MARINE MAMMAL MONITORING AND MITIGATION DURING SHELL'S ACTIVITIES IN THE CHUKCHI SEA, JULY–SEPTEMBER 2013: DRAFT 90-DAY REPORT

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TABLE OF CONTENTS

APPENDICES (ON CD):

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

This report summarizes the mitigation and monitoring efforts performed by Shell Gulf of Mexico, Inc. (Shell) during the 2013 shallow hazards and ice gouge/analog surveys, and equipment maintenance and retrieval at the Burger-A well site in the Chukchi Sea. The shallow hazards and ice gouge surveys were conducted from the M/V *Fennica,* and the equipment maintenance and retrieval program was conducted from the M/V *Nordica*. The *Fennica* towed a small airgun array in addition to other geophysical survey equipment. The *Nordica* conducted equipment recovery and maintenance activities using a dynamic positioning system while stationary at the Burger-A well site.

Marine seismic surveys 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 shallow hazard and ice gouge surveys, and equipment maintenance and retrieval at the Burger well site in the Chukchi Sea, were conducted under the jurisdiction of an Incidental Harassment Authorization (IHA) issued by NMFS and a Letter of Authorization (LOA) issued by the USFWS. The IHA and LOA included provisions to minimize the possibility that marine mammals might occur close to the seismic source 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 IHA and LOA. This required that protected species observers (PSOs) onboard the *Fennica* detect marine mammals within or about to enter the designated exclusion zones, and in such cases request an immediate power down (or shut down if necessary) of the airguns. PSOs aboard the *Nordica* monitored a zone of influence around the vessel while it was stationary and using its dynamic positioning system. The monitoring program also required that PSOs aboard both vessels implement general mitigation measures as stipulated by the IHA and LOA for all vessel-related activities.

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 pulsed seismic sounds or continuous vessel sounds from the dynamic positioning system; and
3. determine the reactions (if any) of marine mammals potentially exposed to underwater industrial sounds.

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

2013 Operations Described

Two vessels were used by Shell in the Chukchi Sea in 2013 in support of marine surveys, and equipment maintenance and retrieval at the Burger A well site. The marine survey vessel, *Fennica*, used a 4-airgun cluster (4×10 in^3 airguns) and a single 10 in^3 airgun for seismic data acquisition. The *Fennica* also used several other low-energy sources for marine survey activity. The equipment maintenance and retrieval vessel, *Nordica*, conducted dynamic positioning testing and calibrations before recovery equipment was deployed, and the vessel remained in dynamic positioning mode throughout maintenance and retrieval operations at Burger.

The geographic region where the shallow hazards survey occurred was on specific Shell lease holdings in the Chukchi Sea Planning Area designated as Oil and Gas Lease Sale 193. Measurements of underwater sound propagation from the airgun array and other low-energy sources on the *Fennica* were conducted by JASCO Applied Sciences (JASCO) on 19 Jul (airguns) and 28 Jul (high frequency equipment). JASCO calculated preliminary disturbance and exclusion radii for seismic activities within 5 days of completion of the measurements. These measurements were smaller than previous measurements of similar airgun arrays used in the Chukchi Sea, however, PSOs continued to use pre-SSV radii for the basis for implementation of mitigation by during seismic activities as a conservative measure. Shell completed 1134 km (704 mi) of seismic data acquisition using a small airgun array and 1045 km (649 mi) of analog data acquisition (e.g. ice gouge survey) without the use of airguns in the Chukchi Sea in 2013.

Equipment retrieval operations occurred on the Shell Burger lease site between 31 Jul and 12 Sep 2013. After an initial delay due to ice, work at Burger resumed on 27 Aug and equipment was successfully retrieved on 8 Sep. The *Nordica* was stationary for the majority of operations within the lease block. JASCO also conducted measurements of underwater sound propagation from activities at the Burger site.

Vessel-based marine mammal monitoring was conducted from the *Fennica* and the *Nordica* throughout the operations in the Chukchi Sea. Observers aboard each vessel collected data, requested mitigation measures as necessary, and ensured both vessels operated in accordance with the provisions of the IHA and the LOA.

Underwater Sound Measurements

As part of the 2013 operations, Shell was required to measure and report sound levels from underwater noise sources involved in its offshore shallow hazards survey and well site equipment retrieval programs. JASCO Applied Sciences measured sounds from these programs in the Chukchi Sea on behalf of Shell for time periods between Jul and Oct 2013. 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 experimental and analysis methods and a summary of the results are given below.

Shell's 2013 IHA stipulated a requirement to measure underwater sound levels in the vicinity of certain noise-generating sources. The measurements were to be analyzed to determine the distances at which broadband sound levels reached the level A (auditory injury) and level B (behavioral disturbance) "take" criterion thresholds. For the purposes of this authorization, the thresholds for impulsive sounds were 190 and 180 dB re 1 μPa (rms) for level A takes of pinnipeds and cetaceans respectively. The level B threshold was 160 dB re 1 μPa (rms). The IHA also required that the distances corresponding to sound levels between 190 and 120 dB re 1 μPa (rms) be reported in 10 dB steps.

The acoustic measurements for the shallow hazards program were performed from the survey vessel MSV *Fennica*. The sound sources characterized from the site survey program included an airgun array consisting of four 10 in^3 airguns that were fired in 10 in³, 20 in³, and 40 in³ configurations. The single 10 in^3 airgun was also used as a mitigation source during turns and on line approaches to encourage marine mammals to stay away from the survey vessel and avoid being exposed to higher-level sounds from the 40 in^3 array when it was ramped up. The shallow hazards program also employed a sub-bottom profiler and single-beam, multibeam and side-scan sonars. All of the above sources and vessel self-noise from the *Fennica* transiting and on dynamic positioning (DP) were measured in this study.

The equipment retrieval program was performed by the MSV *Nordica* while on DP at the Burger A well site. Vessel noise generated by the *Nordica* was measured for two vessel headings and three wind force categories. Ambient noise at the well site was also analyzed for each wind force category.

Underwater sounds below 32 kHz were measured with standard Autonomous Multichannel Acoustic Recorders (AMARs, JASCO Applied Sciences Ltd.) equipped with GeoSpectrum M8E hydrophones at both the Snickers and the Burger A sites. The high frequency sonar sources were measured with a specialized AMAR that captured sounds up to 343.75 kHz with a Reson TC4014 hydrophone. The AMARs were deployed directly on the seabed with their hydrophones approximately 30 cm (12 in) above the ocean floor. In-field calibrations of the OBH systems were performed using GRAS 42AA or 42AC pistonphone calibrators immediately before and after each measurement.

Distances to sound level thresholds from the sources of the shallow hazards and equipment retrieval programs are given below in Table 1 and Table 2, respectively. Source spectrograms, high-frequency sonar pulse spectra and sound level versus range plots are included in Chapter 3 of this report.

TABLE 1. Sound level threshold distances for sources operating at the Snickers SSV site. Distances were obtained from the 90th-percentile fits to sound level versus range.

Source	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
Fennica **stationary DP**	**-**	**-**	**-**	**1400**
Fennica **transiting**	**-**	**-**	**-**	**2700**
Airgun array – 10 in³				
Endfire	**13****	**41** (127*)**	**400**	**20000**
Airgun array – 20 in³				
Endfire	**25****	**79 (133*)**	**760**	**22000****
Broadside	**15****	**60**	**840**	**18000****
Airgun array – 40 in³				
Endfire	**20****	**67 (123*)**	**720**	**29000****
Broadside	**20****	**95**	**1300**	**11000****
Sub-bottom profiler	**-**	**-**	**53**	**1000**
Side-scan sonar	**-**	**1****	**130**	**1400****
Multibeam sonar	**24****	**34****	**67**	**260****
Single-beam echosounder	**-**	**-**	**-**	**45****

*Not from fit. Maximum received range of a pulse with rms SPL greater than threshold value.
**Extrapolated beyond measurement range .

TABLE 2. Sound level threshold distances for the *Nordica* operating on dynamic positioning at the Burger A well site. Distances were obtained from the from the 90th-percentile fits to sound level versus range.

Source	rms SPL Threshold Radii (m)
	120 dB re 1 µPa
Nordica **on DP – heading 45°, wind force 2**	**1600**
Nordica **on DP – heading 180°, wind force 2**	**4500**

Marine Mammal Monitoring Results

Shallow Hazards and Ice Gouge Surveys – M/V Fennica

PSOs recorded a total of 354 sightings of 454 marine mammals from the *Fennica* during Shell's shallow hazards and ice gouge surveys. Observations included a total of 70 sightings of 126 cetaceans, 258 sightings of 284 seals, 26 sightings of 44 Pacific walruses, and no polar bears. Gray whales were the most frequently identified cetacean. Bearded seals were the most frequently identified seal species, although nearly a third of the seals observed could not be identified to species.

Fennica PSOs recorded 186 sightings that were either too brief, too distant, or occurred during periods of low visibility to accurately identify the animals to species. Of the 22 unidentified cetacean sightings, 11 could be assigned a likely species using detailed comments recorded by the PSO at the time of the sighting and led to the designation of seven bowhead whales, six gray whales, one fin whale and one humpback whale. Of the 164 unidentified pinnipeds and seal sightings, 36 could be assigned a likely species and led to the designation of two Pacific walruses, 18 bearded seals, 11 ringed seals, and six spotted seals.

Three cetacean sightings occurred while the *Fennica's* airguns were active, but all individuals were well outside of the ≥160 dB (rms) disturbance zone. The majority of cetacean sightings occurred off the coast of Wainwright from 31 Jul through 5 Aug, well away from the more-offshore survey areas and, therefore, during periods when airguns were not operating.

The majority of walruses were observed on 22 Sep (59%). The *Fennica* was on a survey site on 22 Sep, and the high number of sightings was likely due to the movement of Pacific walruses toward haul outs on the Alaskan Chukchi Sea coast.

The majority of cetacean movements relative to the *Fennica* were either unknown or neutral, meaning neither toward nor away from the vessel. Only three cetaceans were obsserved during seismic activity. One was observed ~10 km (6.2 mi) from the vessel and observer comments indicate that movement was unknown given the distance of the sighting. The other two were observed moving neutral with respect to the vessel. No cetaceans sighted from the *Fennica* exhibited an overt (or discernible) reaction to the vessel regardless of seismic activity.

Most of the seal movements recorded during Shell's marine surveys were neutral relative to the vessel (~45%). Nearly twice as many seals were seen swimming away compared to swimming towards the *Fennica.* Seals observed from the *Fennica* were most often recorded as having no reaction (~43%), while the second-most observed reaction was of seals looking at the vessel (~40%).

Movements neutral relative to the vessel were the most commonly recorded movements of Pacific walruses from the *Fennica* during Shell's marine surveys. Walruses observed from the *Fennica* were most often recorded has having no reaction (~50%) to the vessel or airguns. The second-most observed reaction (~19%) was of walruses looking at the vessel.

There were 31 total marine mammal sightings during seismic periods (i.e., during operation of the mitigation airgun or full airgun array). All of these sightings were of cetaceans and pinnipeds: three unidentified mysticete whales, eight Pacific walruses, five ringed seals, one unidentified pinniped, and 14 unidentified seals. The reactions of these marine mammals were proportionally similar in during seismic compared to non-seismic periods.

General mitigation implemented by PSOs aboard the *Fennica* involved two reductions in vessel speed and three alterations of the vessel's heading to avoid groups of whales. PSOs also worked with vessel operators to reposition the *Fennica* away from a large group of feeding gray whales to facilitate helicopter operations for crew change without whales in close proximity.

Two shut downs of airguns were requested on two separate occasions during Shell's shallow hazards survey as a result of a Pacific walrus approaching the ≥180 dB (rms) exclusion zone. No power downs or shut downs of the airguns were necessary for cetaceans or seals. The two shut downs occurred over a 2-day period, 24 and 25 Sep, around the time when walrus sightings were most numerous in 2013. One of the shut downs occurred when the array was operating at full volume (40-in^3) and the other shut down occurred when the mitigation gun was operating (10-in^3). The PSOs did not observe either walrus enter the ≥180 dB (rms) exclusion zone while the airguns were active.

Based on direct observations, one cetacean (possible gray whale), 21 seals, and seven walruses were likely exposed to airgun sounds above the 160 dB (rms) disturbance threshold. None of the cetacean sightings occurred within the ≥180 dB (rms) exclusion zone. No seals were observed within the ≥190 dB (rms) exclusion zone, and two walruses were observed approaching the ≥180 dB (rms) exclusion zone. Each of these two walrus sightings resulted in a shut down of airguns. The shut downs of airguns in each case occurred prior to the Pacific walruses entering the ≥180 dB (rms) exclusion zone. Given the conservative approach taken with the safety radii used for mitigation purposes, it unlikely that these walruses were exposed to RLs ≥180 dB (rms).

Based on densities calculated from PSO effort and sightings data collected during non-seismic periods, approximately 10 individual cetaceans would each have been exposed to airgun pulses with RLs ≥160 dB (rms) during the survey if they showed no avoidance of active airguns or the vessel. Based on the estimated densities of individual species, the breakdown of cetacean species potentially exposed to pulsed seismic sounds ≥160 dB (rms) may have included approximately two bowhead whales, five gray whales, two minke whales and one harbor porpoise. Since not all cetaceans were identified to species, density based exposure estimates also included approximately four unidentified cetaceans. Density based exposure calculations estimated that ~128 individual seals may have been exposed to sounds from airgun pulses ≥160 dB (rms) during the survey, including ~20 bearded seals, ~18 ringed seals, ~three spotted seals, and ~84 individual pinnipeds of unknown species. An estimated ~25 individual walruses were potentially exposed to airgun pulses at received levels ≥160 dB (rms) during the survey. No polar bears were observed by the *Fennica*; however, density estimates assume that a small number of polar bears could have been in the area and potentially exposed to pulsed seismic sounds ≥160 dB (rms) during the shallow hazards survey.

Equipment Retrieval Operations – M/V Nordica

PSOs aboard the *Nordica* recorded four cetacean sightings of four individuals, 39 sightings of 41 seals, three sightings of eight individual Pacific walruses, and three sightings of five polar bears during Shell's equipment maintenance and retrieval operations.

The *Nordica* PSOs recorded 19 sightings that were either too brief, too distant, or occurred during periods of low visibility to accurately identify to the animal to species. The unidentified mysticete whale sighting contained insufficient information in PSO comments to assign it a likely species. Of the 18 unidentified pinnipeds and seals, six could be estimated to species using the descriptions provided at the time of the sighting and led to the designation of three bearded seals and three spotted seals.

The four cetacean sightings on the *Nordica* were recorded while the *Nordica* was off the project site engaged in general vessel activities. Individuals from two of these sightings exhibited neutral movement with respect to the vessel, and individuals from the other two sightings swam toward the vessel. No cetaceans observed from the *Nordica* exhibited an overt (or discernible) reaction to the vessel.

Of the 39 seal sightings observed from the *Nordica*, 28 occurred during periods when dynamic positioning was being used. Of these 28 seals, 20 were observed to have no movement, and the second most common movement was swim towards the vessel. More than half of the seals did not have a determined movement relative to the vessel. Seals observed from the *Nordica* were most often recorded as looking at the vessel and having no observable reaction. There was no discernible difference between seal reactions relative to the *Nordica*'s activity.

All five polar bears (three sightings) exhibited neutral movement relative to the *Nordica*, four of which were observed walking on ice. The mean closest point of approach to the vessel for polar bears was 2951 m (9681 ft). No visible reaction was observed of the polar bears to the vessel activities.

Walruses from all three sightings (eight individuals) exhibited no discernible movement relative to the vessel and were observed resting on ice. The walruses exhibited no reaction the majority of the time (~66%). In the third sighting, the reaction of the walrus was recorded as "look."

One general mitigation action was requested and implemented on the *Nordica* in the Chukchi Sea to maintain distance from a walrus on ice. PSOs also monitored deployment of equipment to ensure the area was clear of marine mammals while work was occurring to prevent interactions with marine mammals.

No cetaceans or Pacific walruses were observed while the *Nordica* was engaged in dynamic positioning operations at Burger. All four cetacean sightings occurred closer to shore during crew change and resupply operations. All walrus sightings occurred while the *Nordica* was on standby away from the well site due to ice cover on the prospect. Thirty of the 41 individual seals observed from the *Nordica* were present while the vessel was engaged in dynamic positioning during operations. Of these, 28 individual seals were in the water and two seals were on ice. The seals in the water were within the *Nordica's* ≥120 dB (rms) zone of influence for the dynamic positioning system and were likely exposed to continuous sounds ≥120 dB (rms). One polar bear was seen swimming in the water while the *Nordica* was stationary in dynamic positioning at the well site and also may have been exposed to continuous received sound levels of ≥120 dB (rms).

Two methods were used to calculate exposures estimates from the observed densities of marine mammals. The first method used to calculate exposures considered 'turnover' of marine mammals by adding the estimated exposures of animals together from each of the two seasonal periods, Jul–Aug and Sep. It is quite possible that the turnover of animals in the survey area was greater than this, which was accounted for in an alternative exposure estimate. In this second method, a daily multiplier was used to sum the number of animals exposed to continuous sounds ≥120 dB (rms) for each day that dynamic positioning was used at the Burger well site (11 and nine in Jul–Aug, and Sep, respectively).

Based on observed densities and the first method used to calculate exposure estimates by seasonal period, eight cetaceans, 16 seals, three walruses and one polar bear may have been exposed to continuous sounds ≥120 dB (rms) during dynamic positioning activities at Burger. Exposure estimates using observed densities and the second method with a daily multiplier indicated that 40 cetaceans, 169 seals, 28 walruses and five polar bears may have been exposed to continuous sounds ≥120 dB (rms) during dynamic positioning activities at the well site.

Summary of Marine Mammals Potentially Affected

Based upon direct observation, one cetacean was likely exposed to pulsed sounds ≥160 dB (rms) from seismic activity. No cetaceans were observed at Burger within the *Nordica's* ≥120 dB (rms) zone of influence from dynamic positioning operations. Based on observed densities, ~23 individual cetaceans, mostly gray whales, may have been exposed to received levels at or above these two sound thresholds if they showed no avoidance of the operations conducted by the *Fennica* or *Nordica*. Total exposure estimates for cetaceans were substantially lower than those presented in Shell's 2013 IHA application and those allowed under the IHA issued by NMFS. The lower estimated exposures based on the field data resulted from several factors. First, the measured distances of the 120 and 160 dB (rms) sound isopleths around the *Nordica's* dynamic positioning operations and the *Fennica's* airgun array, respectively, were much shorter than those estimated in the application materials. Additionally, dynamic positioning at Burger occurred on 20 days compared to the pre-season estimate of 28 days used in the IHA application to estimate exposures. Lastly, observed densities of cetaceans were lower than those used in the IHA application.

Based on direct observation, 21 seals were likely exposed to received sound levels ≥160 dB (rms) from seismic activity, and 28 seals were likely exposed to continuous sounds ≥120 dB (rms) while the *Nordica* was engaged in dynamic positioning operations at Burger. No seal sightings occurred within the ≥190 dB (rms) exclusion zone during seismic operations, thus, no power downs or shutdowns were requested for seal sightings. Based on density estimates and the area exposed to airgun sounds ≥160 dB (rms) during shallow hazards surveys, and the area exposed to continuous sounds ≥120 dB (rms) during dynamic positioning activities at Burger, ~297 seals, including ~46 bearded seals, ~40 ringed seals, ~six spotted seals, and ~194 unidentified seals may have been exposed to underwater sounds above these disturbance thresholds if they showed no avoidance of the operations. These estimates for seals are lower than those estimated in the IHA application and authorized in the IHA issued by NMFS for the same reasons discussed directly above for cetaceans.

Direct observation of Pacific walruses indicated that seven individuals were likely exposed to ≥160 dB (rms) from seismic activity, and no individuals were observed within the *Nordica's* ≥120 dB (rms) zone of influence from use of the dynamic positioning system. Based on density estimates, ~46 walruses may have been exposed pulsed seismic sounds ≥160 dB (rms) or continuous sounds ≥120 dB (rms) from dynamic positioning activities. These numbers are relatively low compared to exposure estimates from previous exploration programs, as were the numbers of walruses encountered during 2013.

No polar bears were observed in areas where received sound levels were estimated to be ≥160 dB (rms) from seismic activity, and one polar bear was observed within the Nordica's ≥120 dB (rms) zone of influence while the vessel was engaged in dynamic positioning operations at Burger. The polar bear was observed swimming with its head above water and likely would not have experienced levels of sound comparable to marine mammals present well below the surface. Based on density estimates, nine polar bears may have been exposed to seismic sounds ≥160 dB (rms) during shallow hazards surveys or continuous sounds ≥120 dB (rms) during dynamic positioning operations.

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1. BACKGROUND AND INTRODUCTION[1]

This report summarizes the marine mammal monitoring and mitigation efforts performed by Shell (Shell Gulf of Mexico Inc.) during the 2013 shallow hazards and ice gouge surveys, and for equipment retrieval at the Burger well site in the Chukchi Sea.

Marine seismic surveys 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). These 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 (Reiser et al. 2009; Richardson et al. 1995, 1999; Stone and Tasker 2006; Gordon et al. 2004; Smultea et al. 2004), or by implementation of prescribed mitigation measures as outlined in Shell's monitoring and mitigation program and identified within various federal authorizations issued to Shell. 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 Sea. 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*). The bowhead whale population, however, is likely approaching its pre-commercial whaling population size after ~30 years of population growth (Brandon and Wade 2007; Gerber et al. 2007), growing at an estimated 3.7% annually (Givens et al. 2013). In late 2012, NMFS declared the Beringia and Okhotsk distinct population segments (DPSs) of bearded seal, and the Arctic, Okhotsk, and Baltic subspecies of ringed seal as threatened under the ESA (NMFS 2012a,b). NMFS determined that no listing action was warranted for the Bering Sea and Okhotsk populations of spotted seal (NMFS 2010), or the ribbon seal (NMFS 2013a).

USFWS manages two marine mammal species occurring in the Chukchi Sea, 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 endangered was submitted to USFWS (CBD 2008) and resulted in their designation as an ESA candidate species (USFWS 2011).

Because of the potential for marine mammals to be encountered during planned site surveys and equipment retrieval in the Chukchi Sea during the 2013 open-water season, Shell submitted several application revisions in early April 2013 for an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to Shell's proposed activities. The final revised application was submitted to NMFS on 9 Apr 2013. A notice announcing Shell's request for an IHA was published in the *Federal Register* on 14 May 2013 and public comments were invited (NMFS 2013b).

[1] By Lauren Bisson (LGL Alaska Research Associates, Inc.)

An IHA allowing the proposed activities in the Chukchi Sea was issued to Shell by NMFS on 15 Jul 2013 which allowed operations to be conducted from 1 Jul through 31 Oct 2013. The IHA authorized "potential take by harassment" of various cetacean and seal species during the shallow hazards (seismic) survey, active acoustic sources for ice gouge surveys, vessel activities related to these surveys, and vessel activities related to equipment recovery at the well site described in this report. Similarly, on 8 Apr 2013, Shell requested a Letter of Authorization (LOA) from USFWS for the incidental "take" of polar bears and walrus during open-water exploration activities in the Chukchi Sea in 2013. A notice announcing Shell's request for an LOA was published in the *Federal Register* on 12 Jun 2013 and public comments were invited (USFWS 2013). The USFWS issued a LOA on 28 Jun 2013 allowing Shell to "take" small numbers of polar bears and Pacific walruses incidental to proposed activities occurring during the 2013 Chukchi Sea open-water season. The LOA was valid from 30 Jun through 31 Oct 2013.

Having received the necessary authorizations, Shell collected shallow hazards marine seismic data, analog data, and retrieved equipment at the Burger drill site in the Chukchi Sea during the open-water period of 2013 in support of oil and gas exploration. Seismic acquisition for Shell was conducted by Fugro GeoServices, Inc using the M/V *Fennica*, an icebreaker that towed an airgun array, hydrophone streamers to record seismic data, and other higher frequency sonar equipment. The equipment retrieval operations were conducted by Oceaneering International, Inc from the M/V *Nordica*, and utilized an ROV and subsea dredge to complete recovery operations.

This document serves to meet reporting requirements specified in the IHA and LOA. The primary purposes of this report are to describe project activities in the Chukchi Sea, 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 survey activities at or above presumed effect levels as prescribed by the respective agencies.

Incidental Harassment Authorization and Letter 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, impulsive sounds were generated by *Fennica*'s airgun array in order to collect shallow hazards seismic data on Shell's lease holdings in the Chukchi Sea. 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 seismic survey and equipment retrieval operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Certain behavioral disturbances to marine mammals are considered to cause "take by harassment" under the provisions of the MMPA.

Under current NMFS guidelines, "safety radii" for marine mammals around airgun arrays and other sound sources are customarily defined as the distances within which received sound levels are ≥180 decibels (dB) re 1 μPa (rms)[2] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii

[2] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis (sometimes described as Sound Pressure Level, SPL) are generally 10-12 dB lower than those measured on the "zero-to-peak" basis, and 16-18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 2000a,b). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels. Received levels of pulsed sounds can also be described on an energy or "Sound Exposure Level" (SEL) basis, for which the units are dB re $(1\ \mu Pa)^2 \cdot s$. The SEL value for a given airgun pulse, in those units, is typically 10-15 dB less than the rms level for the same pulse (Greene 1997; McCauley et al. 2000a,b), with

are based on an assumption that seismic pulses or 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. Potential effects of marine mammal exposure to the sound-level thresholds of these current mitigation criteria are thought to be temporary. According to NMFS, the high frequency acoustic sources used in Shell's 2013 analog surveys are not likely to result in any takes of marine mammals due to the rapid attenuation and narrow beam-widths of these higher frequency sounds (NMFS 2013c).

Disturbance to marine mammals could occur at distances beyond the safety radii if the mammals were exposed to moderately strong pulsed sounds generated by the airguns or perhaps by vessels (Richardson et al. 1995). The NMFS assumes that marine mammals exposed to pulsed airgun sounds with received levels ≥160 dB re 1 μPa (rms) or continuous sounds from vessel 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. Some individuals may exhibit behavioral responses at received levels somewhat below the nominal 160 (rms) criteria for pulsed sounds, but others may tolerate levels somewhat above 160 (rms) without reacting in any substantial manner. For example, migrating bowhead whales in the Alaskan Beaufort Sea have shown avoidance at received levels substantially lower than 160 dB (rms; Miller et al. 1999). However, recently acquired acoustic evidence suggests that some whales may not react as much or in the same manner as suggested by those earlier studies (Blackwell et al. 2008). Beluga whales may, at times, also show avoidance at received levels below 160 dB (rms; Miller et al. 2005). In contrast, bowhead whales on the summer feeding grounds tolerate received levels of 160 dB (rms) or sometimes more without showing significant avoidance behavior (Richardson et al. 1986; Miller et al. 2005; Lyons et al. 2008).

The IHA issued by NMFS to Shell authorized incidental harassment "takes" of three ESA-listed species including bowhead, humpback, and fin whales, as well as several non-listed species including gray whale (*Eschrichtius robustus*), Minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcincus orca*), narwhal (*Monodon monoceros*), beluga whale (*Delphinapterus leucas*), harbor porpoise (*Phocoena phocoena*), and ringed, spotted, bearded, and ribbon seals.

NMFS granted the IHA to Shell on the expectation that

- the numbers of whales and seals potentially harassed (as defined by NMFS criteria) during survey and vessel 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.

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considerable variability (Madsen et al. 2006; see also Chapter 3 of this report). SEL (energy) measures may be more relevant to marine mammals than are rms values (Southall et al. 2008), but the current regulatory requirements are based on rms values.

The LOA issued to Shell by USFWS was based on similar expectation as described for the IHA, and required Shell to observe a 190 dB (rms) safety radius for polar bears and a 180 dB (rms) safety radius for walruses.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in Shell's IHA and LOA applications and in the IHA and LOA issued to Shell (NMFS 2013a,b) An explanation of the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2013a).

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 strong seismic pulses or vessel sounds; and
- determine the reactions (if any) of marine mammals potentially exposed to industrial sounds.

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

The purpose of the mitigation program was to avoid or minimize potential effects of Shell's shallow hazards survey and equipment retrieval on marine mammals and subsistence hunting. This required that shipboard personnel detect marine mammals within or about to enter the designated safety radii [190 dB (rms) for pinnipeds and polar bears and 180 dB (rms) for cetaceans and Pacific walrus], and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves reducing the source level of the operating airguns, in this case by reducing the number of airguns firing. A shut down involves temporarily terminating the operation of all airguns. Additionally, the safety radii were monitored in good visibility conditions for 30 minutes prior to starting the first airgun and during the ramp up procedure to ensure that marine mammals were not near the airguns when operations began (see Chapter 4).

Mitigation measures within the 160 dB (rms) isopleth were also required, as described in the IHA issued by NMFS, for an aggregation of 12 or more bowhead whales or gray whales and in the LOA issued by USFWS for aggregations of 12 or more Pacific walruses.

Report Organization

This 90–day report summarizes the site survey activities and describes the methods and results of the mitigation and monitoring performed to meet the above objectives as required by the IHA and LOA.

This report includes seven chapters:

1. background and introduction (this chapter);
2. description of Shell's 2013 operations;
3. acoustic sound source measurements during the field season;
4. description of the marine mammal monitoring and mitigation program and the data analysis methods;
5. results of the marine mammal monitoring from the *Fennica* and estimates of potential "take by harassment";
6. results of the marine mammal monitoring from the *Nordica* and estimates of potential "take by harassment";
7. Combined results of marine mammal monitoring from both operations

In addition, there are ten appendices that provide copies of relevant documents and details of field procedures and data analysis methods and results. The appendices include

A. copy of Shell's 2013 Incidental Harassment Authorization
B. copy of Shell's 2013 Letter of Authorization
C. copy of 2013 Conflict Avoidance Agreement
D. descriptions of vessels and equipment;
E. sound source measurement results – cumulative sound exposure level;
F. details of monitoring, mitigation, and data-analysis methods;
G. Beaufort wind force definitions;
H. marine mammal status and abundance in the Chukchi Sea;
I. vessel-based marine mammal monitoring results, including
    a. list of all marine mammal detections
    b. weekly summary maps of vessel activity
    c. data which met analysis criteria

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2. 2013 OPERATIONS DESCRIBED[1]

Operating Areas and Dates

Marine mammal monitoring was conducted from two vessels operated by Shell in the Chukchi Sea in 2013 in support of shallow hazard and ice gouge surveys and equipment retrieval at the Burger drill site. The survey vessel (M/V *Fennica*) used a 4-airgun cluster (4×10 in^3 airguns) for seismic data acquisition as well as other equipment including side-scan sonar, multibeam echosounder, single beam echosounder, magnetometer, and sub-bottom profiler for analog data acquisition. The equipment retrieval vessel (M/V *Nordica*) utilized the Oceaneering Millennium® Plus ROV and GTO® Subsea Dredge to complete recovery operations. Detailed descriptions of these vessels and their equipment can be found in Appendix D. Marine mammal observers (PSOs) aboard the *Fennica* and the *Nordica* collected data and requested mitigation measures, as necessary, during the operations. Both vessels operated in accordance with the provisions of the IHA issued by NMFS and the LOA issued by USFWS.

Shallow Hazards and Ice Gouge Surveys

The geographic region where the shallow hazards site survey occurred was on or near specific Shell lease holdings in the Chukchi Sea Planning Area designated as Oil and Gas Lease Sale 193. These leases are located west of the coast of Alaska (Figure 2.1). The nearest of these survey sites was ~120 km (~75 mi) from Wainwright and the farthest was ~240 km (~ 150 mi) west of Wainwright. The ice gouge survey was located offshore of Wainwright and east of the majority of lease holdings in the Chukchi Sea. The analog survey was located northwest of Point Lay.

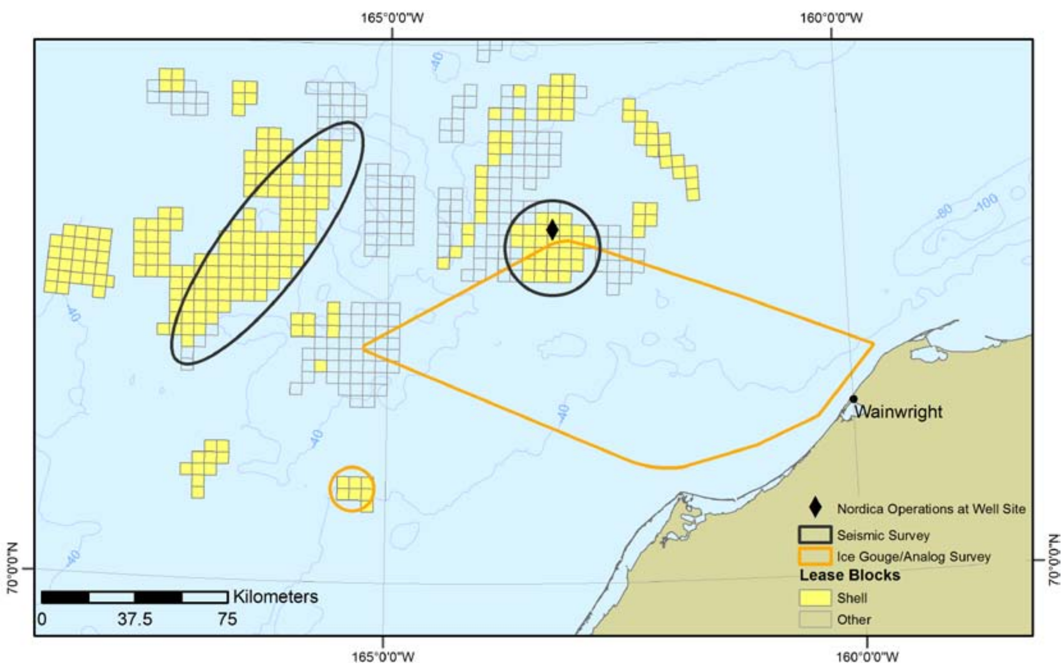

FIGURE 2.1. Location of the seismic activities, ice gouge/analog surveys, and well site equipment recovery.

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The survey vessel *Fennica* left Dutch Harbor on 14 Jul and entered the Chukchi Sea "survey area" (the area north of Point Hope, 68.34ºN latitude) on 17 Jul (Figure 2.2). Shell's seismic contractor, Fugro, deployed the seismic acquisition equipment and JASCO Applied Sciences. (JASCO) began measurements of the underwater sound produced by the airgun array and high frequency sound sources on 18 Jul. Due to partial equipment failure, measurements of high frequency sound sources were conducted a second time on 27 Jul. Both sets of acoustic measurements were conducted near the Snickers lease area in the Chukchi Sea (see Chapter 3 for a complete description of the sound source measurements and analysis). JASCO calculated preliminary disturbance and safety radii within 5 days of completion of the measurements. The more conservative radii of the pre-season and calculated radii were chosen as the basis for implementation of mitigation by PSOs during seismic survey activities thereafter.

The *Fennica* collected seismic and other geophysical survey data in the Chukchi Sea from 18 Jul through 28 Sep (See Figure 2.2 for time spent at each site). Crew changes offshore from Barrow occurred on 2 Aug and 13 Sep, with one mid-season crew change in Dutch Harbor on 23 Aug. A non medical emergency crew change occurred in Nome on 7 Aug. The *Fennica* departed the Chukchi Sea for the last time in 2013 on 28 Sep arriving in Dutch Harbor on 3 Oct. Shell completed 2206 km (1371 mi) of shallow hazards data acquisition (1134 km of seismic data acquired) and 1045 km (649 mi) of analog data acquisition (e.g. ice gouge survey) in the Chukchi Sea in 2013.

On each seismic line, the airguns were firing for a period of time during ramp up, and during "lead in" periods before the beginning of seismic data acquisition at the start of each seismic line. Periods of full array firing including periods of lead in, seismic testing, and ramp up occurred along ~1790 km (1112 mi) of trackline. During turns from one seismic line to the next, firing of a single airgun, or during power down periods for marine mammals observed within the safety radii of the full airgun array, the single mitigation gun was operated along ~658 km (408 mi) of vessel trackline. Thus, one or more airguns were operated along ~2448 km (1521 mi) of total trackline in the Chukchi Sea in 2013.

Throughout the survey, the *Fennica's* position and speed were logged digitally every ~60 s. In addition, the position of the *Fennica*, water depth, environmental information, and information on the number and volume of airguns that were firing were collected by the PSOs while on duty. This includes when the *Fennica* was offline (e.g., prior to shooting at full volume) or was online but not recording data (e.g., during airgun or computer problems).

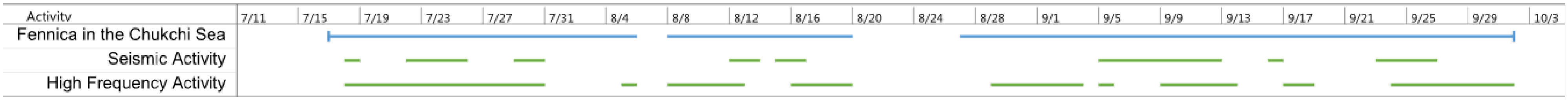

FIGURE 2.2. Location of the *Fennica* and timing of seismic and higher frequency survey activity, as described in *Airgun and Sonar Description.*

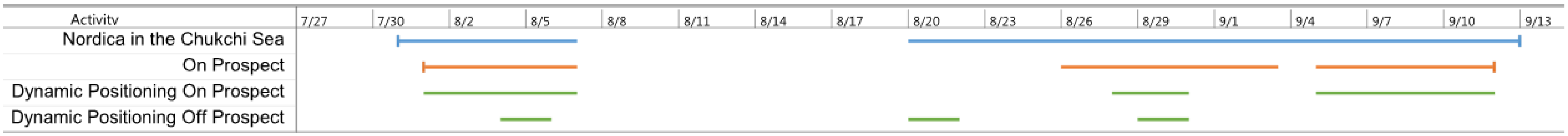

FIGURE 2.3. Location of the *Nordica* and use of dynamic positioning both on and off the Burger Lease Block. Dynamic positioning days were included if any dynamic positioning occurred during that 24 hour period; overlap between dynamic positioning on and off prospect indicates some dynamic positioning activity in both locations within the 24 hour period.

Airgun and Sonar Description

The site survey vessel *Fennica* towed a 40 in^3 airgun cluster (4 × 10 in^3 airguns) at ~2 m (~7 ft) depth and ~23 m (~75 ft) behind the vessel. During the SSC tests, however, the airgun array was towed 15.25 m behind the vessel. The four 10 in^3 airguns were arranged in a rectangular configuration. A single airgun in the array was used as the mitigation gun and was fired between lines to discourage marine mammals from approaching the vessel.

The higher frequency survey equipment included an Edgetech 3200 sub-bottom profiler, an Edgetech 4200 dual frequency side-scan sonar, a Reson 7101 multi-beam echosounder, a marine magnetic SeaSpy magnetometer, and a Skipper GDS 101S single-beam echosounder. The sub-bottom profiler was towed at 10 m (33 ft) depth and 10 m (33 ft) behind the vessel, and the side-scan sonar was towed approximately 91 m (~300 ft) behind the vessel at 20 m (66 ft) depth. The single-beam and multi-beam echosounders were mounted directly under the *Fennica's* hull. This equipment operated for the majority of the time when the *Fennica* was on the survey sites or when collecting ice gouge data. The equipment was turned off for transit, bad weather, and occasional equipment malfunctions, however the *Fennica*'s single beam navigational echosounder was activated when the higher frequency equipment was deactivated. Please refer to Chapter 3 for detailed descriptions of the operating frequencies of all sound sources operated during the seismic surveys and general vessel operations.

Equipment Retrieval Operations

Equipment was recovered from the Burger A well site, approximately 103 km (64 mi) offshore and 126 km (78 mi) northwest of the closest village of Wainwright (Figure 2.1). The Burger prospect comprises part of the Oil and Gas Lease Sale 193 in the Chukchi Sea Planning Area of the Bureau of Ocean Energy Management (BOEM) Alaska Outer Continental Shelf (OCS) lease holdings.

The M/V *Nordica* departed Dutch Harbor on 27 Jul and arrived on prospect on 1 Aug (Figure 2.3). The vessel moved off prospect due to prolonged ice coverage at the well site, and began to transit south to Dutch Harbor on 6 Aug, arriving 10 Aug, and began the return trip north 15 Aug. Due to weather and ice, the start of work was postponed until 27 Aug. Weather interrupted work again until it was resumed on 5 Sep and equipment was successfully recovered on 8 Sep (Figure 2.3). The Nordica then confirmed locations of mooring system components at the Burger A drill site and departed the Chukchi Sea on 11 Sep.

On 11 Sep the vessel departed the prospect area and began transit south, completing her open water season in Dutch Harbor on 15 Sep.

Equipment Description

A manifold was installed on the Burger A well site during the 2012 drilling season and was retrieved by the following process. The *Nordica* conducted dynamic positioning (DP) testing and calibrations before recovery equipment was deployed, and the vessel remained in DP mode throughout retrieval operations.

The Oceaneering Millennium® Plus ROV, equipped with both a camera with fiber optic video transmission as well as the Fugro Chance Inc. Coda© Echoscope Dual Frequency 3D Sonar, was lowered into the water column to assess the well site. It was determined that approximately two meters of silt had accumulated in the mud line cellar (MLC) since October 2012, covering the manifold and other equipment. The Oceaneering GTO® Subsea Dredge was deployed in conjunction with the Millennium ROV to vacuum out the MLC.

Marine Mammal Monitoring

Vessel-based marine mammal monitoring and mitigation was conducted from the *Fennica* and the *Nordica* throughout operations in the Chukchi Sea. Two PSOs were on duty during nearly all daylight periods on both vessels. During seismic activity on the *Fennica*, two PSOs were on duty for all daytime ramp ups and at least one PSO was present for nighttime watches when airguns were active. On the *Nordica*, at least one PSO was on watch during all daylight hours, regardless of vessel activity, with one other PSO available for on-call assistance. During daylight hours, scans were made with Fujinon 7×50 reticle binoculars, the unaided eye, and during excellent visibility conditions Fujinon 25×50 "Big-Eye" binoculars or Zeiss 20×60 image stabilized binoculars.

Chapter 4 provides a detailed description of the methods and equipment used for monitoring and mitigation during the shallow hazards survey and equipment retrieval, as well as the data analysis methodology. Results of the marine mammal monitoring program are presented in Chapters 5 and 6.

Communication with Alaska Native Communities

PSOs aboard the *Fennica* and *Nordica* routinely contacted Alaska Native communities via a network of communication centers (com centers). Com centers were established in Nome, Pt. Hope, Pt. Lay, Wainwright, and Barrow, during the 2013 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 60 miles of the respective com center. Communications were made via phone, VHF radio, or email by each vessel every 6 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 results from an acoustic monitoring study carried out by JASCO Applied Sciences on behalf of Shell. The study consists of two sets of measurements in the Chukchi Sea off Alaska: sound source verification (SSV) measurements of sources involved in the Shell 2013 Shallow Hazards and Ice Gouge Survey, and sound measurements of equipment-retrieval operations at the Burger A well site. The SSV measurements were carried out near the Snickers Prospect on 18, 19 and 27 July 2013 using autonomous sound recorders deployed on the seafloor. The results in this chapter include the representative distances at which impulsive sounds reached rms sound pressure level thresholds of 190, 180, 160, and 120 dB re 1 µPa for three configurations of a 4-element airgun array, and for a sub-bottom profiler, and several sonar sources. Distances to sound pressure level thresholds were also calculated for the continuous self-noise of the survey vessel, MSV *Fennica*, while transiting and while stationary on dynamic positioning (DP). The measurements of equipment retrieval, maintenance activities, and ambient sounds at the Burger A well site were collected in August and September 2013 using a separate set of autonomous sound recorders deployed at the Burger Prospect. Distances to sound pressure level thresholds were calculated for the continuous noise from the MSV *Nordica* on DP at the Burger well site from these measurements.

Study Goals

The goals of the acoustic monitoring study were to:

- Establish distances from the airgun array and each survey sonar source where rms sound pressure levels reached thresholds of 190 to 120 dB re 1 µPa (rms) in 10 dB steps
- Characterize sound emissions as a function of distance from the survey vessel MSV *Fennica* in transit and when stationary on DP
- Characterize sound emissions from the vessel MSV *Nordica* when stationary on DP during equipment retrieval and maintenance at the Burger A well site
- Analyze ambient sound levels at the Burger A well site in differing wind force conditions and compare to the *Nordica* on DP.

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Methods

Measured Sound Sources

Underwater sound levels from the following sources were measured during the shallow hazards and ice gouge survey at the Snickers Prospect:

1. 10 in^3 single airgun
2. 20 in^3 sub-array (two front airguns)
3. 40 in^3 array (all 4 airguns)
4. EdgeTech 3200 sub-bottom profiler with SB216 towfish, 2–16 kHz chirp
5. EdgeTech 4200 side-scan sonar (towed), 120 and 400 kHz
6. RESON 7101 multibeam sonar (pole-mounted), 240 kHz
7. Skipper GDS 101S single-beam echosounder (hull-mounted), 200 kHz
8. Vessel self-noise from the MSV *Fennica* in transit
9. Vessel self-noise from the MSV *Fennica* stationary on DP.

Vessel self-noise from the MSV *Nordica* stationary on DP and ambient sound were measured during equipment retrieval and maintenance operations at Burger A Well Site.

The MSV *Fennica* and MSV *Nordica* are sister vessels. Both are 116 m (380 ft) long ice management vessels operated by Arctia Offshore. Vessel specifications are listed in Table 3.1, and the vessels are depicted in Figure 3.1. The *Fennica* towed the airgun array (Figure 3.2) with airguns at 2 m (6.6 ft) depth and 15.25 m (50 ft) behind the vessel. Figure 3.3 shows the 2 × 1 m (6.6 × 3.3 ft) layout of the array. Three airgun configurations, listed above, were operated on separate passes along the SSV track line. The sub-bottom profiler was towed 10 m (33 ft) behind the vessel at 10 m (33 ft) depth. The side-scan sonar was towed approximately 91 m (300 ft) behind the vessel at 20 m (66 ft) depth (Figure 3.4). The multibeam sonar was pole-mounted under the vessel hull at 9 m (30 ft) depth, and the single-beam echosounder was mounted directly on the vessel hull at 8.4 m (28 ft) depth.

TABLE 3.1. Vessel specifications for the MSV *Fennica* and MSV *Nordica*, sister vessels used for Shell's 2013 operations in the Chukchi Sea.

Length (m)	Width (m)	Draft (m)	Engine	Propeller
116	26	8.4	2 × 16 V 32/6000 kW Wärtsilä Vasa 2 × 12 V 32/4500 kW Wärtsilä Vasa	2 × azimuth, 4 blades, fixed pitch, variable rpm

FIGURE 3.1. Sister vessels MSV *Fennica* (left), used during the shallow hazards and ice gouge survey at the Snickers Prospect, and MSV *Nordica* (right), used during equipment retrieval and maintenance at Burger A Well Site.

FIGURE 3.2. Airgun array consisting of four identical 10 in^3 airguns used during the shallow hazards and ice gouge survey at the Snickers Prospect.

