0	0	0	0
24-26 Oct	5	90	0	0	0	2 (3)	0
Total		1134	1 (2)	25 (26)	1 (1)	33 (43)	1 (1)

Distribution

Walrus were found in the northern portion of the survey area, with most sightings occurring north of Wainwright on the two ice surveys (Fig. 7.4). Bearded, ringed and unknown seals were sighted throughout the survey area during the field season (Fig. 7.4).

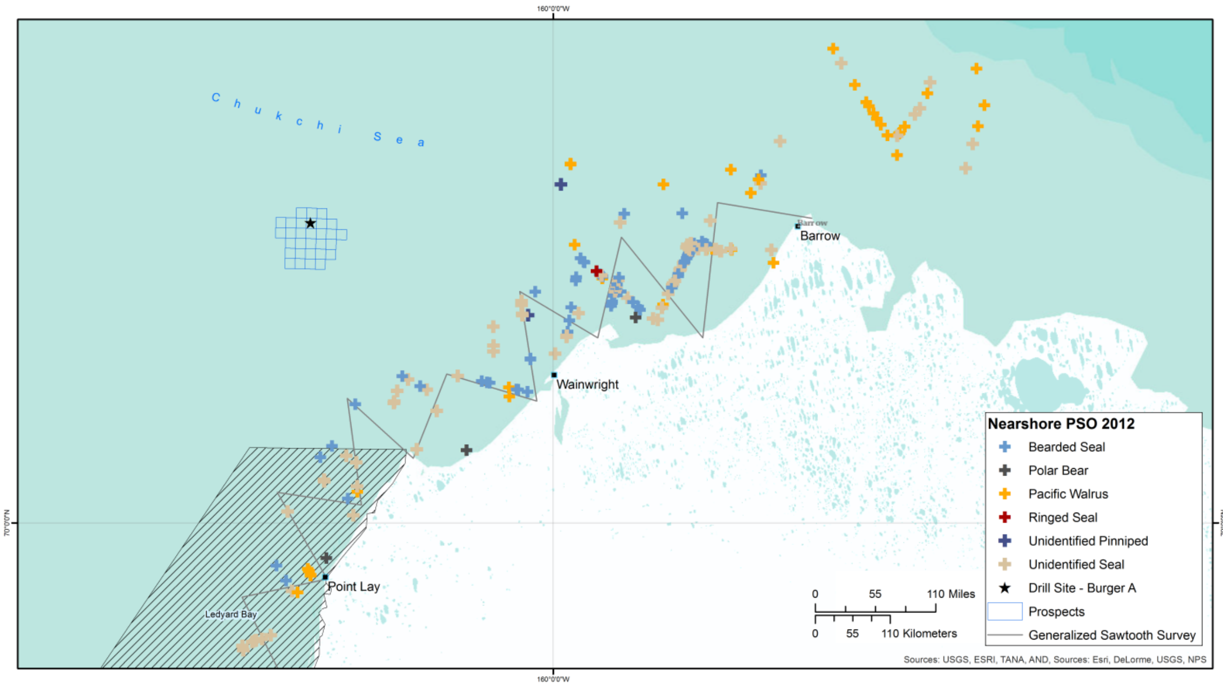

Figure 7.4. Locations of pinniped and polar bear sightings during aerial surveys in the nearshore Chukchi Sea during Aug to Oct 2012. All sightings are shown on this map including on–transect, off-transect, incidental and sightings from the two ice surveys.

Comparison of PSO to Photographic Quick Review Sightings

For the initial comparison of PSO to photographic quick review we looked at all on-transect sightings in the field of view of the PSO that should have been photographed and therefore could have been see during the quick review of photographs. A total of 54 marine mammal sightings were sighted by PSOs compared to 53 sightings by reviewers of the photographs (Fig. 7.5). The photographic quick review had more unidentified sightings compared to the PSO sightings. One thing to note is that the detailed review, which is being conducted at this time, will provide more information than the quick review. We anticipate that once the detailed photographic review is completed, we will be able to identify many of the quick review unidentified sightings to species, and likely will find some additional sightings that were missed by PSOs and/or the quick review.

Offshore Photographic Surveys

Cetaceans

<u>*Survey Effort*</u>

Aerial photographic surveys were flown from 19 Aug through 27 Oct 2012 with daily on-transect effort ranging from 0.03 hr to 2.95 hr per survey over the prospect (1% to 100% of the survey grid; Table 7.4). Total or partial aerial survey coverage of the offshore was obtained on 18 surveys. Adequate coverage (>67 min) of the survey area was obtained on 13 surveys. Appendix Table K.3 summarizes the aerial survey effort and whale sightings for each offshore survey with all data including on-transect, off-transect and incidental sightings.

A total of 120,913 images were reviewed using the quick review (slide-show format) by PSOs in the field for the offshore surveys. The following data come from the slide-show review of these digital images taken from the cameras (Fig. 7.6).

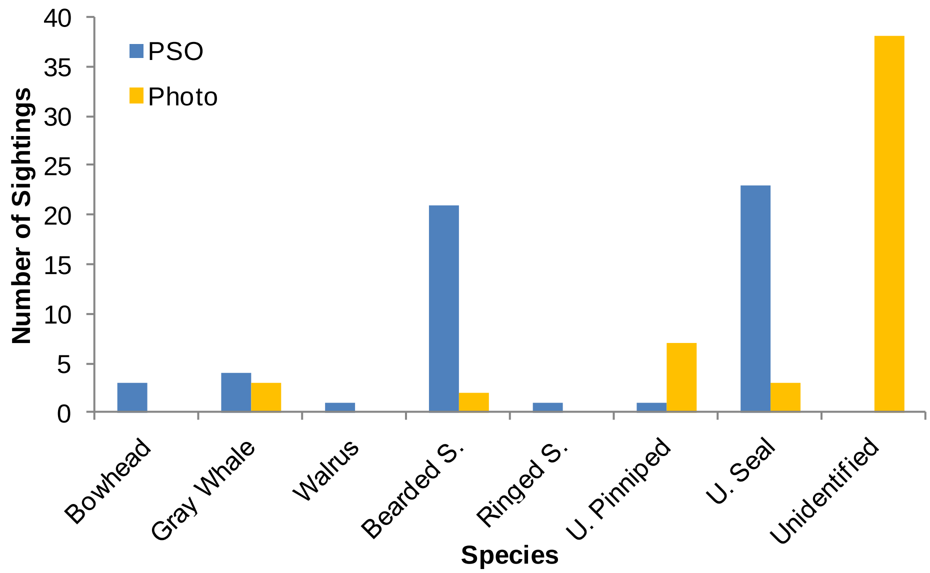

Figure 7.5. Comparison of PSO sightings to photographic quick review sightings for five surveys flown in the nearshore Chukchi Sea during Aug to Oct 2012; (S. is the abbreviation for Seal, and U. is the abbreviation for Unidentified).

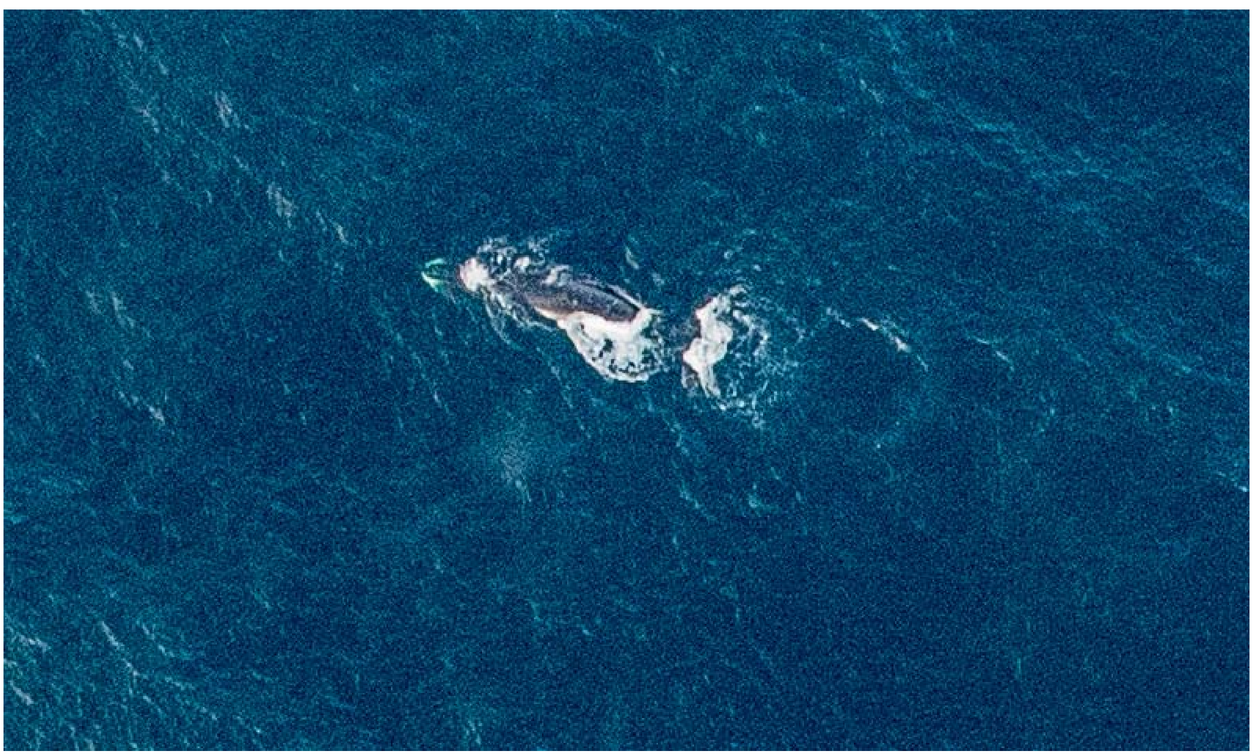

FIGURE 7.6. Cropped and enhanced photograph of a bowhead whale taken during aerial photographic surveys in the offshore Chukchi Sea on 29 Sep 2012.

Sightings

A total of 37 cetacean sightings of an estimated 43 individuals were recorded during offshore surveys within the Chukchi Sea (Table 7.4). Bowhead whales were seen on seven days, and their group sizes varied from 1 to 3 with a mean group size of 1.3. Bowheads were seen only in the last month of the field season. Beluga whales were seen on two days, and their group sizes varied from 1 to 3 with a mean group size of 1.3. Belugas were seen late in the season, in the last half of October. Unknown whales were seen on seven days, and were seen as single animals in all instances except for one group of two.

TABLE 7.4. Summary of offshore aerial survey effort (hours) and number of cetacean sightings (number of individuals) in the Alaskan Chukchi Sea, 2012.

Date in 2012	Survey No.	On-transect Effort	Bowhead Whale	Beluga Whale	Unknown Whale
19-Aug	1	1.98	0	0	0
21-Aug	2	0.93	0	0	0
28-Aug	3	2.17	0	0	0
7-Sep	4	1.31	0	0	0
8-Sep	5	2.53	0	0	0
9-Sep	6	1.94	0	0	1 (1)
10-Sep	7	2.21	0	0	0
26-Sep	8	0.34	0	0	0
29-Sep	9	2.89	2 (3)	0	4 (5)
30-Sep	10	0.42	0	0	1 (1)
6-Oct	11	2.53	5 (6)	0	1 (1)
12-Oct	12	2.57	1 (1)	0	0
15-Oct	13	2.33	1 (1)	0	1 (1)
18-Oct	14	2.95	2 (2)	5 (8)	1 (1)
19-Oct	15	1.53	1 (1)	0	0
22-Oct	16	0.03	0	0	0
23-Oct	17	2.80	0	6 (6)	1 (1)
27-Oct	18	0.55	1 (1)	0	0
Total		31.99	13 (15)	11 (14)	10 (11)

Distribution

Bowhead whales were sighted throughout the offshore survey area during the 2012 field season (Fig. 7.7). Beluga whales were sighted throughout the survey area, although most sightings occurred on the northern portion of the survey area (Fig. 7.7). Unknown whales were seen throughout the survey area and most unknown whales likely consisted of bowhead or gray whales.