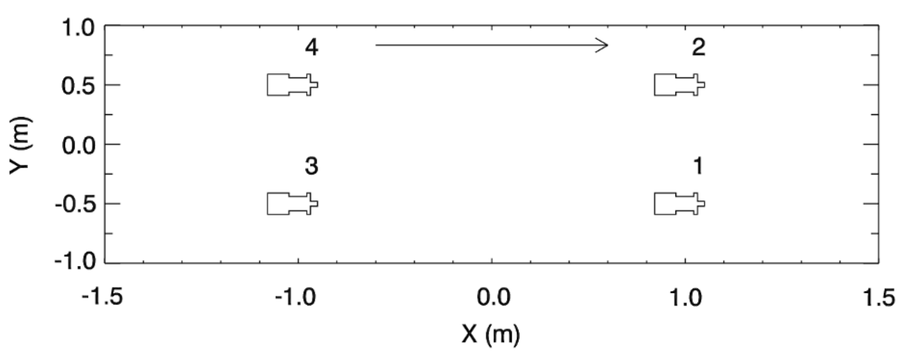

FIGURE 3.3. Layout of the 40 in³ airgun array. Each airgun has a volume of 10 in³. Spacing between the airguns was 2 m (6.6 ft) in the endfire direction and 1 m (3.3 ft) in the broadside direction. The arrow indicates the tow direction.

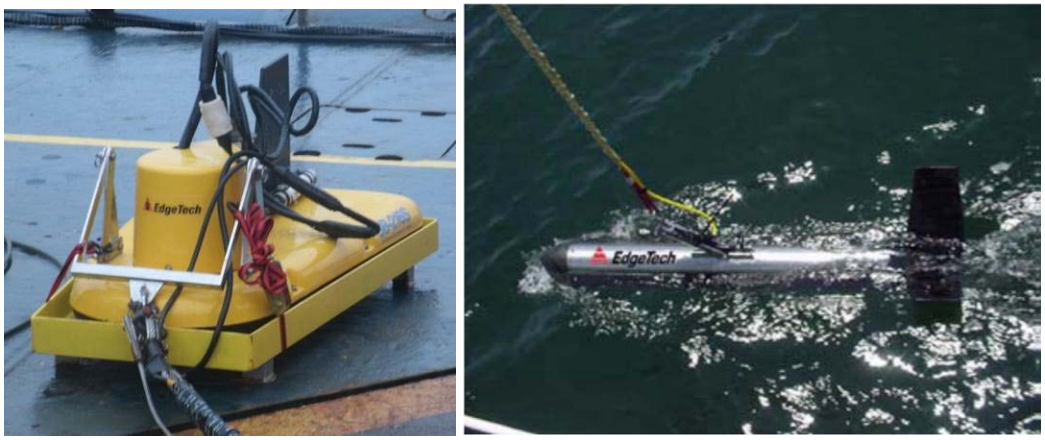

FIGURE 3.4. EdgeTech 3200 sub-bottom profiler (left) and EdgeTech 4200 side-scan sonar (right).

Measurement Apparatus and Calibration

Underwater sounds were measured with Autonomous Multichannel Acoustic Recorders (AMARs, JASCO Applied Sciences Ltd.): four AMARs at the Snickers prospect and five AMARs at the Burger A well site. 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 3.5) to allow retrieval with a grapple hook.

At the Snickers SSV site, three AMARs were outfitted with GeoSpectrum M8E hydrophones with −200 dB re V/µPa nominal sensitivity to measure vessel and airgun sounds. Each AMAR recorded acoustic data at a 64 kHz sample rate with 24-bit resolution, a configuration that captured acoustic frequencies from 10 Hz to 32 kHz. One AMAR was outfitted with a RESON TC4014 hydrophone with −186 dB re V/µPa nominal sensitivity to capture high-frequency sonar sources. This AMAR recorded acoustic data at a 687.5 kHz sample rate with 16-bit resolution, that captured acoustic frequencies from 10 Hz to 343.75 kHz.

At the Burger A well site, five AMARs were outfitted with GeoSpectrum M8E hydrophones with nominal sensitivity −164 dB re V/µPa to measure vessel and ambient sounds. They recorded acoustic data at a 64 kHz sample rate with 24-bit resolution, a configuration that captured acoustic frequencies from 10 Hz to 32 kHz.

The AMAR hydrophones at both sites were protected by a hydrophone cage, which was covered with a black shroud to minimize noise artifacts due to water flow. Acoustic data were stored on 256 GB internal solid-state flash memory chips.

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.

Conductivity-temperature-depth (CTD) casts were performed with an AML Minos-X vertical profiler at the Snickers prospect to derive the sound speed profile of the water column.

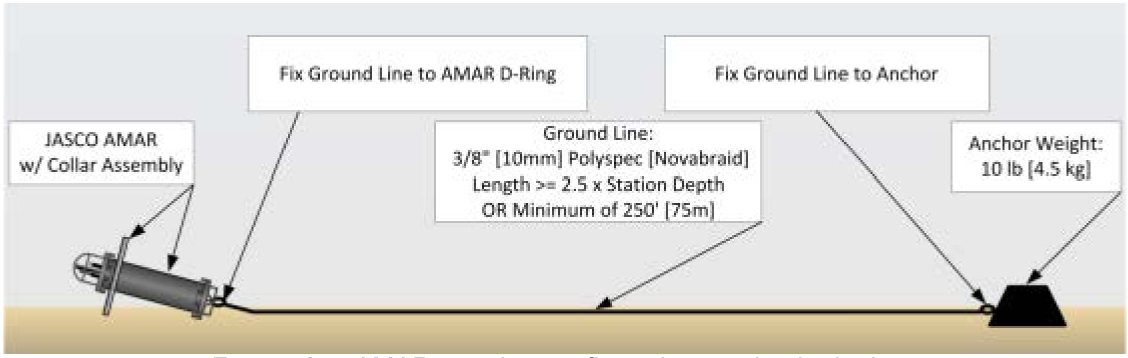

FIGURE 3.5. AMAR mooring configuration used at both sites.

Measurement Procedure

<u>*Shallow Hazards and Ice Gouge Survey at Snickers Prospect*</u>

The SSV measurements were performed with four AMARs deployed from the *Fennica* on 18 July 2013 to capture sound levels as a function of range and direction from each source, and were retrieved on 20 July 2013. Three AMARs were deployed perpendicular to the main SSV track at ranges of 0, 200, and 2000 m (0, 660, and 6560 ft) to record received sound levels at multiple ranges from the sources. The fourth AMAR, outfitted to record high frequencies (AMAR D), was placed 100 m (330 ft) off the main SSV track, opposite the other AMARs. AMAR D was re-deployed from 28-29 July 2013 to measure the high-frequency sonar sources.

Immediately after AMAR deployment, the Fennica maintained position directly over AMAR A for the DP sound level measurement. The three airgun configurations and vessel only travelled 25 km (15.5 mi) along the main SSV track. The sub-bottom profiler traversed 4 km (2.5 mi) of the main SSV track centered over AMAR A. The three high-frequency sources traversed five 1 km (0.6 mi) tracks centered on AMAR D at ranges of 0, 50, 100, 200, and 400 m (0, 160, 330, 660, and 1310 ft). Figure 3.6 shows the track lines and AMAR deployment geometry. Table 3.2 lists the location and water depth of the AMARs and the start and end of the SSV tracks. Table 3.3 lists the start and end times of the SSV measurements.

A conductivity-temperature-depth (CTD) cast was performed at AMAR A (on the main SSV track) and AMAR C (2 km [1.2 mi] from the track) on 18 July 2013, after AMAR deployment. A cast was also performed at AMAR D on 28 July 2013 for the later high-frequency source measurement.

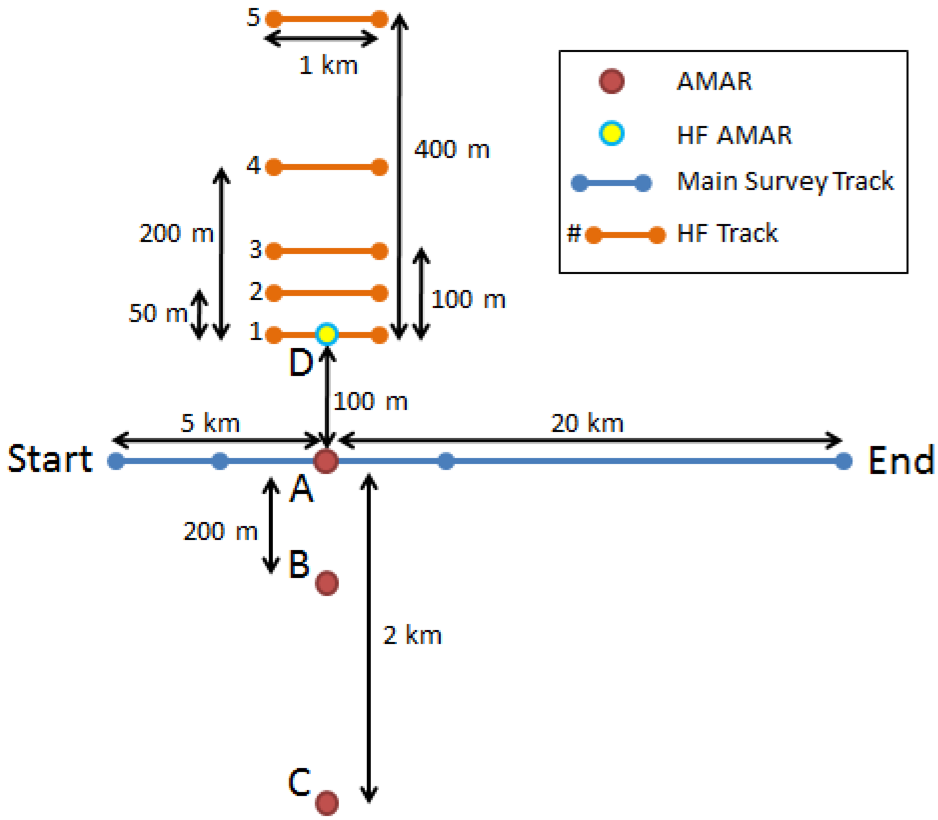

FIGURE 3.6. AMAR deployment geometry and track lines for the SSVs of the shallow hazards and ice gouge survey at the Snickers prospect in the Chukchi Sea.

TABLE 3.2. AMAR deployment locations (WGS 84), and track line start and end for the SSVs of the shallow hazards and ice gouge survey at the Snickers prospect in the Chukchi Sea.

Location	Latitude	Longitude	Water Depth (m)
AMAR A—0 m	70° 55.869’ N	167° 01.936’ W	48
AMAR B—200 m	70° 55.981’ N	167° 01.949’ W	48
AMAR C—2000 m	70° 56.944’ N	167° 02.050’ W	48
AMAR D (HF)—100 m	70° 55.813’ N	167° 01.921’ W	48
Fennica on DP	70° 55.869’ N	167° 01.936’ W	48
Main SSV Track Start	70° 55.775’ N	167° 10.154’ W	43
Main SSV Track End	70° 56.219’ N	166° 29.042’ W	39
Sub-Bottom Profiler Track Start	70° 55.819' N	167° 05.203' W	42
Sub-Bottom Profiler Track End	70° 55.900' N	166° 58.642' W	42
HF Track 1 Start	70° 55.805' N	167° 02.743' W	42
HF Track 1 End	70° 55.823' N	167° 01.099' W	42
HF Track 2 Start	70° 55.778' N	167° 02.740' W	42
HF Track 2 End	70° 55.796' N	167° 01.096' W	42
HF Track 3 Start	70° 55.751' N	167° 02.738' W	42
HF Track 3 End	70° 55.769' N	167° 01.093' W	42
HF Track 4 Start	70° 55.697' N	167° 02.732' W	42
HF Track 4 End	70° 55.715' N	167° 01.088' W	42
HF Track 5 Start	70° 55.590' N	167° 02.721' W	42
HF Track 5 End	70° 55.608' N	167° 01.077' W	42

TABLE 3.3. Schedule of underwater acoustic measurements for the SSVs at the Snickers prospect in the Chukchi Sea. Dates and times are in UTC.

Source	Date	Start	End
Fennica Stationary on DP	18 Jul 2013	19:26	19:38
25 km Main SSV Track			
Airgun Array—10 in³	18–19 Jul 2013	22:52	02:34
Airgun Array—20 in³	19 Jul 2013	03:04	06:30
Airgun Array—40 in³	19 Jul 2013	06:55	10:25
Fennica Transiting	19 Jul 2013	10:46	14:35
4 km of Main SSV Track			
Sub-Bottom Profiler	19 Jul 2013	16:51	17:25
HF SSV Tracks			
Multibeam and Side-Scan Sonar	28 Jul 2013	17:51	20:30
Single-Beam Echosounder	28 Jul 2013	21:02	22:31

Equipment Retrieval and Maintenance at Burger A Well Site

Underwater sound levels at the Burger A well site were measured with five AMARs deployed by the R/V *Westward Wind* from 5 August to 15 October 2013 to capture sound levels as a function of range from the well site (Figure 3.7). The AMARs were deployed in a line heading northeast from the Burger well site at ranges of 0.5, 1, 2, 4, and 8 km (0.3, 0.6, 1.2, 2.5 and 5 mi; Table 3.4). The AMARs recorded data continuously while the *Nordica* performed various equipment retrieval and maintenance activities at the Burger well site (Table 3.5).

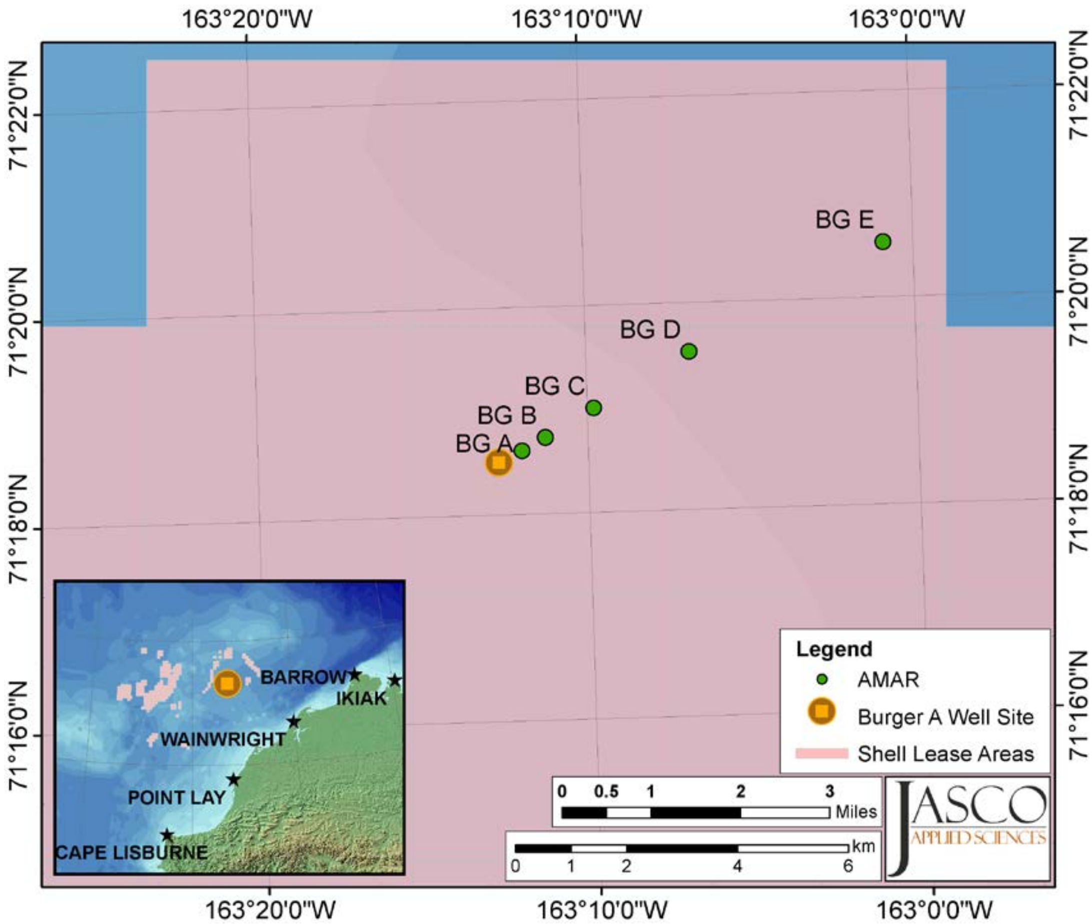

FIGURE 3.7. AMAR deployments relative to the Burger A well site in the Chukchi Sea for measuring sound from the Nordica on DP and ambient sound during equipment and maintenance operations.

TABLE 3.4. Location (WGS 84) and water depths of the AMAR deployments and the well site for the equipment retrieval and maintenance at the Burger A well site in the Chukchi Sea.

Location	Range from Well Site (m)	Latitude	Longitude	Water Depth (m)
AMAR A	500	70° 55.869’ N	167° 01.936’ W	48
AMAR B	1000	70° 55.981’ N	167° 01.949’ W	48
AMAR C	2000	70° 56.944’ N	167° 02.050’ W	48
AMAR D	4000	70° 55.813’ N	167° 01.921’ W	48
AMAR E	8000	70° 55.775’ N	167° 10.154’ W	43
Well Site	0	70° 56.219’ N	166° 29.042’ W	39

TABLE 3.5. Schedule of underwater acoustic measurements for the equipment retrieval and maintenance at the Burger A well site in the Chukchi Sea. Dates and times are in UTC.

Source	Date	Start	End	Wind Force
Nordica on DP, heading 45°, wind force 2	31 Aug 2013	19:19	20:19	2
Nordica on DP, heading 180°, wind force 2	31 Aug 2013	22:18	23:18	2
Ambient	3 Oct 2013	20:03	21:03	0–2
Ambient	7 Aug 2013	19:31	20:31	3–4
Ambient	10 Aug 2013	06:04	07:04	5+

Acoustic Metrics

Underwater sound amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the loudness of impulsive noise, from seismic airguns for example, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate the loudness of impulsive noise and its effects on marine life.

The zero-to-peak SPL, or peak SPL (L_{pk}, dB re 1 µPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic event, $p(t)$:

$$L_{pk} = 10\log_{10}\left(\max\left(\left|p^2(t)\right|\right) / p_0^2\right) \quad (1)$$

The peak SPL metric is commonly quoted for impulsive sounds, but it does not account for the duration or bandwidth of the noise. At high intensities, the peak SPL can be a valid criterion for assessing whether a sound is potentially injurious; however, because the peak SPL does not account for the duration of a noise event, it is a poor indicator of perceived loudness.

The root-mean square (rms) SPL (L_p, dB re 1 µPa) is the rms pressure level in a stated frequency band over a time window (T, s) containing the acoustic event:

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right) \quad (2)$$

The rms SPL is a measure of the average pressure or the effective pressure over the duration of an acoustic event, such as the emission of one acoustic pulse or sweep. Because the window length, T, is the divisor, events more spread out in time have a lower rms SPL for the same total acoustic energy.

In studies of impulsive noise, T is often defined as the "90%-energy pulse duration" (T_{90}): the interval over which the pulse energy curve rises from 5% to 95% of the total energy. The SPL computed over this T_{90} interval is commonly called the 90%-rms SPL (L_{p90}, dB re 1 µPa):

$$L_{p90} = 10\log_{10}\left(\frac{1}{T_{90}}\int_{T_{90}} p^2(t)dt \Big/ p_0^2\right) \quad (3)$$

The sound exposure level (SEL, L_E, dB re 1 µPa^2·s) is a measure of the total acoustic energy contained in one or more acoustic events. The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T_{100}):

$$L_E = 10\log_{10}\left(\int_{T_{100}} p^2(t)dt \Big/ T_0 p_0^2 \right) \quad (4)$$

where T_0 is a reference time interval of 1 s. The SEL represents the total acoustic energy received at some location during an acoustic event; it measures the total sound energy to which an organism at that location would be exposed.

Because the rms SPL and SEL are both computed from the integral of square pressure, these metrics are related by a simple expression, which depends only on the duration of the energy time window T:

$$L_p = L_E - 10\log_{10}(T) \quad (5)$$

$$L_{p90} = L_E - 10\log_{10}(T_{90}) - 0.458 \quad (6)$$

where the 0.458 dB factor accounts for the rms SPL containing 90% of the total energy from the per-pulse SEL.

SEL can be a cumulative metric if calculated over time periods containing multiple acoustic events. The cumulative SEL (L_{EC}) can be computed by summing (in linear units) the SELs of the N individual events (L_{Ei}).

$$L_{EC} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{Ei}}{10}} \right) \quad (7)$$

To compute the SPL and SEL of acoustic events in the presence of high levels of background noise, Equations 3 and 4 are modified to subtract the background noise energy from the event energy:

$$L_{p90} = 10\log_{10}\left(\frac{1}{T_{90}} \int_{T_{90}} p^2(t)dt \Big/ p_0^2 - \overline{n^2} \right) \quad (8)$$

$$L_E = 10\log_{10}\left(\int_{T_{100}} p^2(t)dt \Big/ T_0 p_0^2 - \overline{n^2}T \right) \quad (9)$$

where $\overline{n^2}$ is the mean square pressure of the background noise generally computed by averaging the squared pressure of a nearby segment of the acoustic recording during which acoustic events are absent (e.g., between pulses).

Exponential Time-Average Sound Pressure Level

Exponential time-average SPL (dB re 1 μPa, denoted $L_{p\tau}$) is the rms SPL averaged with respect to an exponential time constant τ (s). It is defined as the integral, from a point of time in the past to the present, at time t, of the squared sound pressure with exponential time-weighting, with ξ as the variable of integration:

$$L_{p\tau}(t) = 10\log_{10}\left(\frac{1}{\tau} \int_{-\infty}^{t} \frac{p^2(\xi)}{p_o^2} e^{-(t-\zeta)/\tau} d\xi \right) \quad (10)$$

This means that when the pressure signal is averaged, more recent signal levels are emphasized over older ones. The time constant determines the breadth of the weighting curve. When the exponential time constant is large, a sharp rise or fall in sound levels will cause a gradual rise or fall in the exponential time-average SPL. When the exponential time constant is small, the time-weighted SPL will respond more rapidly.

Common exponential time constants include the “slow”, “fast”, and “impulse” exponential time-averages as defined in the ANSI standard for assessing in-air loudness for human hearing (ANSI S1.4–1983). For slow exponential time-averaging τ = 1.0 s, and for fast exponential time-averaging τ = 0.125 s. Impulse exponential time-averaging is more elaborate: the impulsive signal is time-weighted with τ = 0.035 s and then the resulting “peaked” output is exponentially attenuated over time with a 1.5 s decay constant. Fast time-weighting was calculated for airgun sources as a comparison to the 90%-rms SPL.

Marine Mammal Frequency Weighting

The potential for anthropogenic noise to affect marine animals depends on how well the animal can hear the noise. For sound levels that are too low to cause physical injury, frequency weighting based on audiograms and critical hearing ratios in noise may be applied to weight the importance of sound levels at particular frequencies in a manner reflective of an animal’s hearing sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

Type I M-Weighting

Based on a literature review of marine mammal hearing and on physiological and behavioral responses to anthropogenic sound, Southall et al. (2007) proposed standard frequency weighting functions—here referred to as Type I M-weighting functions—for five functional hearing groups of marine mammals:

- Low-frequency cetaceans (LFC1)—mysticetes (baleen whales)
- Mid-frequency cetaceans (MFC1)—some odontocetes (toothed whales)
- High-frequency cetaceans (HFC1)—odontocetes specialized for using high-frequencies
- Pinnipeds in water (PW1)—seals, sea lions and walrus
- Pinnipeds in air (not addressed here)

New criteria proposed by the US Navy (Finneran and Jenkins 2012) split the PW1 group to better describe the hearing differences across species. The first group (referred to here as PPW1) covers phocid and sirenian species, and the second group (OPW1) covers otariids, odobenids, mustelids, and ursids.

The Type I M-weighting functions adapt noise levels by frequency according to hearing sensitivity. The discount applied for frequencies with lower hearing sensitivity is less than that indicated by the corresponding audiograms (where available) for member species of these hearing groups. Audiograms test hearing in noise-controlled environments whereas animals usually hear and use acoustic signals in conditions with varying noise levels. Realistic hearing depends on critical ratios (i.e., the amount by which received sound pressure levels must exceed background noise to be detected), which depend on critical bandwidths—the shape of the animal’s hearing filters (Au and Moore 1990). The rationale for applying a smaller discount than suggested by audiograms is due in part to an observed characteristic of mammalian hearing that perceived-equal-loudness contours have increasingly slower roll-off outside the most sensitive hearing frequency range as sound levels increase. This is also why, for example, C-weighting curves for humans are used for assessing loud sounds such as blasts and A-weighting curves are used for quiet to mid-level sounds—the C-weighting curves are flatter than the A-weighting curves. Additionally, out-of-band frequencies, though less audible, can still cause physical injury if pressure levels are sufficiently high or last a sufficiently long time. The Type I M-weighting functions therefore are primarily intended to be applied at high sound levels where effects such as temporary (TTS) or permanent (PTS) hearing threshold shifts may occur.

The use of M-weighting is considered precautionary because it potentially overestimates the onset of harmful exposure and in terms of the range of frequencies for which no weighting is applied. M-weighting assumes that the observable onsets of behavioral responses to noise (e.g., animals moving rapidly away or increasing respiration rates) are already potentially harmful. And behavioral responses can be elicited by noise at frequencies outside the peak range of hearing sensitivity.

Figure 3.8 shows the decibel frequency weighting of the five underwater Type I M-weighting functions. The Type I M-weighting functions have unity gain (0 dB) through the passband and their high and low frequency roll-offs are approximately –12 dB per octave. The amplitude response as a function of frequency for the Type I M-weighting functions is defined by:

$$W_I(f) = K + 20\log_{10}\left[\frac{b^2 f^2}{\left(a^2 + f^2\right)\left(b^2 + f^2\right)}\right] \qquad (11)$$

where $W_1(f)$ is the weighting function amplitude (in dB) at the frequency f (in Hz), K is a constant used to normalize the function at a reference frequency, and a and b are the estimated lower and upper hearing limits, respectively, and control the roll-off and passband of the function (Table 3.6). The M-weighting functions for the PPW1 and OPW1 hearing groups are the same as that proposed by Southall et al. for pinnipeds in water except that a smaller bandwidth is applied for OPW.

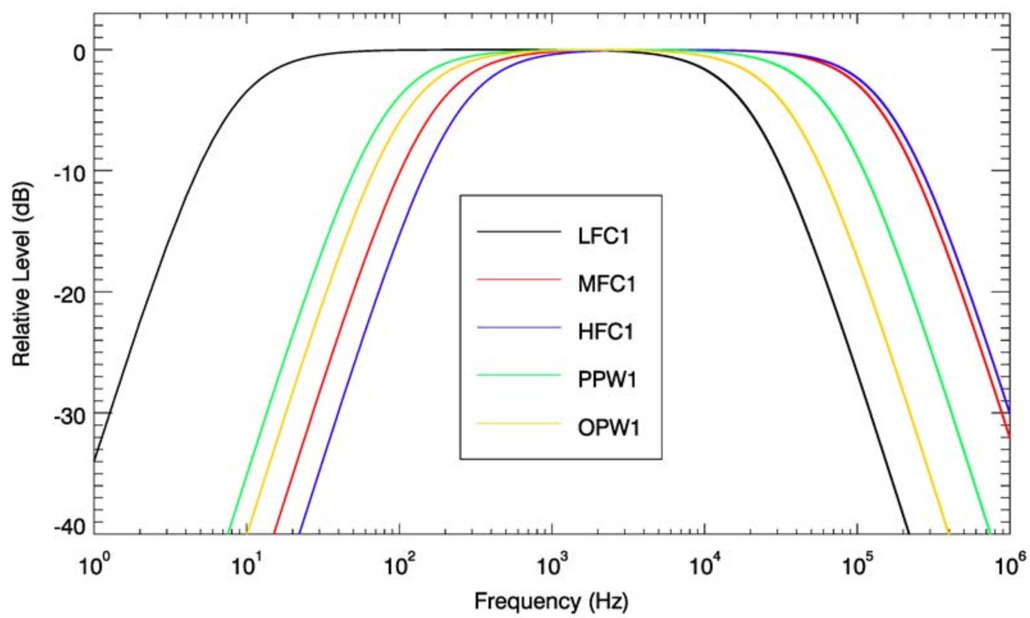

FIGURE 3.8. The Type I M-weighting functions for five marine mammal functional hearing groups (Southall et al. 2007).

TABLE 3.6. Parameters of the Type I M-weighting functions for five marine mammal functional hearing groups (Southall et al. 2007).

Functional hearing group	*K* (dB)	*a* (Hz)	*b* (Hz)
LFC1	0	7	22,000
MFC1	0	150	160,000
HFC1	0	200	180,000
PPW1	0	75	75,000
OPW1	0	100	40,000

Type II M-Weighting

Marine mammals, especially mid- and high-frequency cetaceans, have greater hearing sensitivity at high frequencies compared to other mammals. This is in part because they use sound underwater in the form of echolocation in the manner that terrestrial mammals use light on land (Wartzok and Ketten 1999). To better account for the increased susceptibility of marine mammals to noise at high frequencies (>1 kHz), the US Navy developed Type II M-weighting functions derived from equal-loudness contours for bottlenose dolphins (Finneran and Jenkins 2012). The Type II M-weighting functions incorporate a component based on the Type I functions at low frequencies and an equal-weighting component at high frequencies (Figure 3.9).

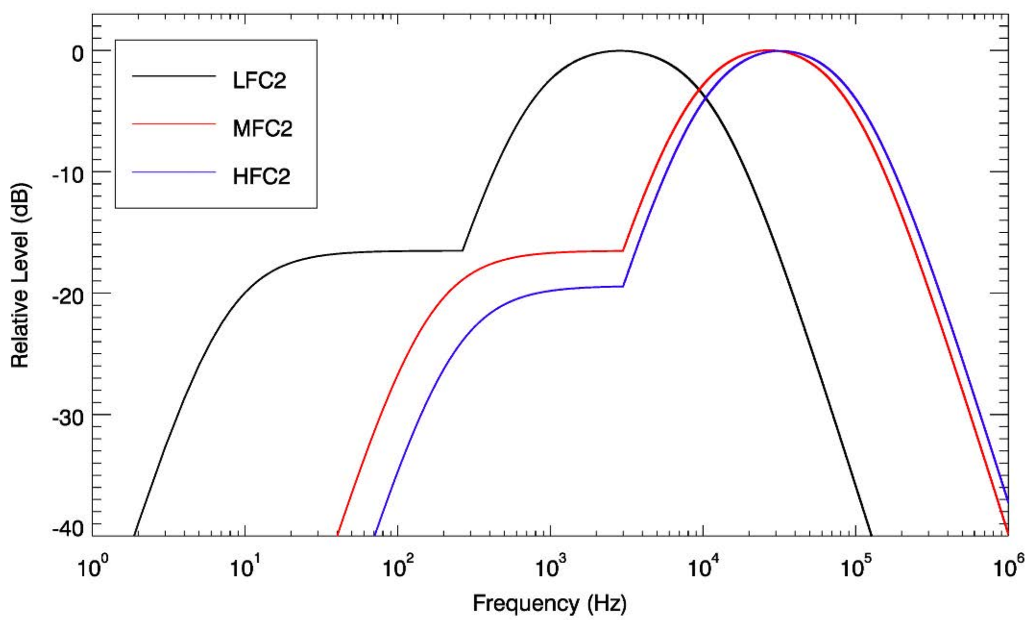

FIGURE 3.9. The Type II M-weighting functions for the low- (LFC2), mid- (MFC2), and high-frequency cetacean (HFC2) functional hearing groups (Finneran and Jenkins 2012).

Equal-loudness contours are unavailable for marine mammals other than the bottlenose dolphin, so the Type II M-weighting functions can be extended to other cetacean species only by adjusting the parameters to the estimated hearing responses in noise of other mammals. Each Type II M-weighting function is a simple reformulation of the Type I function and the equal-loudness contour, equal to the higher of the two curves at each frequency yielding a conservative estimate:

$$W_{II}(f) = \max[G_1(f), G_2(f)]$$
$$G_n(f) = K_n + 20\log_{10}\left[\frac{b_n^2 f^2}{(a_n^2 + f^2)(b_n^2 + f^2)}\right] \quad (12)$$

To account for an increased susceptibility observed in odontocetes to noise above 3 kHz, the MFC2 and HFC2 functions (Table 3.7) are adjusted to place the inflection point at this frequency. The LFC2 function is adjusted so the flat portion is 16.5 dB below the peak of the equal-loudness contour, mimicking the trend of the MFC2 function (Finneran and Jenkins 2012) with the inflection point set at 267 Hz.

TABLE 3.7. The parameters of the Type II M-weighting functions for the cetacean functional hearing groups and the resulting inflection points (Finneran and Jenkins 2012).

Functional hearing group	K_1 (dB)	a_1 (Hz)	b_1 (Hz)	K_2 (dB)	a_2 (Hz)	b_2 (Hz)	Inflection point (Hz)
LFC2	-16.5	7	22,000	0.9	674	12,130	267
MFC2	-16.5	150	160,000	1.4	7829	95,520	3000
HFC2	-19.4	200	180,000	1.4	9480	108,820	3000

Acoustic Signal Analysis

Acoustic data were analyzed with JASCO's custom processing software.

Impulsive Source Sound Levels

For each recorded pulse from the airgun array, the sub-bottom profiler, and the sonar sources, the slant range to the source was computed from GPS coordinates of the AMARs and time referenced navigation logs (provided by Fugro Geoservices), with an offset applied for the center of the acoustic source. The loudness or magnitude of each recorded pulse was quantified by computing three noise metrics: peak SPL, 90%-rms SPL, and SEL.

The digital recording units were converted to micropascals (μPa) by applying the hydrophone sensitivity, the analog circuit frequency response, and the digital conversion gain. An automated feature detection algorithm picked the start and end times of the individual pulses in the acoustic data. The automated detections were supplemented by manual picks as required. Each pulse was then analyzed as follows:

1. A high-pass frequency filter at 10 Hz was applied to the acoustic data.
2. The peak SPL (symbol L_{pk}) was computed according to Equation 1.
3. The cumulative square pressure was computed over the duration of the pulse.
4. The 90%-energy pulse duration (T_{90}) was determined and the 90%-rms SPL (L_{p90}) was computed according to Equation 3.
5. The SEL (L_E) was computed according to Equation 4 over the duration of the pulse.

Vessel and Ambient Sound Levels

Vessel sound levels were characterized with rms SPLs calculated over 1 s long Hanning-weighted time windows with 50% overlap. Slant range between the *Fennica* and the AMARs was computed from time-referenced vessel position logs (provided by Fugro Geoservices). Navigation information and activity records for the *Nordica's* equipment retrieval and maintenance activities were obtained from logs maintained by the protected species observers onboard the *Nordica*. These logs were used to obtain ranges between the *Nordica* and the AMARs at the Burger A well site, and to correlate received sound levels with the activities at the well site.

Percentile spectral levels were calculated for the *Nordica* on DP and for the background noise. For each recording, 1-second sound spectra were computed from the acoustic data using 1-second analysis windows (64,000 samples) with 50% overlap. The time-domain data were shaded using a normalized Hamming window to minimize spectral leakage. Sound power spectral levels were computed with 1 Hz frequency resolution up to the Nyquist frequency (32 kHz). The statistical distribution of the noise was calculated by constructing a histogram of the 1-second spectral values. A bin width of 0.1 dB was used for the noise histograms. The histogram distributions were used to calculate the 5th, 25th, 50th, 75th, and 95th percentile noise spectral levels (where the nth percentile level is the sound level exceeded n% of the time, as defined in ISO standard 1996-1:1982).

Sound Level versus Range

To estimate the distance to sound level thresholds, the 90%-rms SPLs as a function of range were fit with the following empirical propagation loss curves:

$$L_{p90} = \mathrm{SL} - A \log_{10} R - B\,R \quad (13)$$

where R is the slant range from the source to the acoustic recorder (m), SL is the estimated source level at a reference distance of 1 m (dB re 1 μPa @ 1 m), A is the geometric spreading loss coefficient (dB), and B is the absorption loss coefficient (dB/m). Equation 13 was fit to the SPLs by minimizing (in the least-squares sense) the difference between the trend line and the measured SPLs. To conservatively estimate the distance to the sound level thresholds, the best-fit line was shifted upward (by increasing the constant SL term) until the trend line exceeded 90% of all the data points (called the 90th-percentile fit, here the term percentile is used in the statistical sense).

Cumulative Sound Exposure Levels

M-weighted (Types I and II) SELs were computed for the data recorded at each AMAR. The M-weighted SELs from all received airgun pulses were summed on a linear scale to yield the cumulative SELs.

Measurement Terminology

Acoustic energy loss due to spherical spreading depends on the *slant range*, which is the true separation between the source and receiver (Figure 3.10). The horizontal range is the distance in the horizontal plane from the source to the receiver. The vertical separation between the source and receiver is the water depth minus the source depth and minus the elevation of the hydrophone above the seabed. When the slant range is several times greater than the vertical separation, the slant range and the horizontal range are effectively equal. Slant range is used throughout this chapter.

Endfire and *broadside* are the principal directions in the horizontal plane relative to the acoustic source. The endfire direction is along the tow axis (i.e., fore and aft), and the broadside direction is perpendicular to the tow axis (i.e., port and starboard). Seismic airgun arrays are often directional sources, so the received levels in both the broadside and endfire directions were assessed.

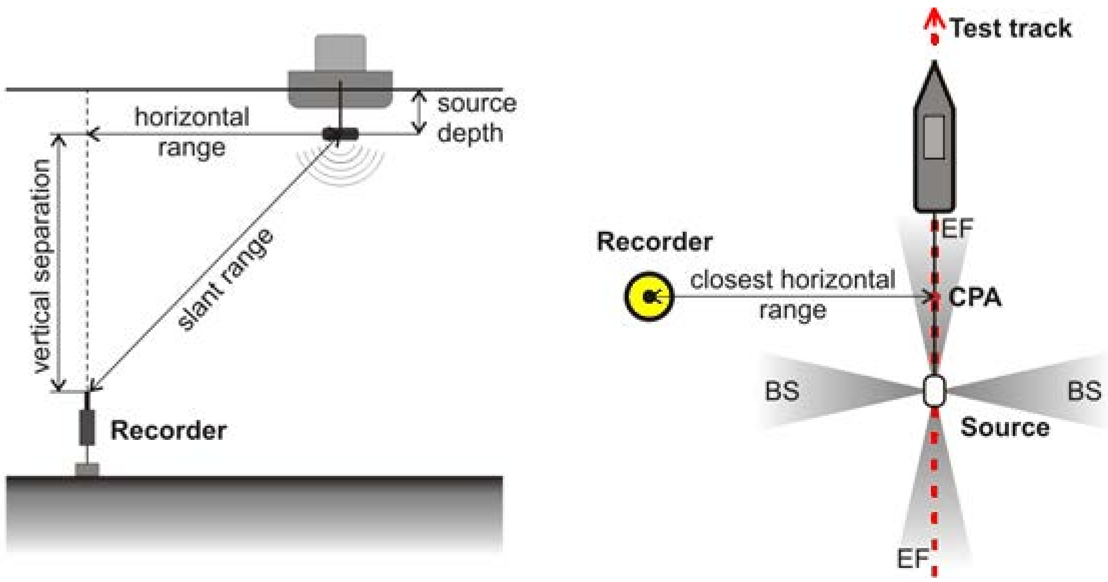

FIGURE 3.10. Typical geometry of sound source verification (SSV) measurements and the associated terminology used in this chapter. Abbreviations: BS, broadside, CPA, closest point of approach; and EF, endfire.

Sound Exposure Criteria

Operational marine mammal safety radii for this seismic survey were based on auditory injury criteria developed by the National Marine Fisheries Service (NMFS). NMFS defines two noise exposure criteria, corresponding to Level A harassment (auditory injury) and Level B harassment (behavioral disturbance) as defined in the US Marine Mammal Protection Act (MMPA 2007). The NMFS criteria are based on the unweighted rms SPL of single airgun pulses.

The NMFS Level A criteria are based on estimates of marine mammal hearing damage thresholds extrapolated from known Damage Risk Criteria for humans (see discussion in Richardson et al. 1995, §10.5). The NMFS Level A criteria, intended to represent cautionary estimates for the onset of auditory system injury, are 190 dB re 1 µPa rms SPL for pinnipeds and 180 dB re 1 µPa rms SPL for cetaceans (e.g., NMFS 1995). The airgun array was to be powered down or shut down when marine mammal observers detected seals within the pre-defined 190 dB re 1 µPa safety radius and/or whales within the pre-defined 180 dB 1 µPa safety radius.

The NMFS Level B criterion for behavioral disturbance is based on estimated received seismic noise levels during behavioral studies in which baleen whales exhibited avoidance behavior around airgun pulses (e.g., Malme et al. 1984, 1986). The threshold for the onset of behavioral disturbance to airgun pulses is 160 dB re 1 µPa rms SPL. The airgun array was to be powered down or shut down when aggregations of 12 or more bowhead or gray whales appeared to be engaged in a non-migratory, significant biological behavior (e.g., feeding, socializing) within the pre-defined 160 dB 1 µPa safety radius.

NMFS is currently in the process of revising the sound exposure criteria for noise from seismic surveys. It is anticipated that the revised criteria will include M-weighted cumulative SEL exposure thresholds. Southall et al. (2007) proposed injury thresholds of 198 dB re 1 $\mu Pa^2 \cdot s$ (Type I M-weighted) for cetaceans and 186 dB re 1 µPa^2·s (Type I M-weighted) for pinnipeds under water. Finneran and Jenkins (2012) proposed physiological effects thresholds for permanent and temporary threshold shift from sonar and other active acoustic sources (Table 3.8).

TABLE 3.8. M-weighted SEL thresholds for permanent (PTS) and temporary (TTS) hearing threshold shifts in marine mammals exposed to sonar and other active acoustic sources.

Functional hearing group	PTS M-weighted SEL threshold (dB re 1 µPa²-s)	TTS M-weighted SEL threshold (dB re 1 µPa²-s)
Low- and mid-frequency cetaceans, Type II (LFC2, MFC2)	198	178
High-frequency cetaceans, Type II (HFC2)	172	152
Phocids and sirenians in water, Type I	197	183
Otariids, odobenids, mustelids, ursids in water, Type I	220	206

Results

Shallow Hazards and Ice Gouge Survey at Snickers Prospect

Sound Speed Profiles

Figure 3.11 shows the sound speed profiles derived from CTD casts measured at AMAR A (0 m from the main SSV track) and AMAR C (2 km [1.2 mi] from the track). A cast (shown in green) was also measured at AMAR D for the later high-frequency source measurements.

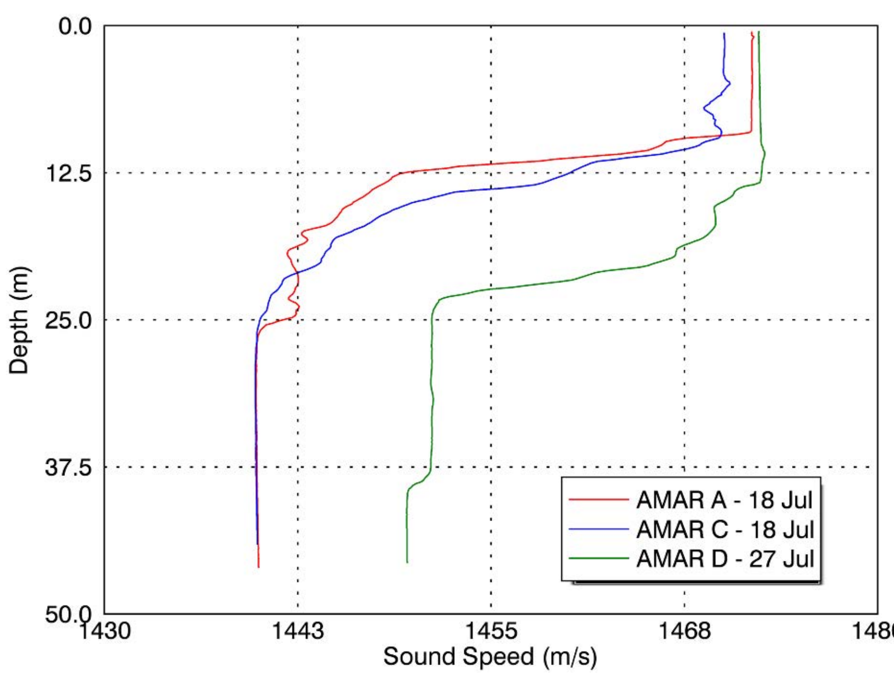

FIGURE 3.11. Sound speed profiles measured at AMAR A (red), AMAR C (blue), and AMAR D (green) at the Snickers prospect in July 2013.

Airgun Array—10 in³ Configuration

The peak SPL, 90%-rms SPL and SEL for each pulse were computed from the acoustic data from AMARs A through D. Figure 3.12 shows sound levels from the 10 in^3 airgun versus range. The single airgun showed no variation in level with direction, so only endfire levels from AMAR A are presented. Table 3.9 shows distances to best-fit and 90th percentile fit rms SPL thresholds from 190 dB to 120 dB re 1 μPa, which were computed from the curve fits to the rms SPL versus range data. A propagation effect related to the geometry of the source and receiver reduced the low-frequency pulse content for a few airgun pulses. This effect is evident for all airgun array configurations. For the 10 in^3 airgun this effect occurred between approximately 80 and 130 m (330 and 430 ft) slant range, reducing the 90%-energy pulse duration and consequently increasing the 90%-rms SPL above the nominal trend. The maximum ranges at which the measured rms SPL for these pulses exceeded the thresholds are given in parenthesis in Table 3.9.

Figure 3.13 compares the waveforms for a pulse at the 47 m (150 ft) CPA and a pulse at 112 m (370 ft) with a very short 90%-energy pulse duration. The evolution of the 90%-energy pulse duration with range is compared with the rms SPL in Figure 3.14.

Figure 3.15 presents spectrograms of 10 in^3 airgun pulses received at AMAR A at the CPA (47 m [150 ft]) and at the farthest range (19.8 km [12.3 mi]). Figure 3.16 shows the 1/3-octave-band SELs versus range and frequency for the 10 in^3 airgun. This contour plot shows the spectral distribution of the sound energy and the frequencies that dominated sound propagation at the SSV site. Sounds at frequencies between 100 and 300 Hz propagated the farthest.

The cumulative SELs received at each AMAR were calculated without M-weighting and with both Type I and Type II M-weighting. Those received at AMAR A are shown in Figure 3.17 (see Appendix E for AMARs B and C). The cumulative SELs increased with shot number as the airgun traversed the SSV track and passed the CPA. Beyond the CPA, the weaker pulses contributed little to the cumulative SELs, which plateaued. These cumulative SELs represent the exposure to an animal that would have remained stationary at AMAR A throughout the exposure as the airgun operated along the entire SSV track. The total cumulative SEL for each hearing group is listed in Table 3.10. The total cumulative SEL did not reach the proposed cSEL thresholds (see Sound Exposure Criteria) at the closest measurement range of 47 m (150 ft).

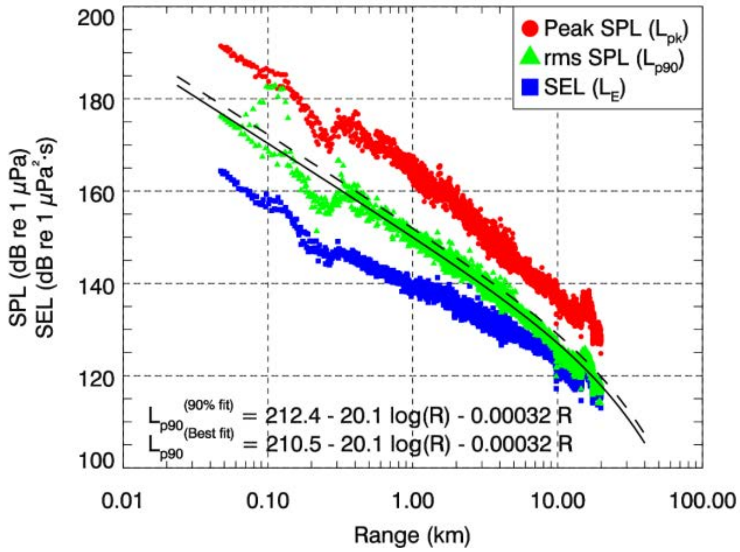

FIGURE 3.12. Peak SPL, rms SPL, and SEL versus range for 10 in^3 airgun pulses at the SSV site in the endfire direction. The airgun showed no variation in level with direction, so only endfire levels from AMAR A are shown. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.9. Distances to rms SPL thresholds at the SSV site for the 10 in^3 airgun as determined from fits to the rms SPLs in FIGURE 3.12. The airgun showed no variation in level with direction, so only endfire values are presented.

	Endfire Direction	
rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	10*	13*
180	33* (127†)	41* (127†)
170	100 (137†)	130 (137†)
160	320	400
150	1000	1200
140	2900	3600
130	7700	9200
120	17,000	20,000

* Extrapolated beyond the closest measurement.
† Not from fit—maximum range at which the measured rms SPL exceeded the threshold value.

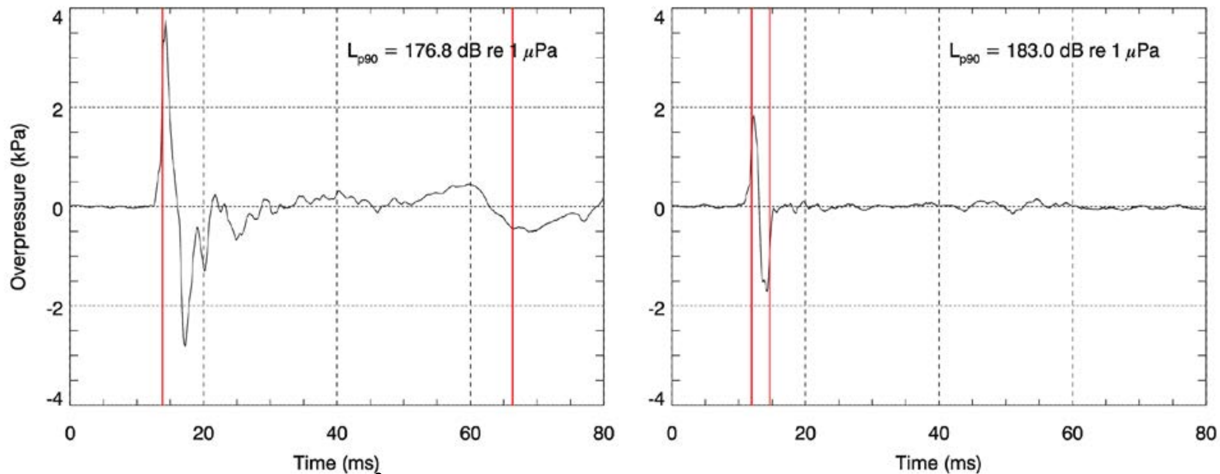

FIGURE 3.13. Waveforms of 10 in^3 airgun pulses received at AMAR A at the CPA (47 m [150 ft], left) and just before the CPA (112 m [370 ft], right) showing the difference in the 90%-energy pulse duration (red lines). The pulse on the right has a greater rms SPL than on the left.

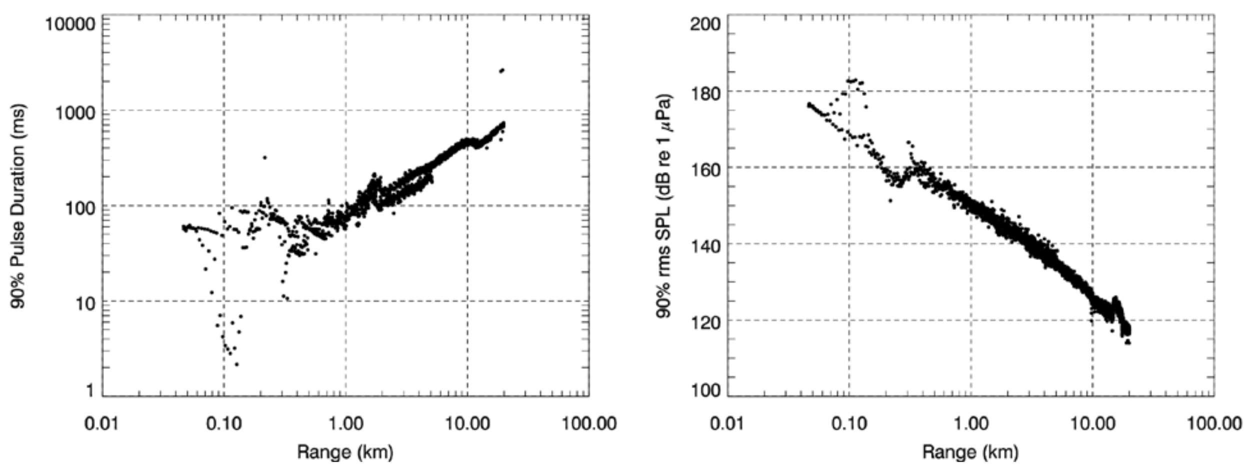

FIGURE 3.14. The 90% energy pulse duration (left) and 90%-rms SPL (right) as functions of range for pulses from the 10 in^3 airgun received in the endfire direction on AMAR A.

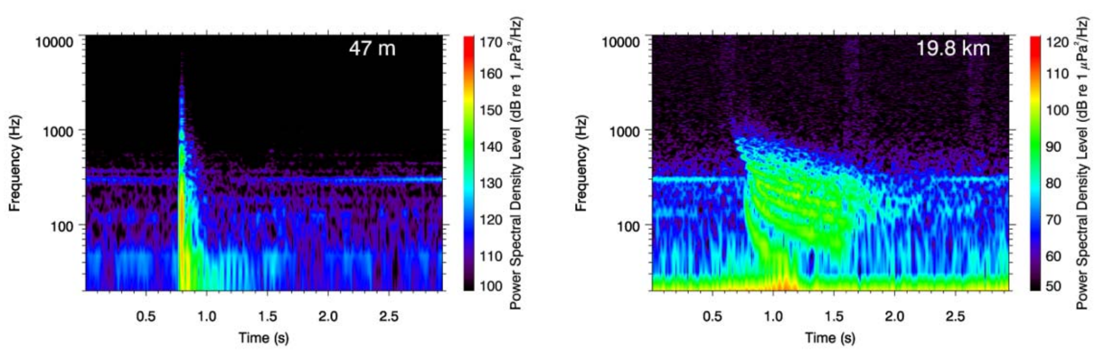

FIGURE 3.15. Spectrograms of 10 in^3 airgun pulses received at AMAR A at the CPA (47 m [150 ft], left) and at long range (19.8 km [12.3 mi], right). 4096 pt FFT length, 87.5% overlap, Hanning window.

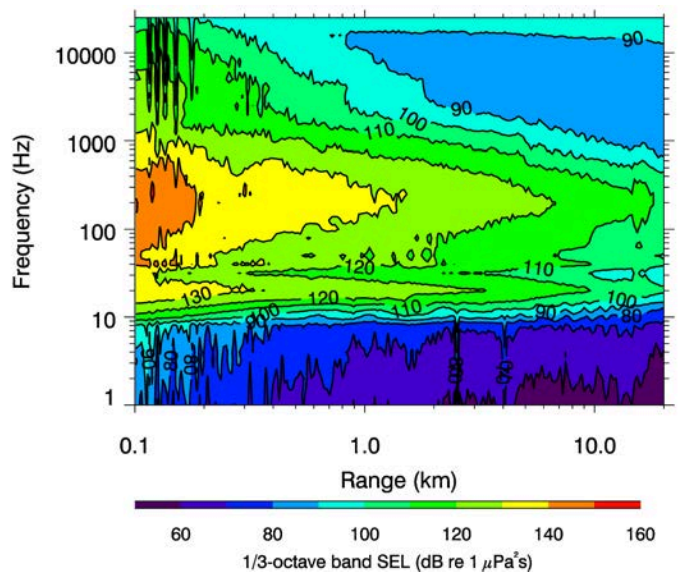

FIGURE 3.16. One-third-octave-band SEL as a function of range and frequency for the 10 in³ airgun.

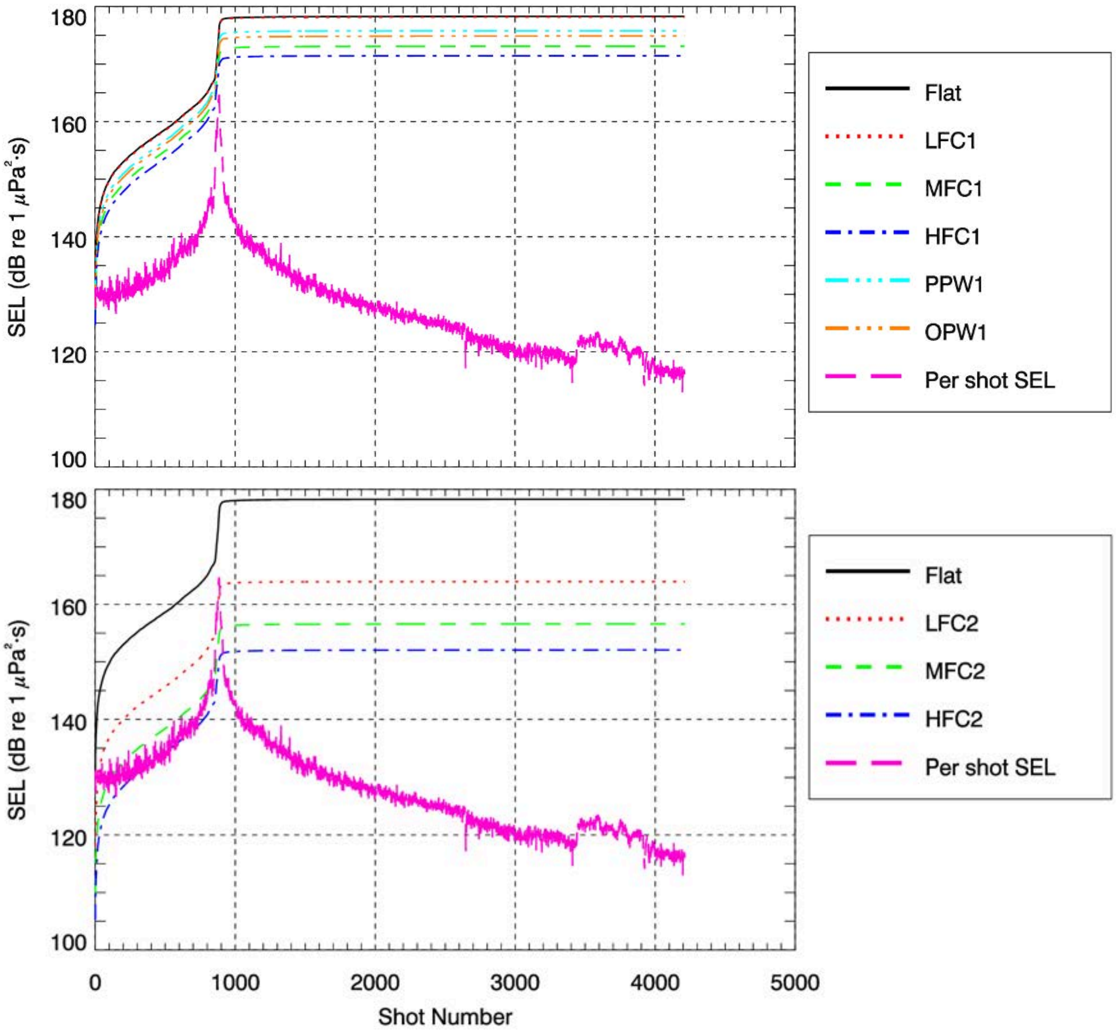

FIGURE 3.17. Per-shot and cumulative sound exposure levels received at AMAR A (47 m [150 ft] CPA) as a function of airgun shot number as the 10 in^3 airgun transited the main SSV track. Flat-weighted (i.e., unweighted) and Type I (top) and Type II (bottom) M-weighted cumulative SELs are shown.

TABLE 3.10. Total cumulative sound exposure level (cSEL) received at AMAR A (46 m [150 ft] CPA), without M-weighting and with Type I and Type II M-weighting, from the 10 in³ airgun.

M-Weighting	cSEL (dB re 1 μPa²·s)
None (Flat)	178.3
LFC1	178.2
MFC1	173.0
HFC1	171.5
PPW1	175.6
OPW1	174.5
LFC2	178.3
MFC2	156.6
HFC2	152.1

Airgun Array—20 in³ Configuration

The peak SPL, 90%-rms SPL and SEL for each pulse were computed from acoustic data from AMARs A through D. Figure 3.18 shows sound levels from the 20 in^3 airgun array versus range in both the endfire and broadside directions. Table 3.11 shows the distances to best-fit and 90th percentile fit rms SPL thresholds from 190 dB to 120 dB re 1 µPa, which were computed from the curve fits to the rms SPL versus range data. These data contain some pulses that exhibit the pulse-shortening effect described above for the 10 in^3 airgun. For the 20 in^3 airgun array this effect occurred between approximately 70 and 130 m (230 and 430 ft) slant range. The maximum ranges at which the measured rms SPL for these pulses exceeded the thresholds are given in parenthesis in Table 3.11.

Figure 3.19 compares a pulse at the CPA (46 m [150 ft]) and a pulse at 122 m (400 ft) with a very short 90%-energy pulse duration. The evolution of the 90%-energy pulse duration with range is compared with the rms SPL in Figure 3.20.

Figure 3.21 presents spectrograms of the 20 in^3 airgun array pulses received at AMAR A at the CPA (46 m [150 ft]) and at the farthest range (19.9 km [12.4 mi]). Figure 3.22 shows the 1/3-octave-band SELs versus range and frequency for the 20 in³ airgun array. This contour plot shows the spectral distribution of the sound energy and the frequencies that dominated sound propagation at the SSV site. Sounds at frequencies between 100 and 300 Hz propagated the farthest.

The cumulative SELs received at each AMAR were calculated without M-weighting and with both Type I and Type II M-weighting. Those received at AMAR A are shown in Figure 3.23 (see Appendix E for AMARs B and C). The cumulative SELs increased with shot number as the airgun traversed the SSV track and passed the CPA. Beyond the CPA, the weaker pulses contributed little to the cumulative SELs, which plateaued. These cumulative SELs represent the exposure to an animal that would have remained stationary at AMAR A throughout the exposure as the airgun operated along the entire SSV track. The total cumulative SEL for each hearing group is listed in Table 3.12. The total cumulative SEL did not reach the proposed cSEL thresholds (see Sound Exposure Criteria) at the closest measurement range of 46 m (150 ft).

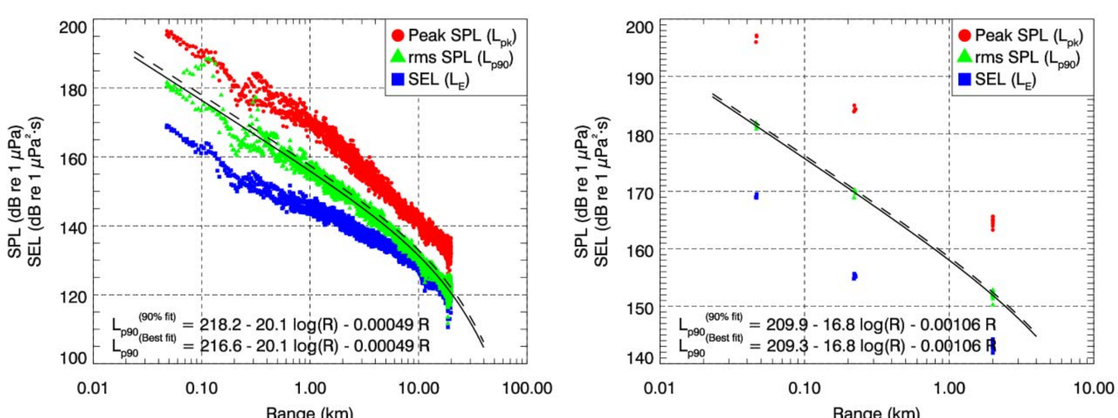

FIGURE 3.18. Peak SPL, rms SPL, and SEL versus range for 20 in^3 airgun array pulses at the SSV site in the endfire (left) and broadside (right) directions. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.11. Distances to rms SPL thresholds at the SSV site for the 20 in^3 airgun array as determined from fits to the rms SPLs in FIGURE 3.18.

	Endfire Direction		Broadside Direction	
rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	21†	25†	14†	15†
180	66 (133*)	79 (133*)	56	60
170	200	250	220	230
160	640	760	790	840
150	1900	2200	2400†	2600†
140	4900	5700	5900†	6000†
130	11,000	12,000	11,000†	11,000†
120	20,000†	22,000†	17,000†	18,000†

* Not from fit—maximum range of a pulse with a received rms SPL greater than threshold.
† Extrapolated beyond the measurement range.

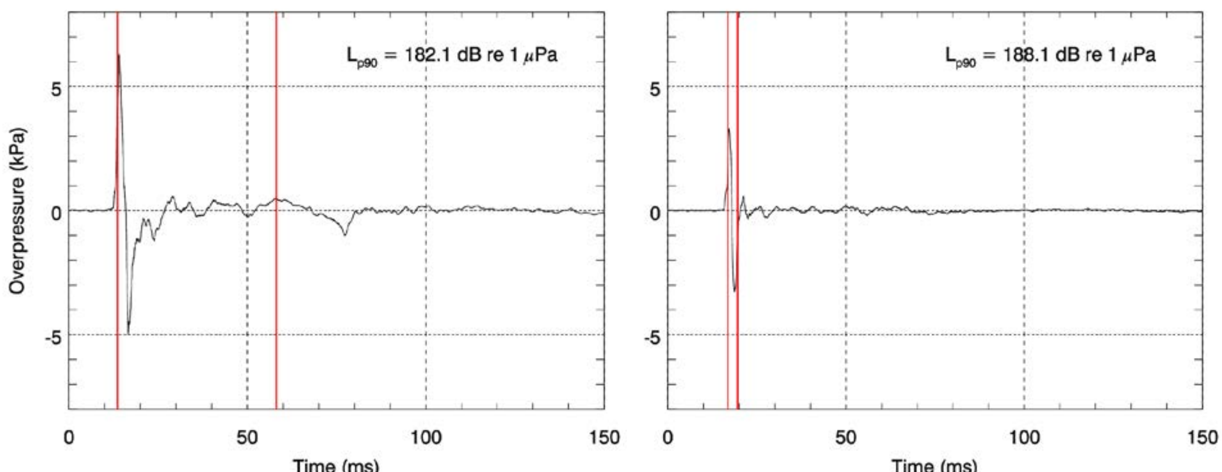

FIGURE 3.19. Waveforms of 20 in^3 airgun array pulses received at AMAR A at the CPA (46 m [150 ft], left) and just before the CPA (122 m [400 ft], right) showing the difference in the 90%-energy pulse duration (red lines). The pulse on the right has a greater rms SPL than on the left.

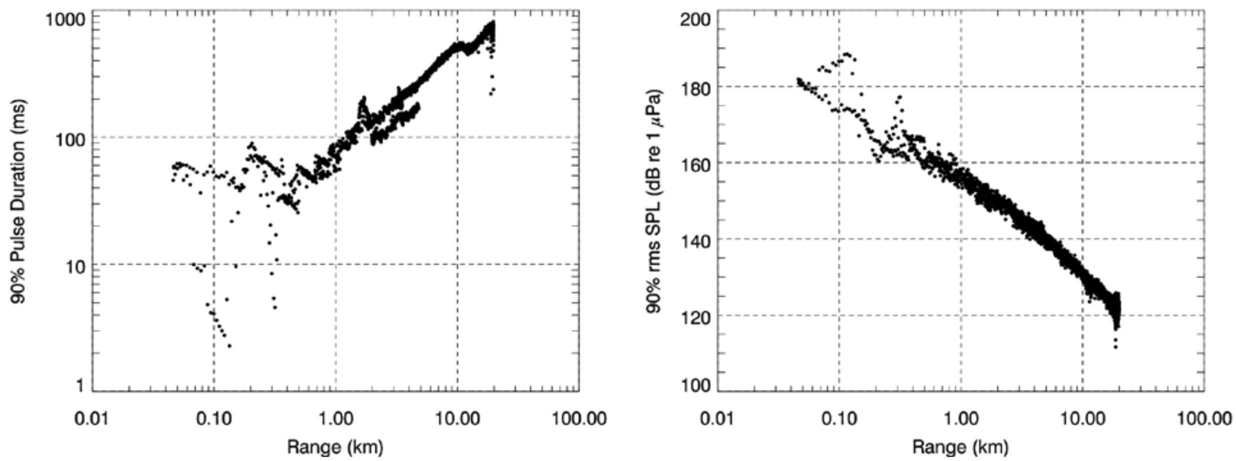

FIGURE 3.20. The 90%-rms pulse duration (left) and 90%-rms SPL (right) as functions of range for pulses from the 20 in^3 airgun array received in the endfire direction on AMAR A.

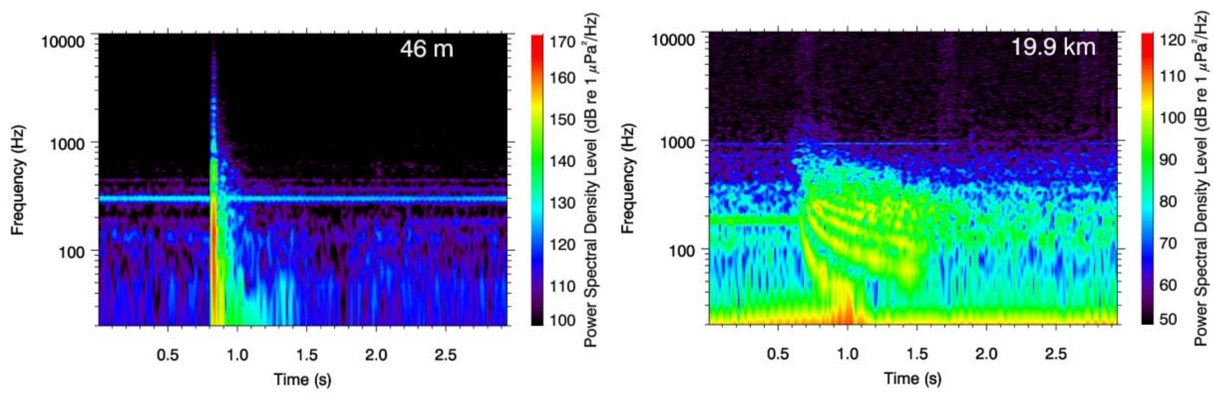

FIGURE 3.21. Spectrograms of 20 in^3 airgun array pulses received at AMAR A at the CPA (46 m [150 ft], left) and at long range (19.9 km [12.4 mi], right). 4096 pt FFT length. 87.5% overlap, Hanning window.

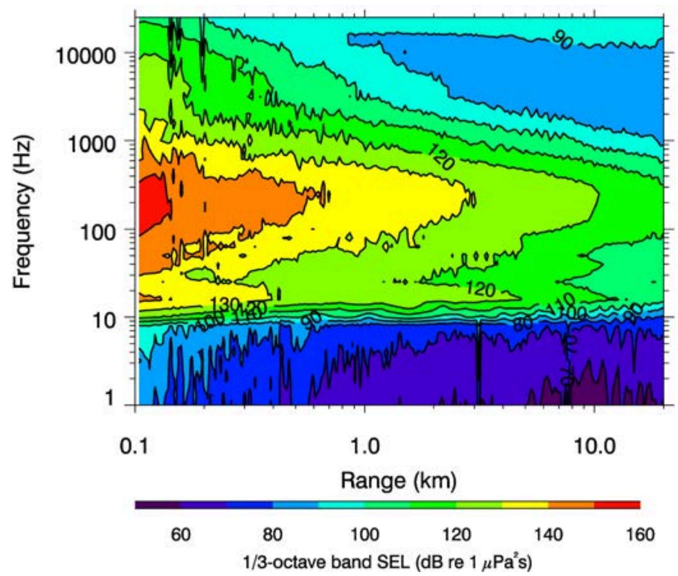

FIGURE 3.22. One-third-octave-band SEL as a function of range and frequency for the 20 in³ airgun array.

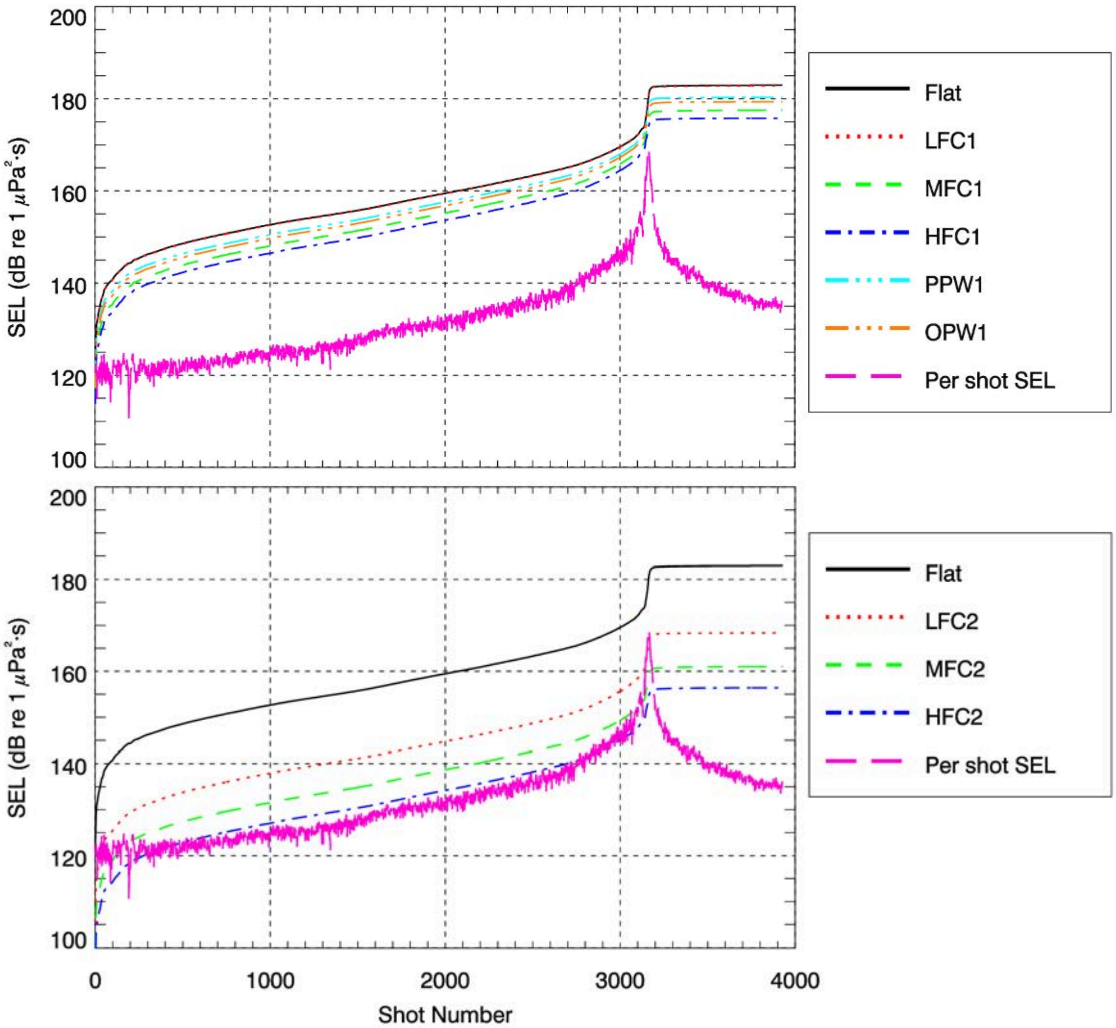

FIGURE 3.23. Per-shot and cumulative sound exposure levels received at AMAR A (46 m [150 ft] CPA) as a function of airgun shot number as the 20 in^3 airgun array transited the main SSV track. Flat-weighted (i.e., unweighted) and Type I (top) and Type II (bottom) M-weighted cumulative SELs are shown.

TABLE 3.12. Total cumulative sound exposure level (cSEL) received at AMAR A (46 m [150 ft] CPA), without M-weighting and with Type I and Type II M-weighting, from the 20 in^3 airgun array.

M-Weighting	Maximum cSEL (dB re 1 μPa²·s)
None (Flat)	182.9
LFC1	182.8
MFC1	177.5
HFC1	175.8
PPW1	180.3
OPW1	179.3
LFC2	168.3
MFC2	161.0
HFC2	156.4

Airgun Array—40 in³ Configuration

The peak SPL, 90%-rms SPL and SEL for each pulse were computed from acoustic data from AMARs A through D. Figure 3.24 shows sound levels from the 40 in^3 airgun array versus range in both the endfire and broadside directions. Table 3.13 shows distances to best-fit and 90th percentile fit rms SPL thresholds from 190 dB to 120 dB re 1 μPa, which were computed from the curve fits to the rms SPL versus range data. These data contain some pulses that exhibit the same pulse-shortening that was described above for the 10 in^3. For the 40 in^3 airgun array this occurred between approximately 80 and 120 m (260 and 390 ft) slant range. The maximum ranges at which the measured rms SPL for these pulses exceeded the thresholds are given in parenthesis in Table 3.13.

Figure 3.25 compares a pulse at the CPA (46 m [150 ft]) and a pulse at 80 m (260 ft) with a very short 90%-energy pulse duration. The evolution of the 90%-energy pulse duration with range is compared with the rms SPL in Figure 3.26.

Figure 3.27 presents spectrograms of 40 in^3 airgun array pulses received at AMAR A at the CPA (46 m [150 ft]) and at the farthest range (19.9 km [12.4 mi]). Figure 3.28 shows the 1/3-octave-band SELs versus range and frequency for the 40 in³ airgun array. This contour plot shows the spectral distribution of the sound energy and the frequencies that dominated sound propagation at the SSV site. Sounds at frequencies between 50 and 300 Hz propagated the farthest.

The cumulative SELs received at each AMAR were calculated without M-weighting and with both Type I and Type II M-weighting. Those received at AMAR A are shown in Figure 3.29 (see Appendix E for AMARs B and C). The cumulative SELs increased with shot number as the airgun traversed the SSV track and passed the CPA. Beyond the CPA, the weaker pulses contributed little to the cumulative SELs, which plateaued. These cumulative SELs represent the exposure to an animal that would have remained stationary at AMAR A throughout the exposure as the airgun operated along the entire SSV track. The total cumulative SEL for each hearing group is listed in Table 3.14. The total cumulative SEL did not reach the proposed cSEL thresholds (see Sound Exposure Criteria) at the closest measurement range of 46 m (150 ft).

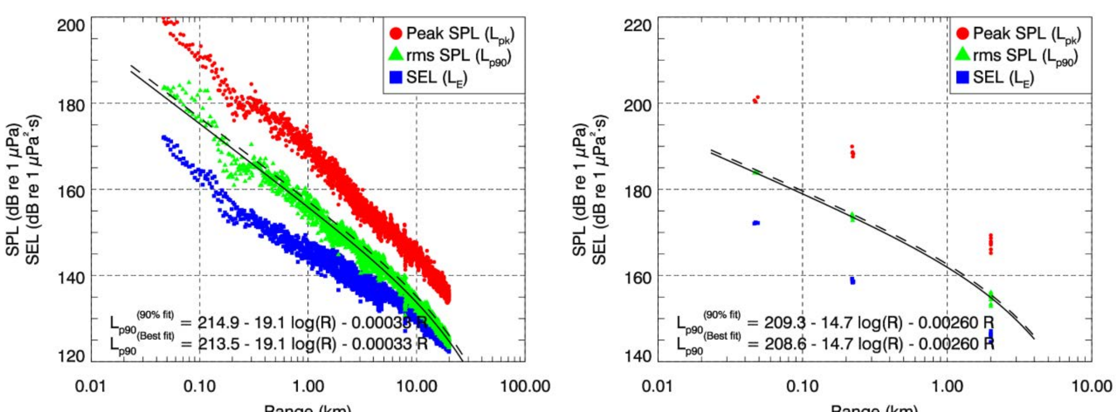

FIGURE 3.24. Peak SPL, rms SPL, and SEL versus range for 40 in^3 airgun array pulses at the SSV site in the endfire (left) and broadside (right) directions. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.13. Distances to rms SPL thresholds at the SSV site for the 40 in^3 airgun array as determined from fits to the rms SPLs in FIGURE 3.24.

	Endfire Direction		Broadside Direction	
rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	17†	20†	18†	20†
180	56 (123*)	67 (123*)	90	95
170	190	220	370	400
160	620	720	1200	1300
150	1900	2300	2900†	3100†
140	5600	6400	5300†	5500†
130	14,000	15,000	8100†	8300†
120	27,000†	29,000†	11,000†	11,000†

* Not from fit—maximum range at which the measured rms SPL exceeded the threshold.
† Extrapolated beyond the measurement range.

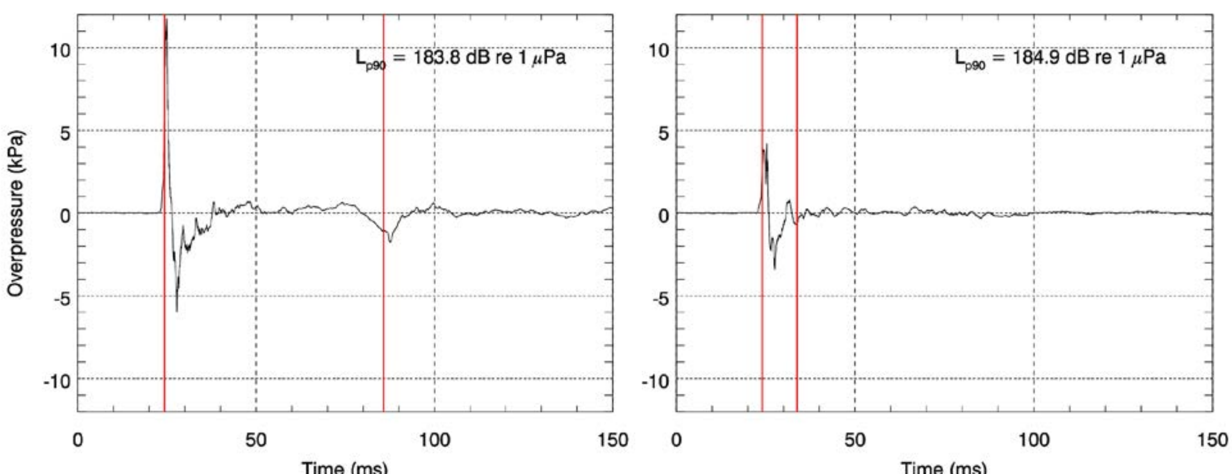

FIGURE 3.25. Waveforms of 40 in^3 airgun array pulses received at AMAR A at the CPA (49 m [160 ft], left) and just before the CPA (80 m [260 ft], right) showing the difference in the 90%-energy pulse duration (red lines). The pulse on the right has a greater rms SPL than on the left.

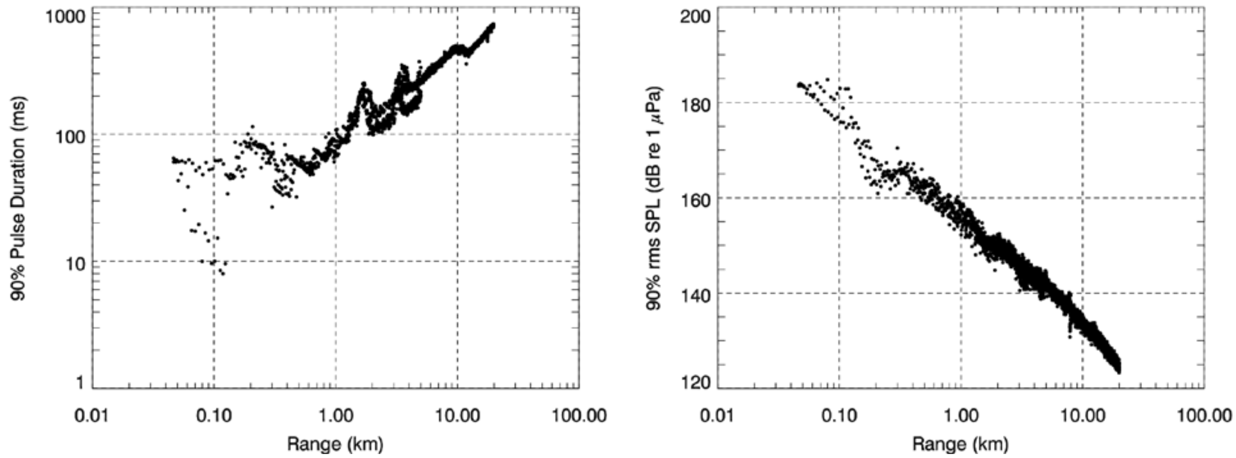

FIGURE 3.26. The 90%-rms pulse duration (left) and 90%-rms SPL (right) as functions of range for pulses from the 40 in^3 airgun array received in the endfire direction on AMAR A.

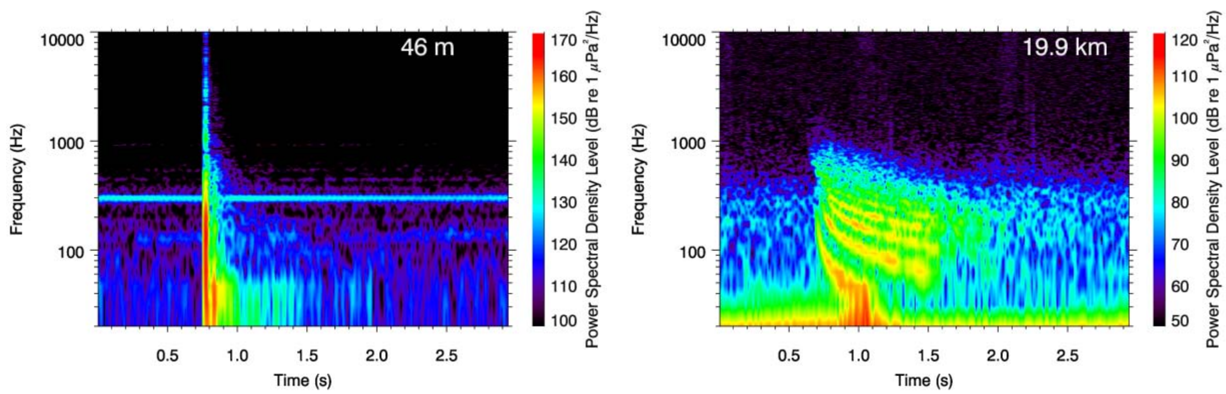

FIGURE 3.27. Spectrograms of 40 in^3 airgun array pulses received at AMAR A at the CPA (46 m [150 ft], left) and at long range (19.9 km [12.4 mi], right). 4096 pt FFT length. 87.5% overlap, Hanning window.

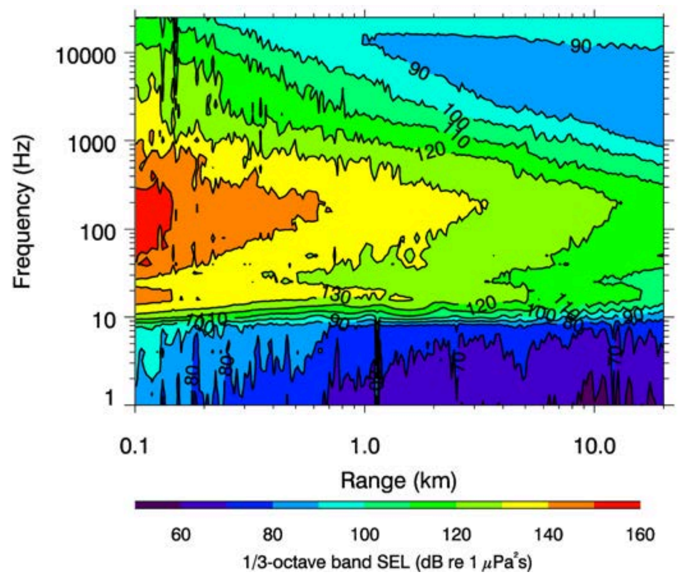

FIGURE 3.28. One-third-octave-band SEL as a function of range and frequency for the 40 in³ airgun array.

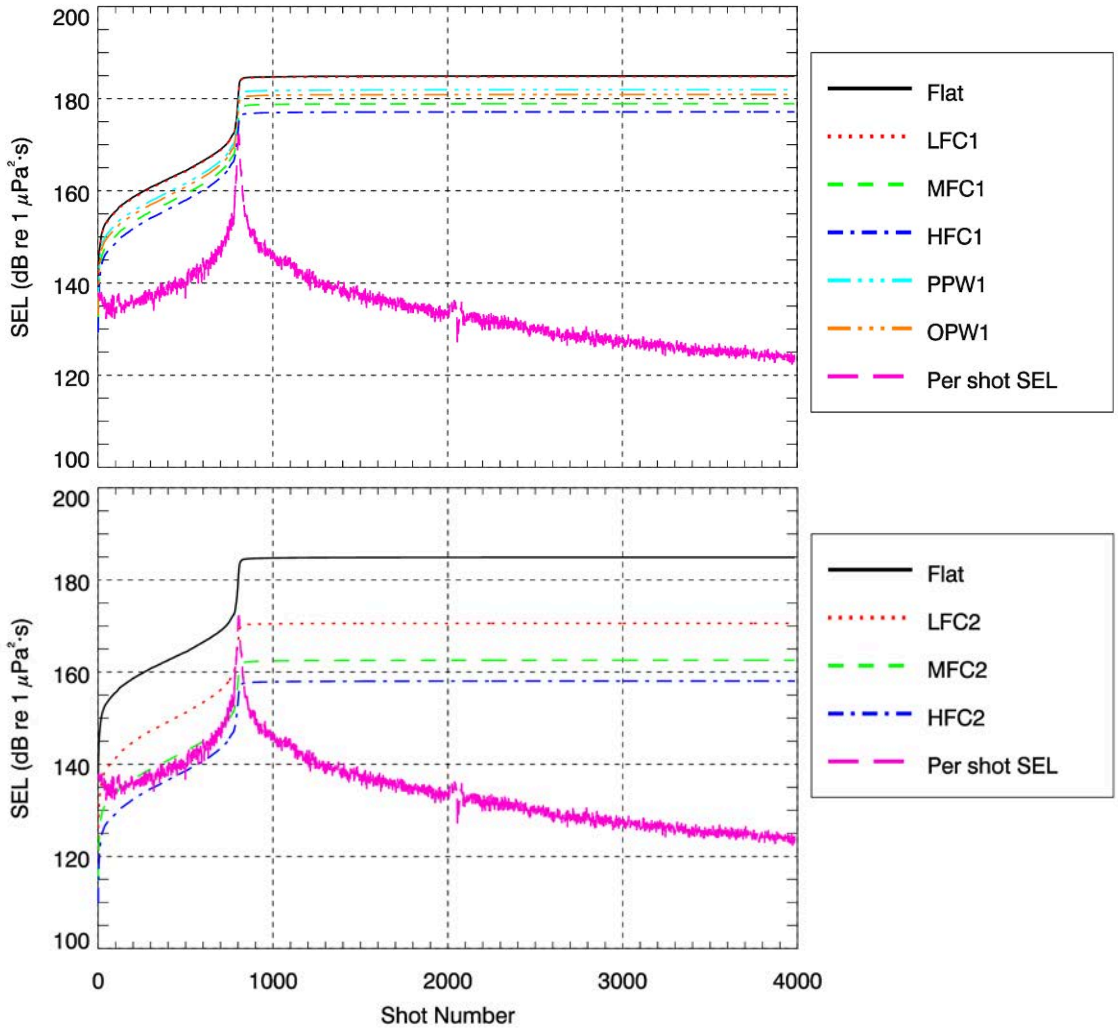

FIGURE 3.29. Per-shot and cumulative sound exposure levels received at AMAR A (46 m [150 ft] CPA) as a function of airgun shot number as the 40 in^3 airgun array transited the main SSV track. Flat-weighted (i.e., unweighted) and Type I (top) and Type II (bottom) M-weighted cumulative SELs are shown.

TABLE 3.14. Total cumulative sound exposure level (cSEL) received at AMAR A (46 m [150 ft] CPA), without M-weighting and with Type I and Type II M-weighting, from the 40 in³ airgun array.

M-Weighting	Maximum cSEL (dB re 1 μPa²·s)
None (Flat)	184.9
LFC1	184.8
MFC1	178.9
HFC1	177.1
PPW1	181.9
OPW1	180.9
LFC2	170.6
MFC2	162.6
HFC2	158.0

EdgeTech 3200 Sub-Bottom Profiler

Sound levels were computed for the sub-bottom profiler traversing 4 km (2.5 mi) of the main SSV track centered over AMAR A. The profiler was towed 10 m (33 ft) behind the survey vessel at 10 m (33 ft) depth at a nominal speed of 3.8 kts. A band-pass filter between 1 kHz and 20 kHz was applied to the acoustic data to isolate the sub-bottom profiler pulses from the background noise. Figure 3.30 presents the sound levels versus range, as well as the best-fit and 90th-percentile fits to the rms SPLs and the equations thereof. The distances to sound level thresholds of 160 to 120 dB re 1 µPa (rms) are listed in Table 3.15. Figure 3.32 shows the waveform and spectral density of pulses measured at the CPA (40 m [130 ft]) and at 1 km (0.6 mi). Figure 3.31 displays the corresponding spectrograms.

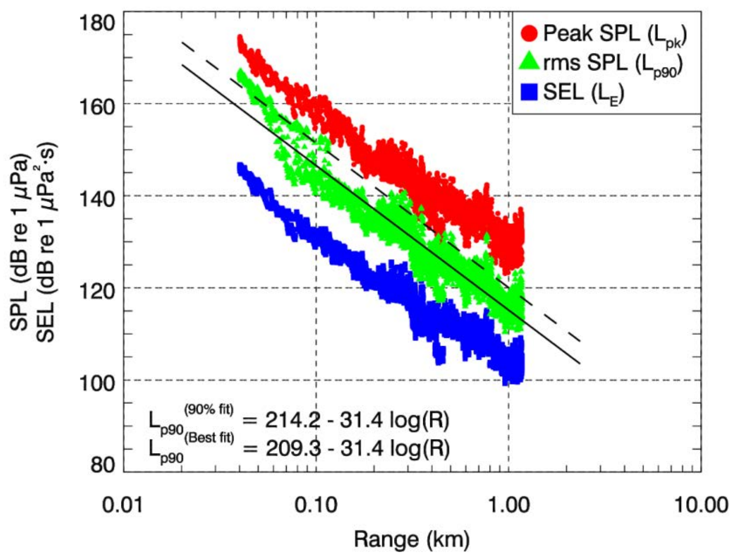

FIGURE 3.30. Peak SPL, rms SPL, and SEL versus range for sub-bottom profiler pulses at the SSV site. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.15. Distances to rms SPL thresholds at the SSV site for the sub-bottom profiler as determined from fits to the rms SPLs in FIGURE 3.30.

rms SPL (dB re 1 µPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
160	37*	53
150	78	110
140	160	230
130	340	480
120	700	1000

* Extrapolated beyond the closest measurement range of 40 m (130 ft).