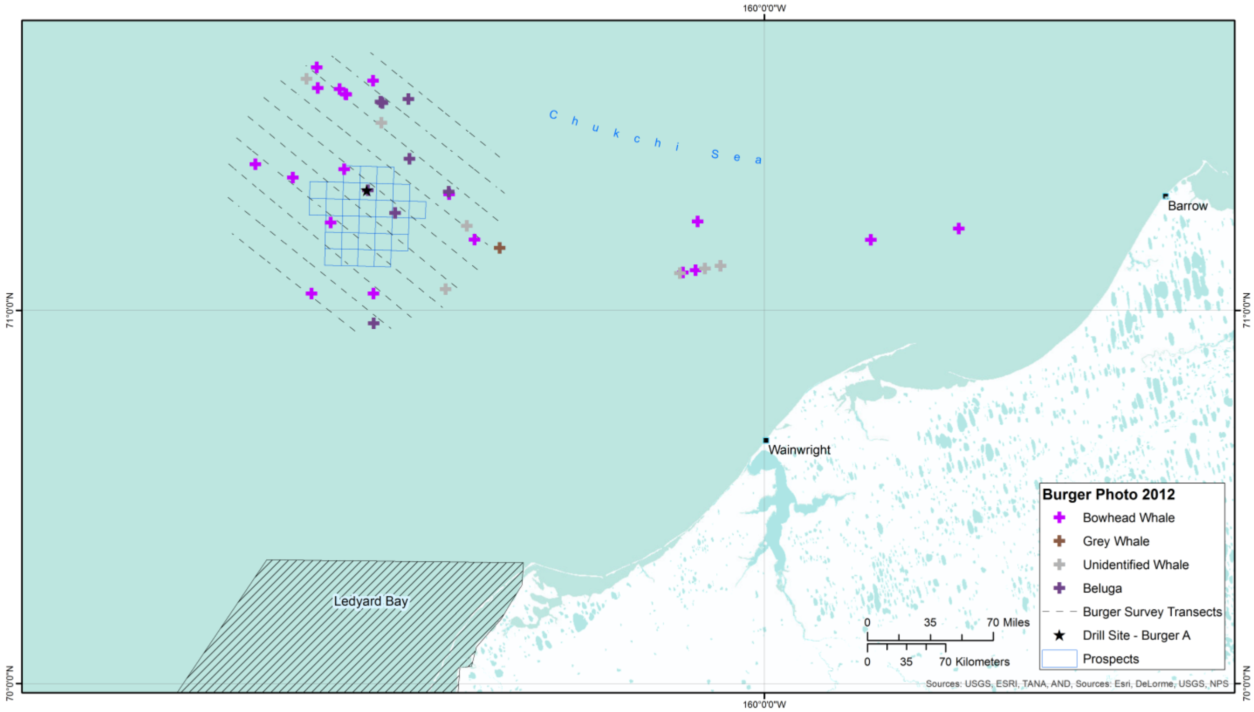

FIGURE 7.7. Locations of cetacean sightings during aerial surveys in the offshore Chukchi Sea during Aug to Oct 2012. All sightings are shown on this map including on–transect, off-transect, and incidental sightings.

Pinnipeds

<u>*Survey Effort*</u>

Aerial photographic surveys were flown from 19 Aug through 27 Oct 2012 with daily on-transect effort ranging from 0 hr to 2.95 hr per survey (0% to 100% of the survey grid; Table 7.6). Total or partial aerial survey coverage of the offshore was obtained on 16 surveys. Adequate coverage (>67 min) of the survey area was obtained on 7 surveys. Appendix Table K.4 summarizes the aerial survey effort and pinniped sightings for each offshore survey with all data including on-transect, off-transect and incidental sightings.

As stated in the previous section the following data come from the slide-show review of the digital images taken from the cameras.

<u>*Sightings*</u>

In total, 329 pinniped sightings of an estimated 1558 individual pinnipeds were recorded during offshore surveys within the Chukchi Sea (Table 7.6). It is important to note that the pinniped sightings have not been examined to remove resightings on the opposite camera in the overlap zone so these numbers will be an overestimate. This overestimate may be substantial because pinnipeds, because of their small size, are more likely to be detected near the track-line where there is overlapping coverage by the two cameras, than at the outer areas of the digital imagery. Because ringed and spotted seals were difficult to distinguish during aerial surveys at 305 m (1000 ft) most ringed, ribbon or spotted seals are classified as unknown seals. Some of the larger pinniped species, like walrus and bearded seals, were also at times difficult to distinguish and were classified as unknown pinnipeds if an identification was not possible. The most commonly recorded pinniped species were walrus.

Walrus were sighted on four days, and their group sizes varied from 1 to 150 with a mean group size of 7.9. Walrus were seen only in the month of September. Sightings of ringed and unknown seals were recorded on three offshore surveys and their group sizes varied from 1 to 3 with a mean group size of 1.3.

TABLE 7.6. Summary of offshore aerial survey effort (hours) and numbers of pinniped sightings (number of individuals) in the Alaskan Chukchi Sea, 2012.

Date in 2012	Survey No.	On-transect Effort	Walrus	Unknown Seal	Unknown Pinniped
19-Aug	1	1.64	0	2 (2)	0
21-Aug	2	0.01	0	0	0
28-Aug	3	1.94	0	2 (2)	9 (9)
7-Sep	4	0.18	0	0	0
8-Sep	5	2.37	28 (316)	0	0
9-Sep	6	0.86	28 (140)	0	0
10-Sep	7	0.40	65 (788)	0	0
26-Sep	8	0.02	0	0	0
29-Sep	9	2.89	42 (90)	0	142 (200)
30-Sep	10	0.00	0	0	0
6-Oct	11	2.44	0	1 (1)	5 (5)
12-Oct	12	1.00	0	0	3 (3)
15-Oct	13	0.60	0	0	0
18-Oct	14	2.95	0	0	2 (2)
19-Oct	15	0.03	0	0	0
22-Oct	16	0.03	0	0	0
23-Oct	17	2.23	0	0	0
27-Oct	18	0.00	0	0	0
Total		19.59	163 (1334)	5 (5)	161 (219)

Distribution

Walrus were sighted throughout the survey area (Fig. 7.8). For the first three surveys that walrus were sighted (8-10 Sep), their distribution was mainly concentrated on the northeastern area of the survey grid where ice had accumulated. On the fourth survey (29 Sep) walrus were sighted throughout the survey area and there was no ice in the survey grid. Unknown pinnipeds were sighted throughout the survey area during the 2012 field season and most were likely walrus based on their vicinity to other walrus sightings (Fig. 7.8). Unknown seals were rarely seen in the survey area.

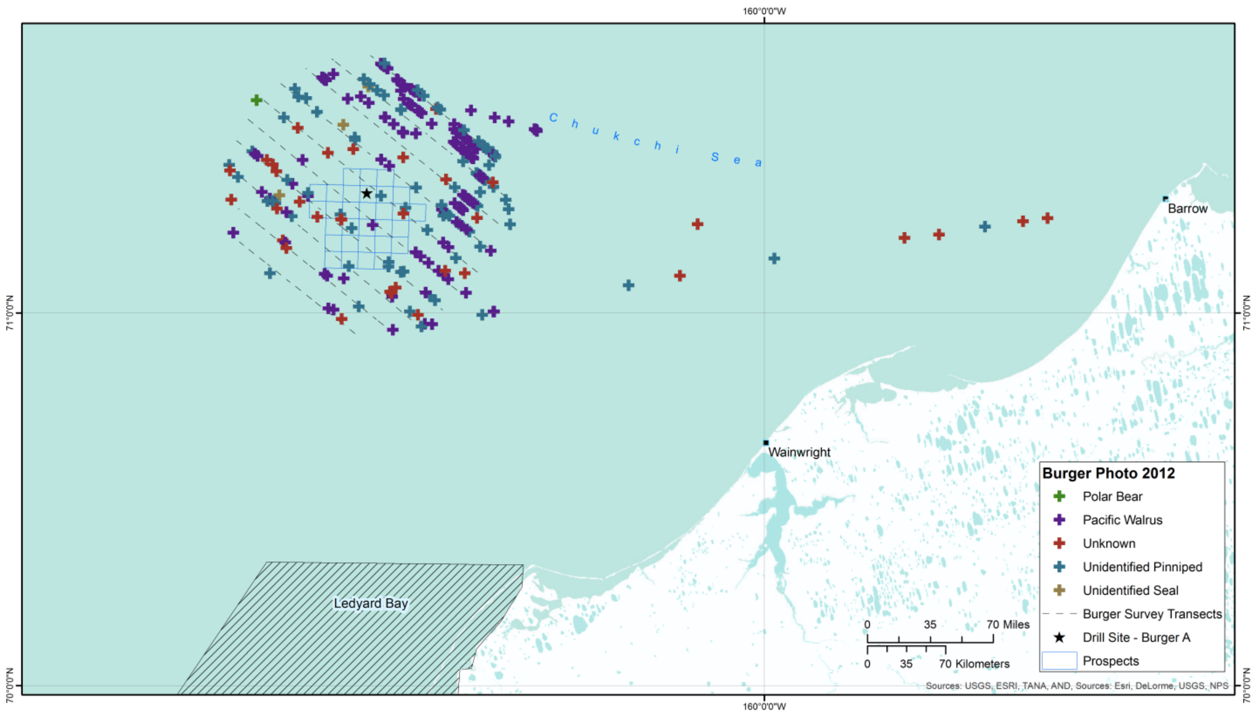

Figure 7.8. Locations of pinniped and polar bear sightings during aerial surveys in the offshore Chukchi Sea during Aug to Oct 2012. All sightings are shown on this map including on–transect, off-transect, and incidental sightings.

Polar Bears

Three polar bear sightings (3 individuals) were made during 2012 nearshore aerial surveys, all of which were off–transect seen on the coast (Fig. 7.4). One incidental polar bear sighting (1 individual) was made by the pilots during one the offshore survey (Fig. 7.8), but it was not seen during the slide-show review by the PSOs. More polar bears are expected to be detected in the imagery during detailed reviews of the photographs because polar bears are difficult to see when they are on the ice.

Discussion

Cetacean sightings during the study season are consistent with the general pattern and distribution seen in previous years. Bowhead sightings were first observed in the nearshore survey area on 15 Sep and in the offshore survey area on 26 Sep, coinciding with the bowhead whale fall migration from the Beaufort Sea to overwintering areas in the Bering Sea. Belugas were seen early in the season on one of the ice reconnaissance surveys that we flew in August when there was still plenty of ice in the area. They weren't seen again until mid-Oct on two of the offshore surveys which would have been during the beluga fall migration through the eastern Chukchi Sea. Gray whales were seen on all of the nearshore surveys except the last one in late October. This is consistent with their distributions in previous years with most gray whales leaving the nearshore area by October (Thomas and Koski 2011). The peak of gray whale sightings occurred in August and is also consistent with sighting rates seen in previous years.

The distributions and habitat use by Pacific walruses have varied considerably since 2007 in the Chukchi Sea nearshore area. During four years (2007, 2009, 2010, and 2011) walrus used terrestrial haulouts in large numbers along the Chukchi coastal area. These years were exceptionally ice–free years and early in the seasons the pack ice retreated far to the north beyond the relatively shallow habitats (i.e. Hanna Shoal) of the Chukchi Sea that are used by walruses for foraging. Walruses appeared to have abandoned the pack ice by late Aug during those four years to use terrestrial haulouts along the Chukchi coastal area, which were presumably closer to their Chukchi Sea feeding grounds than any remaining pack ice. On Sep 16 2012 the frozen cap of the Arctic Ocean reached its minimum extent and broke a new record low at almost 300,000 square miles less ice than the previous lowest extent in the satellite record, set in mid-September 2007. Despite the record low level of sea ice in the Arctic this year, walrus did not haul out in large numbers along the Chukchi coast as they did in the previous years. One possible reason for their failure to haul out on terrestrial sites in 2012 may be the presence of ice in the area of Hanna Shoal until mid-Sep. This ice may have provided haul out platforms for them over or near their feeding areas. Use of terrestrial haulouts by walruses is common on the Chukotka coast (Belikov et al. 1996), but is less common on the Alaska side of the Chukchi Sea. The large number of different terrestrial haulout sites during 2007 and 2009–2011 and the large numbers of walruses at these sites on the Alaskan side of the Chukchi Sea had not been documented before 2007, but it may become more common if the trend of reduced ice cover in the Chukchi Sea in summer continues.

This report includes only the digital imagery examined during the quick slide-show review of the offshore surveys as described in the methods section. We are in the process doing a more detailed review of the nearshore surveys along with the Beaufort surveys which are surveys that included both PSOs and the capture of digital imagery. The detailed review involves enlarging the imagery and looking at each slide by making 3-4 passes through it to view all regions of the slide at full 7360 × 4912 resolution of the image. During this pass image enhancing software (Adobe Photoshop CS6 Extended) is used to adjust the photos to maximize detection, for counting, identification of animals in the slides and to record the location on the photo where each sighting is found. The latter information is used to determine the distance from the track line for later DISTANCE analyses. We are comparing PSO sightings to the quick slide-show review and to the more detailed image review, but too few images have been analyzed at this time to warrant presentation. This type of analysis will help in validating whether the technology of UAS with digital cameras such as those on our Twin Otter in 2012 can replace manned aerial surveys.

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8. BEAUFORT SEA AERIAL SURVEY RESULTS[1]

Introduction

An aerial monitoring program for marine mammals was conducted from 15 Aug to 3 Nov 2012 in support of exploratory drilling activities by Shell Offshore, Inc. (Shell) in the Central Alaskan Beaufort Sea. Surveys were flown to meet monitoring requirements and obtain detailed data on the occurrence, distribution, and movements of marine mammals, particularly bowhead whales. Several cetacean species might be encountered near the Shell drilling activities but only two of these species (bowhead whales and beluga whales) are regularly encountered (Miller et al. 1999; Christie et al. 2010; Brandon et al. 2011). A few other species of cetaceans such as harbor porpoise and gray whales (e.g., Miller et al. 1999) are encountered in low numbers some years, and a few other species such as humpback, minke and killer whales have been recorded near Barrow but have not been recorded as far east as the drilling prospect and so are unlikely to be seen there. Two species of pinnipeds, ringed and bearded seals, are abundant near Shell's drilling operation in the Central Alaskan Beaufort Sea and three other species, Pacific walrus, spotted and ribbon seals, are found there in low numbers. Polar bears are also found in the proposed drilling area outside of the drilling season when sea ice is present but are found in low numbers during the open-water drilling season.