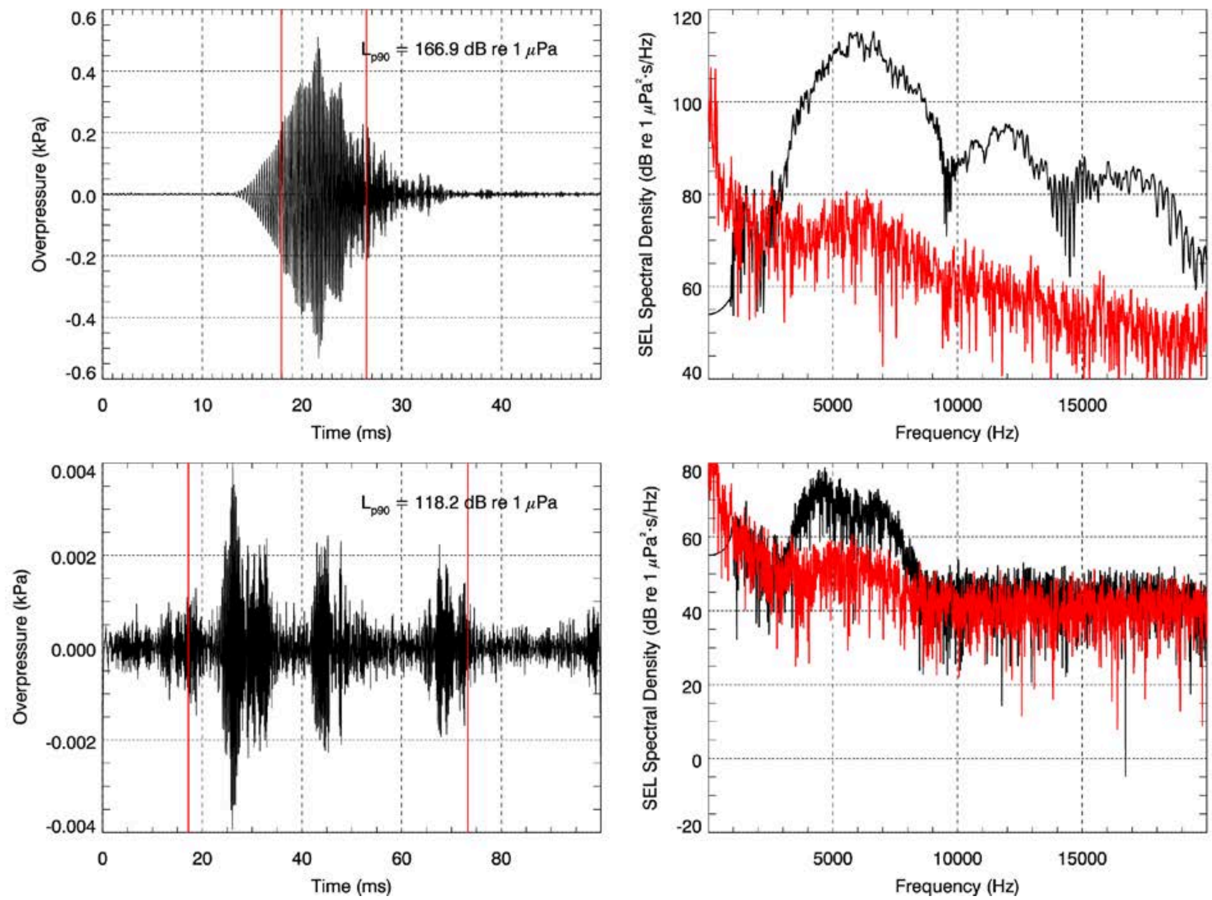

FIGURE 3.31. Waveform (left) and spectral density (right) of sub-bottom profiler pulses received at AMAR A at the CPA (40 m [130 ft], top) and at 1 km range (0.6 mi, bottom) showing the difference in the 90%-energy pulse duration (red vertical lines). The spectral density of the background noise is plotted in red for comparison.

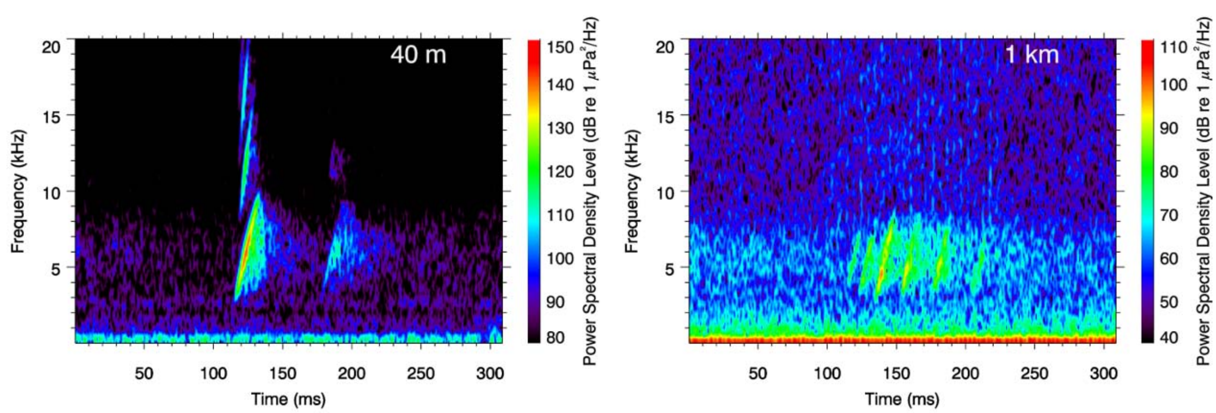

FIGURE 3.32. Spectrograms of the sub-bottom profiler pulses shown in FIGURE 3.31 at the CPA of 40 m (130 ft, left) and at 1 km range (0.6 mi, right). 256 pt FFT length. 87.5% overlap, Hanning window.

EdgeTech 4200 Side-Scan Sonar

Sound levels were computed for the side-scan sonar towed 90 m (300 ft) behind the survey vessel at an average depth of 20 m (66 ft) as it transited over the five HF tracks at a nominal speed of 3.8 kts. A band-pass filter between 105 and 135 kHz was applied to the data to isolate the 120 kHz pulses from background noise. The side-scan sonar also emits pulses at 400 kHz. This frequency is beyond the sampled bandwidth of the AMAR and could not be quantified, but it is also well outside the hearing range of marine mammals. Figure 3.33 presents the sound levels versus range, as well as the best-fit and 90th-percentile fits to the rms SPLs and the equations thereof. Because of the directionality of the sonar, only (up to) the 10 loudest received pulses per track judged as being from the main beam of the sonar are plotted. These pulses were received at the CPA of each of the five HF tracks. The distances to rms SPL thresholds of 160 to 120 dB re 1 μPa are listed in Table 3.16. Figure 3.34 shows the waveform and spectral density of a pulse measured at the CPA (39 m [130 ft]) with the background noise plotted in red for comparison. Figure 3.35 displays the corresponding spectrogram.

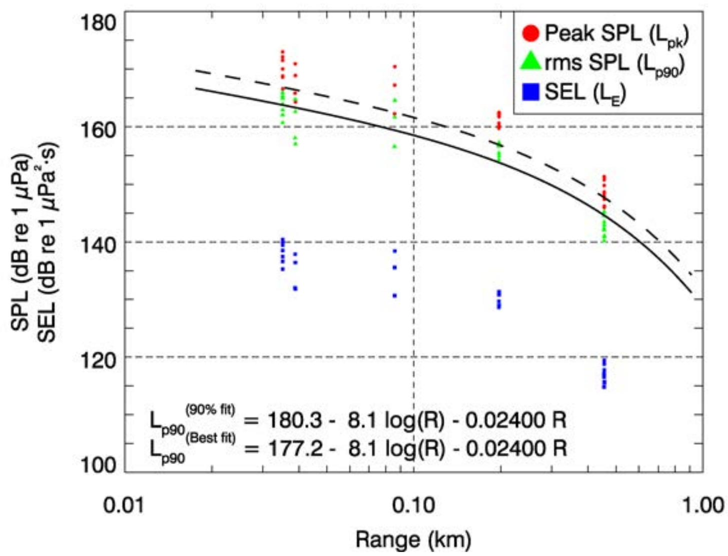

FIGURE 3.33. Peak SPL, rms SPL, and SEL versus range for side-scan sonar pulses at the SSV site. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit). The acoustic data were band-pass filtered between 105 and 135 kHz before the sound levels were calculated.

TABLE 3.16. Distances to rms SPL thresholds at the SSV site for in-beam pulses from the side-scan sonar being towed at 3.8 kts as determined from fits to the rms SPLs in FIGURE 3.42.

rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
180	--	1*
170	7*	16*
160	76	130
150	290	380*
140	600*	710*
130	950*	1100*
120	1300*	1400*

* Extrapolated beyond the measurement range.

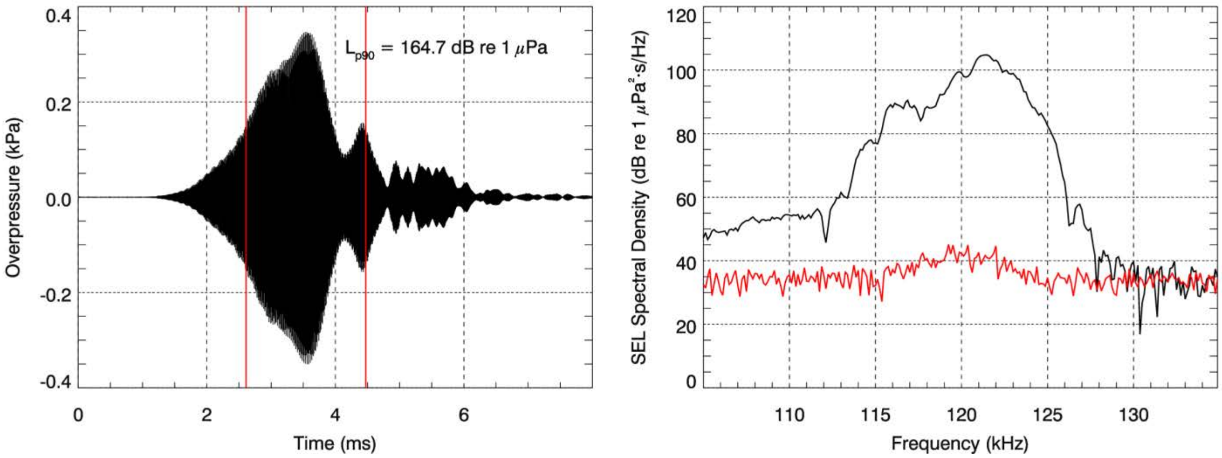

FIGURE 3.34. Waveform (left) and spectral density (right) of side-scan sonar pulses measured on AMAR D near the CPA (39 m [130 ft]). The spectral density of the background noise is plotted in red for comparison. The acoustic data were band-pass filtered between 105 and 135 kHz.

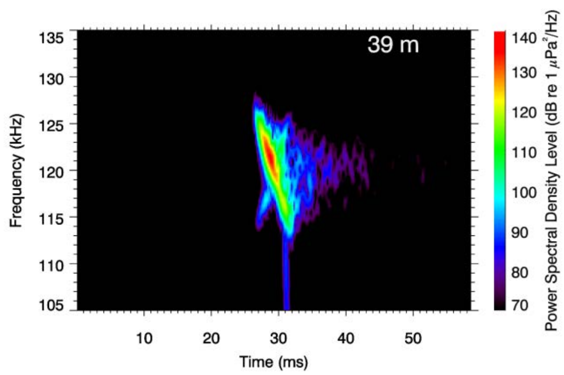

FIGURE 3.35. Spectrogram of the side-scan sonar pulse shown in FIGURE 3.34 near the CPA (39 m [130 ft]). 1024 pt FFT length. 87.5% overlap, Hanning window.

<u>RESON 7101 Multibeam Sonar</u>

SPLs were computed for the multibeam sonar, pole-mounted below the vessel at 9 m (30 ft) depth as the survey vessel transited over the five HF tracks at a nominal speed of 3.8 kts. A band-pass filter between 200 and 280 kHz was applied to the acoustic data to isolate the 240 kHz pulses from the background noise. Figure 3.36 presents the sound levels versus range, as well as the best-fit and 90th-percentile fits to the rms SPLs and the equations thereof. Because of the directionality of the source, only (up to) the ten loudest received pulses per line judged as in-beam were included in the plot. These pulses occurred at the CPA of each of the five lines. This directionality is also likely responsible for pulses at the CPA of HF Track 1 (42 m [140 ft]) being received at lower levels than the CPA of HF Track 2 (61 m [200 ft]). For this reason, the fit equation was only applied to HF Tracks 2–4. The distances to sound level thresholds of 190 to 120 dB re 1 µPa (rms) are listed in Table 3.17. Figure 3.37 shows the waveform and spectral density of a pulse measured at the CPA (42 m [140 ft]) with background noise plotted in red for comparison, and Figure 3.38 displays the corresponding spectrogram.

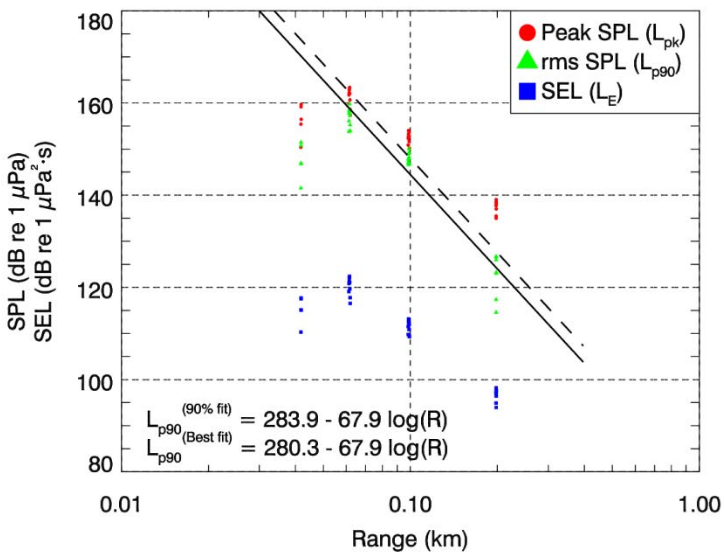

FIGURE 3.36. Peak SPL, rms SPL, and SEL versus range for multibeam sonar pulses at the SSV site. Solid line is the best fit of the empirical function to the rms SPLs from HF Tracks 2–4. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit). The acoustic data were band-pass filtered between 200 and 280 kHz before the sound levels were calculated.

TABLE 3.17. Distances to rms SPL thresholds at the SSV site for in-beam pulses from the multibeam sonar as determined from fits to the rms SPLs in FIGURE 3.36.

rms SPL (dB re 1 µPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	21*	24*
180	30*	34*
170	42*	47*
160	59*	67
150	83	93
140	120	130
130	160	180
120	230*	260*

* Extrapolated beyond the measurement range.

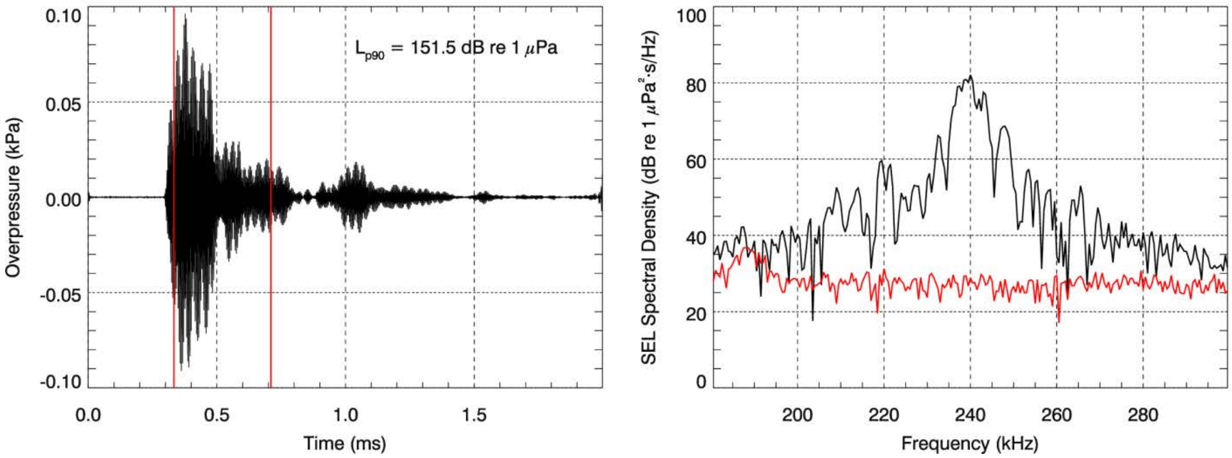

FIGURE 3.37. Waveform (left) and spectral density (right) of a multibeam sonar pulse measured on AMAR D near the CPA (42 m [140 ft]). The spectral density of the background noise is plotted in red for comparison. The acoustic data were band-pass filtered between 200 and 280 kHz.

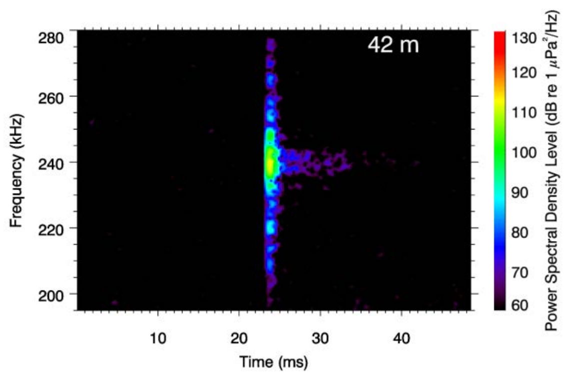

FIGURE 3.38. Spectrogram of the multibeam sonar pulse shown in FIGURE 3.37 near the CPA (42 m [140 ft]). 1024 pt FFT length. 87.5% overlap, Hanning window.

Skipper GDS 101S Single-Beam Echosounder

SPLs were computed for the single-beam echosounder mounted on the hull of the vessel at 8.4 m (28 ft) depth as it transited over the five HF tracks at a nominal speed of 3.8 kts. A band-pass filter between 150 kHz and 250 kHz was applied to the acoustic data to isolate the pulses, centered at 200 kHz, from the background noise. Figure 3.39 presents the sound levels versus range, as well as the best-fit and 90th-percentile fits to the rms SPLs and the equations thereof. Because of the narrow beam pattern, in-beam pulses were captured only from HF Track 1, passing directly over AMAR D. Since in-beam sound levels are encountered only directly below the vessel, the in-beam pulses were excluded from the curve fits in Figure 3.39. The fits include only data from out-of-beam pulses, which were received at ranges beyond approximately 55 m (180 ft). This longer-range fit was used to compute the distances to the 130 and 120 dB re 1 μPa (rms) thresholds, which are listed in Table 3.18. Figure 3.40 shows the waveform and spectral density of a pulse measured at the CPA (44 m [140 ft]) with background noise plotted in red for comparison. Figure 3.41 displays the corresponding spectrogram.

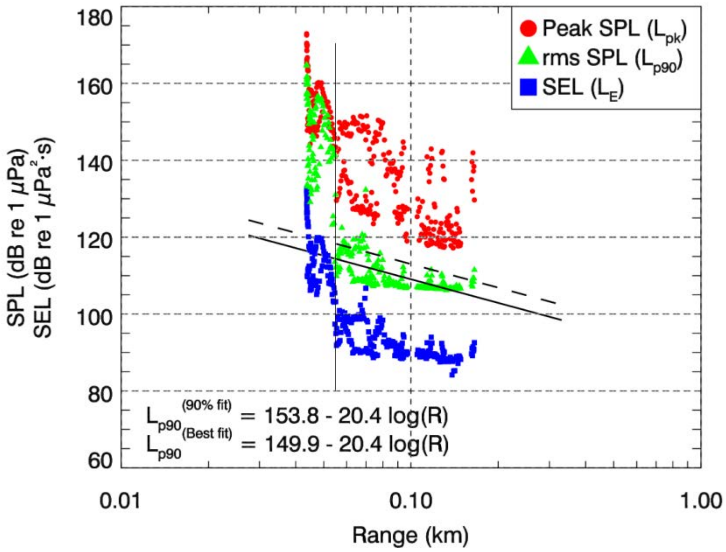

FIGURE 3.39. Peak SPL, rms SPL, and SEL versus range for single-beam echosounder pulses at the SSV site from HF Track 1. Only data from HF Track 1 are shown because no in-beam pulses were detected from the other HF tracks due to the narrow beam pattern of this source. Solid line is the best fit of the empirical function to the rms SPLs at ranges greater than 50 m. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit). The acoustic data were band-pass filtered between 150 and 250 kHz before the sound levels were calculated.

TABLE 3.18. Distances to rms SPL thresholds at the SSV site for out-of-beam pulses from the single-beam echosounder as determined from fits to the rms SPLs in FIGURE 3.39.

rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
130	9*	15*
120	29*	45*

* Extrapolated beyond the measurement range.

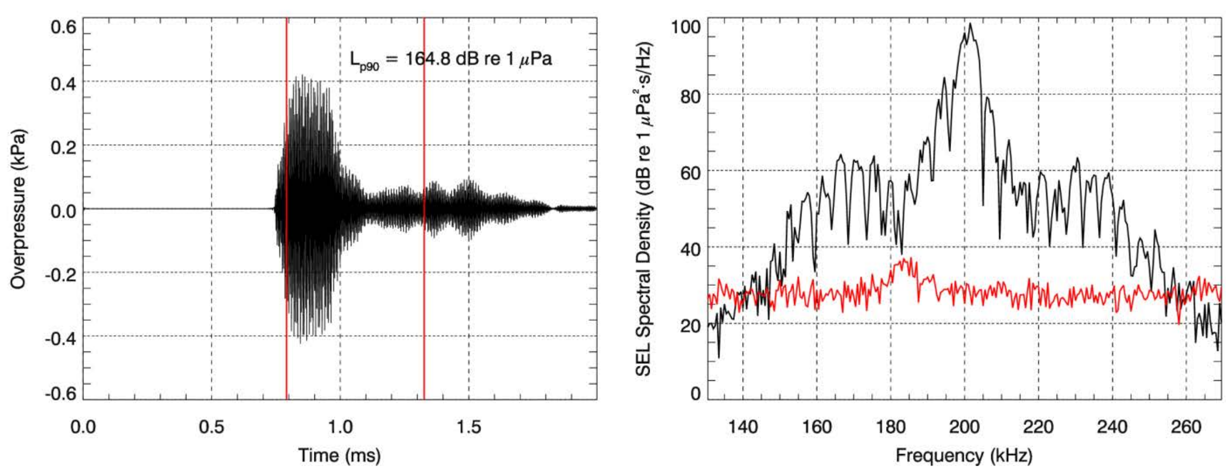

FIGURE 3.40. Waveform (left) and spectral density (right) of a single-beam echosounder in-beam pulse measured on AMAR D near the CPA (44 m [140 ft]). The spectral density of the background noise is plotted in red for comparison. The acoustic data were band-pass filtered between 150 and 250 kHz.

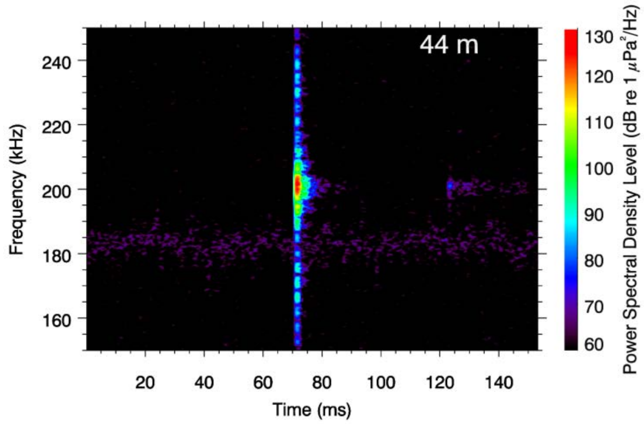

FIGURE 3.41. Spectrogram of the single-beam echosounder in-beam pulse shown in FIGURE 3.40 near the CPA (44 m [140 ft]). 2048 pt FFT length. 87.5% overlap, Hanning window.

MSV Fennica in Transit

One-second rms SPLs were computed for the vessel self-noise of the *Fennica* transiting over the 25 km (15.5 mi) long main SSV track at a nominal speed of 3.5 kts. Figure 3.42 presents the sound levels versus range, as well as the best-fit and 90th-percentile fits to the rms SPLs and the equations thereof. The distances to rms SPL thresholds of 150 to 120 dB re 1 µPa are listed in Table 3.19. Conditions during the transit were 0.3–0.6 m (1–2 ft) seas with 5 kt winds.

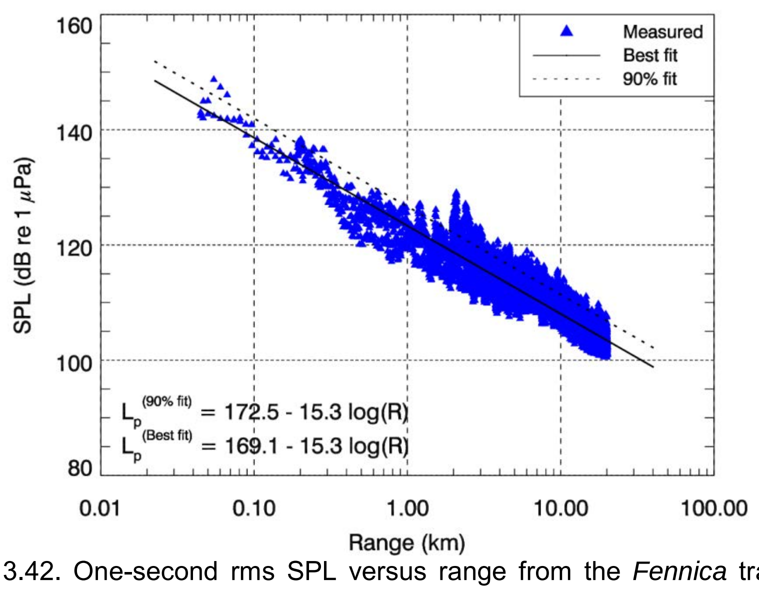

FIGURE 3.42. One-second rms SPL versus range from the *Fennica* transiting the main SSV track at 3.5 kts. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.19. Distances to rms SPL thresholds at the SSV site for the *Fennica* transiting at 3.5 kts as determined from fits to the rms SPLs in FIGURE 3.42.

rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
150	18*	30*
140	80	130
130	370	600
120	1700	2700

* Extrapolated beyond the closest measurement range of 45 m.

MSV Fennica Stationary on DP

One-second rms SPLs were computed for the vessel self-noise of the *Fennica* when stationary on DP directly above AMAR A. Conditions during this time were 0.3–0.6 m (1–2 ft) seas with 5 kt winds. Figure 3.43 presents the sound levels versus range, as well as the best-fit and 90th-percentile fits to the rms SPLs and the equations thereof. The distances to rms SPL thresholds of 150 to 120 dB re 1 μPa are listed in Table 3.20. Figure 3.44 shows the received 1/3-octave-band SPL received from the *Fennica* on DP at 40 m slant range.

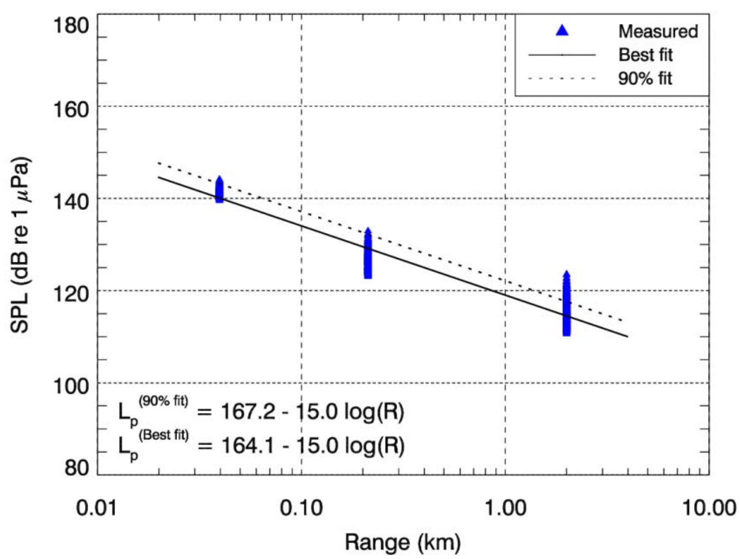

FIGURE 3.43. One-second rms SPL versus range from the *Fennica* stationary on DP above AMAR A. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.20. Distances to rms SPL thresholds at the SSV site for the *Fennica* stationary on DP as determined from fits to the rms SPLs in FIGURE 3.43.

rms SPL (dB re 1 µPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)
150	9*	14*
140	40	60
130	190	300
120	860	1400

* Extrapolated beyond the closest measurement range of 40 m.

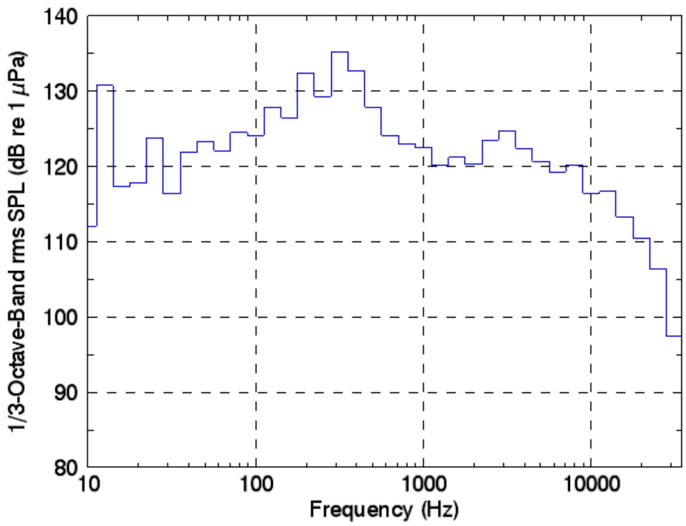

FIGURE 3.44. Received 1/3-octave-band rms SPL from the *Fennica* stationary on DP above AMAR A in 48 m (160 ft) water depth.

Equipment Retrieval and Maintenance at Burger A Well Site

MSV Nordica on DP

One-second rms SPLs were analyzed for times when the *Nordica* was on DP performing equipment retrieval and maintenance operations at the Burger A well site. Sound levels received during periods with different wind force conditions were compared to determine whether greater wind forces resulted in higher sound levels from the *Nordica* on DP. There is no obvious correlation between wind force and the distance to the 120 dB re 1 µPa (rms SPL) threshold derived from the levels recorded on AMARs A through E (Figure 3.45). The received sound levels did change, however, with the *Nordica*'s heading relative to the line of AMARs. The increase in received underwater sound levels associated with the *Nordica*'s change of heading at approximately 21:00 UTC on 31 August 2013 is depicted in Figure 3.46. The constant tonal structure indicates that the engine, thrusters, etc. were under the same operating conditions before and after the heading change and that the sound level increase likely resulted from the heading change.

Figure 3.47 shows the spectrogram and band-levels of sound received at 500 m (1640 ft) range over 1 h when the *Nordica*'s heading was 45°, with the forward aspect in-line with the line of AMARs. Figure 3.48 is the same plot for a subsequent one-hour time window when the *Nordica*'s heading was 180°, with the AMARs aligned with an aspect in between forward and broadside. The data in both of these plots were measured under wind force 2 conditions. Figure 3.49 and Figure 3.50 show percentiles for these same data. Distances to rms SPL thresholds were computed using data from all five AMARs for these two periods: *Nordica* at 45° (Figure 3.51), and *Nordica* at 180° (Figure 3.52). Table 3.21 lists the radii for each heading.

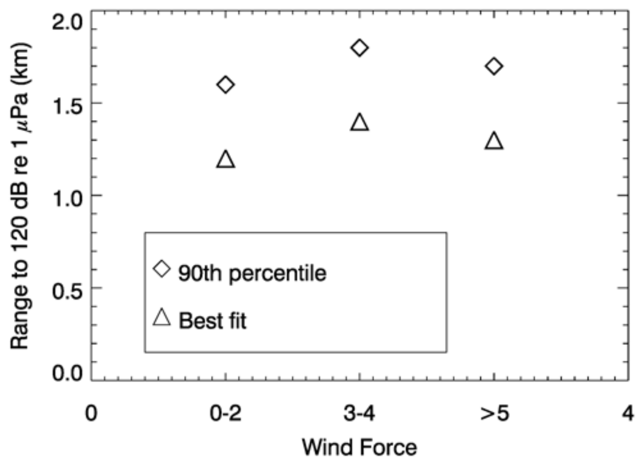

FIGURE 3.45. Distances to rms SPL threshold of 120 dB re 1 μPa, derived from the best-fit and 90th-percentile fit lines, from the *Nordica* as functions of wind force.

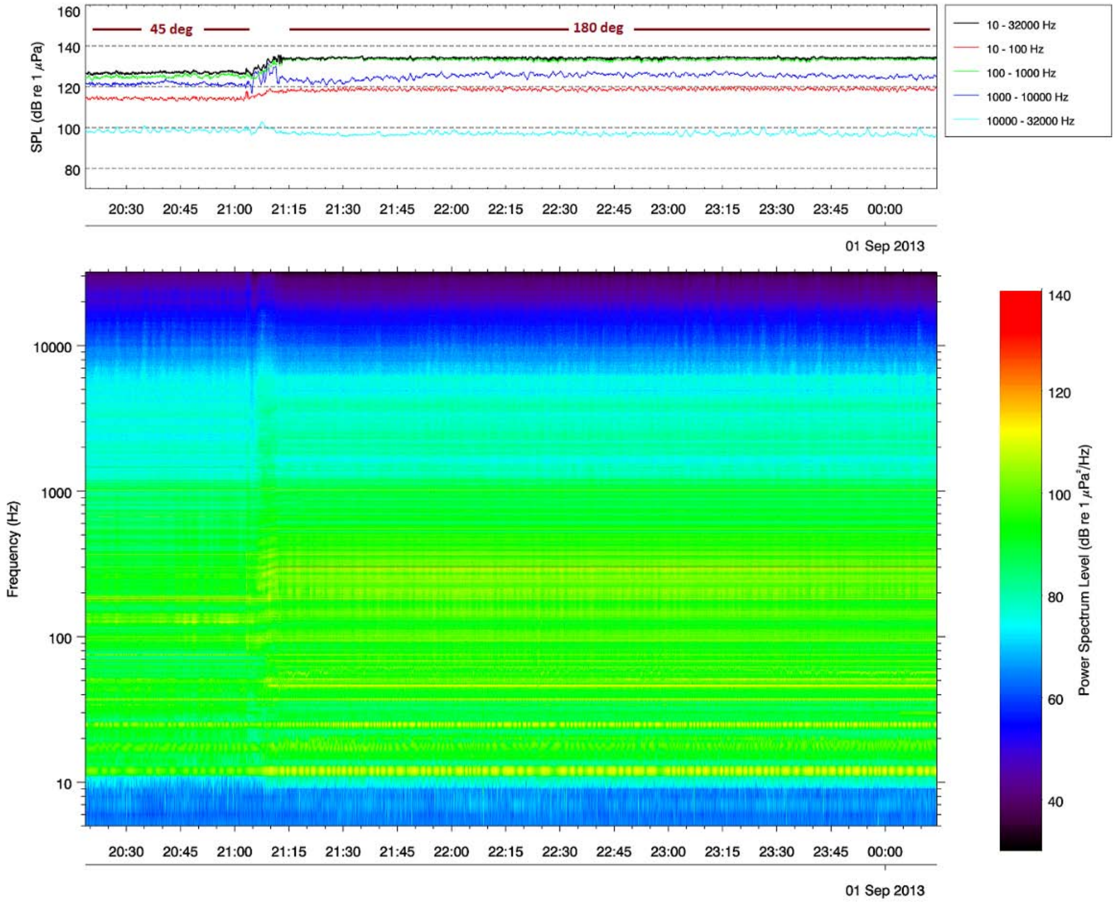

FIGURE 3.46. In-band sound pressure levels (top) and spectrogram (bottom) over time of underwater sound received at AMAR A at 500 m (1640 ft) range from the *Nordica* as the vessel changed headings from 45° to 180° on DP at the Burger A well site performing equipment retrieval operations from, 20:18 31 Aug to 01:18 01 Sep 2013 UTC. Wind force: 2.

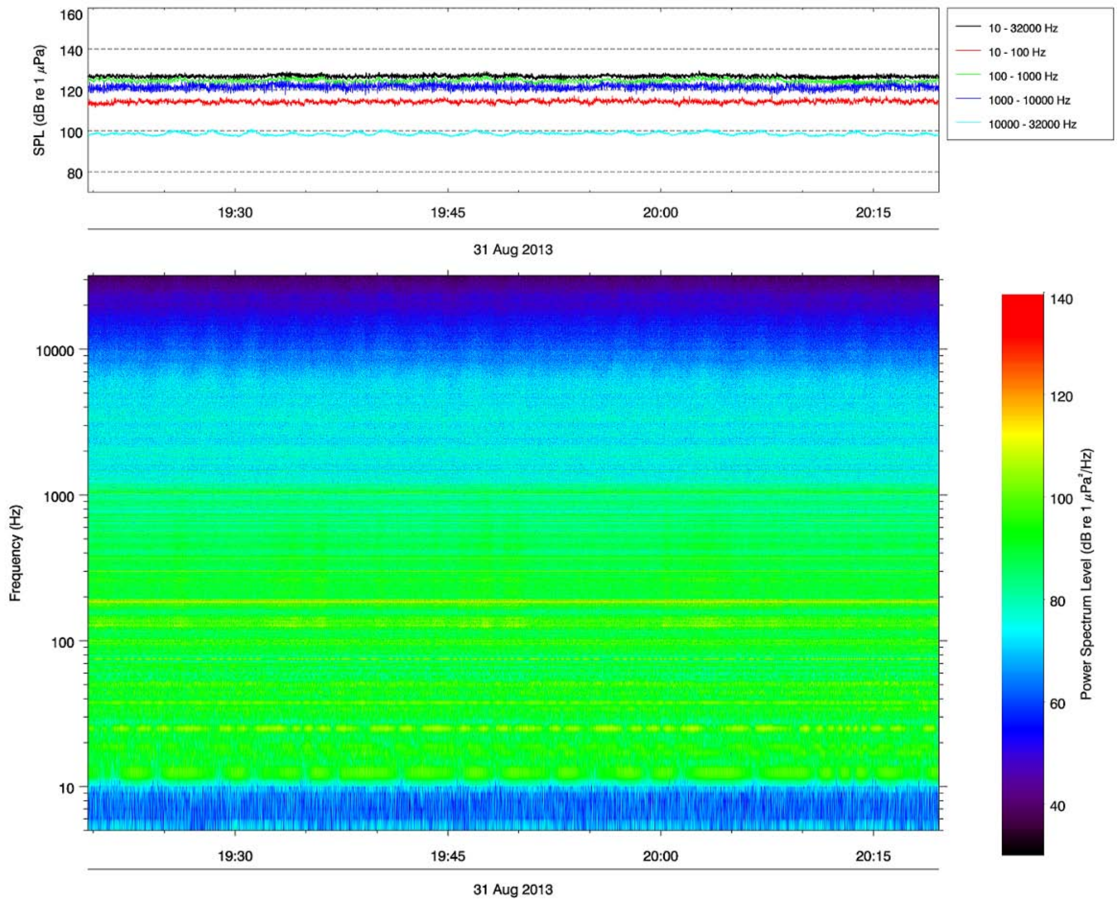

FIGURE 3.47. In-band sound pressure levels (top) and spectrogram (bottom) over time of underwater sound received at AMAR A at 500 m (1640 ft) range from the *Nordica* while the vessel was on DP at the Burger A well site performing equipment retrieval operations, 19:19 to 20:19 on 31 Aug 2013 UTC. *Nordica* heading: 45°. Wind force: 2.

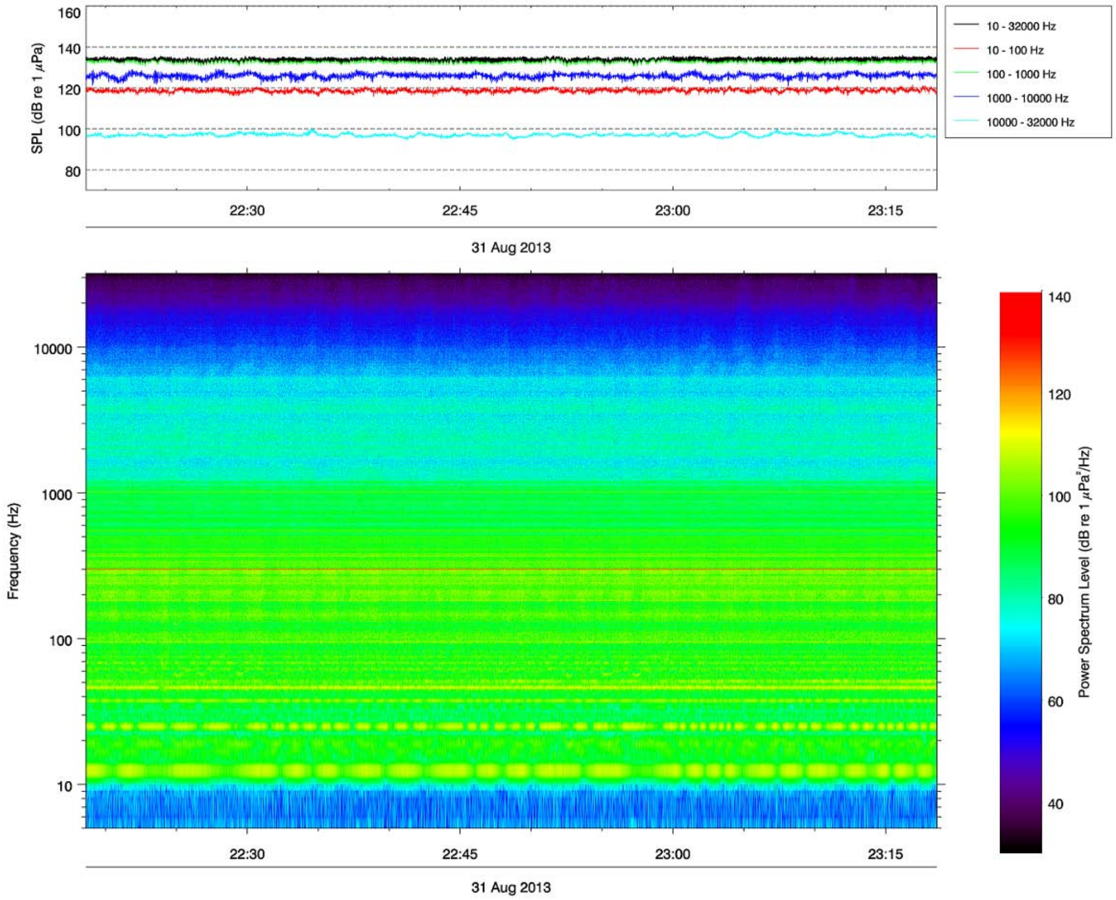

FIGURE 3.48. In-band sound pressure levels (top) and spectrogram (bottom) over time of underwater sound received at AMAR A at 500 m (1640 ft) range from the *Nordica* on DP at the Burger A well site performing equipment retrieval operations, 22:18 to 23:18 on 31 Aug 2013 UTC. *Nordica* heading: 180°. Wind force: 2.

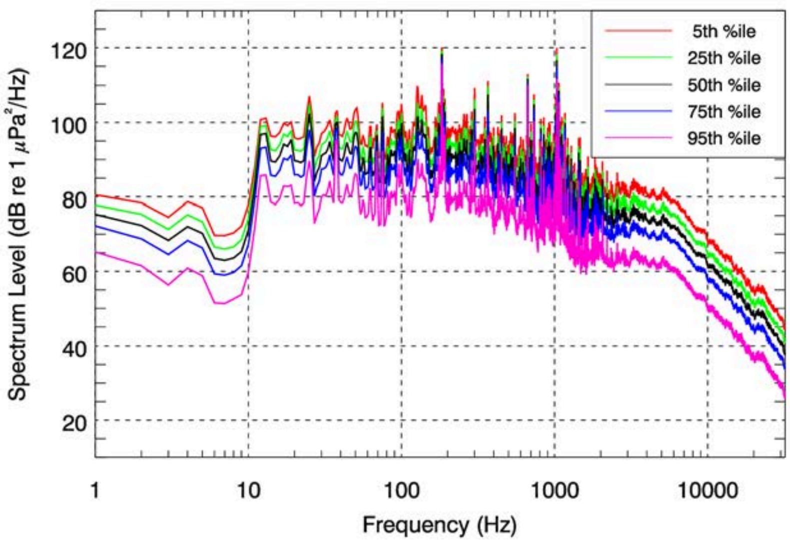

FIGURE 3.49. Spectrum level percentiles of noise received at AMAR A at 500 m (1640 ft) range from the *Nordica* on DP at the Burger A well site performing equipment retrieval operations, 19:19 to 20:19 on 31 Aug 2013 UTC. *Nordica* heading: 45°. Wind force: 2.

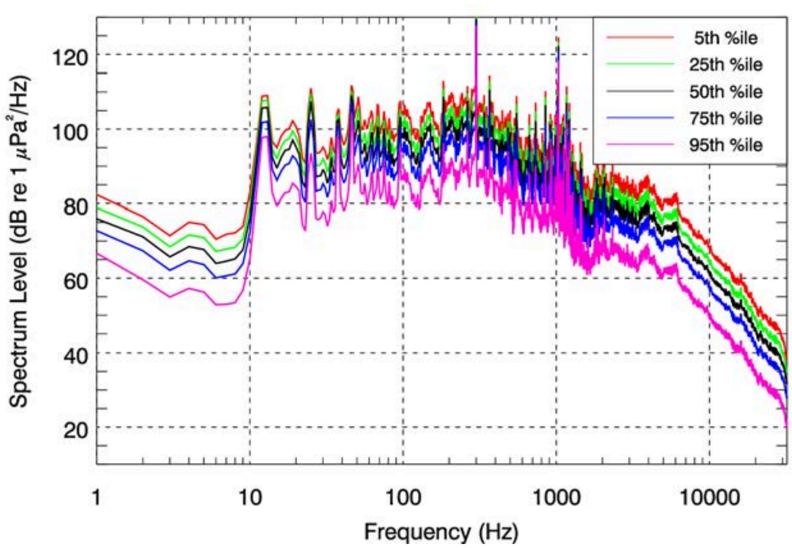

FIGURE 3.50. Spectrum level percentiles of underwater sound received at AMAR A at 500 m (1640 ft) range from the *Nordica* on DP at the Burger A well site performing equipment retrieval operations from 22:18 to 23:18 on 31 Aug 2013 UTC. *Nordica* heading: 180°. Wind force: 2.