Bowhead whales are the principal species of concern related to a drilling operation in the Central Alaskan Beaufort Sea. They are listed as endangered under the Endangered Species Act, they are hunted by local native communities near the drilling activities, and most of the population migrates west through the general area of the drilling operation during their fall migration.

Typically, bowhead whales migrate eastward through the Alaskan Beaufort Sea in the spring to reach summer feeding grounds in the Canadian Beaufort Sea (Braham et al. 1984; Moore and Clarke 1989; Moore and Reeves 1993). Recent satellite telemetry data indicate that some whales travel back to the western Beaufort or Chukchi seas (Quakenbush et al. 2011), presumably when feeding conditions in Canadian waters are not optimal. In late summer and fall, bowheads begin a westward migration from Canadian feeding grounds to wintering areas off the Siberian coast (Bogoslovskaya et al. 1982; Quakenbush et al. 2010a,b). The first westward migrating whales are typically seen in the Central Alaskan Beaufort Sea in late Aug. During the fall migration, whales may linger on occasion in Alaskan waters to feed (Würsig et al. 2002), resulting in higher residence times (Koski et al. 2002) and potentially higher sighting rates in some years. In general, however, peak sighting rates during the fall migration in the Alaskan Beaufort tend to occur in mid–Sep and sighting rates decline through late Sep and Oct (Miller et al. 2002).

Within a season, the migration is not continuous, but is pulsed in nature with large numbers of whales moving westward for periods of days followed by periods when few whales are seen (Moore and Reeves 1993). Like the spring migration, the fall migration appears to be size structured with large whales seen at the start of the migration; those whales head west to Barrow or the Chukotsk coast, usually without stopping along the Alaskan Coast. After this initial early pulse of whales, the sizes of whales gradually increases from small subadult whales during the first part of the migration (late August to mid-September) to large adult whales during the last part of the migration (mid-September onward) (Koski and Miller 2009). Whales of different sizes tend to use different habitats, with small whales tending to be closer to the coast and larger whales tending to be found farther offshore (Koski and Miller 2009). Mothers and calves migrate throughout the fall period and tend to avoid shallow (<20 m) waters (Koski

[1] By John R. Brandon and William R. Koski (LGL)

and Miller 2009). Ice conditions also appear to influence the distribution of whales during the fall migration with whales being found farther offshore during years with heavier ice cover than during years with light ice cover (Moore 2000; Treacy et al. 2006).

Availability of prey species also influences bowhead whale distribution during the fall because whales stop to feed at locations where their principal prey species are abundant (Landino et al. 1994; Okkonen et al. 2011). The dynamics of local oceanographic features (e.g. frontal boundaries) may result in higher prey concentrations in certain areas and at certain times in the Alaskan Beaufort Sea during the fall migration (Landino et al. 1994; Okkonen et al. 2011) as they do in the summer (Bradsteet et al. 1987). These higher prey concentrations attract whales, which may linger in the area, and result in higher sighting rates in these areas (Moore and Clarke 1989; Moore 2000). Thus within a given season, natural variability in the migratory route is likely a function of (among other things) the interaction between the dynamics of the local environment and the underlying age- and stage-structure (vis-à-vis stage-structured migratory habitat preferences) of the whales migrating through an area. Bowhead whales are most likely to encounter drilling activities during their fall migration from summer feeding areas and their hearing is good at the low frequencies, where most sound is generated by drilling. Previous studies have shown that bowhead whales exhibit various levels of avoidance responses to offshore drilling activities (Richardson et al. 1985, 1995a,b; Koski and Johnson 1987; Hall et al. 1994). For example, during summer drilling operations bowhead whales have often been seen within 10-20 km of drilling operations (Richardson et al. 1985; 1990) and some sightings have been made as close as 0.25 to 5.0 km (Richardson et al. 1995a). Reactions of whales to playback experiments, where the actual drill rigs and support vessels were not present, was variable but some whales reacted to sound levels 94-118 dB re 1µPa and Richardson et al. (1995b) concluded that the variable response could be attributed to a combination of habituation by some animals and variable responsiveness by others. Richardson et al. (1995b) reported changes in surfacing and respiration behavior, and the occurrence of turns during surfacing when bowhead whales were exposed to playback of underwater sound from exploration drilling activities. These subtle behavioral effects were temporary and localized, and occurred at distances up to 1-2 mi (2-4 km).

Responses to full-scale drilling programs with their support vessels may be greater than responses to playbacks. During studies conducted in the mid-1980s and early 1990s in the Central Alaskan Beaufort Sea, migrating bowheads appear to have avoided the area within 10 km of the drillship (Davis 1987; Hall et al. 1994). Because these studies were based on visual detection of bowheads from aerial platforms, it is not clear whether some whales may have been present closer to the operations but were not seen because changes in behavior made them less conspicuous to aerial observers (Robertson et al. 2013). However, the Davis (1987) study showed that at least some whales diverted around the drilling operation in 1986 when 20+ km away (Koski and Johnson 1987), so some, if not all, of the reduced sightings during these studies were due to avoidance of the drilling operations. During studies in the early 1990s, Brewer et al. (1993) and Hall et al. (1994) reported numerous sightings of marine mammals including bowhead whales in the vicinity of offshore exploration drilling operations in the Beaufort Sea. One bowhead whale sighting was reported within ~1,312 ft (400 m) of a drilling vessel, although other sightings were at much greater distances. Few bowheads were recorded near industrial activities by aerial observers, but observations by surface observers suggested that bowheads may have been closer to industrial activities than was suggested by results of aerial observations.

Bowhead whales engaged in feeding activities appear to be more tolerant of seismic sounds than migrating bowheads (Richardson et al. 1986; Miller et al. 2005; Koski et al. 2009). Hence, it is possible that feeding bowheads may react differently to drilling operations than traveling or migrating whales. The 2012 and future aerial surveys will attempt to identify how drilling operations affect the distribution and movements of bowhead whales during their autumn migration through the Central Beaufort Sea in the vicinity of Shell's offshore drilling activities and will examine the effects of environmental factors and whale activity.

Natural factors such as ice cover, water depth, and time of year have also been shown to affect bowhead whale abundance and distributions in the Beaufort Sea (Ljungblad et al. 1986; Moore and Clarke 1989; Treacy et al. 2006). As described earlier, large numbers of bowheads move through the Alaskan Beaufort Sea in Aug through Oct, but movements occur in pulses with periods of large numbers of whales followed by periods with few whales, and the dates of these pulses vary from year-to-year (Moore et al. 1989; Miller et al. 2002). Furthermore, sighting rates of bowhead whales migrating through the Beaufort Sea are higher in deeper water in years of heavy ice cover than in years with light ice cover (Ljungblad et al. 1986; Treacy et al. 2006). Therefore, the assessment of the impact of drilling activities on bowhead whales must also account for the natural variability inherent in the timing and location of the migration within (and in longer term studies, between) years.

The only other cetacean that regularly occurs in the Central Alaskan Beaufort Sea is the beluga or white whale. Beluga whales may also be affected by drilling activities in nearshore waters. They are odontocetes or toothed whales and most toothed whales have their greatest hearing sensitivity at frequencies much higher than that of baleen whales, and so, they may be less responsive to low-frequency sound commonly associated with industry activities than baleen whales such as bowheads. In addition, belugas tend to migrate farther offshore than bowheads (Miller et al. 1999; Christie et al. 2010; Brandon et al. 2011) and so fewer belugas would be expected to encounter drilling operations during their fall migration in the Central Alaskan Beaufort Sea.

Richardson et al. (1995b) reported that beluga whales did not show any apparent reaction to playbacks of underwater drilling sounds at distances greater than 656-1,312 ft (200-400 m). Reactions included slowing down, milling, or reversal of course after which the whales continued past the projector, sometimes within 164-328 ft (50-100 m). The authors concluded (based on a small sample size) that playbacks of drilling sound had no biologically significant effects on migration routes of beluga whales migrating through pack ice and along the seaward side of the nearshore lead east of Pt. Barrow in spring. Their responses to vessels associated with the drilling operation may be greater than responses to the drill ship. Miller et al. (2005) saw few belugas near seismic operations in the Canadian Beaufort Sea although bowheads were commonly seen. Finley et al. (1990) reported that belugas fled from approaching icebreakers at distances between 20 and 80 km but in other situations belugas have been seen within a few meters of commercial fishing vessels (Frost et al. 1984), so reactions to vessels may depend on the activity of the whales and their exposure history to the vessels in question.

Objectives

The objectives of the 2012 Beaufort aerial survey program were to:

- Collect and report information on the distribution, abundance, direction of travel, and activities of marine mammals near the drilling operations with special emphasis on bowhead whales;
- Support regulatory reporting related to the estimation of impacts of drilling operations on marine mammals;
- Document the extent, duration, and location of any bowhead whale deflections in response to drilling activities.

Methods

Study Area and Data Stratification

Beaufort aerial surveys in 2012 were focused around the Sivulliq drill site in the Central Beaufort Sea (Fig. 8.1). In response to the NMFS Peer Review process, a pre-season power analysis was performed to investigate the ability of the proposed survey design (uniform transect spacing) to detect potential changes in bowhead density around drilling activities, and assess alternative designs if such would increase the power of the survey in this regard. The results of that power analysis suggested that the probability of detecting potential effects (all else being equal) was maximized as the spacing between transect lines around drilling activities was minimized. In other words, the power of the survey was maximized by maximizing the length of transect line in the anticipated area of potential effect.

Given the results from previous studies, which suggest some bowheads may deflect around drilling operations at 20+ km, an intensive 60 km x 60 km effort grid, centered over the drill site, was implemented. The spacing between lines in this grid was 6 km, which was deemed an acceptable distance without risk of double counting animals between successive lines. The total track-line in the survey area was 1300 km (808 mi), which if conditions were ideal, could be surveyed in one day given a second flight after re-fueling. The spacing of the outer lines was 10 km, and the line length was equal between the intensive and outer grids (i.e. 650 km (404 mi) of transect line in each grid).

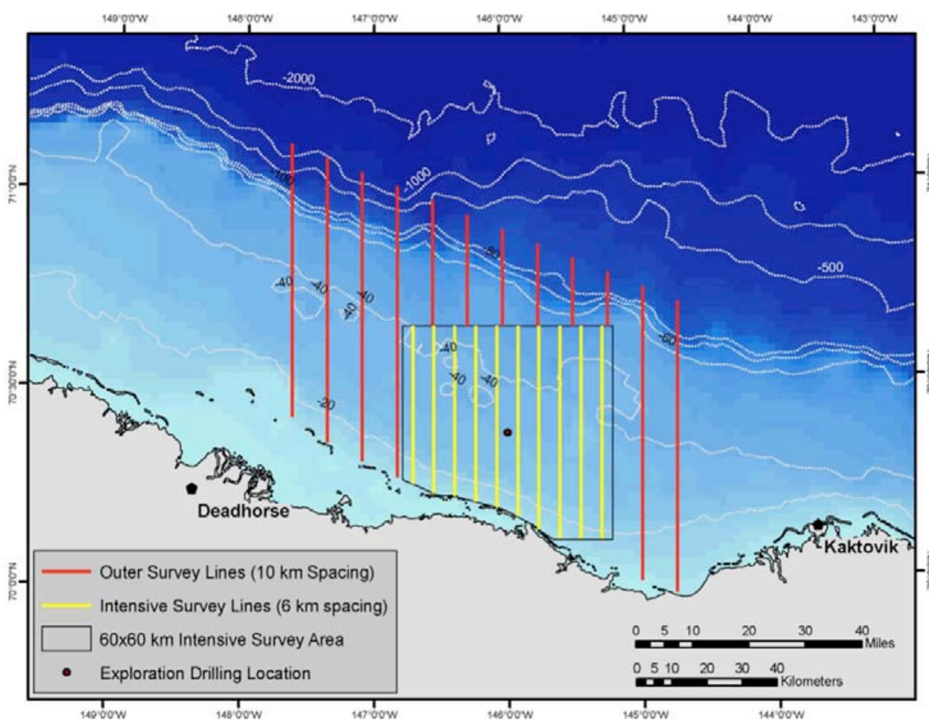

FIGURE 8.1. Aerial survey sub-areas (outer and intensive grids) and transect lines (red and yellow, respectively) in the Alaskan Beaufort Sea surveyed during 15 Aug - 3 Nov 2012. The Shell exploratory drilling location, located in the center of the survey area, is also shown.

Aerial surveys were conducted during 15 Aug to 3 Nov 2012. The survey design consisted of 10 transects in the intensive grid, and 12 transects in the outer grid. The intensive grid transects had an average length of 53 km (33 mi), and the outer grid transects ranged from 15 km (9 mi) to 82 km (51 mi). The total length of all transect lines combined was 1300 km (808 mi), and the total survey area was of 16,907 km^2 (6,528 mi^2; Fig. 8.1).