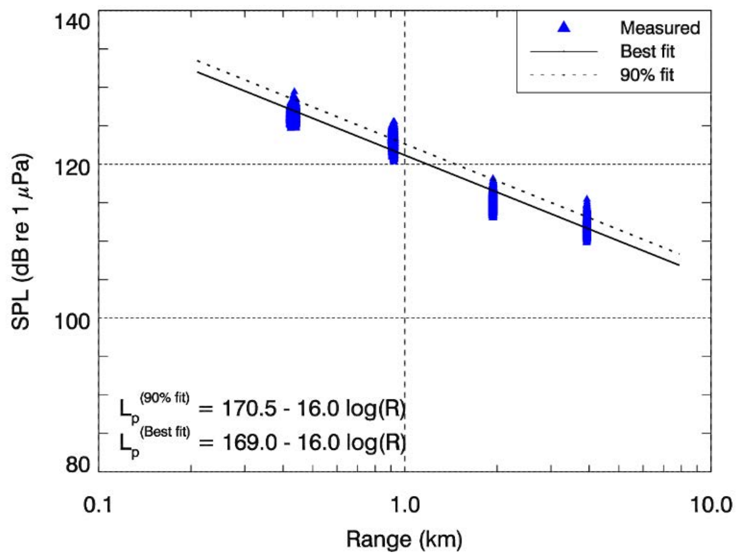

FIGURE 3.51. Received rms SPL versus range from the *Nordica* stationary on DP at the Burger A well site performing equipment retrieval operations, 19:19 to 20:19 on 31 Aug 2013 UTC. *Nordica* heading: 45°. Wind force: 2. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the SPLs (i.e., the 90th-percentile fit).

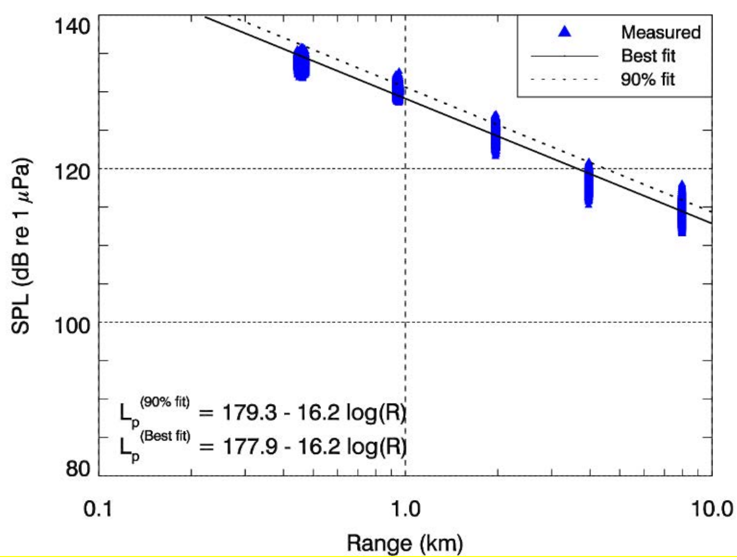

FIGURE 3.52. Sound pressure level (rms) versus range from the *Nordica* while the vessel was stationary on DP at the Burger A well site performing equipment retrieval operations from 22:18 to 23:18 on 31 Aug 2013 UTC. *Nordica* heading: 180°. Wind force: 2. Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the SPLs (i.e., the 90th-percentile fit).

TABLE 3.21. Distances to rms SPL thresholds for the *Nordica* on DP as determined from fits to the rms SPLs in FIGURE 3.51 (45° heading) and FIGURE 3.52 (180° heading).

	Heading: 45°		Heading: 180°	
rms SPL (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)	Best-Fit Distance (m)	90th-Percentile Distance (m)
150	10*	13*	52*	64*
140	48*	64*	210*	260*
130	240*	320*	880	1100
120	1200	1600	3600	4500

* Extrapolated beyond the measurement range.

Ambient Sound

Spectrograms and spectral level percentiles for times when no vessels were near the Burger A well site are shown for data measured for three wind-force categories: 0–2 (Figure 3.53, Figure 3.54), 3–4 (Figure 3.55, Figure 3.56), and 5+ (Figure 3.57, Figure 3.58). The ambient sound levels are positively correlated with wind force (sound levels increased with wind force), but the levels were well below 120 dB in each case. Any correlation between wind force and the range to 120 dB for the *Nordica* on DP would have been discernible above the background noise.

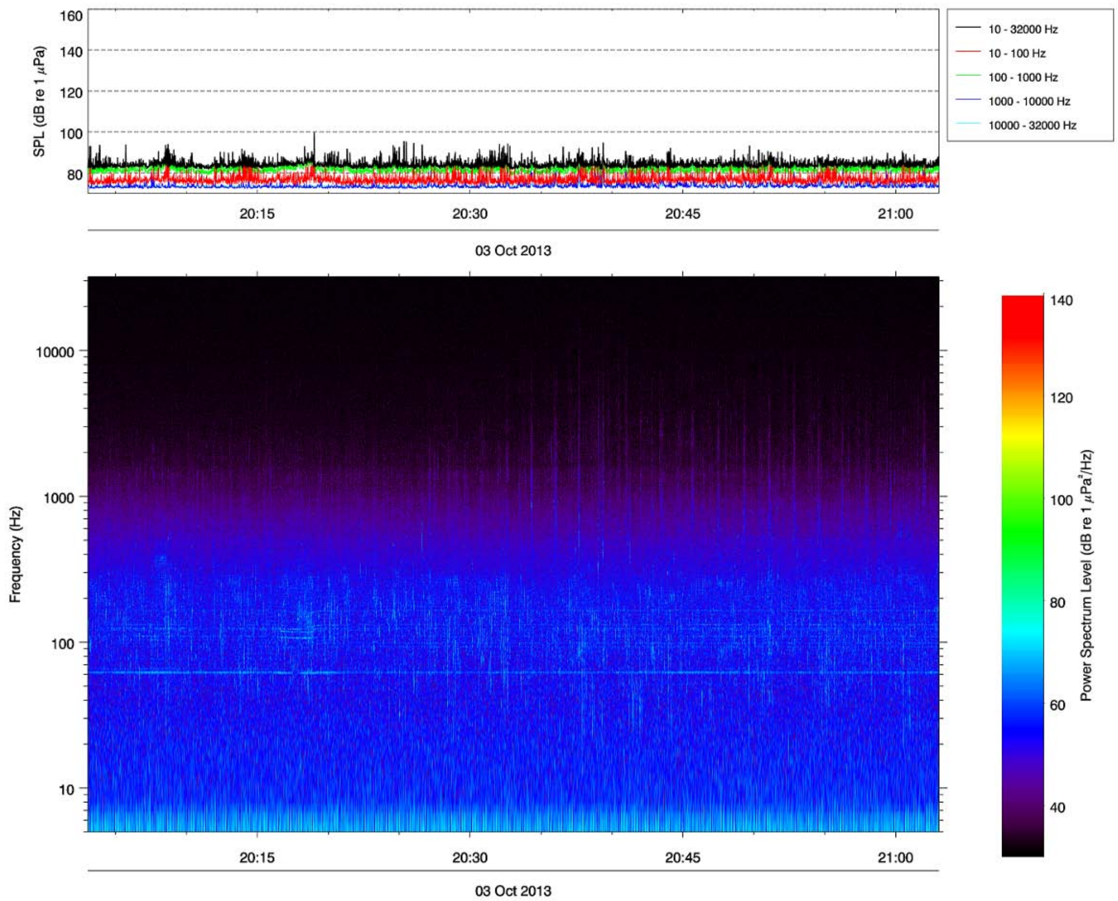

FIGURE 3.53. In-band sound pressure levels (top) and spectrogram (bottom) over time of underwater sound received at AMAR A at 500 m (1640 ft) range from the Burger A well site when no activities occurred, 20:03 to 21:03 on 3 Oct 2013 UTC. Wind force: 0–2.

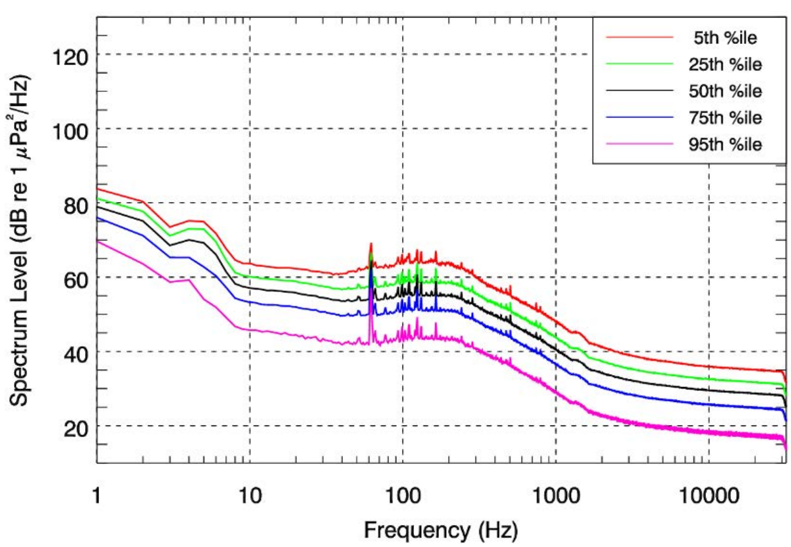

FIGURE 3.54. Spectrum level percentiles for underwater sound received at AMAR A at 500 m (1640 ft) range from the Burger A well site when no activities occurred, 20:03 to 21:03 on 3 Oct 2013 UTC. Wind force: 0–2.

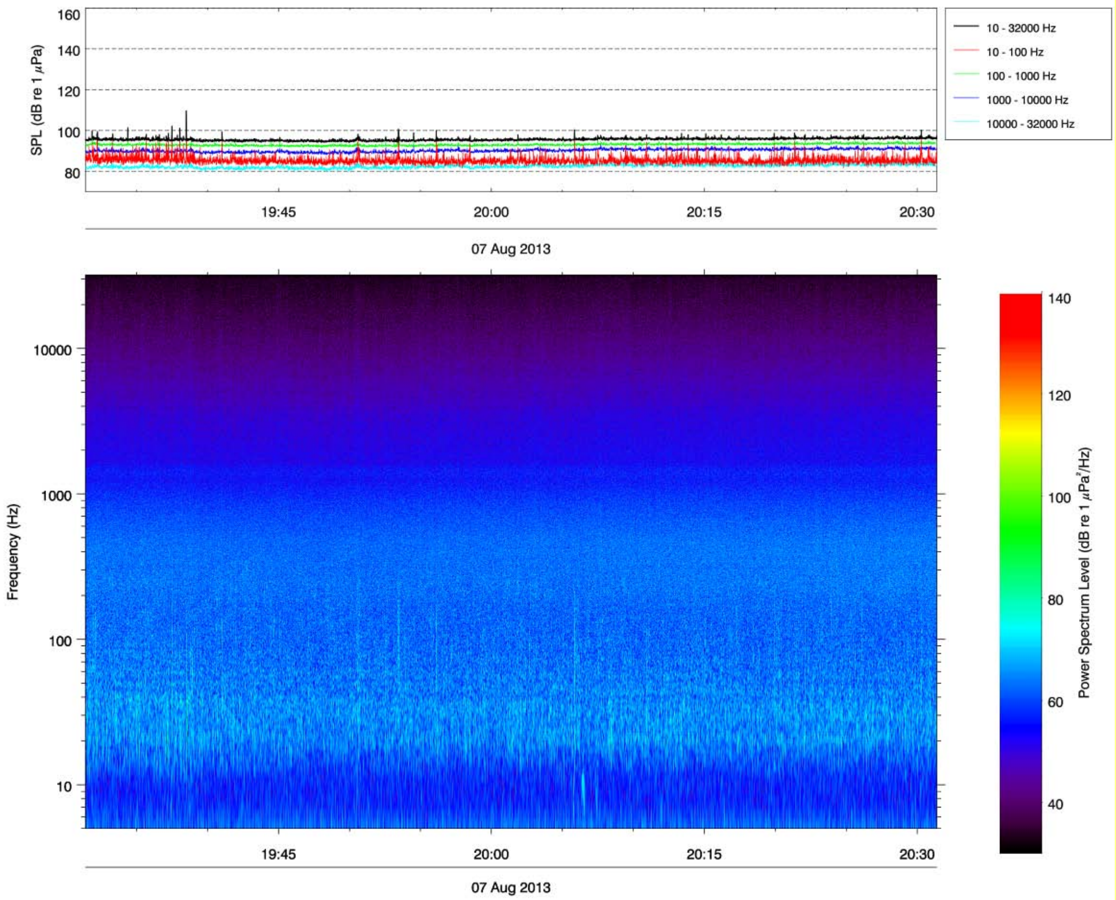

FIGURE 3.55. In-band sound pressure levels (top) and spectrogram (bottom) over time of underwater sound received at AMAR A at 500 m (1640 ft) range from the Burger A well site when no activities occurred, 19:31 to 20:31 on 7 Aug 2013 UTC. Wind force: 3–4.

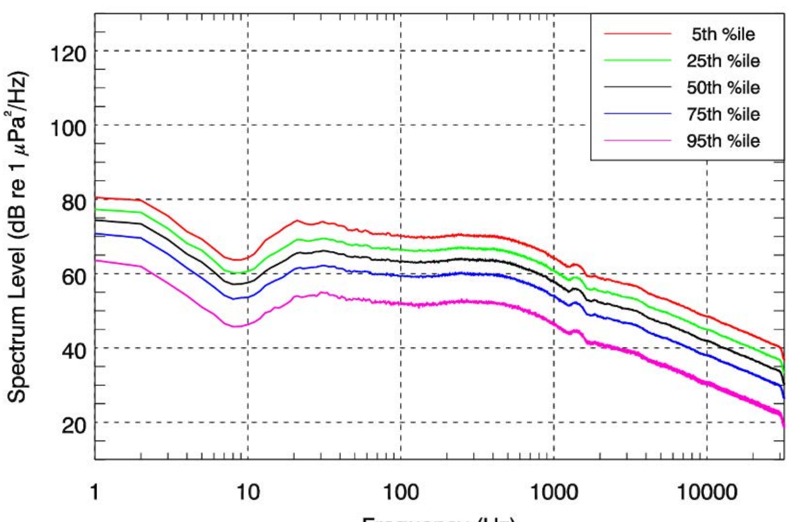

FIGURE 3.56. Spectrum level percentiles of underwater sound received at AMAR A at 500 m (1640 ft) range from the Burger A well site when no activities occurred, 19:31 to 20:31 on 7 Aug 2013 UTC. Wind force: 3–4.

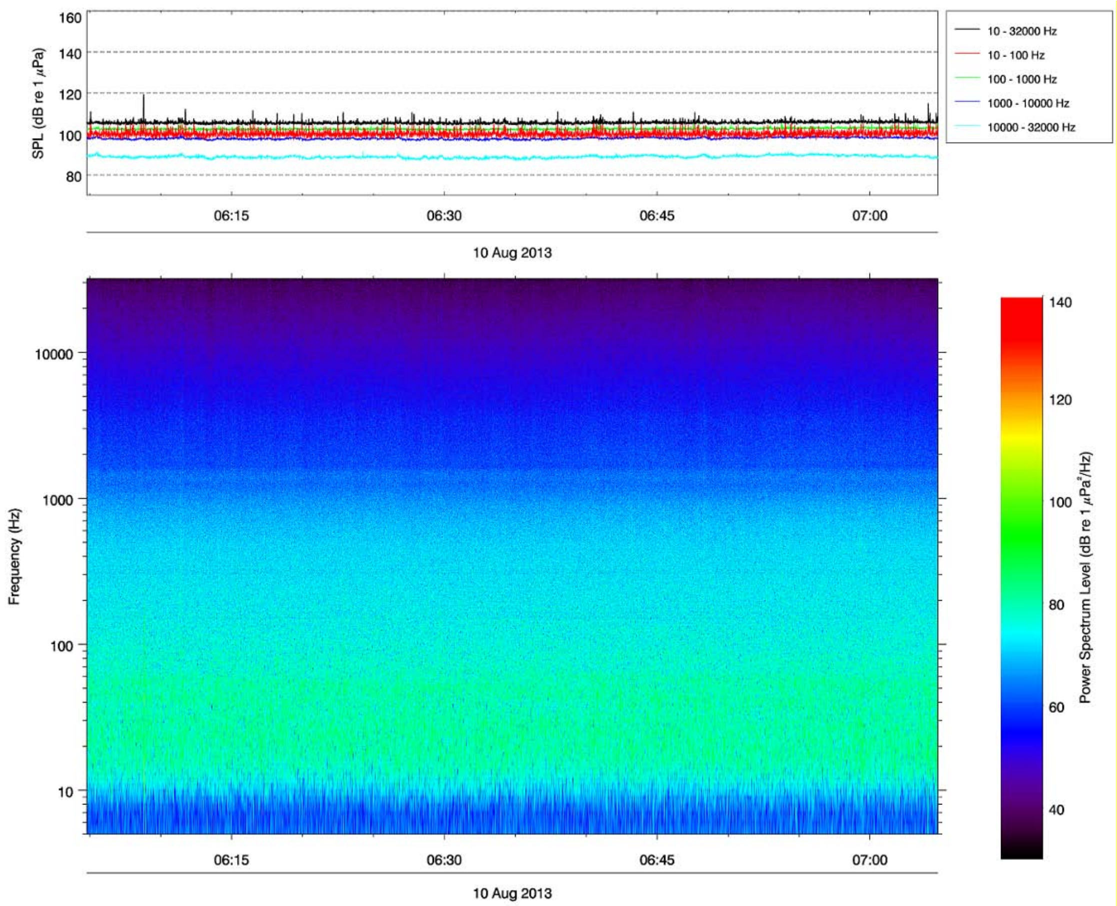

FIGURE 3.57. In-band sound pressure levels (top) and spectrogram (bottom) over time of underwater sound received at AMAR A at 500 m (1640 ft) range from the Burger A well site when no activities occurred, 06:04 to 07:04 on 10 Aug 2013 UTC. Wind force: 5+.

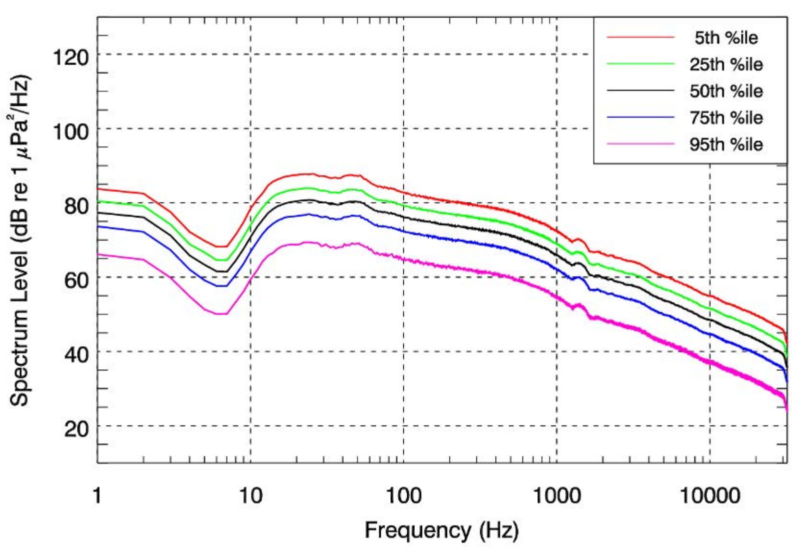

FIGURE 3.58. Spectrum level percentiles of underwater sound received at AMAR A at 500 m (1640 ft) range from the Burger A well site when no activities occurred, 06:04 to 07:04 on 10 Aug 2013 UTC. Wind force: 5+.

Discussion

Airgun Pulse rms SPLs: 90%-Energy versus Fast Time-Weighted

The NMFS level A and B harassment thresholds for airgun sources are typically defined in the 90%-rms SPL metric. With this metric, the SPL of an airgun pulse is the dB level of the root-mean-square pressure averaged over a time window containing 90% of the pulse energy (i.e., the 90%-energy pulse duration). This pulse duration changes with range from the source because of multipath dispersion of sound energy. Depending on the relative strength of the multipath arrivals that constitute the received pulse, the 90%-energy pulse duration of some pulses can be longer or shorter than the nominal trend. These SSV measurements contained pulses with very short 90%-energy pulse durations (<30 ms), which yielded high rms SPLs at ranges of approximately 70–130 m (230–427 ft). Marine mammal mitigation for this survey applied harassment threshold distances that were based on the maximum measured ranges, which are influenced by this anomalous peak in the 90%-rms SPL, instead of ranges based on the nominal trend. In practical terms, these 90%-energy pulse durations are much shorter than integration times of mammalian auditory systems—assumed to be around 200 ms for cetaceans (Madsen 2005)—and the resulting 90%-rms SPL magnitudes likely do not reflect how these very short impulses would be perceived.

Fast-time-weighted rms SPLs, computed over a fixed time window of 125 ms, are a better representation of perceived sound levels than the 90%-rms SPL. Also, the constant integration time window makes the fast-time-weighted level a more consistent estimator of SPL as a function of range because propagation effects do not influence this metric as they do the 90%-rms SPL. Figure 3.59, Figure 3.60, and Figure 3.61 compare the 90%-rms and fast-time-weighted rms SPL as functions of range for the 10, 20, and 40 in^3 airgun array configurations, respectively. Table 3.22, Table 3.23, and Table 3.24 list the corresponding distances to the SPL thresholds computed from the curve fits in these figures. For the 40 in^3 airgun array, the fast-time-weighted rms SPLs at ranges less than 200 m were fit separately from the data at longer ranges to match the trend in the data. The two rms SPL metrics converge at ranges where the 90%-energy pulse durations are close to the 125 ms integration time. There is substantially less scatter in the fast time-weighted levels between 70 and 130 m than in the 90%-rms SPLs, and the fast-time-weighted rms SPLs are approximately 10 dB lower than the 90%-rms SPLs for the pulses in question. These results indicate that the maximum measured ranges to the 90%-rms SPL thresholds that were applied in the survey for marine mammal mitigation are pre-cautionary in terms of sound perception by marine mammals.

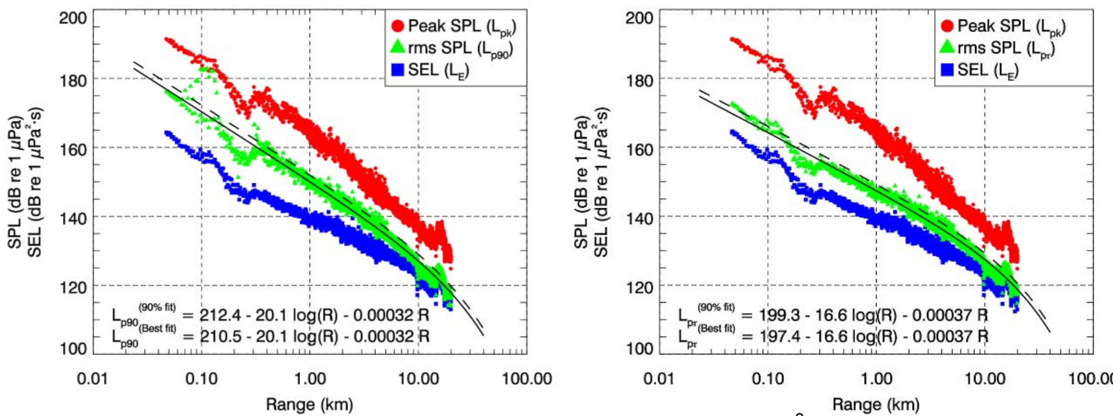

FIGURE 3.59. Peak SPL, rms SPL, and SEL versus range for 10 in^3 airgun pulses at the SSV site using the 90%-energy pulse duration (left) and the fast time-weighting pulse duration of 125 ms (right). Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.22. Distances to rms SPL thresholds at the SSV site for the 10 in^3 airgun as determined from fits to the rms SPLs in FIGURE 3.59.

	90%-rms SPL		Fast-Time-Weighted rms SPL	
SPL Threshold (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	10†	13†	3†	4†
180	33† (127*)	41† (127*)	11†	15†
170	100 (137*)	130 (137*)	45†	58
160	320	400	180	230
150	1000	1200	700	900
140	2900	3600	2600	3200
130	7700	9200	7900	9400
120	170,00	20,000	18,000	21,000†

* Not from fit—maximum range at which the measured rms SPL exceeded the threshold.
† Extrapolated beyond the measurement range.

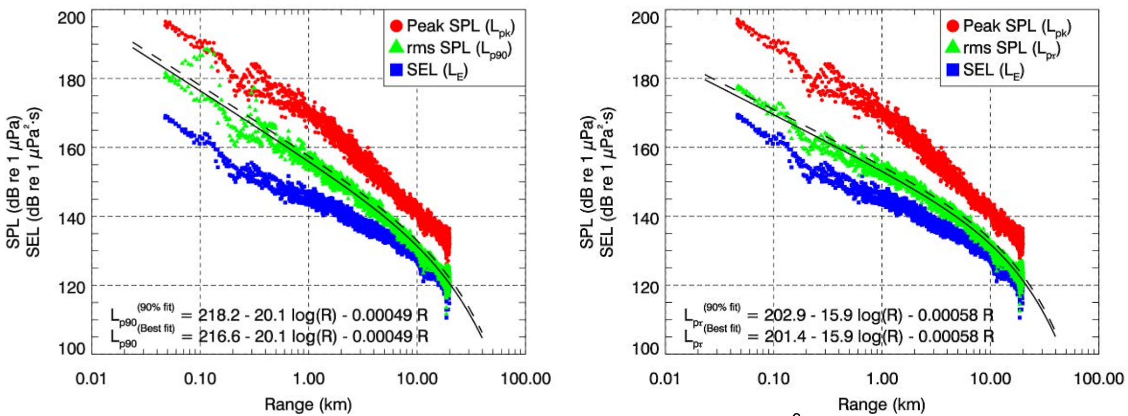

FIGURE 3.60. Peak SPL, rms SPL, and SEL versus range for 20 in^3 airgun array pulses at the SSV site using the 90%-energy pulse duration (left) and the fast time-weighting pulse duration of 125 ms (right). Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.23. Distances to rms SPL thresholds at the SSV site for the 20 in^3 airgun array as determined from fits to the rms SPLs in FIGURE 3.60.

	90%-rms SPL		Fast-Time-Weighted SPL	
SPL Threshold (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	21†	25†	5†	6†
180	66 (133*)	79 (133*)	22†	27†
170	200	250	93	120
160	640	760	380	470
150	1900	2200	1500	1800
140	4900	5700	4800	5600
130	11,000	12,000	12,000	13,000
120	20,000†	22,000†	21,000†	23,000†

* Not from fit—maximum range at which the measured rms SPL exceeded the threshold.
† Extrapolated beyond the measurement range.

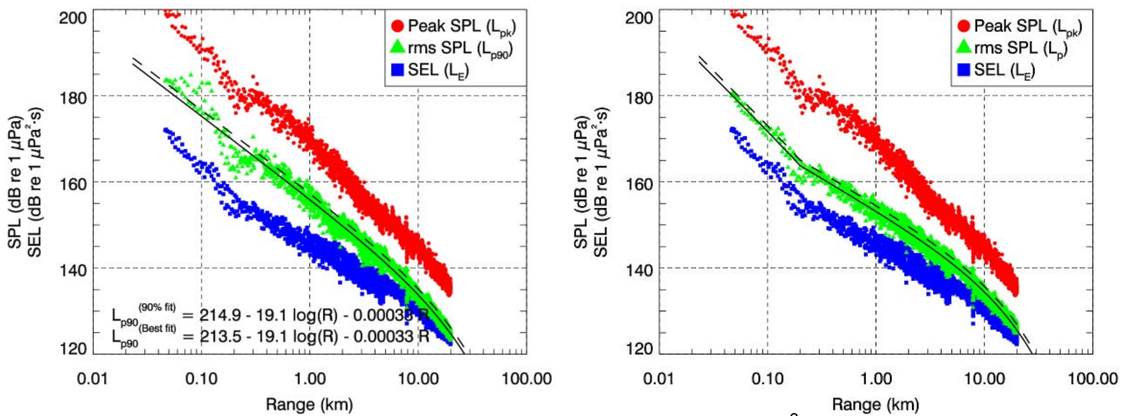

FIGURE 3.61. Peak SPL, rms SPL, and SEL versus range for 40 in^3 airgun array pulses at the SSV site using the 90%-energy pulse duration (left) and the fast time-weighting pulse duration of 125 ms (right). Solid line is the best fit of the empirical function to the rms SPLs. Dashed line is the best-fit line shifted up to exceed 90% of the rms SPLs (i.e., the 90th-percentile fit).

TABLE 3.24. Distances to rms SPL thresholds at the SSV site for the 40 in^3 airgun array as determined from fits to the rms SPLs in FIGURE 3.61.

	90%-rms SPL		Fast-Time-Weighted SPL	
SPL Threshold (dB re 1 μPa)	Best-Fit Distance (m)	90th-Percentile Distance (m)	Best-Fit Distance (m)	90th-Percentile Distance (m)
190	17†	20†	19†	21†
180	56 (123*)	67 (123*)	47	53
170	190	220	120	130
160	620	720	350	430
150	1900	2300	1600	1900
140	5600	6400	5600	6500
130	14,000	15,000	15,000	16,000
120	27,000†	29,000†	28,000†	3,0000†

* Not from fit—maximum range at which the measured rms SPL exceeded the threshold.
† Extrapolated beyond the measurement range.

Comparison of Threshold Distances with Previous SSVs

Airgun Arrays

Airgun arrays with the same volumes were used for the Shell shallow hazards surveys in the Chukchi Sea in 2008 and 2009 (Table 3.25). SSVs for these surveys were conducted in different locations in the Chukchi Sea (Figure 3.62). The 40 in^3 array configuration used in 2009 was the same as for the current study, but in 2008 the four 10 in^3 sleeve guns were suspended from floats in a rectangular arrangement with separations of 61 cm (2 ft) horizontally and 46 cm (1.5 ft) vertically. Figure 3.63 shows the distances to rms SPL thresholds for each SSV as determined from the 90th-percentile fits. The change in array configurations after 2008 may contribute to the difference in propagation distances, but environmental dissimilarities are more likely the main cause (Warner et al. 2010). The threshold distances from the current SSV generally exceed those measured at Honeyguide in 2009 despite similar water depths at the measurement locations. This could be due to differences between the sites in the geoacoustic characteristics or in the sound speed profiles, both of which affect sound propagation (sound speed profiles corresponding to the 2009 measurements were unavailable). This was not investigated in detail for this chapter. The distance to the rms SPL threshold of 190 dB re 1 µPa for the 40 in^3 airgun array is smaller in the current study compared to all other sites and years. This could be because sound levels were measured closer to the SSV track this year compared to previous years, requiring less extrapolation to obtain the threshold distance.

TABLE 3.25. Details of the current and previous SSV measurement programs with similar airgun array configurations. Coordinates are WGS 84.

Program Year	Location	Water Depth (m)	Latitude	Longitude	Airgun Array Configurations (in^3)
2013	Snickers	48	70° 05.586' N	167° 01.938 W	40, 20, 10
2009	Honeyguide	48	71° 06.690' N	168° 16.746 W	40, 20, 10
2009	Burger	41	71° 17.436 N	163° 37.788 W	40, 10
2008	Crackerjack C	45	71° 12.390 N	166° 17.232 W	40, 20, 10

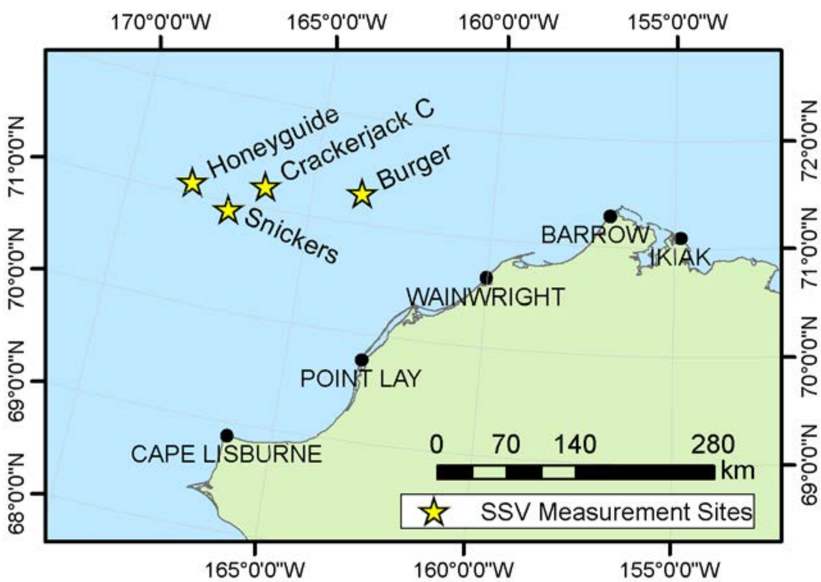

FIGURE 3.62. Locations of shallow hazards survey SSV measurements performed for Shell in 2008, 2009 and 2013 in the Chukchi Sea.

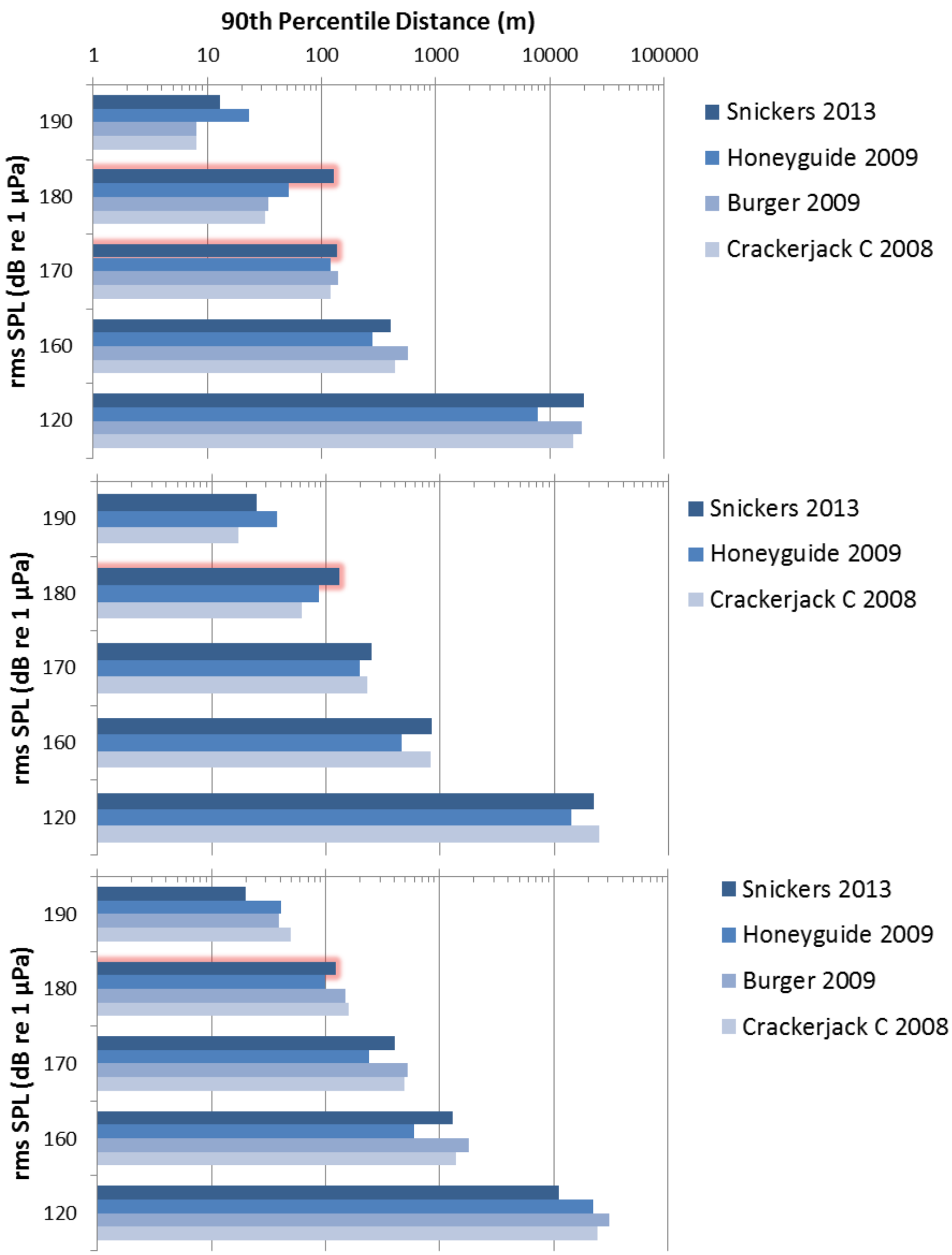

FIGURE 3.63. Distances to sound level thresholds from Chukchi Sea SSV measurements of 10 in^3 (top), 20 in^3 (middle), and 40 in^3 airgun arrays (bottom). Distances are from the 90th-percentile fits to rms SPLs versus range, except those highlighted with red, which are the maximum measured ranges.

Table 3.26 shows the pre-season threshold distances as indicated in the IHA permit application for the 40 in^3 and 10 in^3 airgun arrays along with the SSV results and the updated distances that were implemented during the survey. The pre-season distances are based on the previous years' measurements in the Chukchi Sea shown above. The pre-season distances exceeded nearly all of the distances from the current SSV. The maximum measured range to 180 dB re 1 µPa for the 10 in^3 exceeded the pre-season estimate. The range used for marine mammal mitigation was adjusted accordingly following the SSV. When derived from a fit to the nominal trend of the SPL data for the 10 in^3, the range to this threshold was 41 m. When derived using a fast time-weighted average SPL this range is 15 m. Both of these fall within the pre-season stipulated range. The range to the 190 dB re 1 µPa threshold was also adjusted from 23 to 40 m based on the SSV results.

TABLE 3.26. Pre-season threshold distances as noted in Shell's IHA permit application, SSV results, and updated threshold radii as implemented during the shallow hazards survey after the SSV.

rms SPL Threshold (dB re 1 µPa)	Pre-SSV Distance (m)		SSV Distance (m)		Post-SSV Distance (m)	
	40 in^3 array	10 in^3 airgun	40 in^3 array	10 in^3 airgun	40 in^3 array	10 in^3 airgun
≥ 190	50	23	39	40	50	40
≥ 180	160	52	123	127	160	127
≥ 160	1800	569	1300	400	1800	569

Vessels on Dynamic Positioning

In this study, sounds while on DP were measured for both the *Fennica* and the *Nordica*, identical sister icebreaking vessels. Table 3.27 lists the distances to the rms SPL threshold of 120 dB re 1 µPa for each vessel from the 90th-percentile fit to the measurements. Sounds from the *Fennica* were measured from only one aspect, directly astern of the vessel. Sounds from the *Nordica* were measured from the forward and off-axis aspects. Although the on-axis sound levels—astern of the *Fennica* and forward of the *Nordica*—were measured at different locations and at different times, the distances to the 120 dB re 1 µPa threshold are similar. These distances are approximately 1/3 the distance for the off-axis aspect of the *Nordica*.

By comparison, sound levels from the vessel R/V *Ocean Pioneer* on DP measured at the Burger prospect in 2010 (Chorney et al. 2011) yielded a range of 5600 m (3.5 mi) to the 120 dB re 1 µPa threshold. The R/V *Ocean Pioneer* is a 205 ft research/supply vessel that is smaller than the *Fennica* and *Nordica* and is driven by a less-powerful engine. She has a 40 ft beam, 17 ft depth, and 14 ft draft and is operated by Stabbert Maritime. She has two Alco 12-251 main engines driving two electronic variable pitch props, with 5600 HP (at 900 rpm) total horsepower (Stabbert Maritime 2009).

TABLE 3.27. Distances to the rms SPL threshold of 120 dB re 1 µPa for vessels on DP as determined from 90th-percentile fits to sound level versus range data.

Vessel	Program year	Aspect	Distance to 120 dB re 1 µPa (m)
Fennica	2013	Stern	1400
Nordica	2013	Forward	1600
Nordica	2013	Off-axis	4500
Ocean Pioneer	2010	Off-axis	5600

Summary

This chapter presents results from an acoustic monitoring study that characterized sounds from vessels and equipment associated with Shell Exploration and Production Company's 2013 operations in the Chukchi Sea. Sounds from airguns and sonar sources associated with a shallow hazard and ice gouge survey were measured, as were those from equipment retrieval and maintenance activities at the Burger A well site. AMARs recorded airgun sound levels at slant ranges between 0.45 and 20 km (0.3 and 12 mi), sonar sources at slant ranges between 0.45 and 2 km (0.3 and 1.2 mi), and well site activities at slant ranges between 0.5 and 8 km (0.3 and 5 mi).

Distances to the sound level thresholds of 190, 180, 160, and 120 dB re 1 µPa are summarized in Table 3.28 below for each vessel and for each of the activities characterized in this chapter. The maximum measured ranges are reported when the 90%-rms SPL for a selection of airgun pulses exceeded the nominal trend. The SSV geometry allowed measurements of most threshold distances; however, for thresholds where measurements were unavailable, distances were extrapolated using empirical curve fits to the sound levels versus range. These extrapolations provide the best estimates of the threshold distances given the available data, but their accuracy is limited.

The measured and extrapolated distances to thresholds for the airgun arrays indicate that those stipulated in the IHA are precautionary in most instances. Exceptions are the distances to the thresholds of 190 and 180 dB re 1µPa for the 10 in^3 airgun, for which the SSV results exceed those in the IHA. These exclusion zone distances were updated based on the SSV results from 23 to 40 m and from 52 to 127 m, respectively.

The airgun array data were analyzed to compute M-weighted cumulative SELs (both Type I and Type II). The cumulative SEL metric has been recently proposed as an alternative to the rms SPLmetric that is typically applied for marine mammal take estimates. Type I and Type II M-weighted cumulative SELs were computed at each SSV AMAR location, the nearest of which had a CPA of 46 m. None of the array configurations produced cumulative SELs that reached the injury criteria thresholds suggested for cumulative SEL at the AMAR locations. The rms SPL criteria in the IHA are more conservative than the M-weighted cumulative SEL criteria considered in this chapter.

Measurements of the *Nordica* on DP at the well site revealed a dependence of received sound levels on the bearing of the vessel relative to the AMARs (Table 3.29). Sound levels received from a broadside aspect of the vessel exceeded those received from the forward aspect. Whereas measured ambient sound levels increased with higher wind force, there was no corresponding increase in received sound levels from the *Nordica* on DP during higher wind force conditions. Distances to the rms SPL threshold of 120 dB re 1 µPa measured from the aft aspect of the *Fennica* are consistent with those measured from the forward aspect of the *Nordica*.

TABLE 3.28. Distances to rms SPL thresholds for sources operated during the shallow hazards and ice gouge survey at the Snickers prospect. Distances are from the 90th-percentile fits to the rms SPLs versus range.

Source	Distance (m) to rms SPL Threshold			
	190 dB re 1 μPa	180 dB re 1 μPa	160 dB re 1 μPa	120 dB re 1 μPa
Fennica stationary on DP	-	-	-	1400
Fennica in transit	-	-	-	2700
Airgun array—10 in^3, Endfire Direction	13†	41† (127*)	400	20,000
Airgun array—20 in^3, Endfire Direction	25†	79 (133*)	760	22,000†
Airgun array—20 in^3, Broadside Direction	15†	60	840	18,000†
Airgun array—40 in^3, Endfire Direction	20†	67 (123*)	720	29,000†
Airgun array—40 in^3, Broadside Direction	20†	95	1300	11,000†
EdgeTech 3200 Sub-Bottom Profiler	-	-	53	1000
EdgeTech 4200 Side-Scan Sonar	-	1†	130	1400†
RESON 7101 Multibeam Sonar	24†	34†	67	260†
Skipper GDS 101S Single-Beam Echosounder	-	-	-	45†

* Not from fit—maximum range at which the measured rms SPL exceeded the threshold.
† Extrapolated beyond the measurement range.

TABLE 3.29. Distances to sound level thresholds for the *Nordica* on dynamic positioning at the Burger A well site as determined from the 90th-percentile fits to the rms SPLs versus range.

Source	Distance (m) to 120 dB re 1 μPa rms SPL Threshold
Nordica on DP, heading 45°, wind force 2	1600
Nordica on DP, heading 180°, wind force 2	4500

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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

Experienced 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_0 = 1 µPa) and the unit for SPL is dB re 1 µPa:

$$L_P = 10\log_{10}\left(p^2/p_0^2\right) = 20\log_{10}\left(p/p_0\right)$$

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

source level (SL)

The sound pressure level measured 1 meter 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: meter (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 2013 shallow hazards and ice gouge surveys, and Shell's equipment recovery and maintenance operations at the Burger well site. All activities were conducted during the 2013 open-water season in the Alaskan Chukchi Sea. The shallow hazards survey was conducted on Shell lease blocks, and the ice gouge survey was conducted on Shell lease blocks and areas adjacent to these lease blocks as shown in Fig. 2.1. The equipment recovery and maintenance operation occurred at the Burger well site where exploratory drilling was conducted in 2012. The required measures were detailed in the Incidental Harassment Authorization (IHA) and Letter of Authorization (LOA) 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 monitoring data collected by observers and reported in the following chapters, including estimates of the number of marine mammals potentially exposed to underwater sounds from Shell's activities.

Monitoring Tasks

The main purposes of the marine mammal monitoring program were to ensure that the provisions of the IHA and LOA issued to Shell in 2013 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 shallow hazards and ice gouge survey vessel (*Fennica*) and the well-site maintenance vessel (*Nordica*) to visually monitor the occurrence and behavior of marine mammals near the vessels and within specified exclusion zones and zones of influence;
- use the visual monitoring data and observations as a basis for implementing the required mitigation measures;
- record (insofar as possible) the effects of shallow hazards survey and well-site maintenance activities, and the resulting sounds, on marine mammals, and;
- estimate the number of marine mammals potentially exposed to, 1) impulsive airgun sounds at specified levels from the shallow hazards survey, and 2) low-level continuous sounds above 120 dB re 1 μPa (rms) from the *Nordica* operating in dynamic positioning while stationary at the Burger well site or directly adjacent (i.e., within the lease block).

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" or "exclusion zones" for marine mammals around airgun arrays and other impulsive industrial sound sources are customarily defined as the distances within which received levels are ≥180 dB re 1 μPa (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 Pacific walrus and polar bear, respectively, in the LOA issued to Shell. These safety criteria are based on

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[1] By Craig Reiser (LGL Alaska Research Associates, Inc.)

a cautionary assumption that sound energy at lower received levels will not harm these animals or impair their hearing abilities, but that higher received levels might have some such effects. Shell's 2013 authorizations also required implementation of mitigation measures for large groups (≥12 individuals) of bowhead or gray whales (IHA) and Pacific walruses (LOA) that occurred within an area where sound levels were ≥160 dB (rms). 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.

Shell's IHA and LOA applications described the anticipated underwater sound field around the planned airgun cluster (4×10 in^3 airguns) towed at a depth of 2 m (7 ft) based on a series of prior sound source verification (SSV) measurements of a similar array in the same prospects that were planned for survey in 2013, towed at a similar depth (Hannay and Warner 2009; Warner et al. 2010). The most conservative of these previous measurements were used for mitigation purposes at the commencement of 2013 airgun operations prior to SSV field results (Table 1, *Pre-SSV Radii*). Field measurements of the received airgun sounds as a function of distance and aspect were acquired during the beginning of seismic data acquisition in 2013 (Wladichuk and McCrodan 2013; Table 1, *SSV Measurements*) and are reported in detail in Chapter 3 of this report. The 2013 measured sound propagation distances (radii) were similar to previous measurements. All of the measured radii from the 40-in^3 full-array cluster were less than the largest radii from previous measurements, and preliminary measurements from the single 10-in^3 airgun were greater than any of the previous measurements for the ≥180 and ≥190 dB (rms) radii (Table 1). As a conservative measure, PSOs implemented the largest of previous measurements and those from 2013 for mitigation purposes (Table 1, *Post-SSV Radii*). More extensive analysis of the field measurements was completed after the field season as described in Chapter 3 of this report.