Survey Procedures

Surveys were conducted in a DHC–300 Twin Otter aircraft, operated by Bald Mountain Air. The aircraft was specially modified for survey work including upgraded engines, a STOL kit to allow safer flight at low speeds, wing–tip fuel tanks, multiple GPS navigation systems, bubble windows for primary observers, and 110 V AC power for survey equipment. During periods of non-whaling, surveys were conducted at an altitude of 305 m (1000 ft) above sea level. During the Nuiqsut and Kaktovik whaling seasons (the 'whaling black-out') surveys were flown at 457 m (1500 ft) in order to avoid any potential disruption of whaling activities. Likewise, during the whaling black-out, the survey area was limited to exclude the two most western outer transect lines, given that area overlaps the eastern extent of whaling trips from Cross Island during recent years (Galginaitis 2010). All surveys were flown at a groundspeed of approximately 204 km/hr (110 knots). Fuel capacity and weather conditions determined flight duration.

Two primary observers and up to two secondary observers sat at bubble windows on opposite sides of the aircraft and scanned the water within approximately 2 km (1.2 mi) of the aircraft for marine mammals. When a marine mammal was sighted, observers dictated into a digital voice recorder the species, number of individuals sighted, sighting cue, age class (when determinable), activity, heading, swimming speed category (if relevant), and inclinometer reading. The inclinometer reading was recorded when the animal's location was perpendicular to the path of the aircraft, allowing calculation of lateral distance from the aircraft trackline. A GPS position was also marked at this time by the computer operator (see *Data Recording* below).

In addition to marine mammal sightings, each observer recorded the time, sightability (subjectively classified as excellent, good, moderately impaired, seriously impaired, or impossible), sea state conditions (Beaufort wind force), ice cover (percentage), and sun glare (none, little, moderate, or severe) at 2–min intervals along transects, and at the end of each transect. These provided data in units suitable for statistical summaries and analyses of effects of these variables on the probability of detecting animals (see Davis et al. 1982; Miller et al. 1999; Thomas et al. 2002).

Data Recording

An additional observer onboard the aircraft (the data recorder) entered data from primary and secondary observers into a laptop computer and also searched for marine mammals during periods when data entry was not necessary. The data recorder entered transect starts and stops, 2–min intervals at which environmental data were collected, and sightings into the GPS–linked laptop. These data and additional details about environmental variables and each sighting were simultaneously recorded on digital voice recorders by the primary observers for backup, validation, and later entry of additional details about the sightings into the survey database. At the start of each transect, the data recorder also entered the transect start time, ceiling height (ft), cloud cover (%), wind speed (kt), and outside air temperature (°C). *PSOTracker*, a proprietary software package designed to streamline data collection and data QA/QC was used to automatically record time and aircraft position at pre–selected intervals (typically every two seconds for straight–line transect surveys) and for all entries noted above (i.e., start, stop, each 2-min interval) for later calculation and analysis of survey effort.

Analyses of Aerial Survey Data

On–Transect Sightings and Effort

Environmental factors such as sea conditions, low clouds, and glare can affect an observer's ability to see marine mammals during aerial surveys and bias results if not accounted for during analysis. To minimize bias, environmental data were used to classify sightings and effort as on–transect or other for quantitative analyses. Sightings and effort were considered on–transect when the following criteria were met: the animal was sighted while the aircraft was flying a pre–established north–south oriented transect, Beaufort wind force was 4 or less (winds 20–30 km/h; 11–16 kt), glare covered 30% or less of the viewing field, and overall sightability was described as excellent to moderately impaired. Pinnipeds were only visible during optimal sightability conditions and were difficult to identify to species (especially from a survey altitude of 457 m (1500ft), at which the majority of surveys were flown); therefore, no in–depth analyses of pinniped data were conducted.

Drilling Activity State

Broadly, there were four drilling activity states during the course of the aerial survey season: pre-drilling, anchor-handling, drilling and post-drilling. There were two potential survey days during the anchor-handling period (26-27 Sep); however, due to weather conditions there were no aerial surveys during that time. Likewise, due to weather, there was only very limited survey effort (one short flight) after drilling operations had ended. Therefore, it was only possible to compare data between the pre-drilling and drilling time-periods. Sighting rates between pre-drilling and drilling were compared using a Chi-square test for goodness-of-fit.

Mapping

Sightings made during aerial surveys were mapped using ArcMap 10.1 (ESRI 2011) and coded with different symbols to indicate drilling state and species. Each symbol represented one sighting, regardless of the number of individuals recorded within that sighting. We emphasized sightings rather than individuals for analyses because sightings were statistically independent, whereas a tally of individuals would include groups of individuals that were not independent of one another. In addition, bowheads often travel alone or in pairs and average group sizes seen during previous offshore aerial surveys of the Beaufort Sea have not been higher than 1.5 (e.g., Christie et al. 2010).

Abundance and Density

Bowhead and beluga whale densities and abundances were calculated using DISTANCE software (Thomas et al. 2006) for each survey if effort was greater than 250 km (155 mi). Detection functions were allowed to differ by survey altitude (where survey altitude was either 305 m (1000 ft) or 457 m (1500 ft)), and the effective strip widths for each altitude (the inverse of $f(0)$) were calculated by pooling available sightings across surveys at each altitude.

There were not enough beluga sightings in 2012 to robustly estimate a detection function; hence sightings data were augmented by sightings data from 2007 and 2008 (Thomas et al. 2010, Christie et al. 2010). Corrections for groups that were on or near to the trackline but unavailable for detection by observers, $g(0)$ values, were based on previous research (bowhead whales $g(0) = 0.144$, Thomas et al. 2002; beluga whales $g(0) = 0.58$, Martin and Smith 1992). In addition, right truncation distances were calculated by excluding sightings where the detection probability was <0.10. Left truncation distances were set at 100 m (328 ft) for belugas after a preliminary visual inspection of the perpendicular sightings data indicated that these animals had a lower detection probability below the aircraft. Excluding those beluga sightings led to a more desirable shape for the detection function, i.e. one that did not violate the assumptions of the line transect analyses. Several models were investigated for the detection functions, and the results from the most parsimonious model, with the lowest Akaike's Information Criterion (AIC, Burnham and Anderson, 1998), were selected.

Spatial differences

To assess potential differences in the distribution of animals relative to drilling activity, effort and sightings data were divided into 5–km distance-from-shore bins, with a “0-km from shore” line approximating the shoreline or the outer edge of the barrier islands. To assess any offshore deflections, sighting rates were computed within each of these bins and plotted by drilling state and survey strata (i.e. intensive vs. outer grid).

Sightings data were also divided into 5–m depth bins and plotted to investigate patterns in distribution relative to water depth. Because distance from shore and depth are strongly correlated, we would expect that patterns in sighting rates by depth would be similar to those observed for distance from shore.

Distribution Relative to the Drill Site

The distance from cetacean sightings to the drill site was calculated in R, using the library ‘geosphere’. These distances were compared using the non–parametric Mann-Whitney U test to determine whether average distance from the drill site differed among drilling states.

Headings, Activities, and Speed

Headings were plotted by survey sub-area and drilling state, and circular-median and –standard deviations were calculated in R using the ‘circular’ library. Speeds and headings were assessed only for whales observed to be either traveling or swimming. If possible, behavior (movements or processes in which an animal is engaged) and activity (a collection of behaviors that indicate the animal is working toward an overall goal such as migrating) were recorded for each sighting. Behaviors included swimming, diving, surface active (flipper or fluke slaps, splashing, etc.); whereas activities included feeding, traveling, socializing, resting, and milling. Due to the limited time period for which an animal was observed, it was not always possible to determine the behavior, activity, speed, and/or heading; as a result, often only a subset of this information was collected.

Results

Survey effort

Aerial surveys were flown over the Alaskan Beaufort Sea from 15 Aug through 3 Nov 2012 (Fig 8.2); a total of 9112 km (5662 mi) of effort was obtained during 24 surveys. Survey effort ranged from 26 km (16 mi) to 773 km (480 mi) per survey.

The pre–drilling survey period comprised approximately sixty percent of the total survey effort (5538 km of effort; 3441 mi) and lasted until 2 Oct. The drilling period occurred from 3 Oct through 28 Oct (Fig. 8.2), and 3480 km (2162 mi) of survey effort was achieved during this time. One abbreviated survey flight was attempted post-drilling, but only 94 km (58 mi) of useable effort was flown during this period due to poor weather.

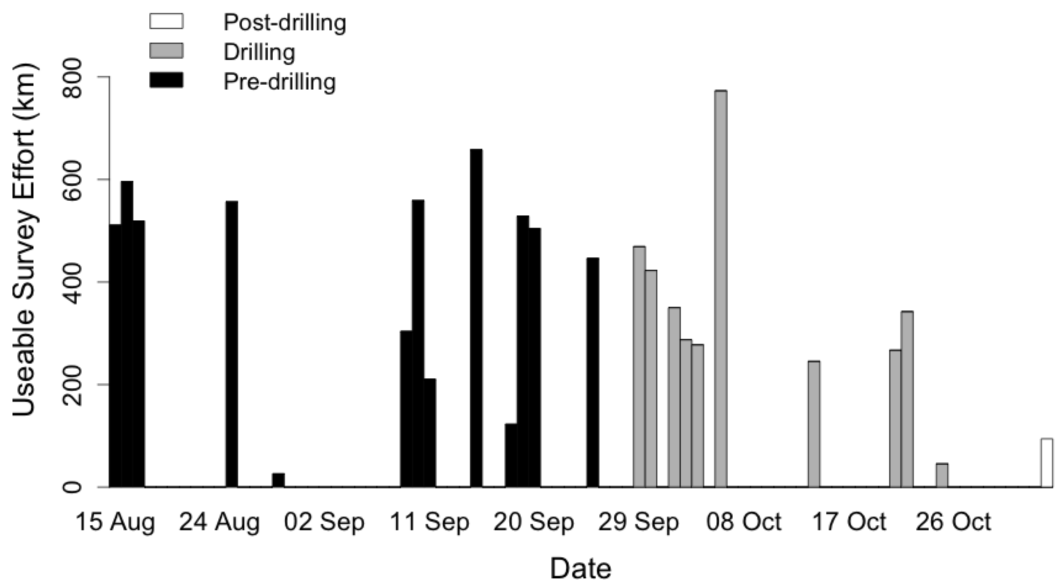

FIGURE 8.2. Daily aerial survey effort by drilling status during 15 Aug - 3 Nov 2012.

When assessed by 5–km (3–mi) distance-from-shore bins, survey effort was highest in the 20–25 km (12–16 mi) from shore bin (Fig. 8.3). In general, effort was uniformly high between 10 km (34 mi) and 50 km (31 mi) offshore and dropped off on either side of those distances (Fig. 8.3).

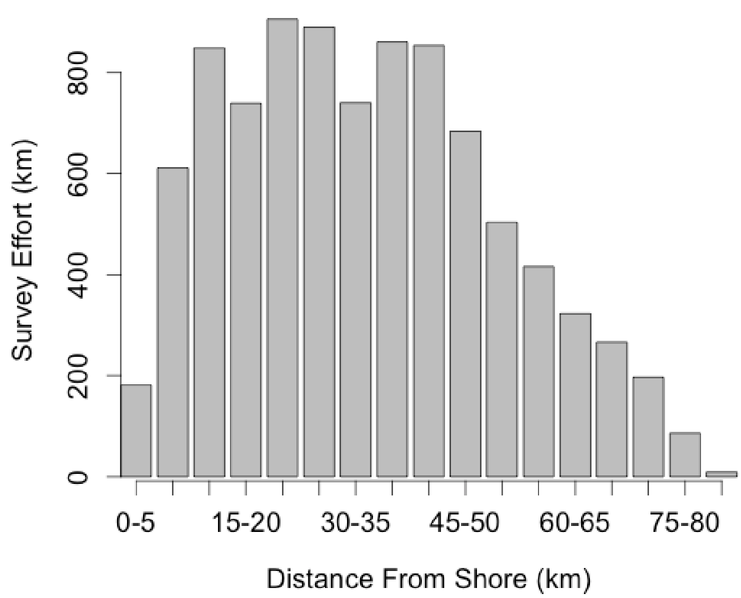

FIGURE 8.3. Aerial survey effort by 5–km distance-from-shore bins during 15 Aug - 3 Nov 2012.

Among survey sub-areas, effort during pre-drilling was higher in the intensive grid 3895 km (2420 mi) than the outer grid 1970 km (1224 mi). In part this was due to the fact that the two most western transect lines (Fig. 8.1) were not flown during the whaling black-out (to avoid the potential for disturbing whaling at Cross Island), and the whaling black-out overlapped with the majority of the pre-drilling survey period. During drilling, the effort between survey sub-areas was roughly equivalent: 1643 km (1021 mi) for the intensive vs. 1510 km (938 mi) for the outer. Table 8.1 summarizes on-transect survey effort (and bowhead whale sightings) by survey sub-area and drilling state, and spatial effort is shown by drilling state in Fig. 8.4 and Fig. 8.5.

Bowhead Whales

***Sightings and Sighting Rates*—**A total of 57 bowhead whale sightings (67 individual whales) was recorded during Shell's aerial surveys in the Beaufort in 2012 (Figs. 8.4 and 8.5). However, only 32 of these sightings (39 individuals) were recorded on–transect in acceptable sightability conditions (Table 8.1) and were used in the following analyses and discussion. Bowhead whales were observed on 50% of surveys and the overall sighting rate was 3.5 sightings/1000 km (5.7 sightings/1000 mi). Sighting rates ranged from 0–15 sightings/1000 km (0–24 sightings/1000 mi) and 0-16 individuals/1000 km (0–26 individuals/1000 mi). Bowhead whale sighting rates were consistently highest during the second and third weeks in Sep, although, the highest daily sighting rate occurred during a later pulse in the migration on 21 Oct, when the sighting rate was 15 sightings/1000 km (24 sightings/1000 mi).