Shell's IHA and LOA applications described the predicted ensonified areas from the *Nordica* due to sounds produced by the dynamic positioning system based on previous measurements of a similar vessel using dynamic positioning. These previous measurements were made near a drillship in the Chukchi Sea during Shell's exploratory drilling program in 2012 (Austin et al. 2013). The pre-SSV estimate for the ≥120 dB (rms) radius from the *Nordica* while stationary in dynamic positioning was 13 km (8.1 mi; Table 2). This estimate was considered to be conservative as it was considerably larger than previous dedicated measurements of dynamic positioning for other vessels, and the measurement was made while other industry activities were ongoing in 2012 (e.g., drilling, other vessel activities). Per Shell's IHA, PSOs aboard the *Nordica* established a ≥120 dB (rms) zone of influence (ZOI) around the Nordica using the pre-season estimate of 13 km (8.1 mi). PSOs monitored this ZOI before, during, and after all dynamic positioning operations at the well site in 2013. Field measurements of sounds produced by the *Nordica* in dynamic positioning at the Burger well site were acquired periodically (whenever the vessel was present and using dynamic positioning) from 5 Aug through the end of operations on 11 Sep. The most conservative measurements of dynamic positioning sounds from this period are shown in Table 2, which were less than half the value of the pre-season estimate for the ≥120 dB (rms) ZOI. See Chapter 3 for additional details on *Nordica* measurements of dynamic positioning operations during 2013.

Table 1. Pre-SSV, 2013 SSV, and post-SSV radii for the ≥190, 180, and 160 dB (rms) radii (in m) for sound pulses for the 40–in^3 array and the 10–in^3 mitigation airgun deployed from the *Fennica* during Shell's shallow hazards survey in the Chukchi Sea, 2013. Note that the most conservative measurement for each radius was implemented for the purpose of mitigation by PSOs. See Chapter 3 for detailed 2013 SSV results.

	Pre-SSV Radii		**SSV Measurements**[a]		**Post-SSV Radii**[b]	
	Full Array (40-in^3)	**Mitigation Gun (10-in^3)**	**Full Array (40-in^3)**	**Mitigation Gun (10-in^3)**	**Full Array (40-in^3)**	**Mitigation Gun (10-in^3)**
≥190	50	23	20	40 (13)	50	40
≥180	160	52	123	127	160	127
≥160	1800	569	1300	400	1800	569

[a,b]The preliminary SSV measurement for the 10-in^3 mitigation airgun ≥190 dB (rms) radius was 40 m and was reduced to 13 m following additional analysis. PSOs, however, continued to use 40 m for mitigation purposes.

Table 2. Pre-SSV estimates and SSV measurements of the ≥170, 160, 150, 140, 150, 160 and 170 dB (rms) radii (in m) for the *Nordica* while operating in dynamic positioning at the Burger well site during Shell's equipment recovery and maintenance operations in the Chukchi Sea, 2013. See Chapter 3 for detailed 2013 SSV results.

	Pre-SSV Radii	**Post-SSV Radii**
≥170	<10	<10
≥160	22	<10
≥150	110	64
≥140	530	260
≥130	2600	1100
≥120	13000	4500

Mitigation Measures as Implemented

Through pre-season meetings with coastal communities and stakeholders, the location and timing of survey activities, especially in relation to subsistence uses of marine mammals, were considered when developing the mitigation plan for Shell's 2013 surveys and equipment retrieval and maintenance operations. The primary mitigation measures identified for shallow hazards survey operations included ramp up, delayed ramp up, power down, and shut down of the airguns. These measures are standard procedures during seismic surveys and are described in detail in Appendix F. Mitigation also included those measures specifically identified in the IHA and LOA, including measures for routine maritime activities such as transit. Seismic and general vessel-based mitigation measures are described below.

Seismic and General Mitigation Measures

Standard seismic mitigation measures implemented by *Fennica* PSOs during the shallow hazards survey included the following:

- The most conservative (i.e., largest) of previously-measured safety radii for a comparable airgun source in the Chukchi Sea were implemented at the commencement of seismic activities prior to the availability of 2013 SSV results. Following the 2013 SSV, the largest radii from either previous measurements or the 2013 SSV results were implemented by PSOs for mitigation (Table 1).
- In order for seismic operations to begin, the entirety of the ≥180 dB (rms) safety radius must have been visible for at least 30 minutes.
- A ramp up procedure was implemented whenever operation of the airguns was initiated if >10 min had elapsed since shut down or power down of the full airgun array.
- Power down or shut down procedures were implemented when a marine mammal was sighted within or approaching the applicable exclusion zone while the airguns were operating.
- A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal or group of mammals was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius.

The specific seismic procedures applied during ramp ups, power downs, and shut downs are described in Appendix F. Briefly, a ramp up involved a gradual increase in the number of airguns operating (from no airguns or one airgun firing) usually accomplished by an addition of airguns such that the number of airguns operating is doubled approximately every five min. For the *Fennica*, the ramp up duration was between 10 and 15 min depending on whether the single "mitigation" gun was already firing. A power down involved reducing the number of operating airguns from the full array (40 in^3) to a single mitigation airgun (10 in^3) when a marine mammal was observed approaching or was first detected already within the full array exclusion zone. Power downs also occurred when the survey vessel was between seismic survey lines to reduce the amount of sound energy introduced into the water. A shut down involved suspending operation of all airguns. A shut down was implemented if a marine mammal was sighted within or approaching the safety radius of the mitigation airgun either after the full array had been powered down or upon initial observation.

In addition to the standard safety radii based on the ≥190 and ≥180 dB (rms) distances for pinnipeds and cetaceans, NMFS and USFWS required Shell to monitor the ≥160 dB (rms) radius for aggregations of 12 or more non-migratory bowhead or gray whales and Pacific walruses during all seismic activities. Due to the relatively small size of the ≥160 dB (rms) zone, observers aboard the *Fennica* could monitor this area without the need for observers on additional vessels. Power down or shut down procedures were to be implemented if groups of 12 or more bowhead whales, gray whales, or Pacific walruses were observed within the ≥160 dB (rms) radius while the airguns were in operation.

The most common forms of mitigation implemented by *Fennica* and *Nordica* PSOs during 2013 occurred during routine vessel operations, which included reductions in vessel speed and alterations of vessel headings. 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 included postponement of equipment deployments (e.g., remotely operated underwater vehicles) due to the presence of marine mammals in the deployment area, and relocation of the vessel for helicopter operations to an area without feeding whales in close proximity. Mitigation measures implemented by PSOs in 2013 during Shell's activities are summarized in detail in Chapter 5 (*Fennica*; shallow hazards and ice gouge surveys) and 6 (*Nordica*; well site equipment retrieval and maintenance).

Marine Mammal Monitoring Methods

Marine mammal monitoring methods were designed to meet the requirements specified in the IHA and LOA as listed above. The main purposes of PSOs aboard the shallow hazards survey source vessel *Fennica* were as follows:

- Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans and walruses to airgun sounds with received levels ≥180 dB (rms), or of other pinnipeds and polar bears to ≥190 dB (rms).
- Conduct monitoring and implement mitigation measures to avoid or minimize exposure of groups of 12 or more bowhead or gray whales and/or Pacific walruses to airgun sounds with received levels ≥160 dB (rms).
- Document numbers of marine mammals present, any reactions of marine mammals to seismic activities, and whether there was any possible effect on accessibility of marine mammals to subsistence hunters in Alaska.

Detailed results of marine mammal monitoring are presented in Chapters 5 (*Fennica*; shallow hazards and ice gouge surveys), 6 (*Nordica*; well site equipment retrieval and maintenance), and 7 (summary of vessel-based monitoring from both vessels). The visual monitoring methods that were implemented during Shell's 2013 operations were similar to those used during similar previous operations conducted under IHAs since 2003. The standard visual observation methods are described below and in Appendix F.

During the shallow hazards survey, at least one PSO onboard the seismic source vessel *Fennica* maintained a visual watch for marine mammals 24 h per day while airguns were in use. Observers focused their search effort forward and to the sides of the vessel but also searched aft of the vessel occasionally. Watches were conducted with the unaided eye, Fujinon 7×50 reticle binoculars, Zeiss 20×60 image stabilized binoculars, Fujinon 25×150 "Big-Eye" binoculars, or U.S. Nightvision class 3 night vision goggles. PSOs instructed seismic operators to power down or shut down the airguns if marine mammals were sighted within or about to enter applicable exclusion zones.

Similarly, at least one PSO aboard the *Nordica* maintained a visual watch during all dynamic positioning operations at the Burger well site. Observers utilized the same visual detection tools listed above for the *Fennica*, including 25×150 "Big-Eye" binoculars that were important for monitoring more distant areas of the ≥120 dB (rms) ZOI and pack ice. Visual monitoring was routinely conducted in a full 360-degree swath around the vessel, and particular attention was given to monitoring of operations that involved deployment and recovery of equipment to ensure there was no interaction between marine mammals and project activities.

Changes or Pre-existing Monitoring Protocols from NMFS Expert Panel Recommendations

As part of the NMFS IHA application processes, an independent peer review panel reviewed and provided comments and recommendations on the proposed marine mammal mitigation and monitoring plan. 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 2013. These recommendations included:

- pre-season training with vessel operators to ensure on-duty PSOs had the ability to successfully request required mitigation measures;
- 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 exclusion and disturbance 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;
- 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 mitigation;
- stationing PSOs in the best possible positions for observing: the bridge, bridge wings, flying bridge, or stern; 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 periods when vessels were moving, effort was quantified as the distance the vessel traveled while PSOs actively looked for marine mammals and recorded environmental and vessel activity data. For periods when vessels were stationary, 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 and density estimates in the following chapters of this report.

Observer effort and marine mammal sightings data 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; Bisson et al. 2013). These categories are defined briefly below, with a more detailed description provided in Appendix F.

<u>*Species Groups*</u>

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 exploration activities and related support activities. Pacific walrus and polar bear are presented separately due to their management by USFWS.

Geographic Boundaries and Vessel Role

Data were collected during the entire cruise period for both vessels including transits between Dutch Harbor and survey areas in the Chukchi Sea, and the transit to more nearshore areas for crew changes. For the purposes of this report, only data recorded north of Point Hope were included in the Chukchi Sea Study Area (Fig. 1) and summarized in Chapters 5, 6 and 7. Appendix I includes weekly sighting maps for both vessels and an all-sightings table, which includes all marine mammal detections by PSOs, including those from outside the Chukchi Sea Study Area.

Data were categorized by the duties of the vessel on which the data were collected. All data collected by PSOs aboard the shallow hazards and ice gouge survey vessel, *Fennica*, were categorized as "seismic vessel" data and are presented in Chapter 5. All data collected by PSOs aboard the *Nordica* were categorized as "dynamic positioning vessel" data, and these data are further broken down into periods when the vessel was moving or stationary. All *Nordica* vessel data are presented in Chapter 6.

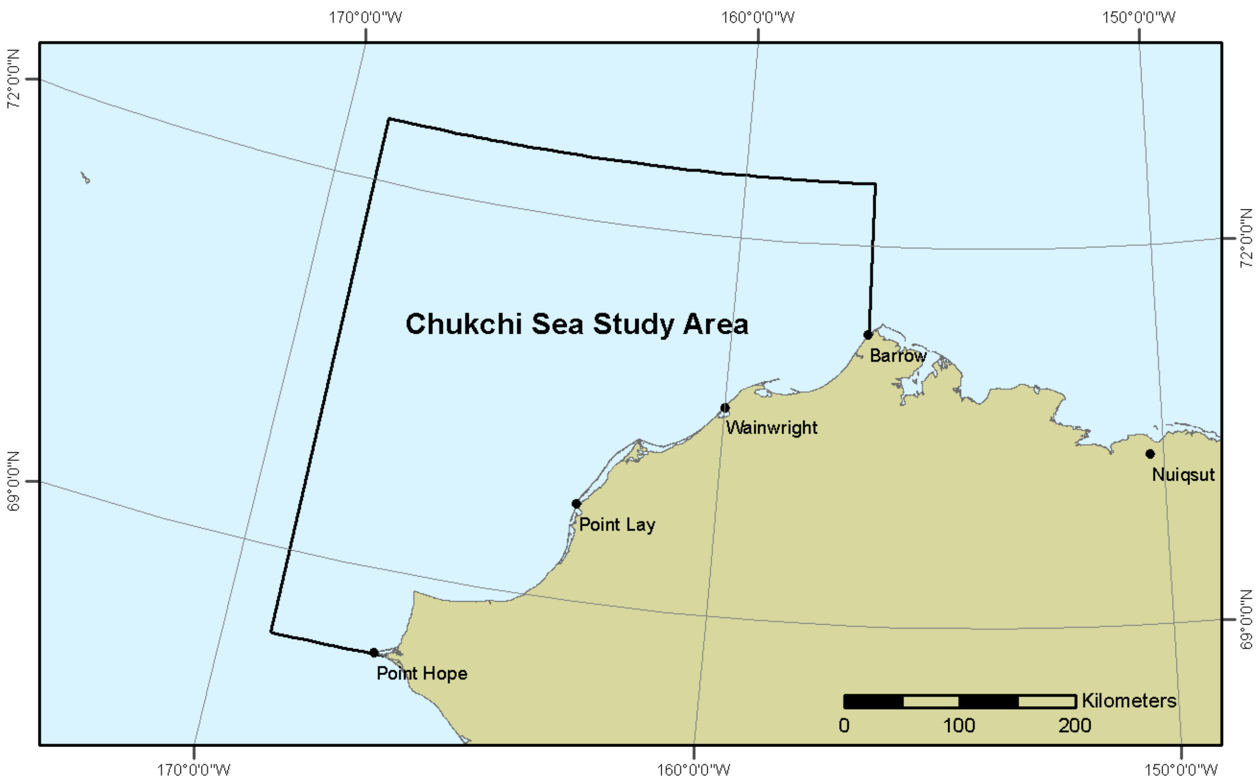

Figure 4.1. The Chukchi Sea Study Area boundaries used to categorize marine mammal data for analysis and presentation in Chapters 5, 6, and 7.

Vessel Activity

Sighting and observer effort data from the *Fennica* were categorized into two groups depending on airgun status. Periods of seismic testing, ramp up, mitigation gun activity, and full array activity were grouped as "seismic" data. Periods with no airgun activity were categorized as "non-seismic" data.

Sighting and observer effort data from the *Nordica* were categorized into three primary bins. These included periods while the vessel was operating in dynamic positioning, general vessel activity (e.g., transit), and idle vessel activity (e.g., drifting).

Sighting Rate Calculation and Comparisons

Sighting rates (sightings per 1000 km of PSO effort, or sightings per 10 h of PSO effort) are presented for both vessels within the analysis categories of Beaufort wind force (Bf), number of PSOs on watch, and by seismic status (for the *Fennica*) or vessel activity status (for the *Nordica*). Sighting rates are presented independently by species groups including cetaceans, pinnipeds (excluding walrus), Pacific walrus, and polar bear. Where appropriate and sample sizes permitted, comparisons of sightings rates between categories were made using a chi-square (χ^2) test. In general, however, small sample sizes precluded meaningful statistical analyses in most cases.

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 seismic activity on the distribution and behavior of marine mammals, effort and sightings data were categorized by sighting conditions (e.g. environmental conditions) and operational conditions. The criteria were intended to exclude data from periods of observation effort when conditions would have made it unlikely for PSOs to be able to detect marine mammals that were at the surface. If those data were to be included in analyses, important metrics like sightings rates and density estimates would be biased downward. It is important to note that data from periods that met the following analysis criteria were used to estimate the number of animals potentially exposed to underwater sounds from Shell's activities for the entirety of the project, including periods of reduced visibility and darkness.

Criteria for Sighting Rate Data

Different definitions were used for pinnipeds and cetaceans in order to account for assumed differences in their reactions to seismic survey and vessel activities. Therefore, effort and sightings occurring under the following conditions were excluded when calculating sighting rates and densities:

- periods 3 min to 2 h after the airguns were turned off (post-seismic period);
- for moving-vessel data, periods when ship speed was <3.7 km/h (2 kt);
- periods with seriously impaired visibility including:
  - all nighttime observations;
  - visibility distance <3.5 km (2.2 mi);
  - Beaufort wind force (Bf) >5 (Bf >2 for minke whales, belugas, and porpoises; See Appendix G for Beaufort wind force definitions);
  - >60º of severe glare in the forward 180° of the vessel.

This categorization system was designed primarily to allow identification of potential differences in behavior and distribution of marine mammals during periods with airgun activity versus periods without airgun activity. The rate of recovery toward "normal" behavior and distributions during the post-seismic period 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-seismic period was defined as a time long enough after cessation of airgun activity to ensure that any carry-over effects of exposure to sounds from the airguns 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 F. Data that met these criteria are presented in Part 3 of Appendix I.

Distribution and Behavior

Initial Sighting Distance and Distribution

For each sighting, PSOs recorded an initial sighting distance and a direction of animal movement. Polar plots created for each vessel display the distribution, direction, and initial sighting distance of marine mammals. Sightings were classified by seismic activity for the *Fennica* and vessel activity for the *Nordica*. Sightings were also categorized by those made during periods of good visibility and sightings made during periods of poor visibility.

Closest Point of Approach

The closest point of approach (CPA) of each sighting to the observer position or airgun array was calculated in a geographic information system (GIS) using the closest sighting record to the PSO position on the vessel and then triangulating to the airgun array for sightings recorded from the *Fennica*. The mean, standard deviation, and range of CPA distances to the airgun array was calculated within the seismic activity bins for data from the *Fennica* or to the observer within the vessel activity categories for data from the *Nordica*.

Similar to sighting rate calculations, the calculation of mean CPA distances and subsequent comparisons during different seismic or 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 seismic sounds. Therefore, only sightings that met the criteria for inclusion in the sighting rate calculations were used in the calculation of mean CPA distances.

Movement

Animal movements relative to the vessel were grouped into five categories: swim (move) away, swim (move) towards, neutral (e.g. parallel), none, or unknown. The observed movements of animals that fell into these categories were compared for each vessel across the seismic or vessel activity bins.

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, 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 for each vessel and across the seismic or vessel activity bins.

Reaction Behavior

Animal reactions in response to the vessel, seismic sound source, or dynamic positioning activities were recorded during each sighting. Reaction behavior codes included: change in direction, increase or decrease in speed, look, splash, rush, bow or wake ride, interaction with gear, and no reaction. The reaction behaviors of animals that fell into these categories were compared for each vessel and across the seismic or vessel activity bins.

Line Transect Estimation of Densities

Marine mammal sightings recorded during seismic and non-seismic periods were used to calculate separate densities (#/km^2) of marine mammals near the vessels during those periods. Because there were relatively few sightings from the *Nordica* while it was stationary in dynamic positioning at the well site, and data from stationary periods that did *not* involve dynamic positioning were minimal, densities could not be calculated and compared between these two stationary activity states. Therefore, only sightings and effort from the two vessels while they were underway were used to calculate densities. Density calculations were based on line-transect principles (Buckland et al. 2001). Correction factors for animals not detected at greater distances from the vessels, $f(0)$, were calculated from data collected from *tall* (observation platforms >11 m or 36 ft) project vessels in the Chukchi Sea during previous seasons to increase sample sizes. Correction factors for animals near the vessel, but underwater and therefore unavailable for detection by observers, $g(0)$, were taken from related studies, as summarized by Koski et al. (1998), Barlow (1999), Forney and Barlow (1998), Barlow and Gerrodette (1996), and Bengston et al. (2005). This was necessary because of the inability to assess trackline sighting probability, $p(0)$, during a project of this type. Further details on the line transect data analysis are provided in Appendix F.

Estimating Numbers Potentially Affected

NMFS and USFWS practice 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 the dynamic positioning, 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 ≥160 dB (rms) distances from the seismic source shown in Table 4.1 (1.3 km or 0.81 mi), and the measured ≥120 dB (rms) distance from the *Nordica* during dynamic positioning shown in Table 4.2 (4.5 km or 2.8 mi).

Three primary 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) minimum estimates based on direct observations during seismic surveys by the *Fennica* and dynamic positioning activities by the *Nordica* at Burger;

(B1) estimates based on densities calculated from data collected from the two vessels during good visibility conditions and **non-seismic** periods multiplied by the area of water exposed to seismic sounds ≥160 dB (rms) or dynamic positioning sounds ≥120 dB (rms) during all operations in Jul–Aug, *plus* the respective densities and periods in Sep;

(B2) estimates based on densities calculated from data collected from the two vessels during good visibility conditions when **seismic** operations were ongoing multiplied by the area of water exposed to seismic sounds ≥160 dB (rms) or dynamic positioning sounds ≥120 dB (rms) during all operations in Jul–Aug, *plus* the respective densities and periods in Sep;

(C1) for dynamic positioning sounds only, estimates based on densities calculated from data collected from the two vessels during good visibility conditions and **non-seismic** periods multiplied by the area of water exposed to dynamic positioning sounds ≥120 dB (rms) during all operations in Jul–Aug multiplied by 11 to account for the 11 days on which dynamic positioning occurred in those months, *plus* the respective densities and periods in Sep multiplied by nine to account for the nine days on which dynamic positioning occurred during Sep; and

(C2) for dynamic positioning sounds only, estimates based on densities calculated from data collected from the two vessels during good visibility conditions when **seismic** operations were ongoing multiplied by the area of water exposed to dynamic positioning sounds ≥120 dB (rms) during all operations in Jul–Aug multiplied by 11 to account for the 11 days on which dynamic positioning occurred in those months, *plus* the respective densities and periods in Sep multiplied by nine to account for the nine days on which dynamic positioning occurred during Sep.

As noted above, separate density estimates were calculated from data collected during seismic and non-seismic periods or locations. The use of non-seismic densities in method (B1) provides an estimate of the number of animals that presumably would have been present in the absence of seismic activities. The use of seismic densities in method (B2) provides an estimate of the number of animals that were likely present in the area of seismic activity during this project. In cases where seismic densities are lower than non-seismic densities, the difference between the two estimates could be taken as an estimate of the number of animals that moved in response to the operating seismic vessel, or that changed their behavior sufficiently to affect their detectability by visual observers. In cases where seismic densities are greater than non-seismic densities, it suggests that individuals of that species did not move in response to the operating seismic vessel, or that they altered their behavior in such a way that made them more detectable by visual observers (e.g. increased their time spent at the surface). The actual number of individuals exposed to, and potentially affected by, seismic survey or dynamic positioning sounds was likely between the minimum and maximum estimates resulting from methods (A) and (B1) or (B2).

Method (B1) above provided an estimate of the number of animals that would have been exposed to airgun sounds at various levels if the seismic activities did not influence the distribution of animals near the activities. However, it is known that some animals are likely to have avoided the area near the seismic vessel while the airguns were firing (see Richardson et al. 1995, 1999; Stone and Tasker 2006; Gordon et al. 2004; Smultea et al. 2004, Funk et al. 2008). Within the ≥160 dB (rms) radii around the seismic source (i.e., 1.3 km [0.81 mi]), the distribution and behavior of cetaceans and pinnipeds may have been altered as a result of the seismic survey. These effects could occur because of reactions to the active airgun array, or to other sound sources or other vessels working in or transiting through the area.

Density estimates for each species group were used to estimate the number of animals potentially affected by seismic and dynamic positioning operations (methods B1 and B2). In the case of airgun sounds from site survey activities, this involved multiplying the following three values:

- km of seismic survey;
- width of area assumed to be ensonified to ≥160 dB (rms) by pulsed airgun sounds (2 × ≥160 dB measured radius), counting the areas ensonified on more than one occasion only once; and
- densities of marine mammals estimated from data collected during this survey as described above.

The ensonified area used in the above calculations for seismic exposures did not include multiple counts of the same area of water that was exposed on multiple occasions. Areas within the seismic survey area may have been ensonified by airgun sounds multiple times during the site surveys because survey transect lines were spaced closer together than twice the measured ≥160 dB distance (2 × 1.3 km = 2.6 km or 1.6 mi). The ratio of the area of water ensonified including multiple counts of areas exposed more than once to the area of water ensonified excluding multiple counts of areas exposed more than once represents the average number of times a given area of water was ensonified to the specified level. If an animal remained at the survey site through the duration of the survey activities it would have been, on average, exposed an equivalent number of times.

This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys in the Alaskan Beaufort Sea conducted under IHAs (Harris et al. 2001). The method has recently been used in estimating numbers of seals and cetaceans potentially affected by other seismic surveys conducted under IHAs (e.g., Funk et al. 2008; Ireland et al. 2007a,b; Patterson et al. 2007).

In the case of dynamic positioning operations for methods (C1) and (C2), the area ensonified by continuous sounds from the *Nordica's* dynamic positioning system was calculated as the area of a circle with a radius equal to the measured ≥120 dB (rms) distance multiplied by the number of days on which the *Nordica* operated its dynamic positioning system in Jul–Aug (n=11) and Sep (n=9). The resulting product of ensonified area times the daily multiplier for each seasonal period was then multiplied by the respective marine mammal density estimates for each seasonal period. This daily multiplier was a conservative measure that assumed complete turnover of the marine mammal populations in the area each day, and likely overestimates the number of animals exposed to dynamic positioning sounds ≥120 dB (rms). Shell's IHA application for 2013 also used this alternative approach as an upper estimate of marine mammal exposures from dynamic positioning sounds (Shell 2013).

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5. MARINE MAMMAL MONITORING RESULTS DURING SHALLOW HAZARDS AND ICE GOUGE SURVEYS[1]

Monitoring Effort and Marine Mammal Encounter Results

This chapter summarizes the visual observer effort from the *Fennica* during Shell's 2013 shallow hazards and ice gouge surveys in the Chukchi Sea. It does not include effort conducted during transit from Dutch Harbor to and from the survey area (the survey area is defined as waters north of Point Hope, Alaska). The *Fennica* entered the Chukchi Sea survey area on 17 Jul 2013 Alaska Daylight Time (AKDT) and departed the area on 28 Sep 2013. Survey activities on the Shell leases began with airgun testing on 18 Jul and continued through 28 Sep.

The *Fennica* traveled along a total of ~10,888 km (6765 mi) of trackline in the Chukchi Sea survey area. Airgun operations occurred along ~2448 km (1521 mi) of that trackline. The full airgun array was ramping up or active along ~ 1790 km (1112 mi) while the single mitigation airgun operated along ~ 658 km (408 mi), including turns and power downs. The airguns did not operate along the remaining~ 8440 km (5244 mi) of trackline in the Chukchi Sea.

Vessels other than the *Nordica*, which was 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 (>24 km; >15 mi) and PSOs observed no instances of harassment or disturbance to marine mammals due to the presence of these other ships.

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 the *Fennica*, effort was quantified as the distance the vessel traveled while PSOs actively looked for marine mammals and recorded environmental and vessel activity 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 *Fennica* were on watch for a total of ~ 10,705km (6651 mi; 1426 h), or 98% of all operations. At least one observer was on watch during 100% (~1969 km; 1223 mi; 276 h) of daylight seismic operations and two observers were on watch for ~96% (1890 km; 1175 mi; 265 h) of daylight seismic operations. At least one observer was on watch during 100% (~479 km; 298 mi; 70 h) of nighttime seismic operations and two observers were on watch for ~ 88 % (425 km; 264 mi; 62 h) of nighttime seismic operations. Of the total observation effort, ~ 23 % (2464 km; 1531 mi; 316 h) occurred during darkness (Figure 5.1).

[1] By Heather Reider, Lauren Bisson, Kenneth Matthews and Craig Reiser (LGL Alaska Research Associates, Inc.)

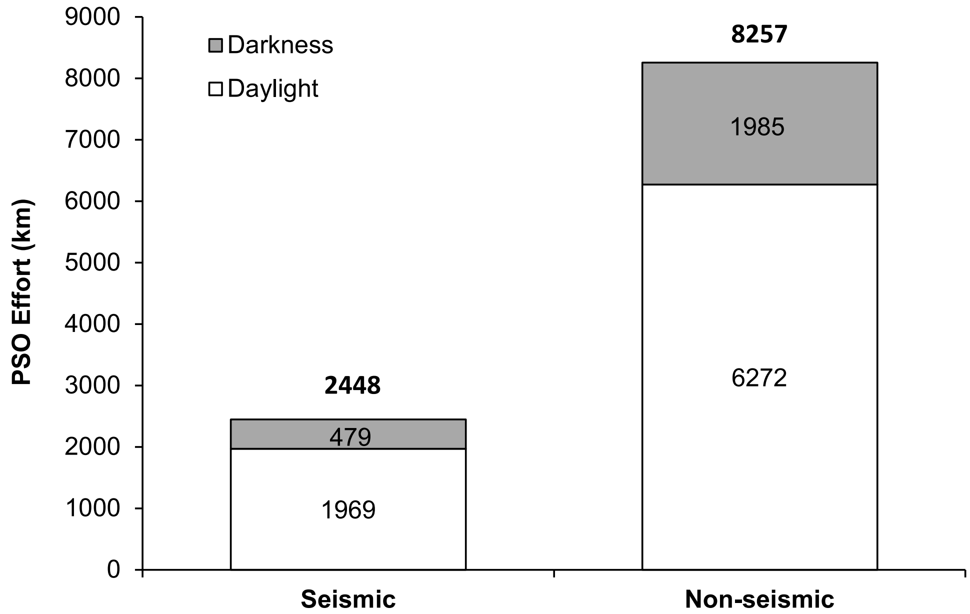

FIGURE 5.1. Total PSO observation effort (km), and PSO effort during daylight and darkness periods from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Observer Effort by Beaufort Wind Force

Observer effort from the *Fennica* occurred between Beaufort wind force Bf 0 and Bf 7 (Figure 5.2). The greatest amount of observer effort for both seismic and non-seismic activities occurred during Bf 3, which combined accounted for ~36% (3872 km; 2405 mi) of PSO effort aboard the *Fennica.* For both seismic and non-seismic activities, ~84% of the effort occurred in Bf 2 through 5.

Observer Effort by Number of PSOs

On the *Fennica*, two PSOs were on watch during ~89% (9595 km; 5962 mi) of observation effort and one PSO was on watch for ~11% (1110 km; 690 mi) of observation effort (Figure 5.3). PSOs were scheduled to provide 100% coverage during all periods of survey operations, while the airguns were active, and to maximize coverage during other operational periods of activity to maximize monitoring and mitigation efforts.

Observer Effort by Seismic Status

Most observer effort from the *Fennica* occurred while the airguns were inactive; ~16% of total observer effort occurred while the full array was active and ~6% of total observer effort occurred while the mitigation airgun was active (Figure 5.4). Observer effort during non-seismic activities accounted for the remaining ~77% of total effort.

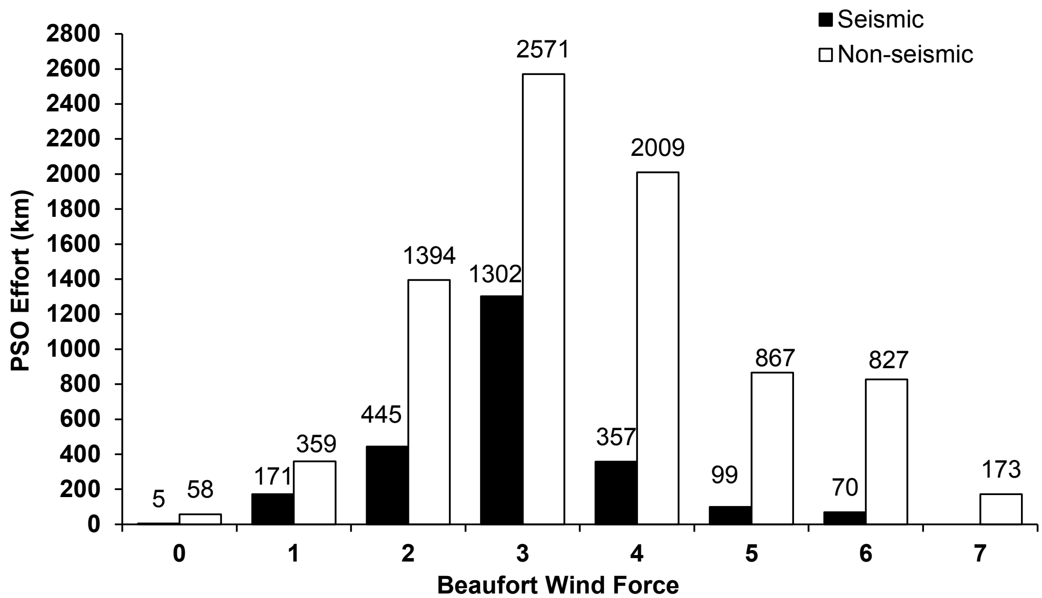

FIGURE 5.2. PSO observation effort (km) by Beaufort wind force from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

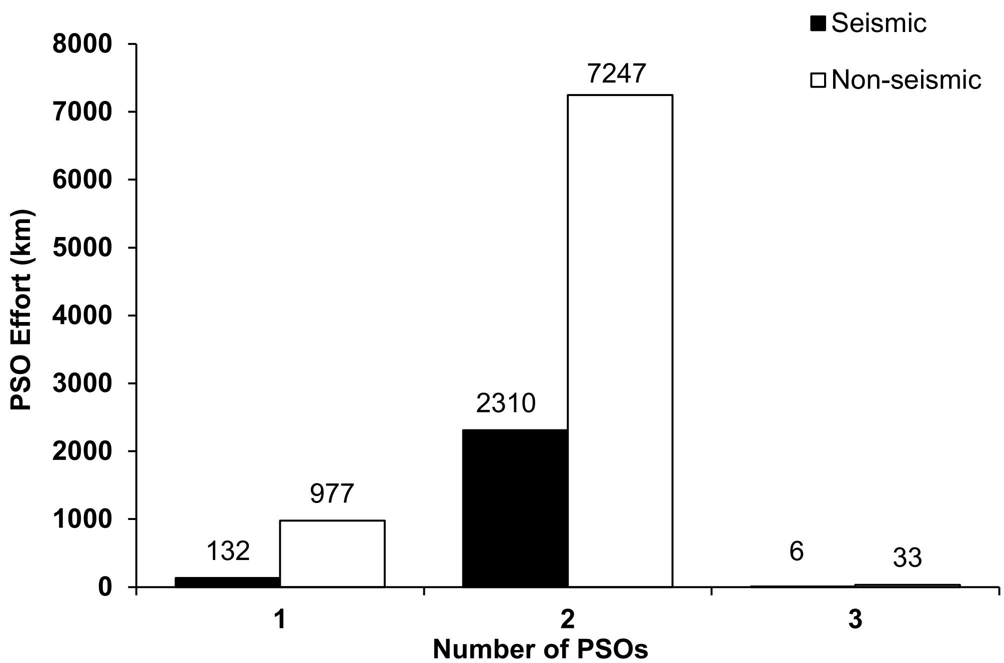

FIGURE 5.3. PSO observation effort (km) for moving periods by number of PSOs from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

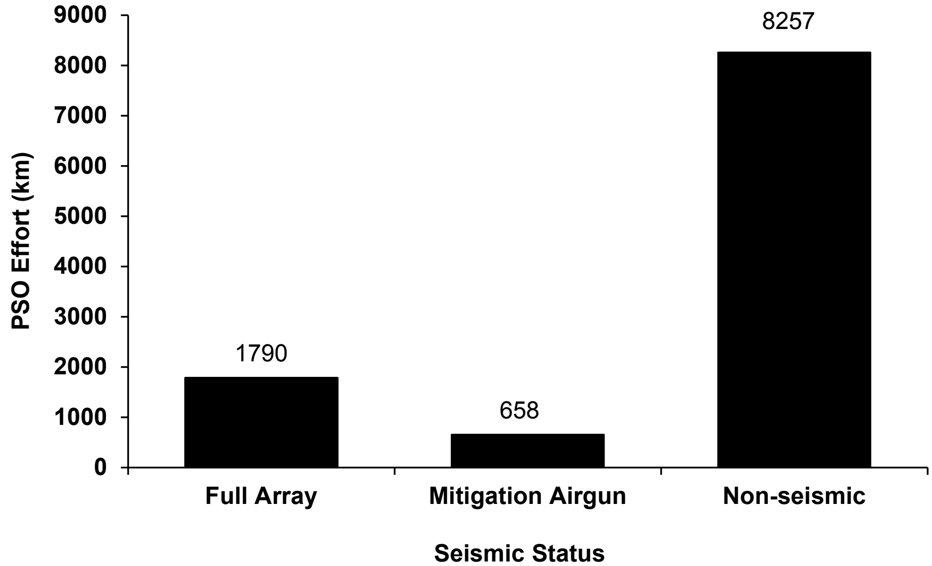

FIGURE 5.4. PSO observation effort (km) by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Marine Mammal Sightings

During the Shell shallow hazards and ice gouge surveys, PSOs observed a total of 354 sightings of 454 marine mammals from the *Fennica*. Details of each marine mammal sighting observed in the survey area are available in Appendix I. Sighting rates from moving vessels are considered as sightings per 1000 km. The sighting data below are presented in three species groups: cetaceans, seals, and Pacific walruses.

Cetacean Sightings

PSOs observed 70 sightings of 126 cetaceans from the *Fennica* (Table 5.1). Of the 70 cetacean sightings, three were observed during seismic activities and 67 were observed during non-seismic activities. Most of the cetacean sightings (n=56) occurred from 31 Jul through 5 Aug while *Fennica* was near Barrow Canyon off the coast of Wainwright engaged in non-seismic activity (i.e., crew change, ice gouge lines; Figure 5.5). Since 2007, gray whales have been observed by industry vessels and aerial surveys feeding in the costal and shoal habitats of the eastern Chukchi Sea, occasionally in groups of up to ~10 individuals (LGL 2013). Approximately 73% of the cetacean sightings were confirmed or suspected gray whales. 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).

TABLE 5.1. Total number of cetacean sightings (total number of individuals) from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Total		
Species	**Seismic**	**Non-seismic**	**Total**
Cetaceans			
Bowhead whale	0 (0)	3 (13)	***3 (13)***
Gray whale	0 (0)	30 (67)	***30 (67)***
Harbor porpoise	0 (0)	1 (1)	***1 (1)***
Humpback whale	0 (0)	1 (1)	***1 (1)***
Minke whale	0 (0)	13 (13)	***13 (13)***
Unidentified mysticete whale	3 (5)	18 (25)	***21 (30)***
Unidentified whale	0 (0)	1 (1)	***1 (1)***
Total Cetaceans	***3 (5)***	***67 (121)***	***70 (126)***

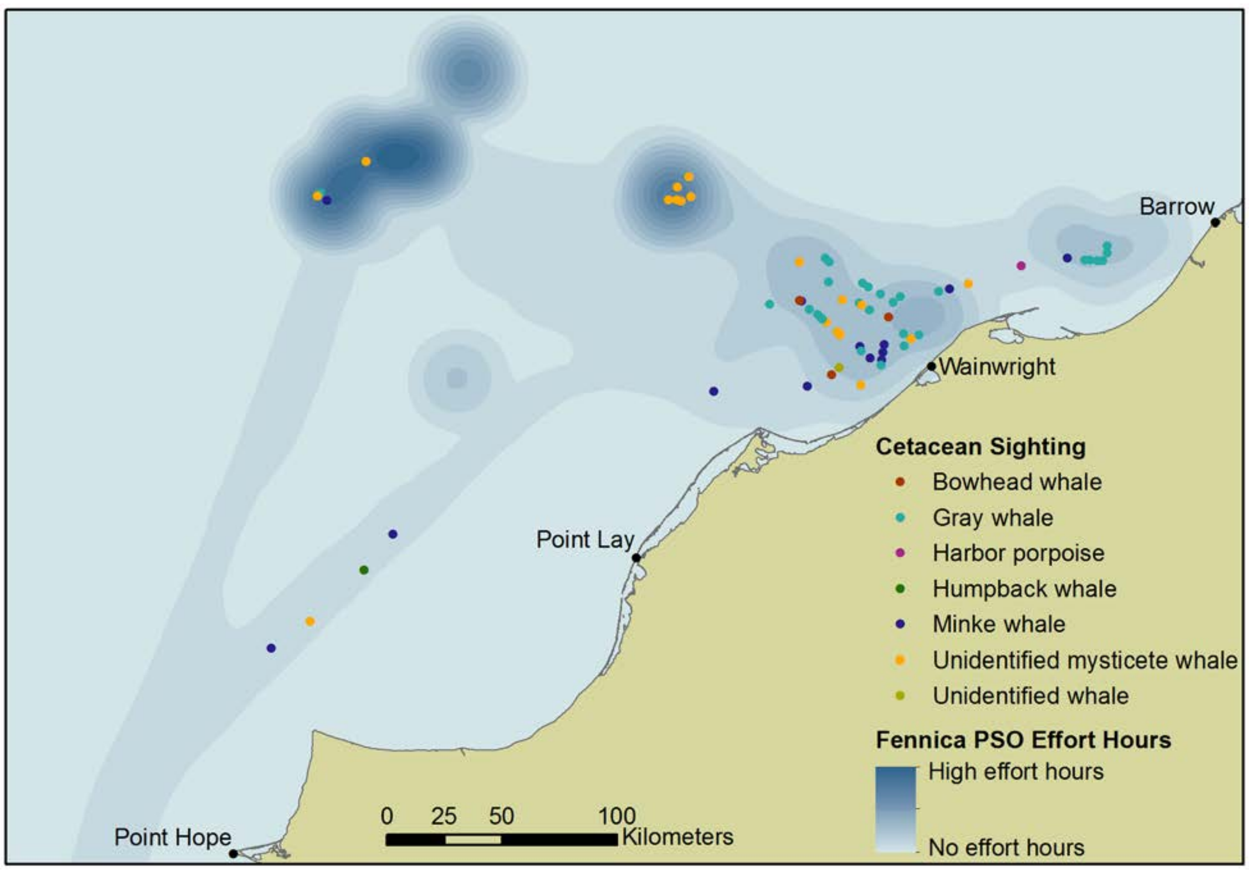

FIGURE 5.5. Location of cetacean sightings by species and *Fennica* effort hours during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

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 I) and the sightings that occurred during those periods. Data that met these criteria are summarized and presented in Section 3 of Appendix I.

Cetacean Sighting Rates by Beaufort Wind Force – Cetacean sighting rates tended to decrease with increased Bf wind force (Figures 5.6 and 5.7). Cetacean sighting rates were highest during Bf 2, although there was no effort in Bf 0 and a limited amount of effort in Bf 1. Gray whales are generally more common along the coast than in offshore areas and consistent with that, the highest number of cetacean sightings occurred from 31 Jul through 5 Aug (during Bf 2/3), as the vessel operated in the nearshore area off of Wainwright to complete ice gouge lines and conduct a crew change.

Cetacean Sighting Rates by Number of PSOs – Regulatory requirements mandated that source vessels, such as the *Fennica*, use two PSOs to monitor the water during daytime active operations. There were relatively few periods on the *Fennica* during which one PSO was on watch and few periods where three PSOs were on watch. Sighting rates were higher with two PSOs on watch during non-seismic periods (Figure 5.8). 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.

Cetacean Sighting Rates by Seismic Status – Cetacean sighting rates were higher during non-seismic activity than during seismic activity. Three of the cetacean sightings occurred while airguns were active (Figure 5.9). Most cetacean sightings occurred in the nearshore area off Wainwright from 31 Jul through 5 Aug, when the vessel was out of the site survey area and was not operating the airguns.

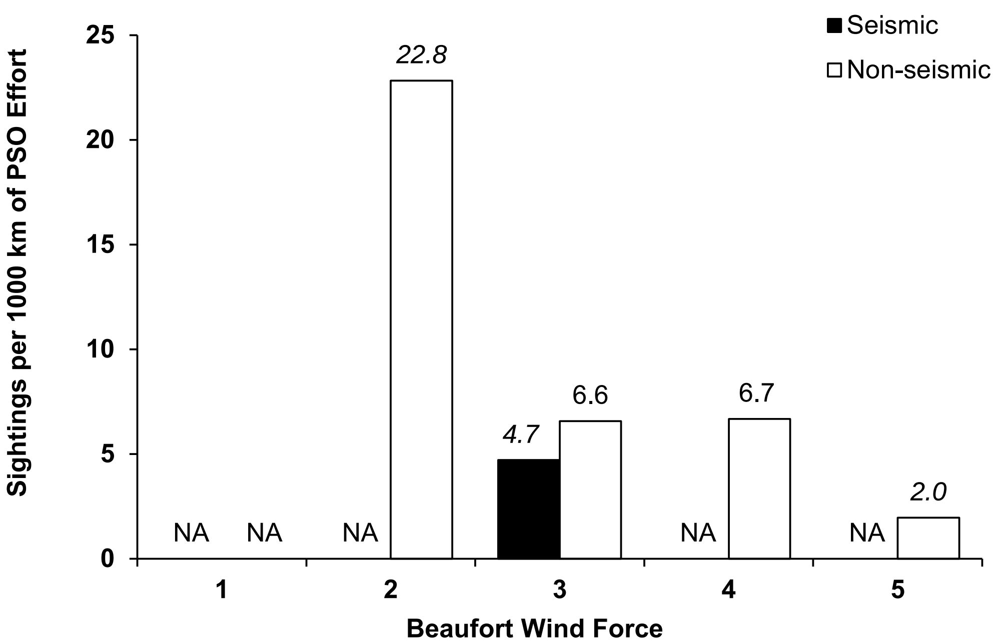

FIGURE 5.6. Cetacean sighting rates by Beaufort wind force conditions from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. NA indicates there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort in the category.