TABLE 8.1. Survey effort, bowhead whale sightings, and bowhead whale sighting rates during aerial surveys in the Beaufort Sea: 15 Aug - 3 Nov 2012.

		Pre-Drilling	Drilling	Post-Drilling	Total or Average
Intensive	Effort (km)	3895	1970	47	5912
	Sightings	19	3	0	22
	Individuals	26	3	0	29
	Sightings / 1000km	4.9	1.5	0	3.7
	Individuals / 1000 km	6.7	1.5	0	4.9
Outer	Effort (km)	1643	1510	47	3201
	Sightings	5	5	0	10
	Individuals	5	5	0	10
	Sightings / 1000km	3.0	3.3	0	3.1
	Individuals / 1000 km	3.0	3.3	0	3.1
Both Areas	Effort (km)	5538	3480	94	9112
	Sightings	24	8	0	32
	Individuals	31	8	0	39
	Sightings / 1000km	4.3	2.3	0.0	3.5
	Individuals / 1000 km	5.6	2.3	0.0	4.3

Overall bowhead whale sighting rates (taken over both the intensive and outer grid) were higher during the pre-drilling period (4.3 sightings/1000 km; 7 sightings/1000 mi) than during drilling (2.3 sightings/1000 km; 3.7 sightings/1000 mi; Table 8.1). But, the difference between observed and expected sighting rates was not statistically significant (Chi–square test, $p = 0.114$, Table 8.2).

Taking into account sightings and effort during drilling only, sighting rates were higher in the outer grid (3.3 sightings/1000 km; 5.4 sightings/1000 mi) than the intensive grid (1.5 sightings/1000 km; 2.5 sightings/1000 mi; Table 8.1). But again, the difference between observed sightings in each sub-area was not statistically different than would be expected by chance (Chi–square test, $p = 0.275$, Table 8.3).

Table 8.2. Chi–square test comparing differences in the number of bowhead whale sightings by drilling status.

Drilling Status	Pre-Drilling	Drilling	X^2	One-tailed *p*-value
Sightings (obs.)	24	8	2.493	0.114
Sightings (exp.)	20	12		
Effort (km)	5538	3480		

Table 8.3. Chi–square test comparing differences in the number of bowhead sightings by spatial strata during drilling.

Area During Drilling	Intensive	Outer	X^2	One-tailed *p*-value
Sightings (obs.)	3	5	1.189	0.275
Sightings (exp.)	4.5	3.5		
Effort (km)	1970	1510		

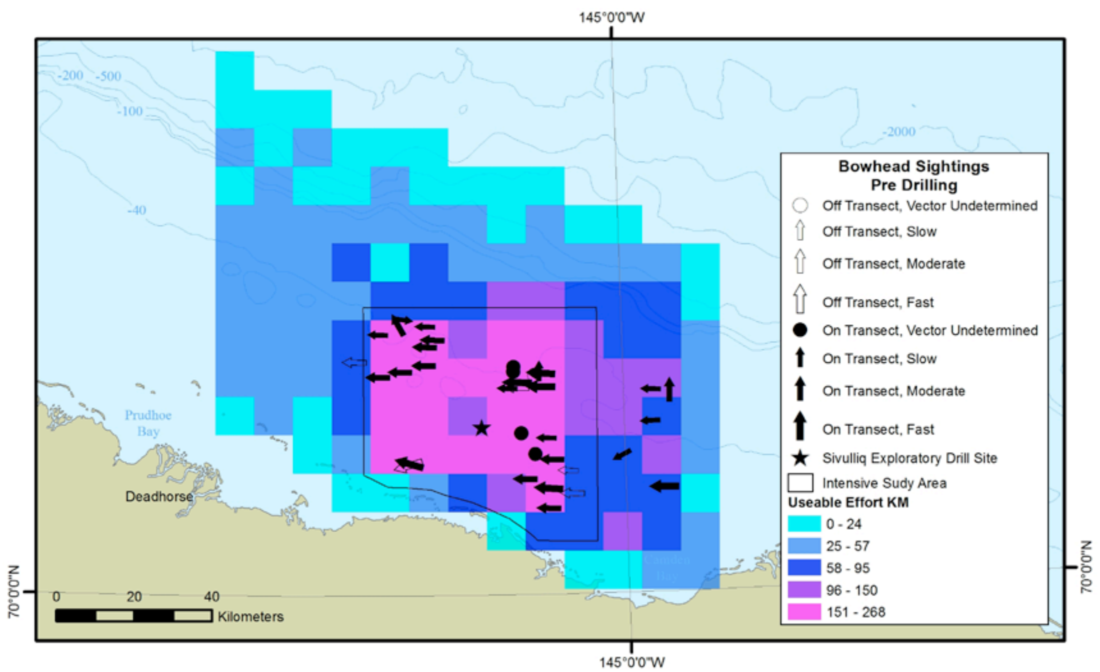

FIGURE 8.4. Aerial survey effort and bowhead whale sightings during the pre-drilling period (i.e. prior to anchor handling) 15 Aug - 25 Sep 2012. Off-transect sightings are shown for reference. Vector arrows correspond with recorded headings of sightings and have lengths proportional to the swim speed recorded for each sighting (slow, moderate or fast). Darker grid cells correspond to areas with more useable survey effort. The Shell exploratory drill location is also plotted for reference.

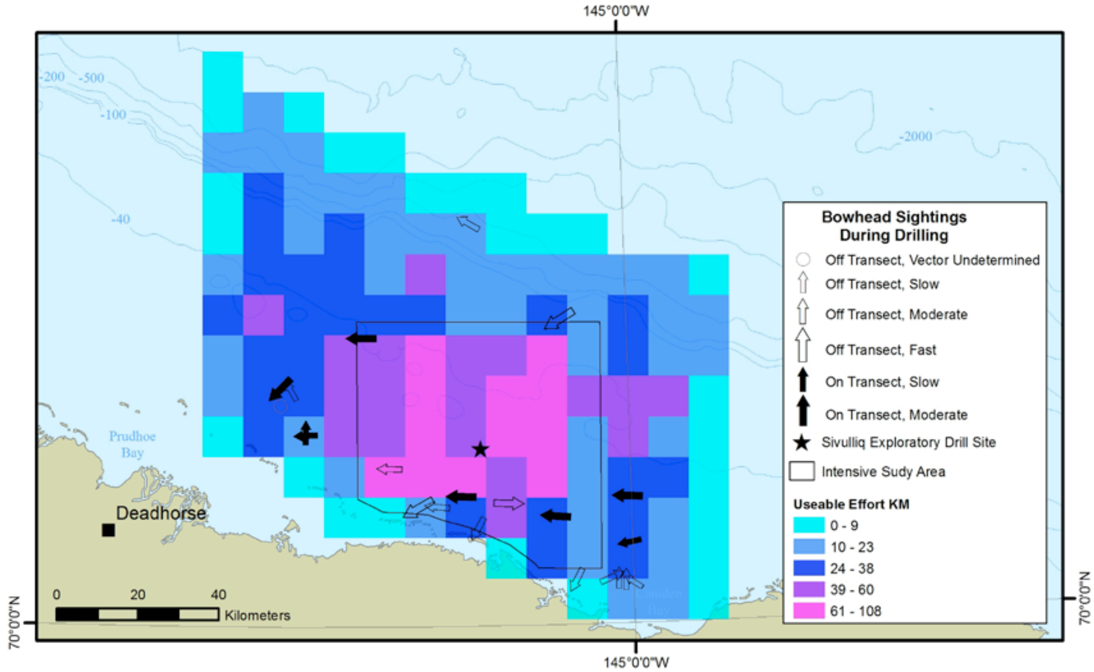

FIGURE 8.5. Aerial survey effort and bowhead whale sightings during the drilling period 28 Sep to 31 Oct 2012. Otherwise as per Fig 8.4 above, except that sightings and effort are shown for the drilling period.

TABLE 8.4. Summary of aerial survey effort, sighting rates and estimated numbers of bowhead whales in the Beaufort survey area during 15 Aug - 3 Nov 2012. Sighting rates etc. were not calculated ("NC") when effort for an individual survey was less than 250 km (155 mi). Estimates were obtained using DISTANCE software for each individual survey. Estimates include allowance for *f*(0) (as calculated by DISTANCE – see results under Abundance and Density) and *g*(0) (value of 0.144 from Thomas et al. 2002).

Date	Survey Number	Altitude (m)	Effort (km)	Drilling Status	Sightings	Individuals	Sightings / 1000 km	Individuals / 1000 km	Density (No. / 1000 km^2)	Est. No. Whales	Lower CI	Upper CI
15-Aug	1	305	511	Pre-Drilling	0	0	0.0	0	0	0		
16-Aug	2	305	596	Pre-Drilling	0	0	0.0	0	0	0		
17-Aug	3	305	519	Pre-Drilling	0	0	0.0	0	0	0		
25-Aug	4	457	556	Pre-Drilling	4	5	7.2	9	38	641	187	2196
29-Aug	5	457	26	Pre-Drilling	0	0	0.0	0	NC	NC		
9-Sep	6	457	303	Pre-Drilling	1	1	3.3	3.3	14	235	36	1543
10-Sep	7	457	559	Pre-Drilling	2	4	3.6	7.2	30	510	86	3030
11-Sep	8	457	210	Pre-Drilling	3	3	14.3	14.3	NC	NC		
15-Sep	9	457	658	Pre-Drilling	3	3	4.6	4.6	12	217	57	823
18-Sep	10	457	122	Pre-Drilling	1	2	8.2	16.4	NC	NC		
19-Sep	11	457	528	Pre-Drilling	2	2	3.8	3.8	16	270	75	973
20-Sep	12	457	504	Pre-Drilling	3	5	6.0	9.9	17	283	68	1169
25-Sep	13	457	446	Pre-Drilling	5	6	11.2	13.5	47	799	245	2607
29-Sep	14	457	469	Pre-Drilling	0	0	0.0	0	0	0		
30-Sep	15	457	422	Pre-Drilling	0	0	0.0	0	0	0		
2-Oct	16	457	350	Pre-Drilling	0	0	0.0	0	0	0		
3-Oct	17	457	288	Drilling	0	0	0.0	0	0	0		
4-Oct	18	305	278	Drilling	0	0	0.0	0	0	0		
6-Oct	19	305	773	Drilling	3	3	3.9	3.9	18	309	107	889
14-Oct	20	305	245	Drilling	0	0	0.0	0	NC	NC		
21-Oct	21	305	267	Drilling	4	4	15.0	15	70	1194	379	3758
22-Oct	22	305	342	Drilling	1	1	2.9	2.9	14	233	41	1309
25-Oct	23	305	45	Drilling	0	0	0.0	0	NC	NC		
3-Nov	24	305	94	Post-Drilling	0	0	0.0	0	NC	NC		
Total/Average	**24**		**9112**		**32**	**39**	**3.5**	**4.3**				

Abundance and Density—The estimated effective strip (half) widths for the detection curves were 824 m (0.51 mi) (SE = 115.16 m; 0.072 mi) and 737 m (0.46 mi) (SE = 75.66 m; 0.047 mi) for surveys flown at 1500 and 1000 ft respectively. These estimates correspond with *f*(0) values of 0.0012 (SE = 0.0001697) and 0.001356 (SE = 0.0001393). Estimated daily numbers of bowheads present within the Beaufort aerial survey area ranged from 0 to 1194, with relatively consistent numbers through much of Sep, and a later peak observed at around the middle Oct. Peak numbers (excluding those survey days with insufficient effort) were estimated on 25 Aug (641 whales), 25 Sep (799 whales) and 21 Oct (1194 whales) (Table 8.4).

Distance from Shore—Peak sighting rates occurred in the intensive grid during the pre-drilling period, and were 35-40 km (37–40 mi) from shore (Fig. 8.6, top panel). During drilling, the highest sighting rates in the intensive grid were at distances between 5-15 km (3-9 mi). In the outer grid, sighting rates were highest during drilling, with a peak between 15-20 km (9–12 mi) (Fig. 8.6, middle panel). During the pre-drilling period, highest sighting rates were seen in water depths >30 m, whereas during the drilling period, highest sighting rates were seen in water depths < 30 m

When sighting rates were combined across sub-areas, sighting rates during the pre-drilling period peaked at 35-40 km (37–40 mi) from shore (Fig. 8.4). During drilling, the highest sighting rates were between 5-20 km (3-7 mi) from shore (Fig. 8.6, bottom panel; Fig. 8.5).