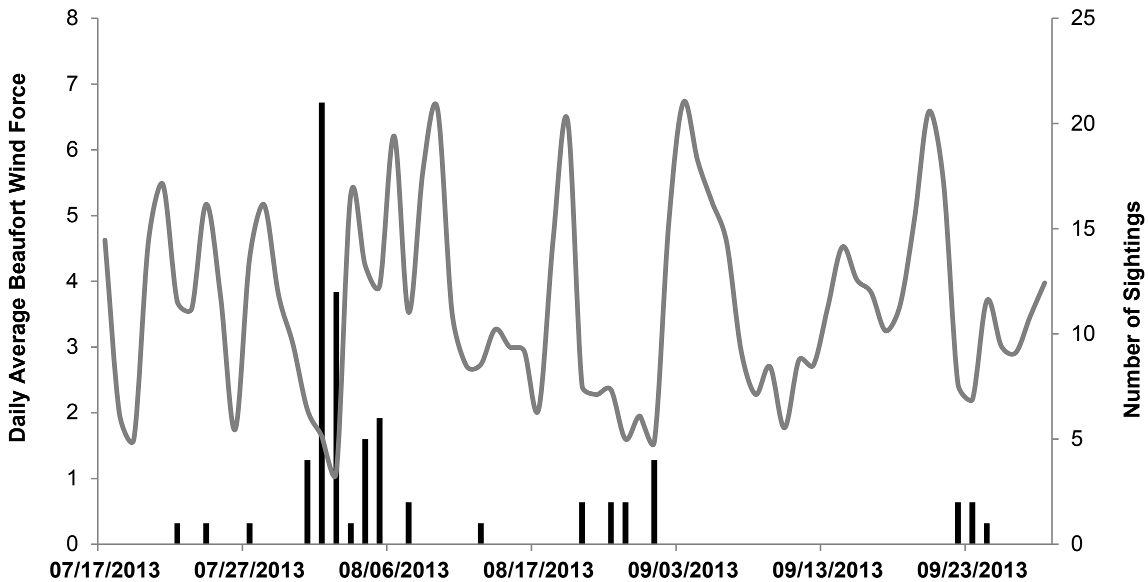

FIGURE 5.7. Number of daily cetacean sightings (bars) and average Beaufort wind force (line) from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

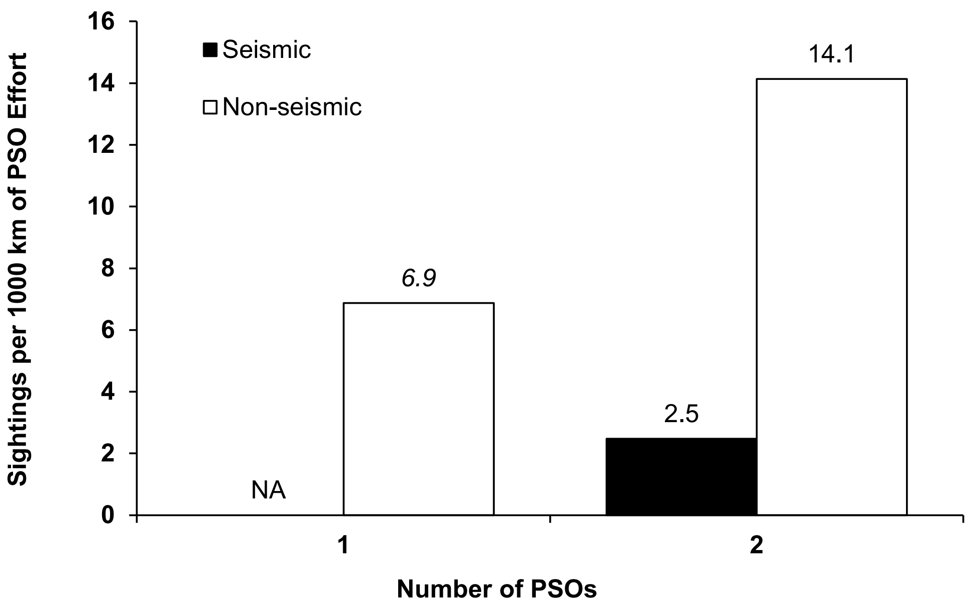

FIGURE 5.8. Cetacean sighting rates from moving vessels by number of PSOs on watch from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. NA indicates insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort within the category. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

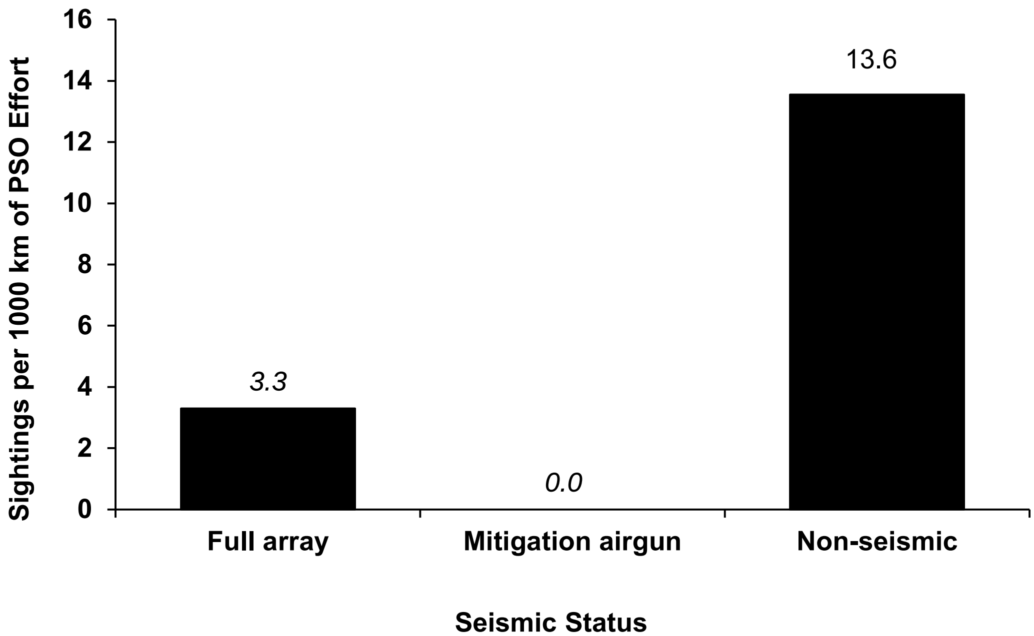

FIGURE 5.9. Cetacean sighting rates by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort within the category.

Seal Sightings

There were 258 seal sightings of 284 individuals by PSOs on the *Fennica* (Table 5.2). Only 7% of the seal sightings occurred during seismic activities. Seal sightings were typically brief in duration and occurred throughout the survey areas (Figure 5.10). Bearded seal was the most frequently identified seal species, although more than half of the seals sighted could not be identified to species.

TABLE 5.2. Number of seal sightings (number of individuals) from the Fennica during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Total		
Species	**Seismic**	**Non-seismic**	**Total**
Seals			
Bearded seal	0 (0)	50 (52)	***50 (52)***
Ringed seal	5 (6)	36 (38)	***41 (44)***
Spotted seal	0 (0)	6 (16)	***6 (16)***
Unidentified pinniped	1 (1)	10 (11)	***11 (12)***
Unidentified seal	14 (14)	136 (146)	***150 (160)***
Total Seals	***20 (21)***	***238 (263)***	***258 (284)***

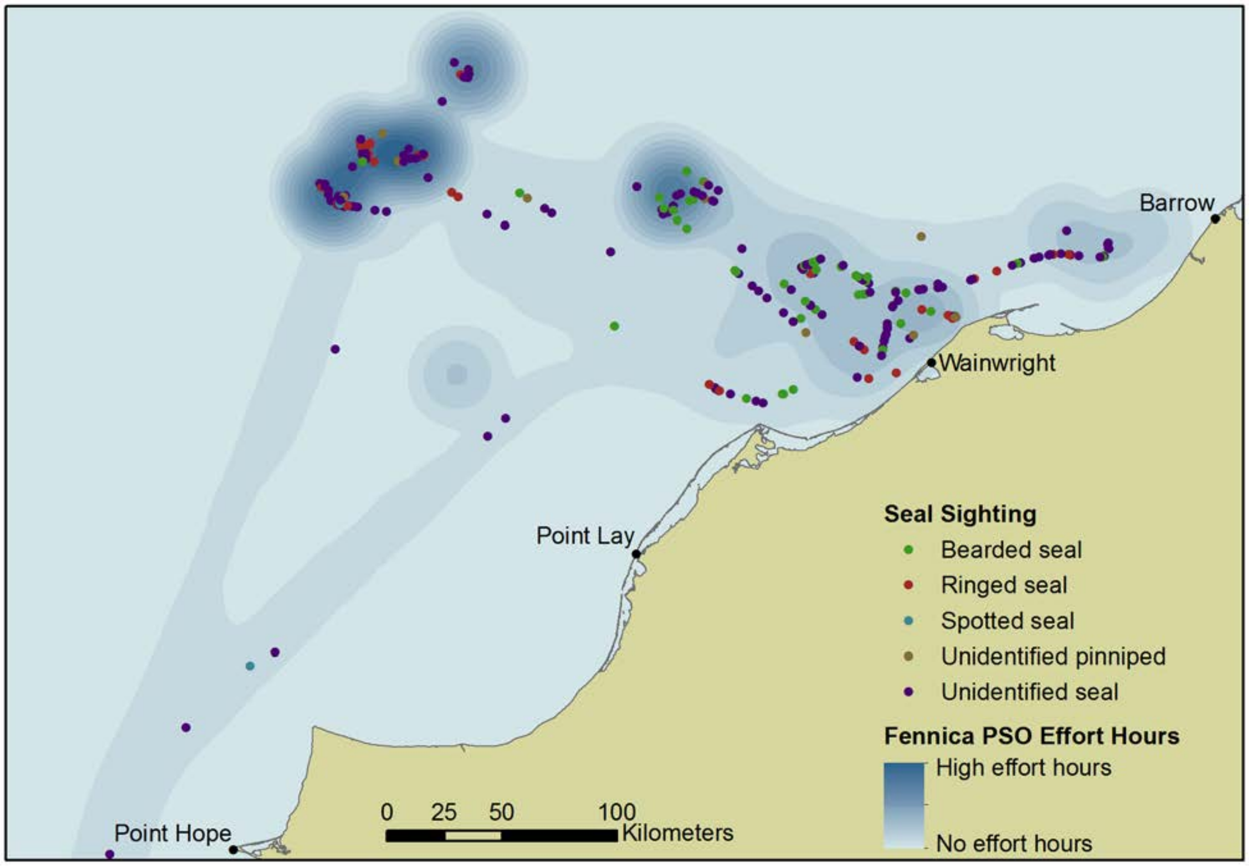

Figure 5.10. Location of seal sightings by species and *Fennica* effort hours during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

<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 I) and the sightings that occurred during those periods.

Seal Sighting Rates by Beaufort Wind Force – As would be expected, seal sighting rates from the *Fennica* decreased with increasing Beaufort wind force (Figure 5.11). During non-seismic activities 70% of the seal sightings occurred during periods of Bf 1 or Bf 2. There was limited observation effort in Bf 1 (205 km; 127 mi) and the sighting rate should be viewed with caution. Overall, very few seals were observed while airguns were active (n=11); however, 90% of the sightings during airgun use were observed during a Bf 1, 2 and 3. Figure 5.12 shows the number of seal sightings each day along with the average daily wind force. As would be expected, most seal sighting from the *Fennica* occurred on days with lower average daily Bf.

Seal Sighting Rates by Number of PSOs – There were two observers on watch aboard the *Fennica* during ~89% of all seismic and non-seismic activities. About 8% of seal sightings occurred during seismic activity. Figure 5.13 indicates that seal sighting rates were much greater with two PSOs on watch and that most sightings occurred during non-seismic watch time. Seal sighting rates with two PSOs on watch (39.1 seals/1000 km) were nearly 7 times greater than with one PSO on watch (5.8 seals/1000 km) and the difference was statistically significant (X^2 = 9.5, df = 1, p = 0.002). This chi square test used a combined seismic and non-seismic sighting rate for the categories of PSO numbers for this comparison as there was limited effort with only one PSO on watch.

Seal Sighting Rates by Seismic Status – The seal sighting rate from the Fennica was highest during non-seismic activities in the Chukchi Sea (Figure 5.14). The sighting rate during non-seismic activities was nearly two times greater than during either full array or mitigation airgun activity. The difference between sighting rates during non-seismic activities and seismic activities was statistically significant (X^2 =35.6, df = 1, p = <0.05). Given the small sample size during seismic activities this result should be viewed with some caution. Seals were widely distributed throughout the survey area (Fig 5.10) and it is possible that some seals avoided the seismic survey activities based on the significantly lower seismic compared to non-seismic sighting rates. Localized avoidance of seismic surveys by seals has been reported in the Alaskan Chukchi Sea (Reiser et al. 2009).

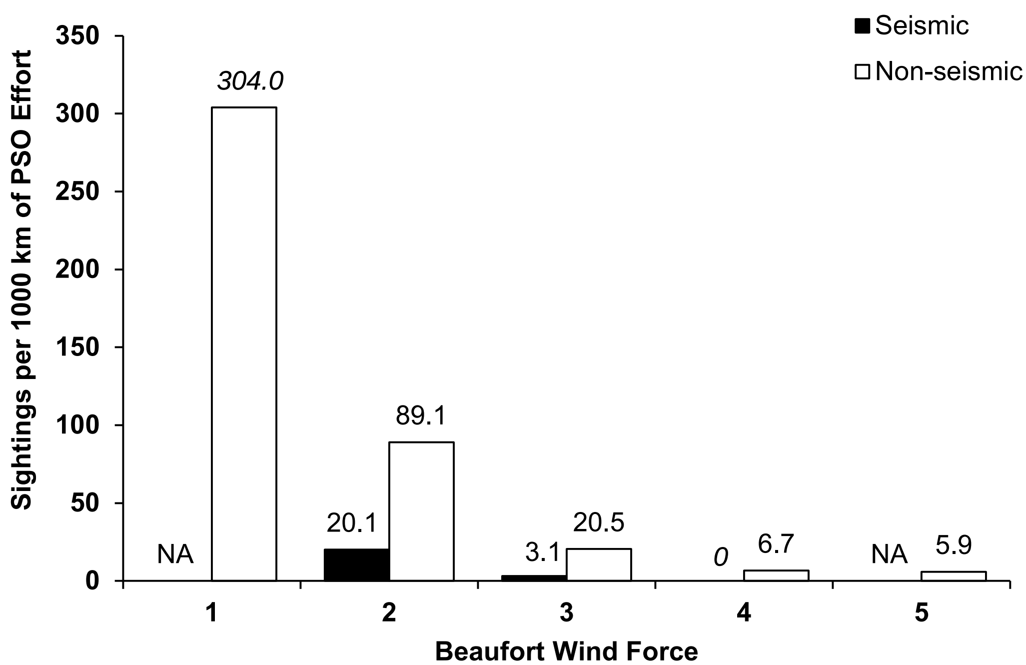

FIGURE 5.11. Seal sighting rates by Beaufort wind force from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. NA indicates insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort within the category.

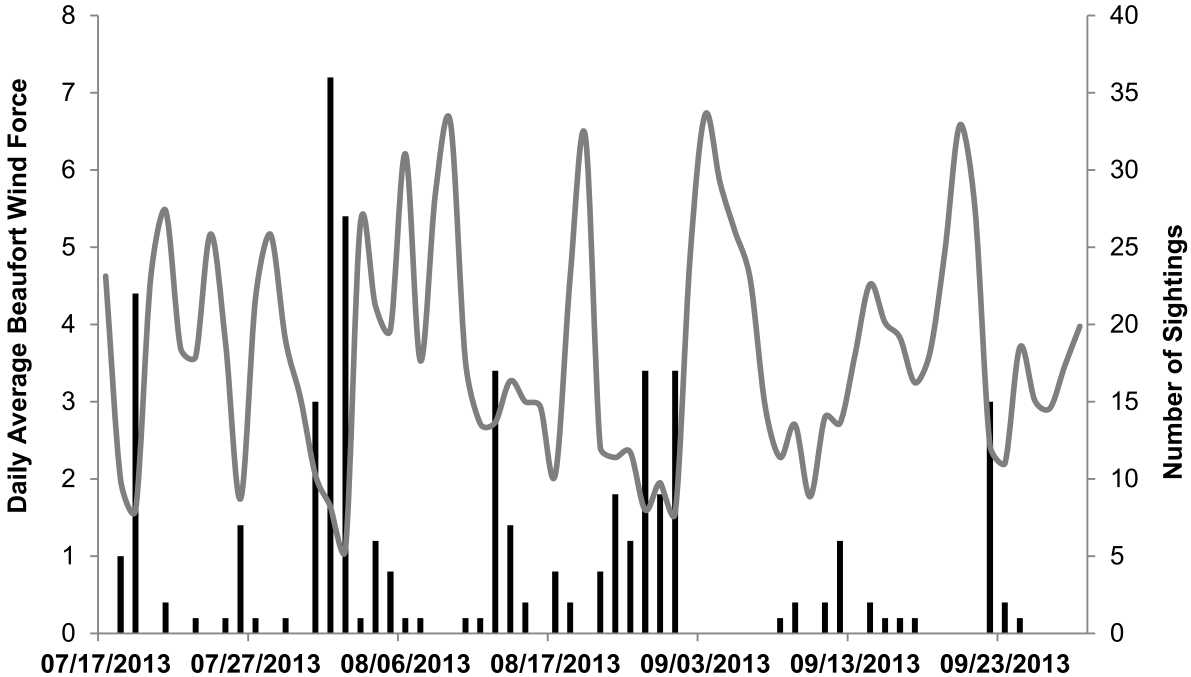

FIGURE 5.12. Number of daily seal sightings (bars) and average Beaufort wind force (line) from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

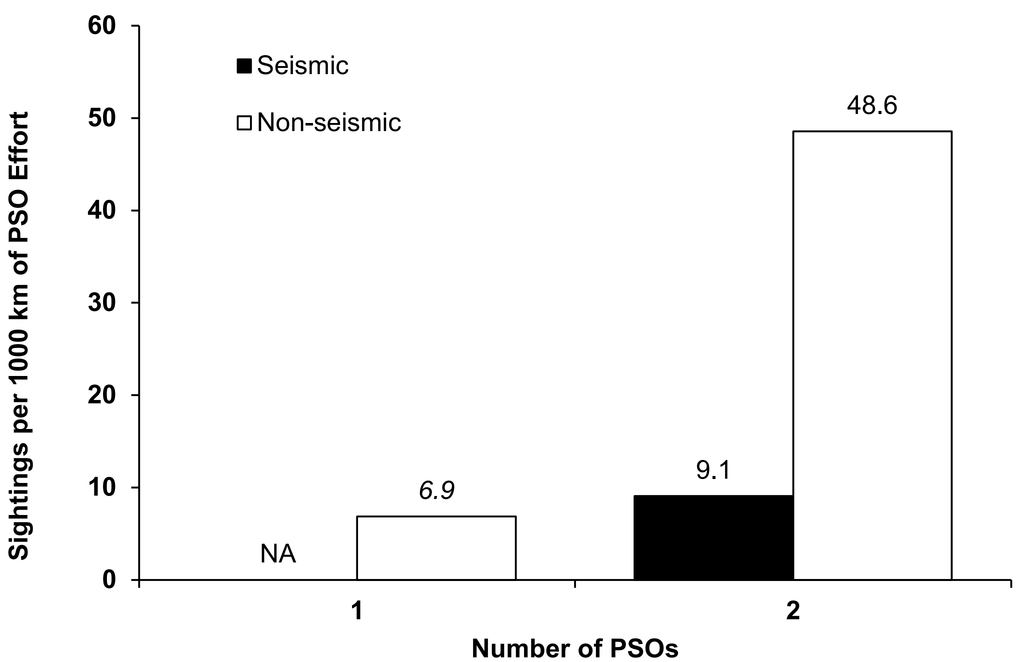

FIGURE 5.13. Seal sighting rates from moving vessels by number of PSOs on watch from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. NA indicates there was insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort within the category. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

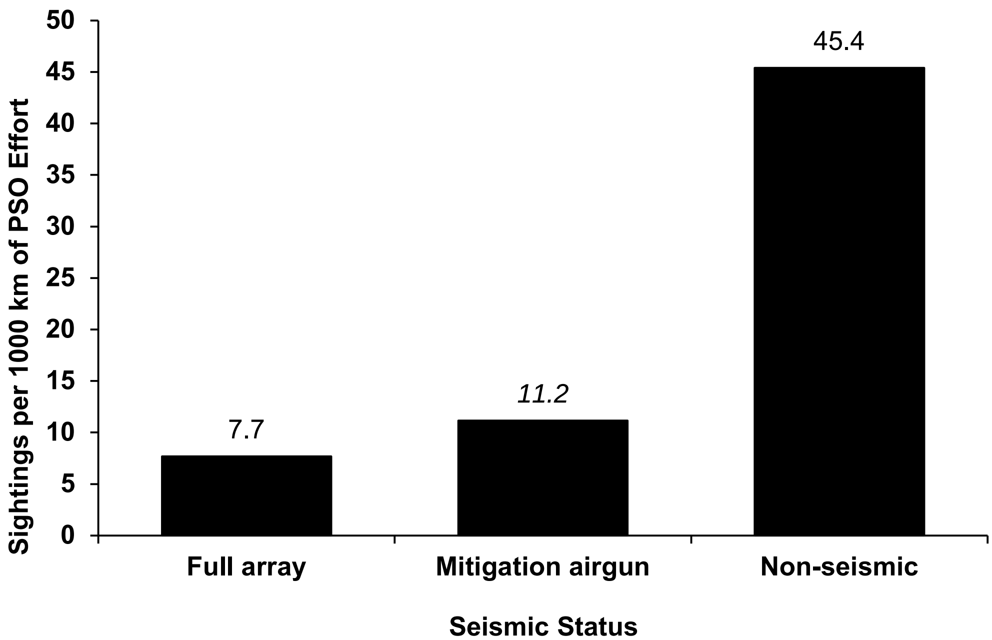

FIGURE 5.14. Seal sighting rates by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Polar Bear Sightings

No polar bears were observed during Shell's shallow hazards and ice gouge surveys in 2013.

Pacific Walrus Sightings

There were 26 Pacific walrus sightings of 44 individuals recorded by PSOs on the *Fennica*. About 58% of the Pacific walruses seen were observed on 22 Sep. On 22 Sep the *Fennica* was on the Burger survey site and the higher number of sightings was likely due to the movement of Pacific walruses toward haul outs on the Alaskan Chukchi Sea coast. Observations of Pacific walruses are probably more influenced by specific time periods during which walrus move towards the coast to potential foraging areas using shore haul outs (Figure 5.15 Map; Funk et al. 2013).

TABLE 5.3. Number of Pacific walrus sightings (number of individuals) from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Total		
Species	**Seismic**	**Non-seismic**	**Total**
Pacific walrus	8 (8)	18 (36)	***26 (44)***

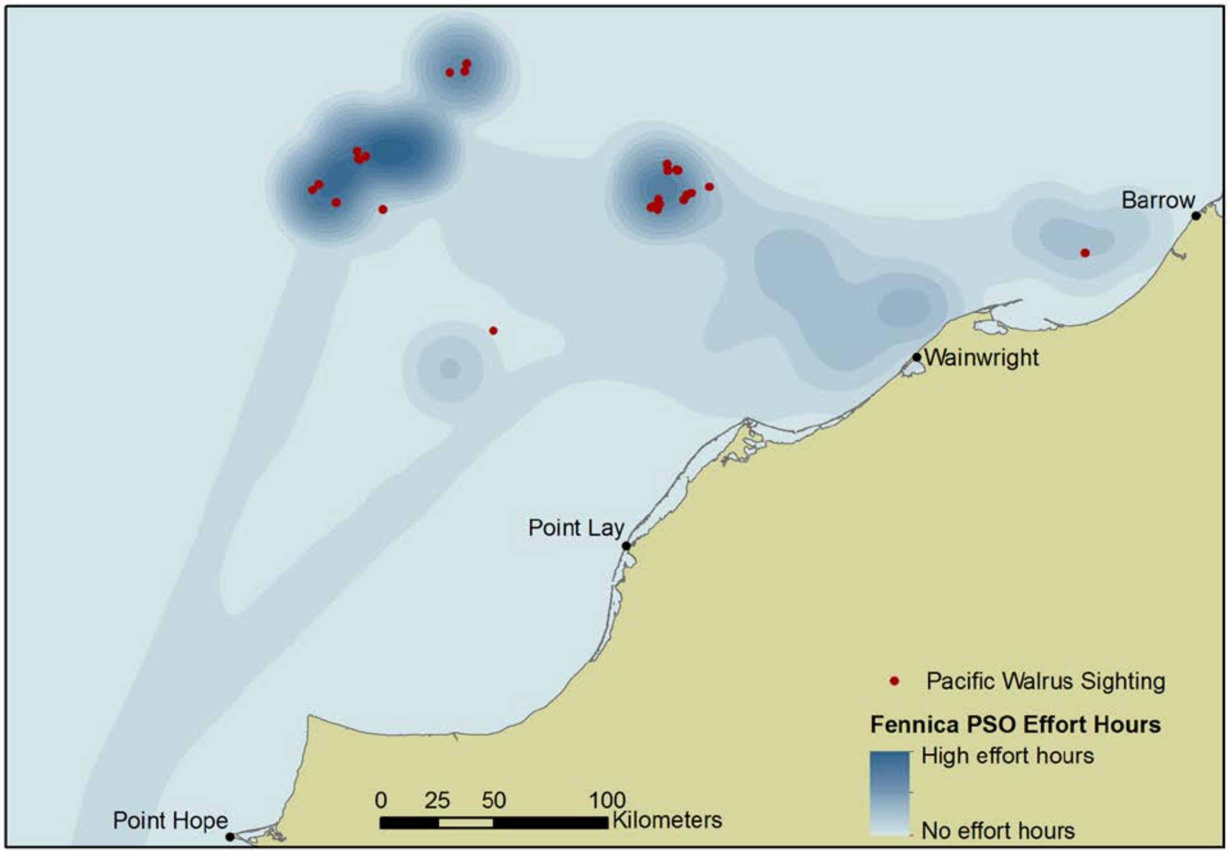

Figure 5.15. Location of Pacific walrus sightings by species and *Fennica* effort hours during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

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 I) and the sightings that occurred during those periods.

Pacific Walrus Sightings by Beaufort Wind Force – The Pacific walrus sighting rate from the *Fennica* was greatest during Bf 1 and 2; however, there was minimal effort within the other Bf wind force categories and sighting rates for those categories should be viewed with some caution (Figure 5.16). There was no clear trend in Pacific walrus sighting rates when compared across Bf wind force (Figure 5.17). Rates of Pacific walrus sightings were probably more influenced by specific time periods during which walrus were moving toward haul outs along the Alaskan Chukchi Sea coast than Bf wind force.

Pacific Walrus Sighting Rates by Number of PSOs – Pacific walrus sighting rates were highest during periods with two PSOs on watch during seismic activities (Figure 5.18). Limited effort occurred with one PSO on watch and therefore sighting rates for seismic and non-seismic activities were combined for comparisons between periods with different numbers of PSOs on watch. Walrus sighting rates with two PSOs on watch (4.5 walrus/1000 km) were nearly 1.5 times greater than with one PSO on watch (2.9 walrus/1000 km) but the difference was not statistically significant ($X^2 = 0.17$, $df = 1$, $p = 0.67$).

Pacific Walrus Sighting Rates by Seismic Status – The Pacific walrus sighting rate from the *Fennica* was slightly higher when the airguns were active than when they were not active, but the difference was not statistically significant ($X^2 = 1.39$, $df = 1$, $p = 0.23$; Figure 5.19). The difference in sighting rates may be more related to the timing of the walrus movement toward coastal haul outs than to airgun status.

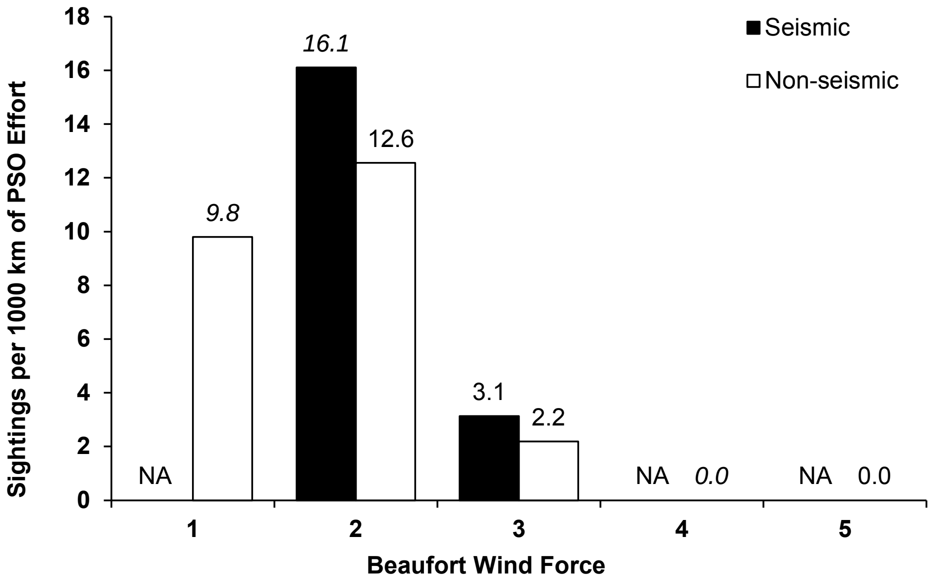

FIGURE 5.16. Pacific walrus sighting rates by Beaufort wind force from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. NA indicates insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate the sighting rate may not be reliable due to limited observation effort within the category.

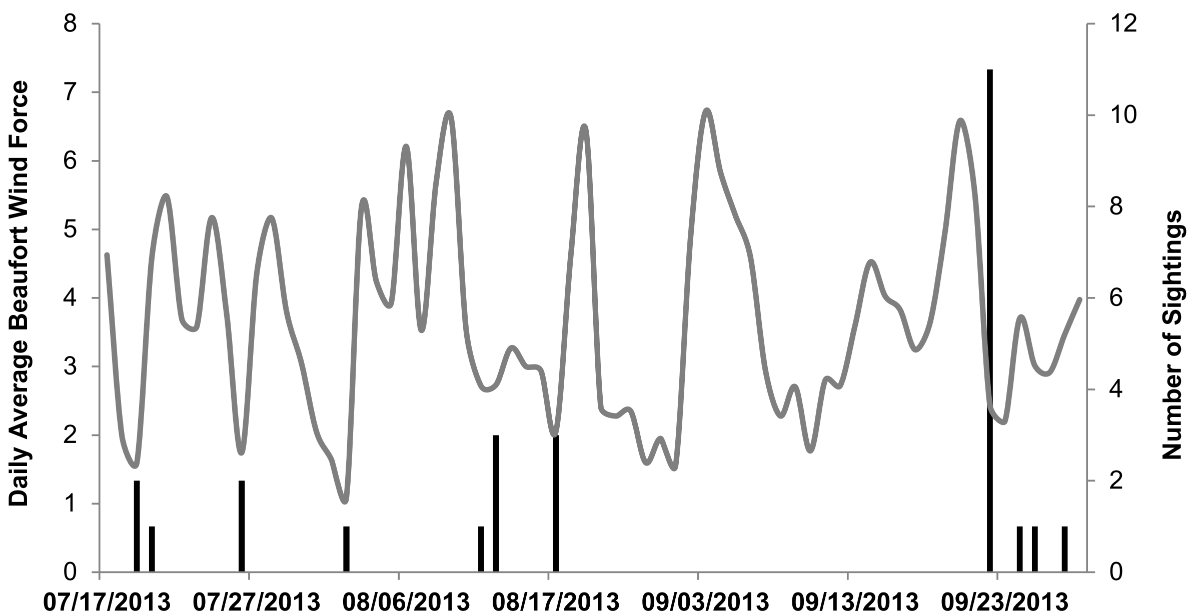

FIGURE 5.17. Number of daily Pacific walrus sightings (bars) and average Beaufort wind force (line) from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

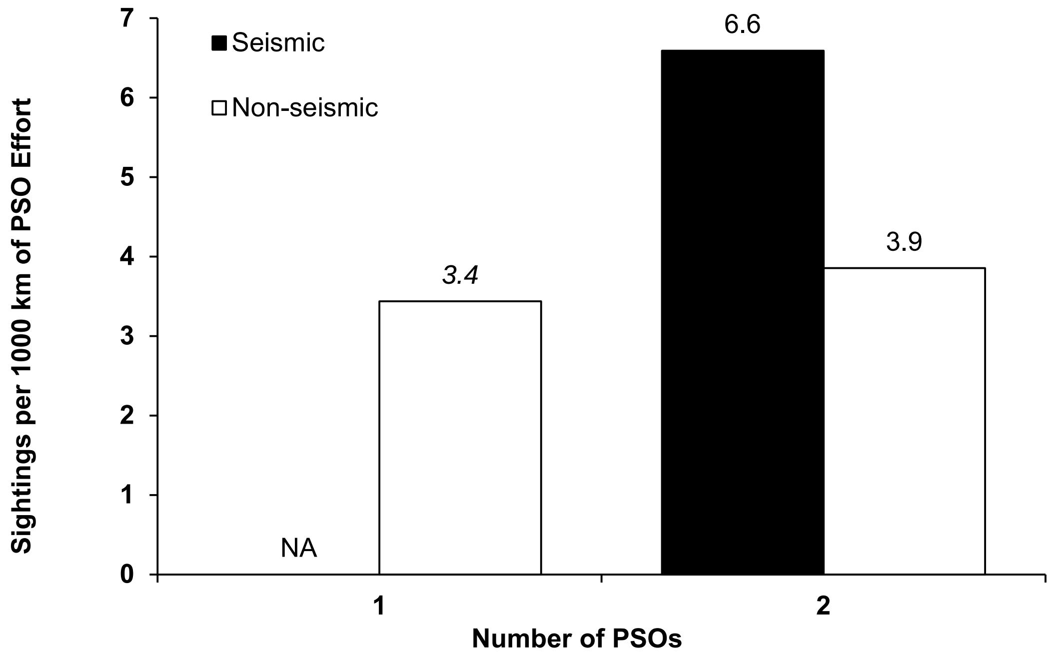

FIGURE 5.18. Pacific walrus sighting rates from moving vessels by number of PSOs on watch from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. NA indicates insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate the sighting rate may not be reliable due to limited observation effort having occurred within the category. Note that < 250 km of observer effort occurred with three PSOs on watch, which precluded meaningful inclusion.

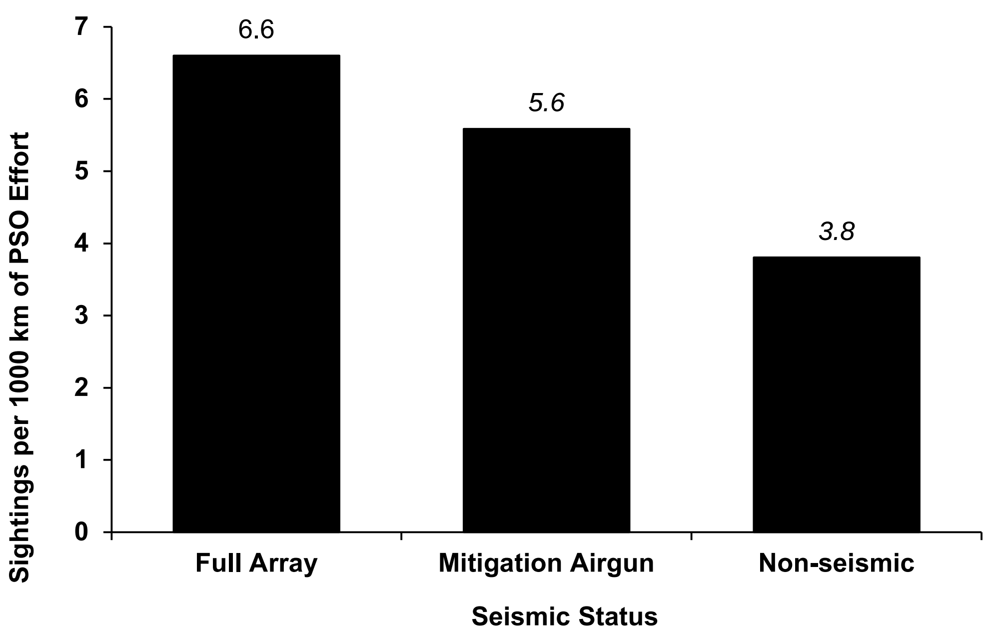

FIGURE 5.19. Pacific walrus sighting rates by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Unidentified Marine Mammal Sightings

Of the 186 unidentified marine mammal sightings, three unidentified seals were carcasses in an advanced state of decomposition. The other 183 unidentified sightings were either too brief, too distant, or were during periods of poor visibility to accurately identify to species (Table 5.4). Comments recorded by the observer at the time of each of these sightings were used to assign a likely species in this section. Sightings with little or no diagnostic information in the comments field were left as unidentified sightings.

TABLE 5.4. Number of unidentified marine mammal sightings from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Species	Sightings (Individuals)
Unidentified Marine Mammals	
Unidentified mysticete whale	21 (30)
Unidentified whale	1 (1)
Unidentified pinniped	11 (12)
Unidentified seal	153 (163)
Total	***186 (206)***

Cetaceans – Of the 22 unidentified cetacean sightings 11 could be assigned a likely species using descriptions recorded by the PSO at the time of the sighting. Details such as the shape and size of the blow as well as physical whale descriptions listed at the time of sighting led to the designation of seven bowhead whales, six gray whales, one fin whale and one humpback whale (Table 5.5). Observer comments for the one unidentified whale did not provide enough additional information to assign the sighting to a likely species.

Pinnipeds – Of the 164 unidentified pinnipeds and seal sightings, 36 could be assigned a likely species using the PSO descriptions. Details such as the size and color of the pinniped, the presence or absence of tusks, and the shape of the face led to the designation of two Pacific walruses, 18 bearded seals, 11 ringed seals, and six spotted seals (Table 5.5). The unidentified seal category consists largely of ringed and spotted seals. Based on the frequency of positively identified small seals and data from previous seasons it is estimated that a higher percent (~85%) of the unidentified seals are likely ringed seals as opposed to spotted seals. There were 128 sightings of pinnipeds that did not contain any additional information in the comments field to assign a likely species.

TABLE 5.5. Number of reclassified sightings from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Species	Sightings (Individuals)
Reclassified Marine Mammals	
Bowhead	5 (8)
Fin whale	1 (1)
Gray whale	4 (6)
Humpback whale	1 (1)
Bearded seal	18 (20)
Pacific walrus	1 (2)
Ringed seal	11 (11)
Spotted seal	6 (6)
Unidentified pinniped	1 (1)
Total	***48 (56)***

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. The PSOs' primary duty was to implement mitigation rather than collect extensive behavioral data. Relevant data collected include initial sighting distance, 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. We present seismic and non-seismic data from the Fennica; however, the low numbers of observations during periods of seismic survey activity for cetaceans, seals and Pacific walruses were insufficient to perform statistical analyses for behavior and distribution.

Cetaceans

Cetacean Initial Sighting Distance and Distribution

The initial sighting distance of cetaceans to the PSO was calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 4 and Appendix I). Sixty of the 70 sightings met the detection criteria. The mean initial sighting distance for cetaceans was greater during seismic activities than during non-seismic activities (4182 m [13,720 ft] and 2334 m [7657 ft] respectively; Figure 5.20). During seismic activities cetaceans (n=3) were initially sighted from the *Fennica* as close as 600 m (1968 ft) and as far as 10,000 m (32,808 ft) and during non-seismic activities cetaceans (n=57) were initially sighted as close as 50 m (164 ft) and as far as 5509 m (18,074 ft). The maximum allowable distance for sightings, 10,000 m, is based on the distance to the horizon from the height of and average observer on a vessel. There was one cetacean sighting which met or possibly exceeded 10,000 m; this was an estimated distance of a cetacean seen on the horizon. Since only three cetacean sightings occurred while airguns are active it is not possible to make a meaningful interpretation of the difference in initial sighting distances between periods when airguns were active and when they were not.

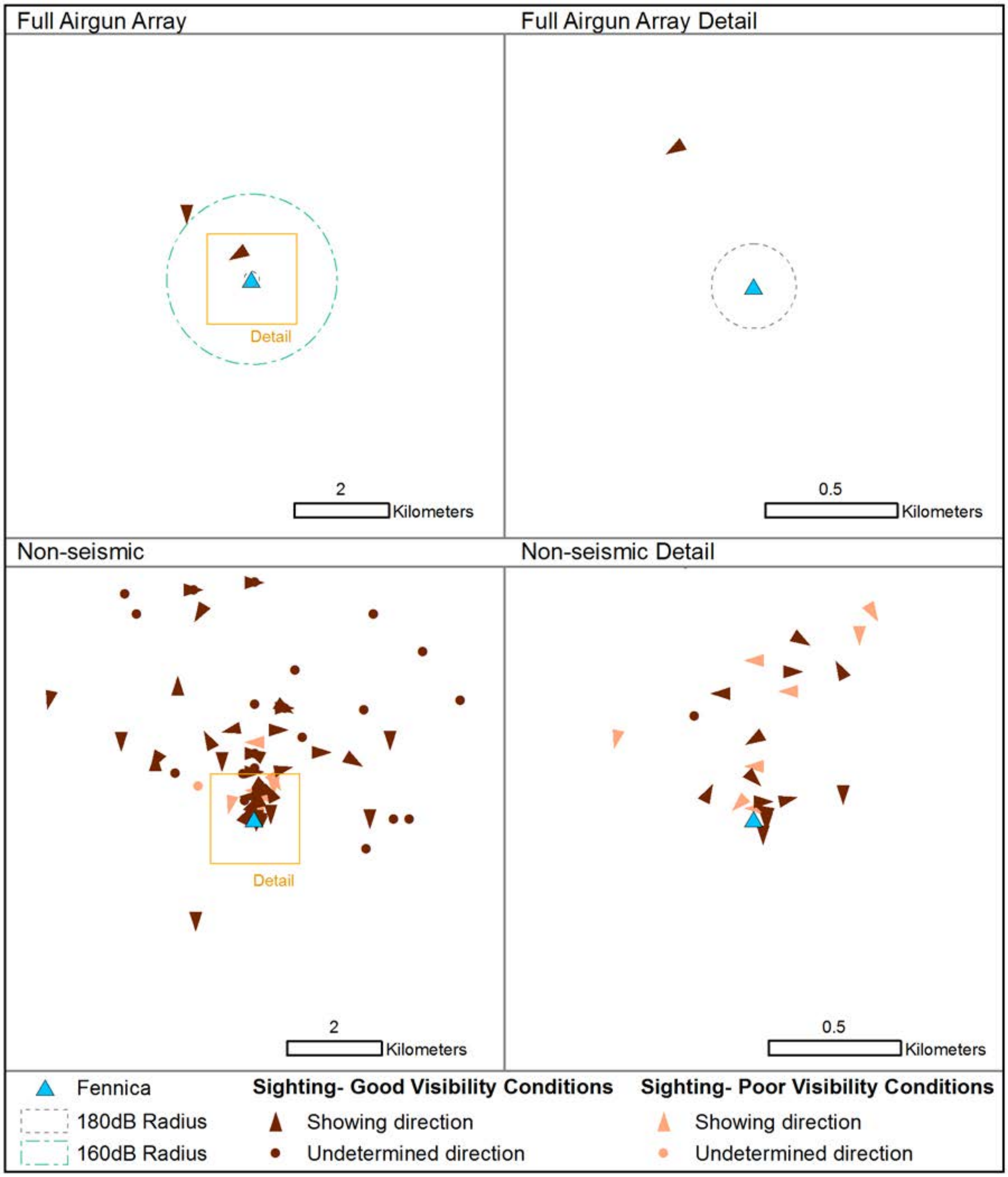

FIGURE 5.20. Initial cetacean sightings from the *Fennica* by airgun status with safety and disturbance radii, during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Arrows indicate direction of animal movement. Note that one cetacean was observed ~10 km (6.2 mi) from the *Fennica* while the full array was active during good visibility conditions. One outlying sighting is not depicted: one cetacean was observed ~10 km (6.2 mi) from the *Fennica* while the full array was active during good visibility conditions.

Cetacean Closest Point of Approach

The same detectability criteria for sightings were used to calculate the mean closest points of approach (CPAs) of cetaceans to the airguns as were used for initial sighting distances (See Chapter 4 and Appendix I). The mean CPA of cetaceans from the *Fennica* was greater during seismic activities 4019 m (13,185 ft) than during non-seismic activities 1898 m (6227 ft; Table 5.6). During seismic activities cetacean CPAs were observed as close as 319 m (1046 ft) and as far as 9907 m (32,503 ft) and during non-seismic activities cetaceans were observed as close as 56 m (184 ft) and as far as 5602 m (18,379 ft; Table 5.6). To standardize the data and allow meaningful comparisons, CPAs were calculated to the position of the airguns even when the actual airguns were not in the water or active. The closest cetacean observed to the active array was 319 m (1046 ft). This occurred while on prospect and the distance of the cetacean to the airguns was well outside the 180 dB (rms) safety radius of 160 m (525 ft). Since only three cetacean sightings occurred while airguns were active it was not possible to compare CPA distances between periods when airguns were active and when they were not.

TABLE 5.6. Comparison of mean cetacean initial sighting distances (m) by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. The overall mean includes initial sightings from seismic status bins.

Seismic Status		Mean CPA[a] (m)	s.d.	Range (m)	*n*
Seismic		4019	5155	319-9907	***3***
Non-Seismic		1898	1680	56-5602	***57***
	Overall	***2004***	***1949***	***56-9907***	***60***

[a] CPA=Closest Point of Approach. For *Fennica* this value is the marine mammal's closest point of approach to the airgun array.

Cetacean Movement

There were 70 cetacean sightings, three during seismic activity and 67 during non-seismic activities. The large distances in which most cetaceans were initially detected from the vessel made it difficult to observe directions of movement and predictably, the most common movements of cetaceans were neutral (55%) and unknown (22%; Table 5.7). Of the three cetaceans observed during seismic activities one was observed ~10,000 m from the vessel and observer comments indicate that movement was unknown given the distance of the sighting. The other two were observed moving neutral to the vessel. Neutral movement included occasions when the animal(s) was swimming neither towards nor away from the vessel (e.g., parallel to vessel).

Cetacean Initial Behavior

The number of cetacean sightings was insufficient to make meaningful comparisons of differences in observed behaviors across periods with and without seismic activity. The five most common initial behaviors are shown in the table below (Table 5.8). Most initial cetacean behaviors recorded from the *Fennica* were blow (32%) and swim (35%). This is typical because a blow is a highly visible sighting cue. Observers also observed log, mill, porpoise and travel in addition to those shown below.

Cetacean Reaction Behavior

No cetaceans sighted from the *Fennica* exhibited an overt (or discernible) reaction to the vessel regardless of seismic activity (Table. 5.9).

TABLE 5.7. Number of cetacean sightings by movement relative to vessels by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Seismic	2	--	--	--	1	***3***
Non-seismic	37	7	6	2	15	***67***
Total	***39***	***7***	***6***	***2***	***16***	***70***

TABLE 5.8. Comparison of cetacean behaviors by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Behavior						
Vessel Activity	**Blow**	**Dive**	**Feed**	**Fluke**	**Swim**	**Other**	***Totals***
Seismic	2	--	--	--	--	1	***3***
Non-Seismic	21	3	5	6	25	7	***67***
Total	***23***	***3***	***5***	***6***	***25***	***8***	***70***

TABLE 5.9. Comparison of cetacean reactions to vessel by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Reaction						
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	***Totals***
Seismic	--	--	--	--	--	3	***3***
Non-seismic	5	--	1	--	--	61	***67***
Total	***5***	***--***	***1***	***--***	***--***	***64***	***70***

Seals

Seal Initial Sighting Distance and Distribution

The initial sighting distance of seals to the PSO was calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect seals (See Chapter 4 and Appendix I). Two hundred and two of the 258 seal sightings met the detection criteria. The mean initial sighting distance of seals from the *Fennica* was similar during seismic activities (206 m; 675 ft) and non-seismic activities (320 m; 1049 ft; Figure 5.21). During seismic activities seals (n=11) were observed as close as 30 m (98 ft) and as far as 516 m (1690 ft) and during non-seismic activities (n=191) seals were observed as close as 20 m (66 ft) and as far as 3000 m (9843 ft).