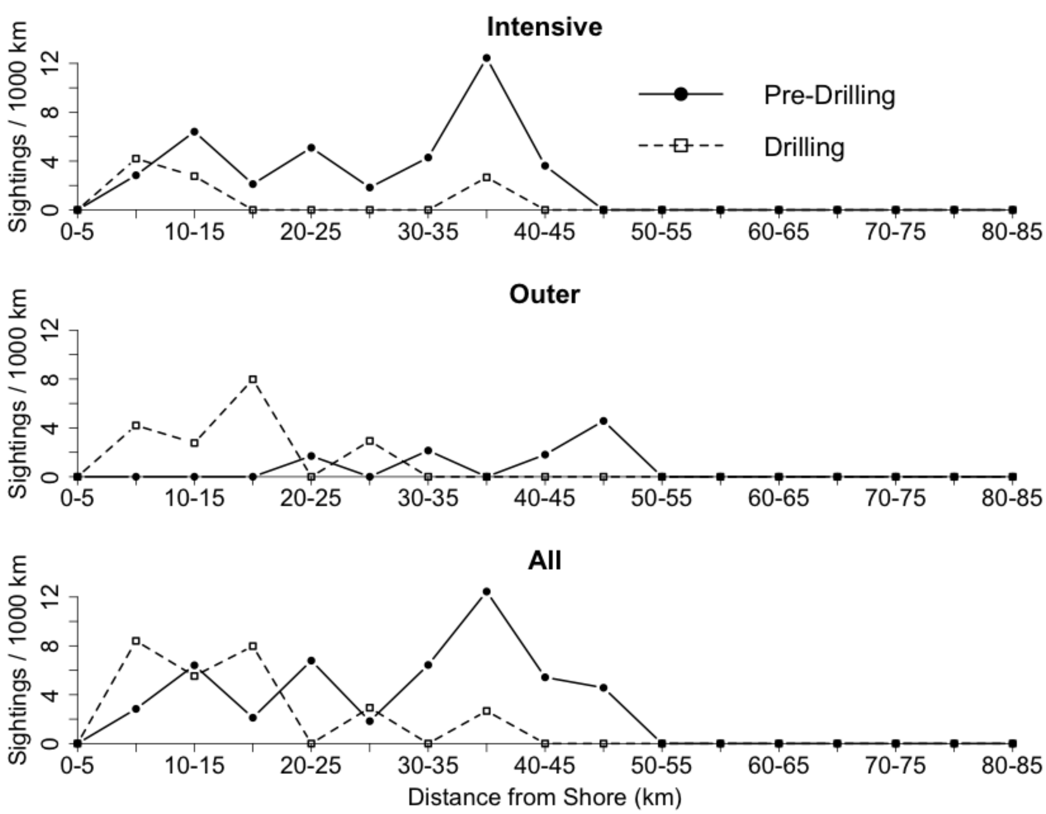

FIGURE 8.6. Bowhead whale sighting rates by distances from shore, drilling states and survey sub-areas are shown. The bottom plot shows those rates calculated over the entire survey area. No sightings were made during post-drilling and there was no survey effort during the anchor handling period.

Water Depth—Observed water depth where bowhead whales were sighted varied from 20 to 50 m (65 to 164 ft). No sightings were made in water less than 20 m (65 ft) deep. During the pre-drilling period, the distribution of sighting depth was bi-model, with a first peak at 25-30 m (82-98 ft) and a second larger peak in sightings made in 35-45 m (115-148 ft) of water. On the other hand, the distribution of sightings-at-depth during drilling was unimodal, and those sightings occurred in a more shallow and tighter range of water depths, between 20-40 m (65- 131 ft; Fig. 8.7)

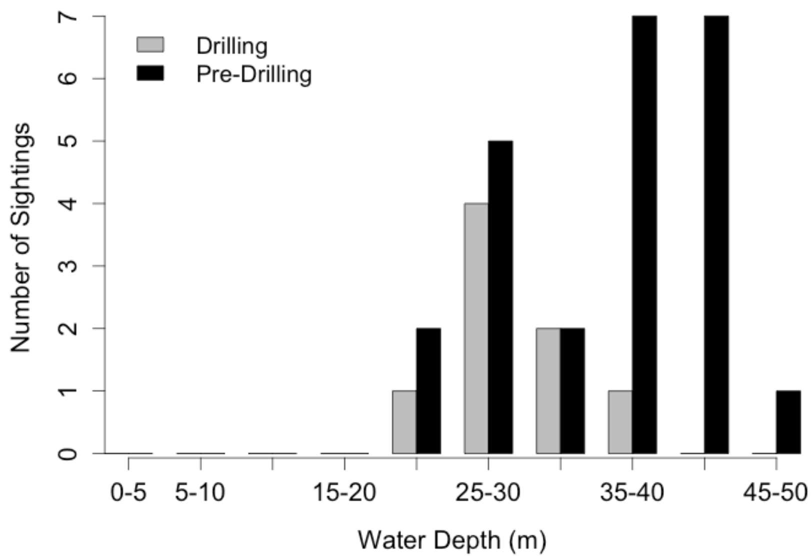

FIGURE 8.7. Number of bowhead whale sightings at 5–m (16–ft)) water depth intervals during aerial surveys during 15 Aug - 3 Nov 2012. Drilling status at the time of sightings is indicated by fill pattern.

Distribution Near The Drill Site Operations—The average distance from the drill-site during the pre-drilling period was less than that during drilling: 26.3 km (16.3 mi) vs. 40.2 km (25.0 mi). This difference between the distributions of sighting distances from the drill-site was statistically significant (Mann-Whitney U, $p = 0.014$; Table 8.5), and suggests that bowhead sightings were farther from the drill-site during drilling than they were during the pre-drilling period. It is important, however, to note that during the pre-drilling period the two transects farthest west from the drill site were often not flown to avoid disturbing whaling (compare the underlying spatial effort in Fig. 8.4 and Fig. 8.5).

Table 8.5. Minimum, maximum and mean distance (km) of bowhead whale sightings from the drill-site by drilling state in the Beaufort aerial survey area. The difference between the distance distributions during seismic and non-seismic periods was examined using the Mann-Whitney U test.

Drilling Status	Sightings n	Distance from Drill Site (km) Min.	Max.	Mean	Two-tailed *p*-value
Pre-Drilling	24	7.63	55.18	26.29	0.014
Drilling	8	24.26	51.39	40.22	

Activities**—**Specific activities were recorded for 23 out of the 32 on-transect bowhead whale sightings. All of these sightings were deemed to have been traveling.

Speed**—**Speeds were recorded for 29 out of the 32 on-transect bowhead whale sightings. Most observations of movement speed were of animals moving slowly or moderately (*n*=14). The most noticeable difference in recorded speeds between the pre-drilling and drilling periods, was that no sightings were recorded as moving fast during drilling (Fig. 6.9).

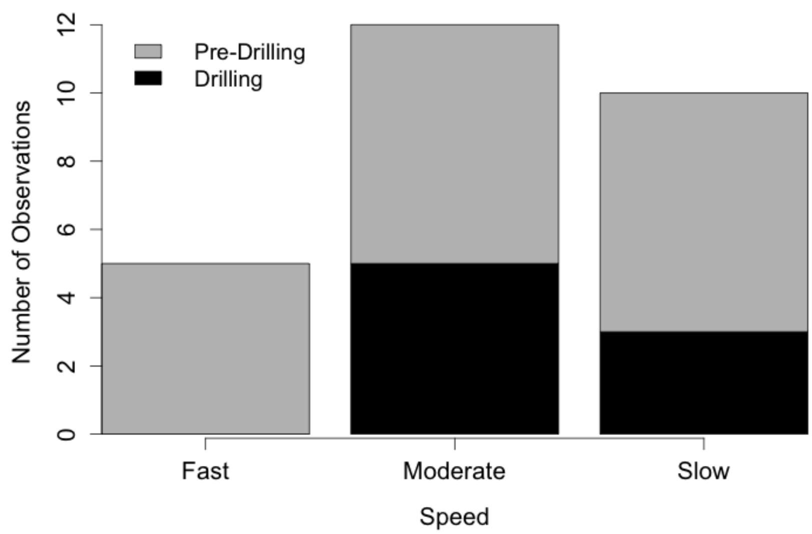

FIGURE 8.8. Observed speeds of bowhead whales sighted during aerial surveys during 15 Aug - 3 Nov 2012. Drilling status at the time of sighting is indicated.

Headings**—**Headings of 25 bowhead whales were recorded: 14 of which were sighted during the pre-drilling period in the intensive grid (median heading = 272ºT; circular SD = 7ºT; Fig. 8.9A), 3 during the pre-drilling period in the outer grid (mean heading = 267ºT; circular SD = 2ºT; Fig. 8.9B), 3 during drilling in the intensive grid (mean heading = 271ºT; circular SD = 0.25ºT; Fig. 8.9C), and 5 during drilling in the outer grid (mean heading = 267ºT; circular SD = 15ºT; ; Fig. 8.9D) which also corresponded to the most variable group of headings.

For all observations combined, the median heading was 271ºT, with a circular standard deviation of 3°T. In general, the vast majority of recorded headings were directed west and the variation in recorded headings was small.

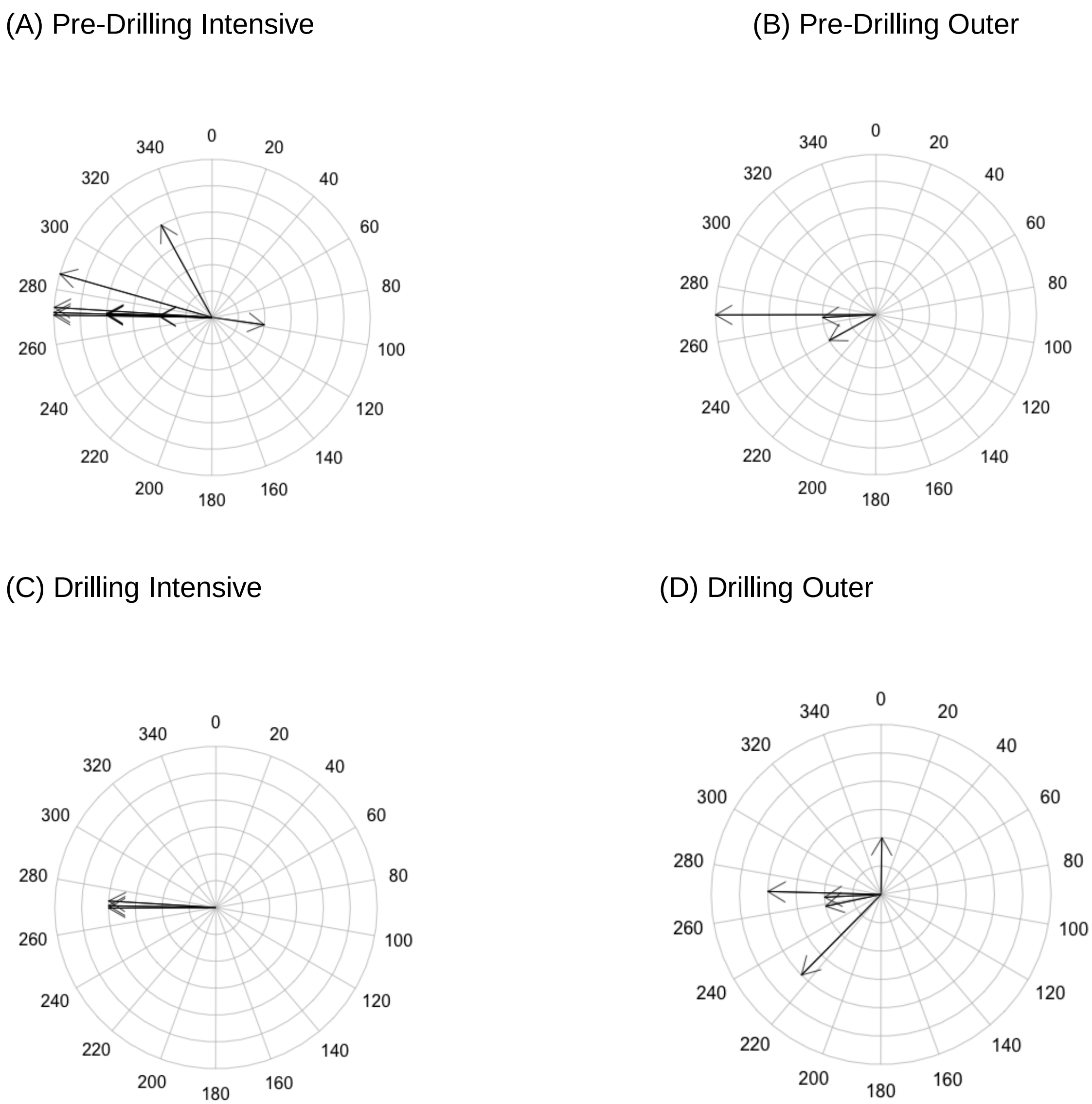

FIGURE 8.9. Headings of on-transect bowhead whales by sub-area and drilling status: (A) Pre-Drilling Intensive; (B) Pre-Drilling Outer; (C) Drilling Intensive, and; (D) Drilling Outer. Arrow lengths correspond with the estimated speed category for each sighting (slow, moderate or fast).

<u>*Beluga Whales*</u>

Sightings and Sighting Rates.—A total of 17 beluga whale sightings (96 individual whales) were recorded during aerial surveys in the Beaufort Sea (Fig. 8.10). Nine of these sightings (16 individuals) were recorded on–transect in acceptable sightability conditions (Table 8.6; see *Methods* for definitions of sightability and on–transect) and are used in the following analyses and discussion. Seven of the nine on-transect beluga whale sightings were made during 15 Aug to 15 Sep , with 44% of the surveys during this time period having at least one sighting (average sighting rate of 2.3 sightings/1000 km; 1.4/ 1000 mi). There was a temporal gap in sightings after 15 Sep, but beluga whales were sighted again on two surveys in mid-to-late Oct.

The estimated effective strip (half) widths for the detection curves were 824 m (0.51 mi) (SE = 115.16 m; 0.072 mi) and 737 m (0.46 mi) (SE = 75.66 m; 0.047 mi) for surveys flown at 1500 and 1000 ft respectively. These estimates correspond with *f*(0) values of 0.0012 (SE = 0.0001697) and 0.001356 (SE = 0.0001393).

Abundance and Density**—**The estimated effective strip (half) widths for the detection curves were 786 m (0.49 mi) (SE = 433.53 m; 0.27 mi) and 591 m (0.37 mi) (SE = 44.4 m; 0.028 mi) for surveys flown at 1500 and 1000 ft respectively. These estimates correspond with *f*(0) values of 0.00127 (SE = 0.000701) and 0.00169 (SE = 0.00013). Estimates of numbers of belugas in the Beaufort aerial survey area ranged from 0 to 233 individuals; corresponding densities ranged from 0 to 14 individuals/1000 km^2 (0 to 8.7 individuals/1000 mi^2, Table 8.6).

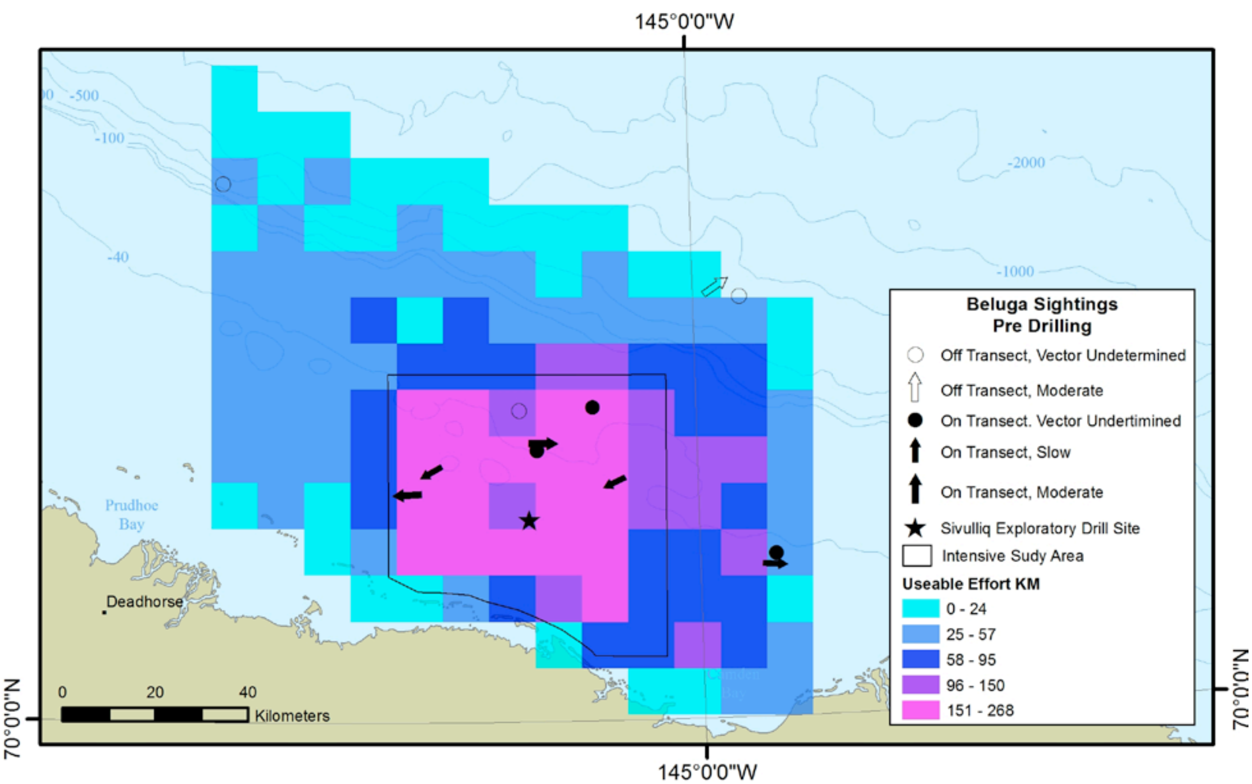

FIGURE 8.10. Beluga whale sightings and useable survey effort are shown during the pre-drilling period from 15 Aug to 25 Sep.

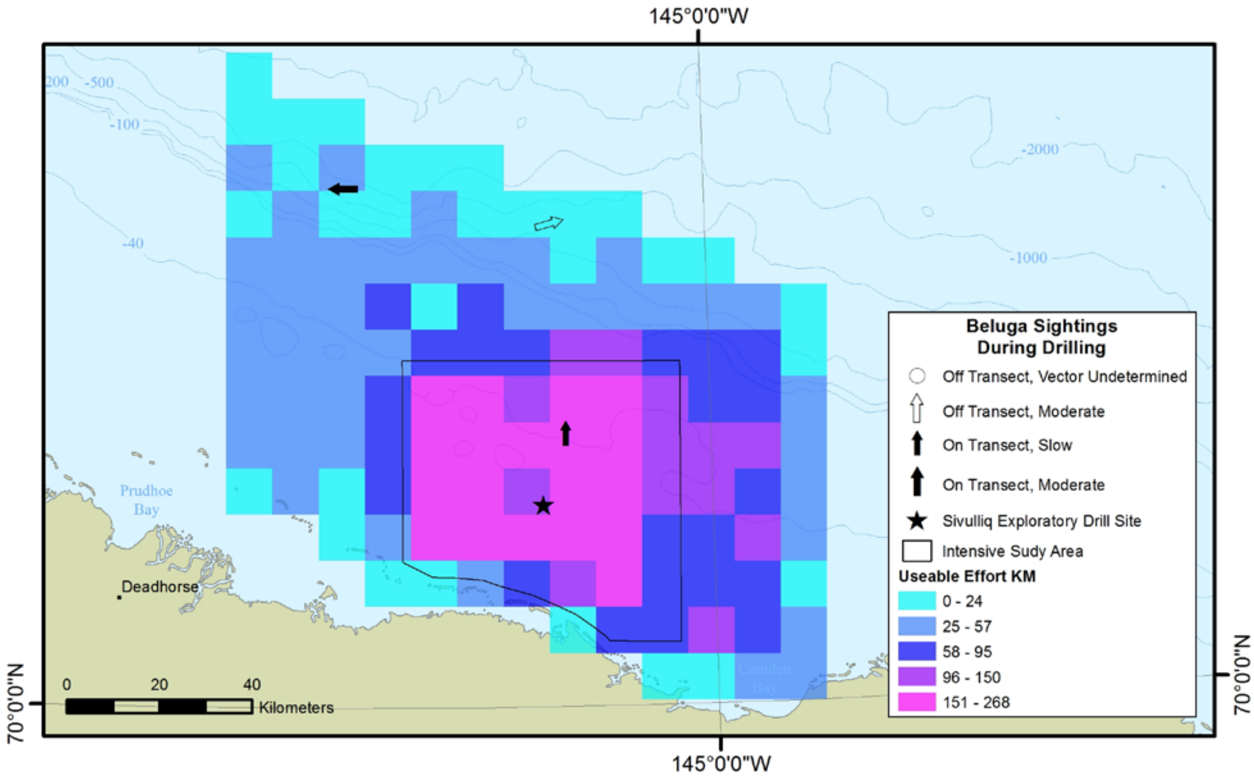

FIGURE 8.11. Beluga whale sightings and useable survey effort are shown during the drilling period from 28 Sep to 31 Oct.

Table 8.6. Estimated numbers of beluga whales in the Beaufort aerial survey area, 15 Aug through 3 Nov 2012. Estimates obtained using DISTANCE software for each individual survey. Estimates of densities and numbers were not calculated for daily survey effort < 250 km (155 mi). Estimates include allowance for *f*(0) (as calculated by DISTANCE – see results under Abundance and Density) and *g*(0) (value of 0.58 from Martin and Smith 1992).

Date	Survey Number	Altitude (m)	Effort (km)	Drilling Status	Sightings	Individuals	Sightings / 1000km	Individuals / 1000km	Density (No. / 1000 km^2)	Est. No. Whales	Lower CI	Upper CI
15-Aug	1	305	511	Pre-Drilling	0	0	0	0	0	0		
16-Aug	2	305	596	Pre-Drilling	0	0	0	0	0	0		
17-Aug	3	305	519	Pre-Drilling	1	4	1.9	7.7	11	191	29	1255
25-Aug	4	457	556	Pre-Drilling	4	7	7.2	12.6	14	233	50	1096
29-Aug	5	457	26	Pre-Drilling	0	0	0	0	NC	NC		
9-Sep	6	457	303	Pre-Drilling	0	0	0	0	0	0		
10-Sep	7	457	559	Pre-Drilling	1	1	1.8	1.8	2	33	5	225
11-Sep	8	457	210	Pre-Drilling	0	0	0	0	NC	NC		
15-Sep	9	457	658	Pre-Drilling	1	1	1.5	1.5	2	28	4	191
18-Sep	10	457	122	Pre-Drilling	0	0	0	0	NC	NC		
19-Sep	11	457	528	Pre-Drilling	0	0	0	0	0	0		
20-Sep	12	457	504	Pre-Drilling	0	0	0	0	0	0		
25-Sep	13	457	446	Pre-Drilling	0	0	0	0	0	0		
29-Sep	14	457	469	Pre-Drilling	0	0	0	0	0	0		
30-Sep	15	457	422	Pre-Drilling	0	0	0	0	0	0		
2-Oct	16	457	350	Pre-Drilling	0	0	0	0	0	0		
3-Oct	17	457	288	Drilling	0	0	0	0	0	0		
4-Oct	18	305	278	Drilling	0	0	0	0	0	0		
6-Oct	19	305	773	Drilling	0	0	0	0	0	0		
14-Oct	20	305	245	Drilling	1	1	4.1	4.1	NC	NC		
21-Oct	21	305	267	Drilling	0	0	0	0	0	0		
22-Oct	22	305	342	Drilling	1	2	2.9	5.8	8	146	23	900
25-Oct	23	305	45	Drilling	0	0	0	0	NC	NC		
3-Nov	24	305	94	Post-Drilling	0	0	0	0	NC	NC		
Total/Average			**9112**		**9**	**16**	**1.0**	**1.8**				

***Distance from Shore and Depth*—**The peak sightings rate for beluga whales was observed at distances 60-65 km (37-40 mi) from shore (Fig. 8.12). The majority of sightings, however, occurred between 25-50 km (16-31 mi) from shore, at depths between 25-50 m (82-164 ft).

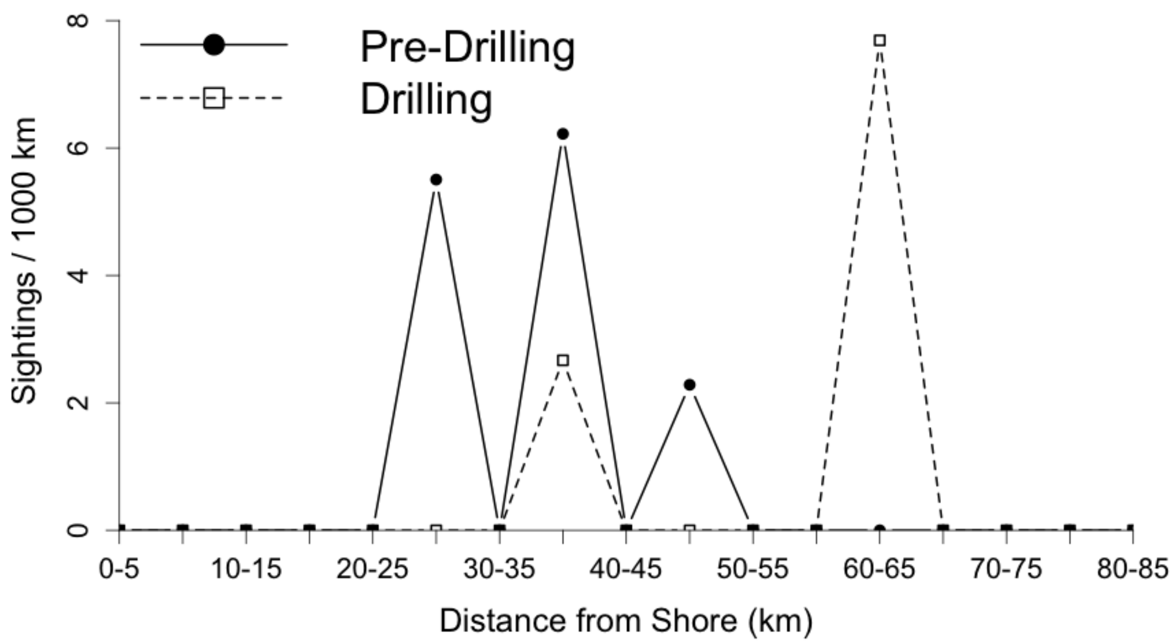

FIGURE 8.12. On-transect beluga sighting rates within 5–km distance-from-shore bins by drilling state during 15 Aug to 3 Nov.

***Activities and Speeds*—** Specific activities were recorded for five of the on-transect beluga whale sightings. Three sightings were of traveling whales and two sightings were recorded as milling. Whales classified as traveling or swimming moved at slow (three sightings) or moderate speeds (two sightings).

***Headings*—**The headings of beluga whales were examined for animals considered to be swimming or traveling. Headings of four beluga whales were recorded that met this criterion. Two of these recorded headings were westerly and two were easterly (Fig. 8.13). The easterly heading sightings were on 17 and 25 Aug, and the westerly recorded sightings were on 10 Sep and 14 Oct.

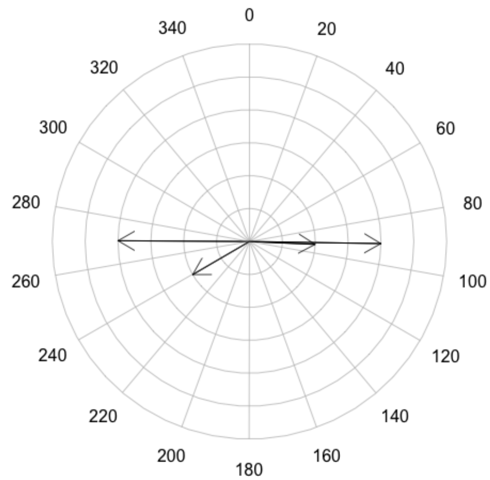

FIGURE 8.13. Headings of on-transect beluga whales sighted in the Beaufort survey area during 17 Aug to 14 Nov 2012.

Polar bears

Four on-transect polar bears sightings (7 individuals) were recorded in the Beaufort aerial survey area (Fig. 8.14). Two sightings were recorded during the pre–drilling period in the intensive grid, and there was one sighting in each sub-area (intensive and outer) during drilling. One of the sightings was a sow with two cubs, and all other sightings were single animals that were either adults or bears of undetermined age.

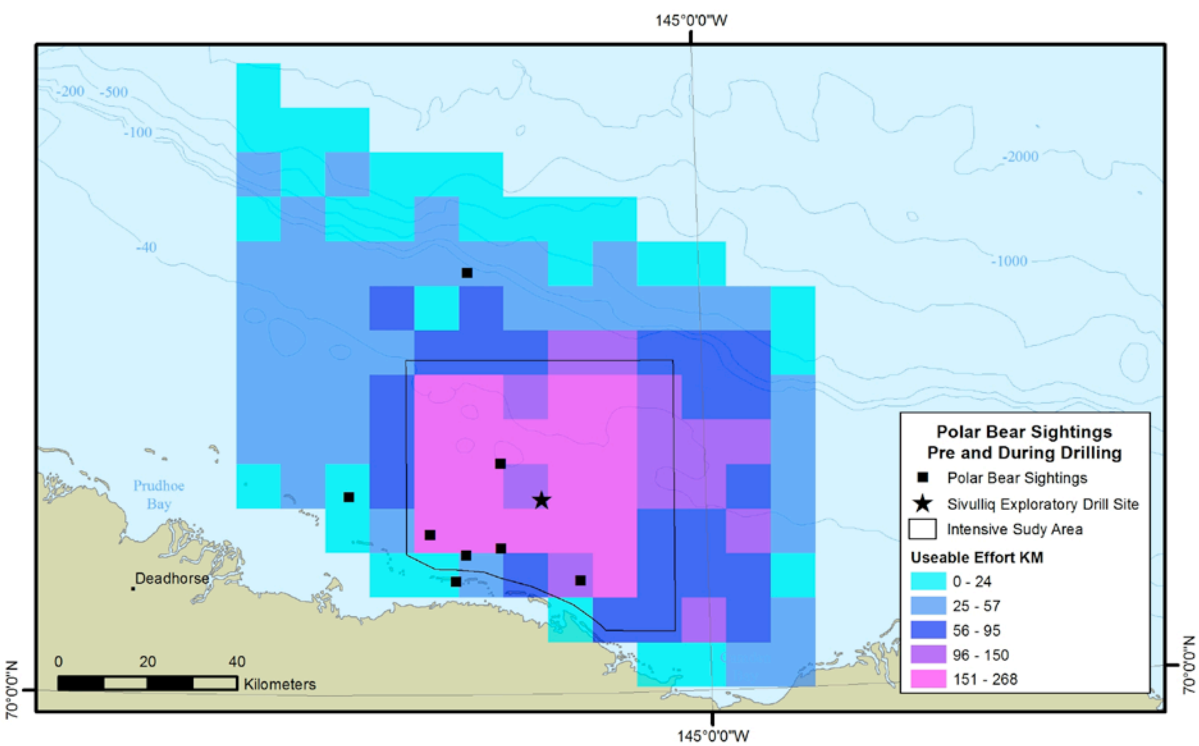

FIGURE 8.14. Polar bear (on- and off-transect) sightings during aerial surveys in the Beaufort Sea during 15 Aug - 3 Nov 2012.

Discussion

Observations of bowhead whales during Shell's 2012 aerial survey program in the central Beaufort Sea are consistent with the general pattern of the bowhead whale fall migration through this area. Peak sighting rates occurred during the middle of Sep, and whales were observed predominately traveling west, as would be expected by fall migrants. A more detailed discussion regarding bowhead whales specific to drilling operations is provided below, after consideration of the survey results for beluga whales and polar bears.

On-transect beluga sighting rates were highest in Sep during the pre-drilling period. Interestingly, the majority of beluga sightings during that period were sighted on the shelf (e.g. on-transect sightings were observed in depths between 25-50m; Fig 8.10 and 8.12). This pattern might be explained by the presence of sea-ice in the survey through late Aug, and an association between beluga whales and sea-ice when the majority of on-transect sightings during the pre-drilling period were made (i.e. 25 Aug). Unfortunately, there were too few sightings (n = 2) during the drilling period to make any meaningful comparisons regarding potential effects of industrial activities for this species. In general however, estimated densities were relatively low (Table 8.6), which is consistent with previous research indicating that a high percentage of migrating belugas in the central Beaufort Sea are likely to be at (and beyond) the northern edge of the survey area, i.e. along the slope or in deeper waters farther offshore (Treacy 1994; Richard et al. 1997, 1998).

The survey area was largely ice-free during Sep. During Oct new sea-ice started to develop and spread north from the barrier islands. Prior to this ice development, there were very few polar bear sightings (the transect lines avoided the barrier islands). Notably, there were two polar bears sighted swimming in open water offshore (23 km and 64 km, 14 and 40 mi from shore, during the pre-drilling and drilling periods respectively). But the majority of sightings can be seen in Fig. 8.14 to trace the developing near-shore ice later in the season.

Bowhead whales and drilling

A major goal of the 2012 Beaufort aerial survey effort was to provide a monitoring tool to address the question of potential effects of drilling activity on the bowhead migration through the study area. The stratified survey design was developed to maximize the power to detect potential spatial changes in bowhead whale density that could result from animals deflecting around drilling activity. To this end, the Chi-square test comparing observed versus expected sightings between the intensive and outer grid did not indicate a difference in the underlying densities between these two sub-areas during drilling (Table 8.3). But, it should also be noted that the drilling season was relatively short (limited to less than four weeks in Oct, due to unexpected delays in the anticipated start of drilling), and hence the amount of aerial survey effort during the drilling period was also necessarily limited. In terms of the statistical power to detect deflection around drilling given the sightings data, the power is a function of (all else being equal) the amount of survey effort that takes place during drilling, the spatial extent of any effect (the radius of deflection) and the time over which such might occur (the duration of the migration potentially affected). Given the relatively short drilling season and limited survey effort during that period, some caution is warranted here against over-confidence in the results of the statistical tests in the context of identifying or refuting deflection.

The two survey periods (pre-drilling and drilling) were spread across different periods of the bowhead whale migration, with the pre-drilling surveys occurring during the expected peak of migration and the drilling surveys occurring after that peak period. Hence, *a priori*, sighting rates would have been expected to be higher during the pre-drilling period, and in that case a comparison of the spatial distribution of sightings during drilling would be more appropriate (as opposed to a comparison of sighting rates before vs. during drilling). Interestingly, although sighting rates were higher during the pre-drilling period than during drilling, this difference was not statistically significant (Table 8.2). Further consideration to the temporal nature of the 2012 fall migration through the survey area is provided below.

During the week straddling the end of the pre-drilling period and the beginning of drilling, good weather allowed for consistent aerial coverage. Although there were no on-transect bowhead sightings during the five surveys from 29 Sep – 4 Oct (Table 8.4), there were off-transect sightings during this time. While it is not possible to estimate densities from these off-transect sightings, or include them in a quantitative comparison of densities between pre-drilling and drilling, taking into account on- and off-transect sightings during this transitional week does indicate that the migration shifted to a more near-shore route in late Sep.

Following the pause in on-transect sightings at the start of the drilling period, there was another apparent migratory pulse later in Oct that was documented by the aerial surveys. This pulse was interesting for several reasons, including a peak sighting rate of 15 sightings per 1000 km (9.3 per 1000 mi) on 21 Oct. Although survey effort was somewhat curtailed that day (only 267 km, 166 mi) due to patchy weather, and hence there is uncertainty in the sighting rate, the number of on-transect sightings during this survey tied for the second highest number of any given survey day during the entire survey season. If the high sighting rate is not an artifact of limited effort that day, but rather a true reflection of the numbers of whales in the area, this pulse could be indicative of more whales remaining in the Eastern Beaufort Sea until late in the season during 2012. Thus the tail of the fall migration through the central Beaufort Sea might have contained more whales than most previous years (see Evans and Holdsworth 1986 for documentation of bowhead feeding off the Yukon coast in mid-Oct of 1986) -- perhaps due to a longer feeding season in the eastern Beaufort as was observed in 1986 (Evans and Holdsworth 1986), increases in population size through time, or some combination of such factors.

With respect to the migratory route during the drilling period, as noted above, the majority of sightings during late Sep through Oct were relatively nearshore, in water-depths of about 20 m (66 ft). While there were near-shore sightings during the pre-drilling period, the average sighting distance from the drill-site was significantly higher during drilling (i.e. on-transect sightings during drilling were more uniformly near-shore) (Table 8.5; Fig. 8.4 and Fig. 8.5). A caveat to this result, however, is that there was also more effort farther from the drill site during drilling (due to not surveying the two most western transect lines during the whaling black-out, which overlapped much of the pre-drilling period).

One possible explanation for the apparent near-shore pattern is that bowheads were deflecting around drilling operations by migrating closer to shore. An alternative explanation is that the near-shore shift was driven by other factors, including perhaps an increase in prey availability due to advection on the shelf that has been noted to happen during the fall months (e.g. Moore et al. 2000). The challenge then is to tease apart what might be natural variation in the migratory corridor from what might be a response to anthropogenic sounds.

If prey availability were the mechanism driving the near-shore distribution of the migratory route during late Sep through Oct, it would be expected that there would also be some indication in the data that whales were foraging there. Indications of foraging behavior could include slower swim speeds and more variable headings. Indeed, there is evidence that observed bowheads were swimming more slowly and had more variable headings during the drilling period. For example, all of the on-transect sightings during drilling were recorded as either swimming at slow or moderate speeds (Fig. 8.8). When all sightings (on- and off-transect) are considered, only 10% (2 / 21) of sightings were recorded as swimming fast during drilling vs. 32% (7 / 22) of sightings recorded as swimming fast during the pre-drilling period. Further, it is evident from the headings of all sightings that during the pre-drilling period bowheads were consistently headed west, whereas the near-shore sightings during drilling were more variable (compare Fig. 8.4 and Fig. 8.5). In combination, these patterns are consistent with animals foraging near-shore as they slowly migrated through the survey area during the drilling period.

There is a confounding consideration in this interpretation however. While foraging animals would be expected to have more variable headings, this variability (i.e. turning during surfacing) has also been observed in bowhead whales exposed to playback of underwater sound from exploration drilling activities (Richardson et al. 1995b). While the behavioral reactions observed during that experiment were localized, and occurred at distances up to 2-4 km (1-2 mi), responses to full-scale drilling programs indicate that at least some whales could deflect at 20+ km (Koski and Johnson 1987). By comparison, bowhead whales during this survey were observed to be moving slower and with more variable headings at distances beyond 30km from drilling activity (Fig. 8.5). This is farther than would be expected given previous studies of behavioral responses to drilling.

Although the alternative hypotheses proposed here as potential explanations for the apparent near-shore shift in the migratory corridor need not be mutually exclusive (or exhaustive), and while it is not possible to rule out the possibility that drilling activity may have contributed (at least at some level) to the observed shift, the evidence is consistent with natural variability in the migration (driven by increased near-shore prey availability starting in late Sep), which could explain the observed pattern.

At this stage, the analyses of the Beaufort aerial survey data have not investigated the potential effect of support vessels on the migratory distribution of bowhead whales and observed patterns in the sightings data. It may be possible to take these vessels into account in a more detailed analysis, incorporating vessel GPS track locations and activity logs. Likewise, this assessment of potential effects of drilling activities on the fall bowhead migration in the study area has not taken into account independent sources of information on the migration, including: acoustic data on call detections collected as part of Shell's monitoring efforts, the National Marine Fisheries Service aerial sightings data in the Beaufort, and Shell vessel sightings (including those from observers on the drill-rig). During future analyses, these additional sources of information will be addressed and a more complete assessment will be provided as part of the Joint Monitoring Program comprehensive report.

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