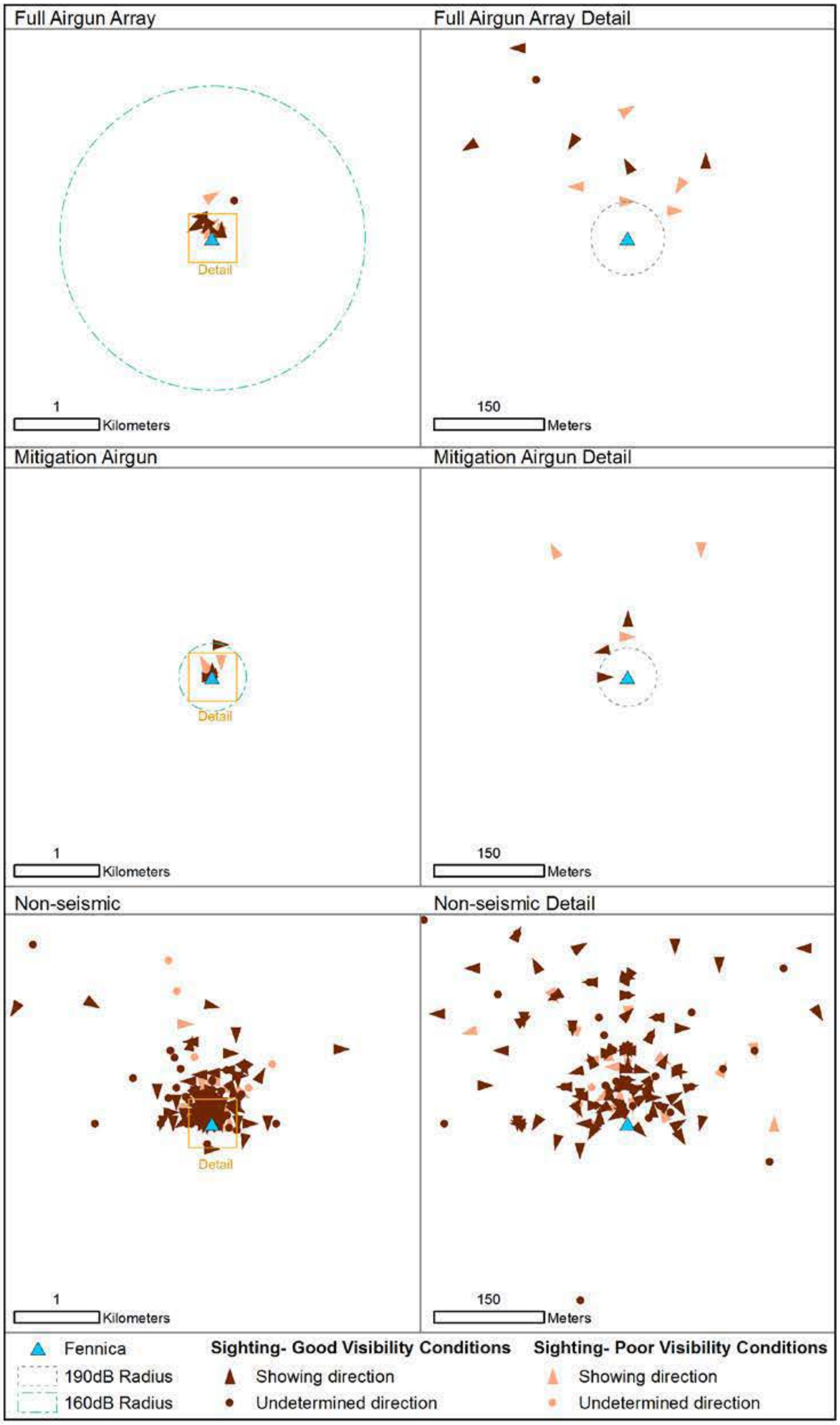

FIGURE 5.21. Initial seal sightings from the *Fennica* by airgun status with safety radii, during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Arrows indicate direction of animal movement.

Seal Closest Point of Approach

The same detectability criteria for sightings were used to calculate the mean closest points of approach (CPAs) of seals to the airguns as were used for initial sighting distances (See Chapter 4 and Appendix I). The mean CPA for seals observed from the *Fennica* was similar during seismic activities (273 m; 896 ft) and non-seismic activities (353 m; 1158 ft; Table 5.10). During seismic activities seals were observed as close as 109 m (357 ft) and as far as 611 m (2004 ft) and during non-seismic activities seals were observed as close as 80 m (262 ft) and as far as 3077 m (10,095 ft). The closest seal observed to the active airgun array (mitigation airgun firing) was 109 m (357 ft). This occurred while on prospect and the distance was well outside the 190 dB (rms) safety radius of 50 m (164 ft).

TABLE 5.10. Comparison of mean seal initial sighting distances (m) by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. The overall mean includes initial sightings from seismic status bins.

Seismic Status	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Seismic	273	154	109-611	***11***
Non-Seismic	353	388	80-3077	**191**
Overall	***349***	***379***	***80-3077***	***202***

a CPA=Closest Point of Approach. For *Fennica* this value is the marine mammal's closest point of approach to the airgun array.

Seal Movement

There were 258 seal sightings, 20 during seismic activity and 238 during non-seismic activities. Most of the seal movements recorded during seismic activities were neutral (~45%) or swim away (~30%) relative to the vessel. During non-seismic activities most seal movements were neutral (~37%) or unknown (~34%; Table 5.11). Nearly twice as many seals were seen swimming away than swimming toward the *Fennica*. Since only 20 of the seal sightings occurred while airguns were active it was not possible to make a meaningful comparison of the differences in initial sighting distances between periods when airguns were active and when they were not.

Seal Initial Behavior

The two most common initial behaviors were swim and look during seismic and non-seismic activities (~65%). Besides swim and look, PSOs aboard the *Fennica* also recorded initial behaviors of thrash (~13%), dive (~8%) and rest (4%). Observers also observed log, mill, porpoise and sink that were captured in 'other' below (Table 5.12).

Seal Reaction Behavior

The pattern in seal reactions observed from the *Fennica* was similar during seismic and non-seismic activities. The most commonly observed reaction was no reaction (~43%) followed by look (~40%). Other reactions to the vessel included splash (~14%), increase in speed (~8%), and change in direction (~4%; Table 5.13).

TABLE 5.11. Number of seal sightings by movement relative to vessels by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Seismic	9	1	6	3	1	***20***
Non-seismic	89	12	36	21	80	***238***
Total	***98***	***13***	***42***	***24***	***81***	***258***

TABLE 5.12. Comparison of seal behaviors by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Behavior						
Vessel Activity	**Dive**	**Look**	**Rest**	**Swim**	**Thrash**	**Other**	***Totals***
Seismic	2	7	1	8	2	--	***20***
Non-seismic	20	78	10	77	34	19	***238***
Total	***22***	***85***	***11***	***85***	***36***	***19***	***258***

TABLE 5.13. Comparison of seal reactions to vessel by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Reaction						
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	***Totals***
Seismic	2	1	9	--	1	7	***20***
Non-seismic	3	5	93	--	33	104	***238***
Total	***5***	***6***	***102***	***--***	***34***	***111***	***258***

Pacific Walruses

Pacific Walrus Initial Sighting Distance and Distribution

There were 24 of 26 sightings that met the detection criteria to calculate initial sighting distances for Pacific walruses (See Chapter 4 and Appendix I). The mean initial sighting distance of Pacific walruses observed from the *Fennica* was similar during seismic activities to those recorded during non-seismic activities (525 m [1722 ft] and 563 m [1847 ft] respectively; Figure 5.22). During seismic activities Pacific walruses (n=8) were observed as close as 70 m (229 ft) and as far as 1084 m (3556 ft) from the *Fennica*. During non-seismic activities Pacific walruses (n=16) were observed as close as 40 m (131 ft) and as far as 1392 m (4567 ft) from the *Fennica*.

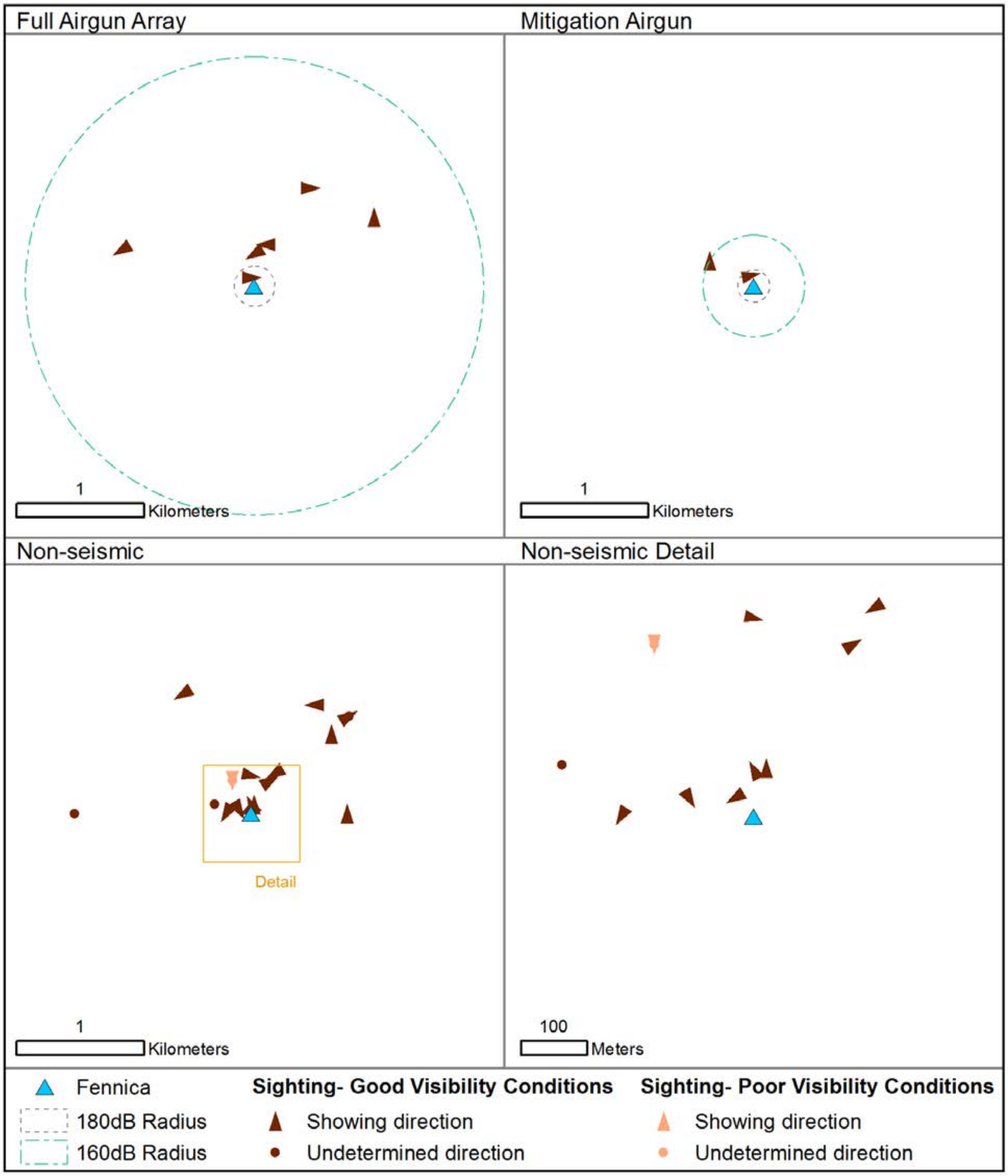

FIGURE 5.22. Initial Pacific walrus sightings from the *Fennica* by airgun status with safety radii, during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Arrows indicate direction of animal movement.

Pacific Walrus Closest Point of Approach

The mean closest points of approach of Pacific walruses were calculated using only sightings that occurred during periods of effort that met the criteria for being able to detect Pacific walruses (See Chapter 4 and Appendix I). The mean CPA of Pacific walruses observed from the *Fennica* was similar during seismic activities than during non-seismic activities (441 m [1446 ft] and 468 m [1535 ft] respectively; Table 5.14). During seismic activity Pacific walruses were observed as close as 125 m (410 ft) and as far as 1141 m (3743 ft) from the *Fennica*. During non-seismic activity Pacific walruses were observed as close as 107 m (351 ft) and as far as 1396 m (4580 ft) from the *Fennica*. The closest two Pacific walruses observed to the active array were 125 m (410 ft) and 139 m (456 ft), respectively. The walrus sighting at 125 m (410 ft) caused the shutdown of the mitigation airgun and the walrus sighting at 139 m (456 ft) caused the shutdown of the full array. For both sightings the airguns were shutdown prior to the Pacific walruses entering the 180 dB (rms) safety radius of 160 m (524 ft).

TABLE 5.14. Comparison of mean Pacific walrus initial sighting distances (m) by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. The overall mean includes initial sightings from seismic status bins.

Seismic Status	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Seismic	441	350	125-1141	***8***
Non-Seismic	468	459	107-1396	***16***
Overall	***459***	***419***	***107-1396***	***24***

a CPA=Closest Point of Approach. For *Fennica* this value is the marine mammal's closest point of approach to the airgun array.

Pacific Walrus Movement

Movements neutral relative to the vessel were the most commonly recorded for Pacific walrus from the *Fennica* during both seismic and non-seismic activity (53%). The second most frequently observed movement of walrus was swim away from the vessel (~23%; Table 5.15). Since there were only a limited number of sightings involving Pacific walrus it is not possible to make a meaningful interpretation of the difference in behavior and movement between periods when airguns were active and when they were not.

Pacific Walrus Initial Behavior

Most of the initial behaviors recorded for walrus observed from the *Fennica* during seismic activities were swim (~50%), and look (~38%). During non-seismic activities look (~22%) and dive (~22%) were the two most common initial behaviors (Table 5.16).

Pacific Walrus Reaction Behavior

Walruses observed from the *Fennica* were most often recorded has having no reaction (~50%) to the vessel or airguns. The second-most observed reaction (~19%) was look, during both seismic and non-seismic activities (Table 5.17).

TABLE 5.15. Number of Pacific walrus sightings by movement relative to vessels by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Seismic	7	--	1	--	--	***8***
Non-seismic	7	1	5	2	3	***18***
Total	***14***	***1***	***6***	***2***	***3***	***26***

TABLE 5.16. Comparison of Pacific walrus behaviors by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Behavior						
Vessel Activity	**Dive**	**Look**	**Sink**	**Swim**	**Thrash**	**Other**	***Totals***
Seismic	--	3	--	4	1	--	***8***
Non-seismic	4	4	2	2	1	5	***18***
Total	***4***	***7***	***2***	***6***	***2***	***5***	***26***

TABLE 5.17. Comparison of Pacific walrus reactions to vessel by seismic status from the *Fennica* during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

	Reaction						
Vessel Activity	**Change Direction**	**Increase Speed**	**Look**	**Rush**	**Splash**	**None**	***Totals***
Seismic	1	2	1	--	--	4	***8***
Non-seismic	3	--	4	--	4	7	***18***
Total	***4***	***--***	***5***	***--***	***4***	***11***	***26***

Mitigation Measures Implemented

The implementation of mitigation measures during Shell's 2013 shallow hazards and ice gouge surveys in the Chukchi Sea spanned all aspects of the operation and was driven by several themes. These Mitigation measures were centered on reducing potential impacts to marine mammals and subsistence activities from seismic and non-seismic related vessel activities. Mitigation measures included:

- minimizing potential impacts on marine mammals by notifying operators of any marine mammals present during offshore crew changes for routing of helicopters,
- minimizing potential impacts to local subsistence activities by the timing and location of Shell's operations in the Chukchi Sea and communicating with the communication centers every six hours in accordance with the CAA,

- monitoring and implementing mitigation for the 180 and 190 dB (rms) exclusion zone for marine mammals around the *Fennica* as stipulated in Shell's Chukchi Sea IHA and LOA for periods with active airgun operations, and
- monitoring and implementing mitigation for the 160 dB (rms) zone of influence per the IHA, or 160 dB (rms) disturbance zone per the LOA, for aggregations of 12 or more cetaceans or Pacific walruses during active airgun operations.

Safety and Disturbance Radii

Prior to completion of the sound source verification measurements, PSOs on the *Fennica* used the modeled safety radii presented in Shell's 2013 IHA application and outlined in the IHA issued by NMFS for mitigation purposes (see Table 4.1). Shell's site specific sound source verification (SSV) was completed on 19 Jul 2013 and the results were reported on 25 Jul 2013 by JASCO (Wladichuk et. al. 2013). Due to partial equipment failure, measurements of high frequency sound sources were conducted a second time on 27 Jul. Both sets of acoustic measurements were conducted near the Snickers lease area in the Chukchi Sea (see Chapter 3 for a complete description of the sound source measurements and analysis). JASCO calculated preliminary disturbance and safety radii within 5 days of completion of the measurements. The more conservative radii of the pre-season and calculated radii were chosen as the basis for implementation of mitigation by PSOs during seismic survey activities on 19 Jul thereafter.

Two shut downs of the airgun array were requested by the *Fennica* PSOs due to Pacific walruses that were sighted approaching the ≥180 dB (rms) safety radius of the active airgun array, during the Chukchi Sea survey. There were no shut downs or power downs of the airguns for cetaceans, seals, or polar bears during the 2013 survey. Additional mitigation implemented by PSOs aboard the *Fennica* were reductions in vessel speed, alterations of vessel headings and repositioning of the *Fennica* due to the close proximity of large groups of whales present during crew change helicopter operations (Table 5.18). All efforts were made to minimize sounds received by marine mammals, maximize distance from marine mammals and avoid separating individuals from groups of marine mammals.

TABLE 5.18. Mitigation measures implemented by vessel-based PSOs during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Species	Shut Down of Airgun(s)	Speed Reduction	Course Alteration	Other Mitigation	*Total*
Gray whale	–	2	1	1	***4***
Pacific walrus	2	–	2	–	***4***
Total	***2***	***2***	***3***	***1***	***8***

The first shut down of the airguns was implemented on 24 Sep when a Pacific walrus was observed approaching the ≥180 dB (rms) safety radius of 160 m (525 ft) for the full array at the Burger prospect area. The walrus was initially detected off the bow by the PSO ~170m (558 ft) from the active airgun array, outside the ≥180 dB (rms) safety radius. The full airgun array was immediately shut down as a precautionary measure to prevent the walrus from entering the ≥180 dB (rms) safety radius while the airguns were active. The PSOs did not observe the walrus entering the ≥180 dB (rms) safety radius while the airguns were active. The final CPA of the walrus to the full airgun array was 139 m (456 ft). The walrus reacted to the vessel by increasing speed and diving with a splash not associated with routine walrus dives (Table 5.19).

The second shut down of the airguns was implemented on 25 Sep when a Pacific walrus was observed approaching the ≥180 dB (rms) safety radius of 127 m (417 ft) for the mitigation airgun at the Burger prospect area. The walrus was initially detected by the PSO crossing the bow ~185m (558 ft) from the active mitigation airgun, outside the ≥180 dB (rms) safety radius. Only the mitigation airgun was active at the time of the sighting and the mitigation airgun was shut down as a precautionary measure prior to the walrus entering the safety radius. The PSOs did not observe the walrus entering the ≥180 dB (rms) safety radius while the airguns were active. The final CPA of the walrus to the airgun array, was 125 m (410 ft). The walrus reacted by increasing in speed, looking, and diving (Table 5.19).

TABLE 5.19. The two shut downs for Pacific walruses observed near the Fennica's ≥180 dB (rms) safety radius (160m; 525 ft) at the Burger prospect during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. There were no other shut downs during this survey.

Sighting ID	Species	Group Size	Date	Reaction to Vessel[a]	Pace of Travel[b]	Behavior[c]	Distance (m) to airguns at first detection	CPA (m) to airguns[d]
436	Pacific walrus	1	24-Sep	IS	VI	TH	~170	139
439	Pacific walrus	1	25-Sep	IS	MO	DI	~185	125

[a] Reaction Codes: IS = Increase in Speed
[b] Pace Codes: VI = Vigerous; MO = Moderate
[c] Behavior Codes: TH=Thrash; DI= Dive
[d] CPA to Airguns = Closest Point of Approach to the airgun array

On 2 Aug, crew change operations occurred off of the coast of Wainwright. Prior to helicopter operations for crew change, several groups of gray whales were observed near the *Fennica* ranging from ~100 m to 1400 m (328 ft to 4593 ft) from the vessel. Mitigation was implemented by the PSOs and crew to minimize potential impacts and maintain the appropriate distance from the marine mammals during aircraft operations per the IHA. This mitigation involved several relocations of the *Fennica* away from the groups of gray whales prior to crew change helicopter operations. After the completion of helicopter operations there was two additional mitigations implemented involving a reduction in speed for three individual gray whales as the *Fennica* transited away from the crew change location. Additional mitigation implemented by PSOs involved three course alterations to avoid Pacific walruses on 1 Sep (n=1) and 22 Sep (n=2), respectively.

As noted above, PSOs aboard the *Fennica* 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. No conflicts were reported between the *Fennica* and subsistence users in the Chukchi Sea during Shell's shallow hazards and ice gouge surveys.

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 (RL) reaches a specific criterion such as 190, 180, 160, or 120 dB re 1 µPa (rms) is variable. The RL 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.

Two methods were used to estimate the number of marine mammals exposed to seismic sound levels strong enough that they might have caused a disturbance or other potential impacts. The procedures included ***(A)*** minimum estimates based on the direct observations of marine mammals by PSOs, and ***(B)*** estimates based on pinniped (seal and Pacific walrus) and cetacean densities obtained during this study. The actual number of individuals exposed to, and potentially impacted by, seismic survey sounds or coring sounds likely was between the minimum and maximum estimates provided in the following sections. Further details about the methods and limitations of these estimates are provided below.

Disturbance and Safety Criteria

Table 4.1 summarizes estimated RLs at various distances from *Fennica's* 4-airgun cluster. The NMFS required that distances to RLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for cetaceans and seals respectively. The USFWS required that distances to RLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for Pacific walruses and polar bears, respectively. The RLs ≥160 dB (rms) was used to implement mitigation measures for cetaceans or Pacific walruses with aggregations of 12 or more. Both agencies assume that disturbance to marine mammals from pulsed airgun sounds may occur at RLs ≥160 dB (rms).

Estimates from Direct Observations

All sightings data from the *Fennica* 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 seismic activity provides a minimum estimate of the number potentially affected by seismic sounds. Some animals probably 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 vessel trackline. 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. Further, marine mammals could not be seen effectively during periods of darkness, which increased as the survey progressed. Nighttime observations were not required, however PSOs aboard the *Fennica* stayed on watch throughout the night to monitor survey operations.

Animals may also have avoided the area near the *Fennica* while the airguns were active (see Richardson et al. 1995, 1999; Stone and Tasker 2006; Gordon et al. 2004; Reiser et al. 2011). Within the assumed ≥160–170 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 seismic survey. Changes in distribution and behavior could result from reactions to the airguns, or to the *Fennica* itself. The extent to which the distribution and behavior of pinnipeds might be affected by the airguns is uncertain, given variable previous results (Harris et al. 2001; Moulton and Lawson 2002; Miller et al. 2005). It was not possible to determine if cetaceans exhibited avoidance behavior beyond the distance at which they were detectable by PSOs.

Cetaceans Potentially Exposed to Received Sound Level ≥160 and ≥180 dB re 1 µPa (rms)

There were three unidentified cetacean sightings of five individuals observed from the *Fennica* during seismic activities while the full array was active. Four of these cetaceans occurred outside the *Fennica's* ≥160 dB (rms) disturbance zone. None of these sightings occurred within the ≥180 dB (rms) safety radius (Table 4.1). One unidentified mysticete whale (possible gray whale) was likely exposed to RLs ≥160 dB (rms) and the closest point of approach of the individual to the airgun was 300 m (984 ft; Table 5.20).

Seals Potentially Exposed to Received Sound Level ≥160 dB and ≥190 dB re 1 µPa (rms)

A total of 20 sightings of 21 individual seals were observed from the *Fennica* while airguns were operating. Seven seals were sighted while the mitigation airgun was active and 14 were sighted while the full airgun array was active. All of these individuals were likely exposed to RLs ≥160 dB (rms) and the range of the closest point of approach of the individuals to the airguns was 135 m to 611 m (443 ft to 2005 ft). Two ringed seals were exposed to RLs ≥180 dB (rms) and the closest point of approach of the individuals to the airguns was 109 m and 123 m (358 ft and 404 ft), respectively (Table 5.20). However, no seal sightings occurred within the ≥190 dB safety radius, so no mitigation measures were requested.

Pacific Walruses Potentially Exposed to Received Sound Level ≥160 dB and ≥180 dB re 1 µPa (rms)

Eight Pacific walrus sightings of eight individuals were observed from the Fennica while airguns were active and of these, seven walruses were likely exposed to RLs ≥160 dB (rms; Table 5.20). The airgun array was shut down for a Pacific walrus approaching the ≥180 dB (rms) safety zone on two separate occasions. PSOs initiated the shutdown of the airgun array for both sightings, and one shutdown involved the full array and the other involved the mitigation airgun. Both shutdowns occurred prior to the Pacific walruses entering ≥180 dB (rms) safety zone. Given the conservative approach taken with the safety radii used for mitigation purposes it unlikely that either of the walruses were exposed to RLs ≥180 dB (rms).

TABLE 5.20. Number of marine mammals observed in areas with estimated RLs of ≥160, ≥180, and ≥190 dB (rms) and potentially exposed to the respective sound levels during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013.

Species or Species Group	Number of Individuals and Exposure Level in dB re 1µPa (rms)		
	≥ 190	**≥ 180**	**≥ 160**
Cetaceans	0	0	1
Seals	0	2	21
Pacific walruses	0	1	7

Estimates Extrapolated from Density

The number of marine mammals visually detected by *Fennica* PSOs likely underestimated the actual numbers that were present for reasons described above. To correct for animals that may have been present but not detected by observers, the sightings recorded during seismic and non-seismic periods along with detectability corrections $f(0)$ and $g(0)$ were used to calculate separate densities of marine mammals present during those two periods. The estimated densities of marine mammals were then multiplied by the area of water ensonified (exposed to seismic sounds) to estimate the number of individual marine mammals exposed to received sound levels (RLs) ≥160 dB (rms). Because the shallow hazard survey transect lines were spaced closer together than twice the measured ≥160 dB (rms) distance (2 × 1.3 km = 2.6 km or 1.6 mi), the same area of water at the survey site would have been exposed to seismic sounds multiple times as the vessel surveyed the nearby transect lines. The ratio of the total area exposed to seismic sounds ≥160 dB (rms) including multiple counts of areas exposed more than once to the area of water exposed excluding multiple counts was 6.5 in Jul–Aug and 6.0 in Sep. These values represent the average number of exposures per individual marine mammal present in the survey area to RLs ≥160 dB (rms) if the individual had remained present through that period of time. The area of water exposed to various sound levels are shown in Table 5.21. The methodology used to estimate the areas exposed to RLs ≥120, 160, 170, 180 and 190 dB (rms) was described in Chapter 4 and in more detail in Appendix F. See Chapter 7 for a summary of exposure estimates from the *Nordica's* dynamic positioning system as well as the *Fennica's* seismic activities presented below.

Marine mammal densities were calculated using data that met the analysis criteria in order to allow for meaningful comparisons (See Chapter 4 and Appendix F). Densities were based on data collected from both the *Fennica* and *Nordica* during Shell's shallow hazards and ice gouge surveys, and the equipment maintenance operations in the Chukchi Sea during 2013. The density estimates for the Shell survey area were calculated separately by seasonal periods of 'summer' (Jul–Aug) and 'fall' (Sep) for consistency and comparison with the NMFS IHA application exposure estimates (Shell 2013). Density estimates from Shell's 2013 survey activities for each seasonal period are summarized in Tables 5.22 and 5.23. The following exposure estimates based on density calculations assume that all mammals present were well below the surface where they were exposed to RLs at various distances as reported in Chapter 3 and summarized in Table 4.1. Some pinnipeds and cetaceans in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Also, some pinnipeds and cetaceans may have moved away from the path of the *Fennica* as it was surveying in an avoidance response to the approaching vessel and airgun sounds.

TABLE 5.21. Estimated areas (km^2) ensonified to various sound levels from airguns during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Note, ice gouge surveys did not involve the use of airguns.

Seasonal Period	Area (km^2)	Level of ensonification in dB re 1 µPa (rms)				
		190	180	170	160	120
Jul - Aug	Including Overlap Area*	52	358	991	3648	267,481
	Excluding Overlap Area*	48	243	358	560	10,040
Sep	Including Overlap Area*	38	255	737	2744	201,693
	Excluding Overlap Area*	34	181	284	455	9153

*The ratio of the total area exposed to seismic sounds ≥160 dB (rms) including multiple counts of areas exposed more than once ('including overlap') to the area of w ater exposed excluding multiple counts ('excluding overlap') w as 6.5 in Jul–Aug and 6.0 in Sep.

TABLE 5.22. Jul–Aug densities of marine mammals in the Alaskan Chukchi Sea observed during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix F). LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively.

	No. individuals / km^2					
	Seismic			Non-seismic		
Species	Density	LCL	UCL	Density	LCL	UCL
Cetaceans						
Bowhead Whale	0.000	--	--	0.002	0.001	0.006
Gray Whale	0.000	--	--	0.006	0.002	0.025
Minke Whale	0.000	--	--	0.002	0.001	0.004
Unid. Mysticete Whale	0.001	0.000	0.003	0.002	0.001	0.006
Harbor Porpoise	0.000	--	--	0.001	0.000	0.005
Unid. Whale	0.000	--	--	0.000	0.000	0.001
Total Cetaceans	***0.001***	***0.000***	***0.003***	***0.014***	***0.007***	***0.029***
Seals						
Bearded Seal	0.000	--	--	0.019	0.009	0.043
Ringed Seal	0.014	0.007	0.032	0.025	0.012	0.054
Spotted Seal	0.000	--	--	0.005	0.002	0.013
Unid. Seal	0.024	0.010	0.055	0.117	0.059	0.235
Unid. Pinniped	0.000	--	--	0.003	0.001	0.010
Total Seals	***0.038***	***0.021***	***0.071***	***0.169***	***0.102***	***0.283***
Pacific Walrus	0.014	0.005	0.038	0.003	0.001	0.010
Polar Bear*	0.000	--	--	0.007	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

TABLE 5.23. Sep densities of marine mammals in the Alaskan Chukchi Sea observed during Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix F). LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively.

	No. individuals / km^2					
	Seismic			Non-seismic		
Species	**Density**	**LCL**	**UCL**	**Density**	**LCL**	**UCL**
Cetaceans						
Gray Whale	0.000	--	--	0.001	0.000	0.006
Minke Whale	0.000	--	--	0.001	0.000	0.004
Unid. Mysticete Whale	0.000	--	--	0.002	0.000	0.012
Total Cetaceans	***0.000***	***--***	***--***	***0.005***	***0.002***	***0.013***
Seals						
Bearded Seal	0.000	--	--	0.019	0.007	0.049
Ringed Seal	0.000	--	--	0.007	0.003	0.018
Unid. Seal	0.009	0.002	0.043	0.039	0.017	0.091
Unid. Pinniped	0.006	0.001	0.034	0.007	0.002	0.023
Total Seals	***0.015***	***0.004***	***0.053***	***0.072***	***0.041***	***0.126***
Pacific Walrus	0.010	0.003	0.029	0.037	0.007	0.179

Cetaceans

The tables following this section present a summary of the estimated numbers of cetaceans that may have been exposed to seismic sounds at received levels ≥160 dB (rms) based on the density estimates, and the ensonified areas (Tables 5.24, 5.25 and 5.26). Higher sighting rates, and resulting density estimates, during non-seismic periods compared to seismic periods from the *Fennica* (Figure 5.9) suggest that some cetaceans may have moved away from the seismic source before being exposed to higher RLs. However, most cetacean sightings from the *Fennica* occurred during transit to and from Wainwright in nearshore areas during crew changes and the ice gouge survey (Figure 5.5), so the difference in sighting rates and densities between seismic and non-seismic periods may actually be a result of the overall distribution of cetaceans in the Chukchi Sea and not seismic sounds (LGL 2012). In order to provide a maximum exposure estimate for cetaceans, the totals below were based on non-seismic densities.

Approximately 10 individual cetaceans would each have been exposed to airgun pulses with RLs ≥160 dB (rms) during the survey if they showed no avoidance of active airguns or vessels (Table 5.26). Based on the individual species values the species breakdown may have included approximately, two bowhead whales, five gray whales, two minke whales and one harbor porpoise. Since not all cetaceans were identified to species, density based estimates also included approximately four unidentified cetaceans. There was a single humpback whale observed from each vessel during 2013, however, both were recorded during periods that did not meet analysis criteria and were not captured in these density-based exposure estimates. It is possible that a few humpback whales were exposed to seismic sounds ≥160 dB (rms).

Seals

Tables 5.24, 5.25, and 5.26 summarize the estimated numbers of seals potentially exposed to RLs ≥160 dB (rms) during the shallow hazards survey. Avoidance of seismic surveys may not always occur or be detected; however, localized avoidance of seismic operations by seals has been observed in some cases (Reiser 2009). The higher sightings rates, and corresponding density estimates of seals during non-seismic periods than during seismic periods suggests that seals potentially avoided airgun sounds. Seal sightings were distributed throughout the survey areas (Figure 5.10).

Density based calculations suggest up to ~128 individual seals may have been exposed to airgun pulses with RLs ≥160 dB (rms) during the survey, assuming no avoidance of the ≥160 dB (rms) radius (Table 5.26). The individual species estimates may have included ~20 bearded seals, ~18 ringed seals and ~three spotted seals. Since the majority of seals could not be identified to species, the density based estimates also include ~84 unidentified seals.

Pacific Walruses

Tables 5.24, 5.25, and 5.26 summarize the estimated number of Pacific walruses potentially exposed to RLs ≥160 dB (rms) during the shallow hazards survey. Pacific walrus densities were higher during seismic compared to non-seismic periods in Jul−Aug, however the opposite was observed in Sep (Table 5.22; Table 5.23). In order to provide a maximum exposure estimate for walruses, the following totals are based on seismic densities for Jul-Aug and non-seismic densities in Sep.

The density based calculations result in an estimate of ~25 individual walruses having been potentially exposed to airgun pulses with RLs ≥160 dB (rms) during the survey, eight in Jul–Aug and 17 in Sep, assuming no avoidance of the ≥160 dB (rms) radius (Table 5.24 and 5.25).

Polar Bears

Two of three polar bears observed during 2013 operations, both of which were from the *Nordica* during Jul–Aug, were on ice. It is unlikely these bears would have been exposed to RLs comparable to marine mammals present in the water at the same location. Nonetheless, density estimates assume that a small number of polar bears could have been in the area and potentially exposed to RLs ≥160 dB (rms) during the shallow hazards surveys (Table 5.26).

TABLE 5.24. Estimated numbers of individual marine mammals exposed to pulsed seismic sounds at received levels of ≥160 dB (rms) based on densities observed during seismic and non-seismic periods in Jul–Aug of Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0	--	--	2	1	4
Gray Whale	0	--	--	4	1	15
Minke Whale	0	--	--	1	1	3
Unid. Mysticete Whale	1	1	2	2	1	4
Harbor Porpoise	0	--	--	1	1	3
Unid. Whale	0	--	--	1	1	1
Total Cetaceans	***1***	***1***	***2***	***8***	***4***	***17***
Seals						
Bearded Seal	0	--	--	11	5	24
Ringed Seal	9	4	18	14	7	31
Spotted Seal	0	--	--	3	1	8
Unid. Seal	14	6	31	66	33	132
Unid. Pinniped	0	--	--	2	1	6
Total Seals	***22***	***12***	***40***	***95***	***57***	***159***
Pacific Walrus	8	3	22	2	1	6
Polar Bear*	0	--	--	4	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

TABLE 5.25. Estimated numbers of individual marine mammals exposed to pulsed seismic sounds at received levels of ≥160 dB (rms) based on densities observed during seismic and non-seismic periods in Sep of Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and species were calculated on the sum of the densities within that group, not the sum of the rounded up estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Gray Whale	0	--	--	1	1	3
Minke Whale	0	--	--	1	1	2
Unid. Mysticete Whale	0	--	--	2	1	6
Total Cetaceans	***0***	***--***	***--***	***3***	***1***	***7***
Seals						
Bearded Seal	0	--	--	9	4	23
Ringed Seal	0	--	--	4	2	9
Unid. Seal	4	1	20	18	8	42
Unid. Pinniped	3	1	16	4	1	11
Total Seals	***7***	***2***	***24***	***33***	***19***	***58***
Pacific walrus	5	2	14	17	4	82

TABLE 5.26. Estimated numbers of individual marine mammals exposed to pulsed seismic sounds at received levels of ≥160 dB (rms) based on densities observed during seismic and non-seismic periods during all of Shell's shallow hazards and ice gouge surveys, 17 Jul to 28 Sep 2013. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0	–	–	2	1	4
Gray Whale	0	–	–	5	2	17
Minke Whale	0	–	–	2	1	4
Unid. Mysticete Whale	1	1	2	3	1	9
Harbor Porpoise	0	–	–	1	1	3
Unid. Whale	0	–	–	1	1	1
Total Cetaceans	***1***	***1***	***2***	***10***	***5***	***23***
Seals						
Bearded Seal	0	–	–	20	9	47
Ringed Seal	9	4	18	18	8	39
Spotted Seal	0	–	–	3	1	8
Unid. Seal	18	7	51	84	41	174
Unid. Pinniped	3	–	–	5	2	16
Total Seals	***29***	***14***	***64***	***128***	***76***	***216***
Pacific Walrus	13	5	35	19	4	88
Polar Bear*	0	–	–	4	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

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6. MARINE MAMMAL MONITORING RESULTS DURING WELL SITE EQUIPMENT RETRIEVAL OPERATIONS[1]

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes visual observer effort from the *Nordica* during Shell's 2013 equipment retrieval operations in the Chukchi Sea (north of Point Hope, Alaska; see Chapter 4 for details), and does not include effort conducted during transit from Dutch Harbor to and from the survey area. The survey period began when the *Nordica* entered the Chukchi Sea survey area on Jul 31 (AKDT) and ended when the *Nordica* departed the area on Sep 12.

The *Nordica* traveled along a total of ~2958 km (1838 mi) of trackline in the Chukchi Sea while moving around the well site and moving off the site for bad weather, ice presence, and crew changes. The Nordica was within the survey area for ~392 h. The *Nordica* was stationary in dynamic positioning mode for ~362 h (~15 d) on prospect for related activities and ~57 h off prospect for general vessel operations.

Due to the nature of equipment retrieval activities at the well site, the *Nordica* was stationary for the majority of operations. PSOs aboard stationary vessels typically record fewer sightings than PSOs aboard moving vessels (Bisson et al. 2013). Additionally, densities of marine mammals in the Arctic in the open water season tend to decrease with increased distance from shore (LGL 2013). As a result of these factors, few sightings were recorded by PSOs aboard the *Nordica* in 2013 and limited conclusions may be drawn about marine mammals with respect to equipment retrieval and associated vessel activities.

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 (>24 km; 15 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 the *Nordica*, effort was quantified both as the distance the vessel traveled and the duration in which PSOs actively looked for marine mammals and recorded environmental and vessel activity 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 *Nordica* were on watch for a total of ~2169 km (~1348 mi) while the vessels was moving and ~525 h while it was stationary. At least one PSO was on watch for ~89% (323 h) of dynamic positioning activity at the well site. PSOs spent similar amounts of time (Figure 6.1) on prospect and off prospect, but had much greater km of effort off prospect than on prospect (Figure 6.2), since on prospect activities were mostly stationary. The great disparity in moving data precludes meaningful comparison between on prospect and off prospect activities. For this reason, any comparison between off prospect and on prospect effort was calculated using only stationary data.

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[1] By Lauren Bisson, Heather Reider, Kenneth Mathews, and Craig Reiser (LGL Alaska Research Associates, Inc.)

At least one observer was on watch during 95% of daylight hours and during transitional hours between darkness and morning daylight, regardless of vessel activity (Figures 6.1 and 6.2).

Observer Effort by Beaufort Wind Force

Observer effort from the *Nordica* while stationary occurred during Beaufort wind force (Bf) 3 and Bf 4 (Figure 6.3), which combined accounted for ~63% of PSO effort aboard the *Nordica*. In general, observer effort off and on prospect during stationary periods were greatest in Bf 3 and 4. The greatest amount of observer effort while moving occurred during Bf 6 (~28%; Figure 6.4).

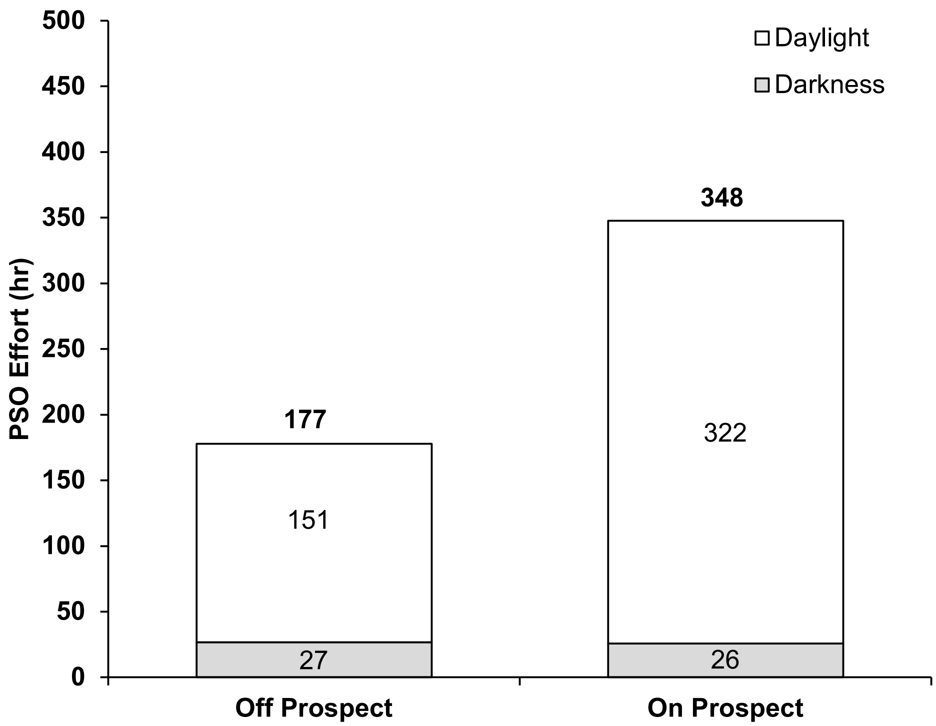

FIGURE 6.1. Total PSO observation effort (h) for stationary periods and PSO effort during daylight and darkness periods from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Observer Effort by Number of PSOs

On the *Nordica*, two PSOs were on watch during 99% of observation effort while stationary and 98% of observation effort while moving (Fig. 6.5). PSO schedules were designed to maximize time with two PSOs on watch both off and on the prospect.

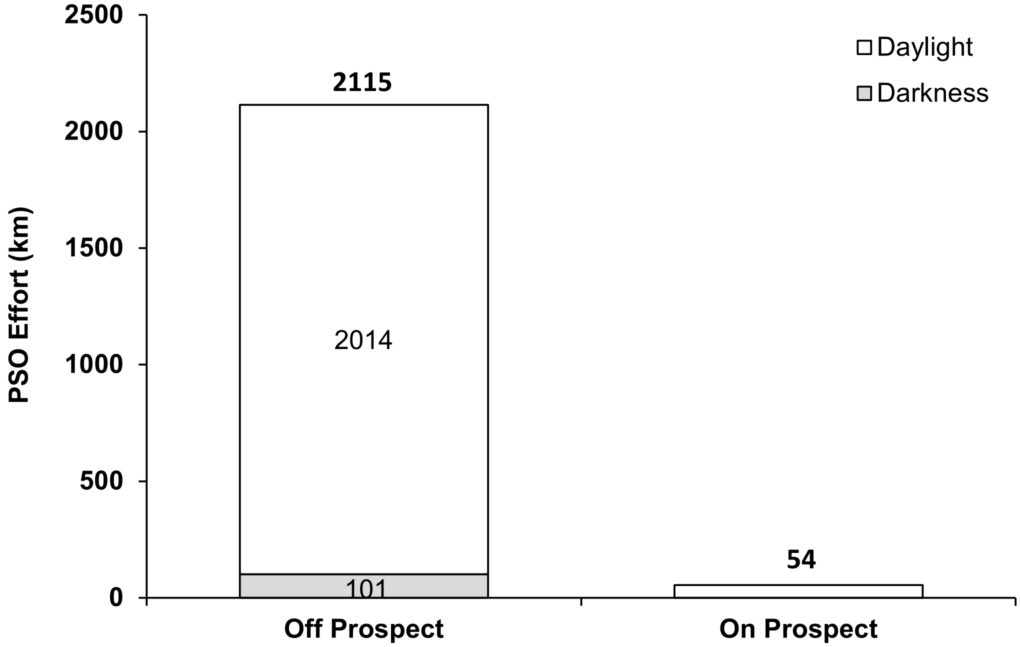

FIGURE 6.2. Total PSO observation effort (km) for moving periods and PSO effort during daylight and darkness periods from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

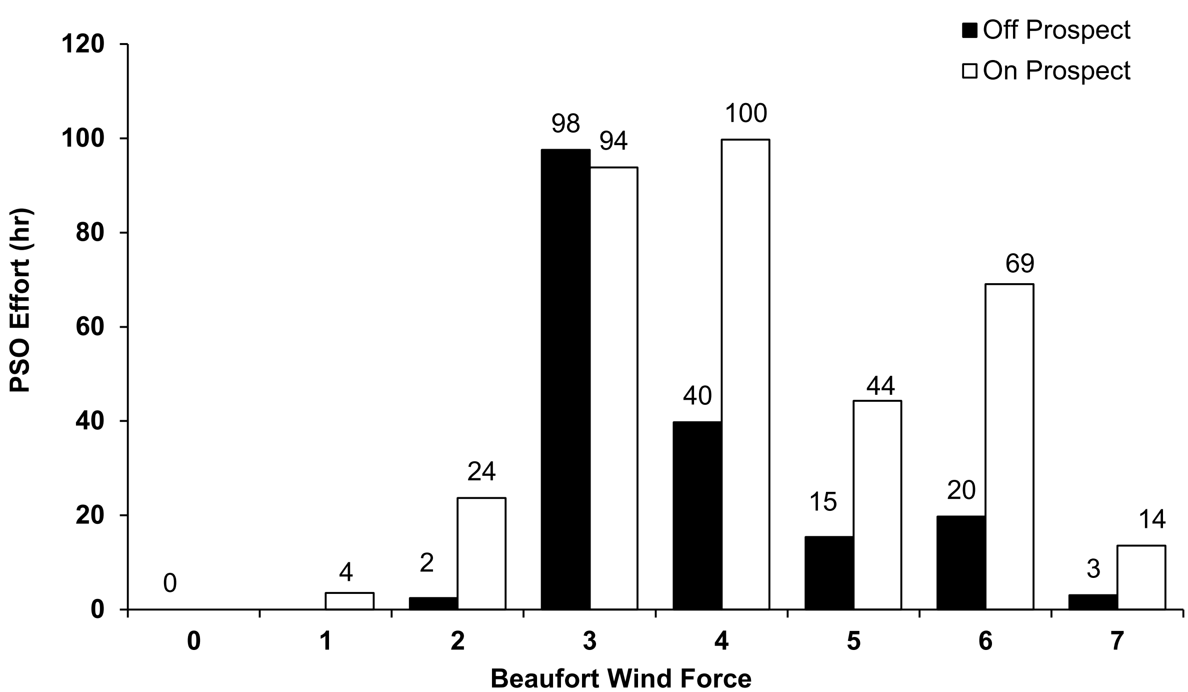

FIGURE 6.3. PSO observation effort (h) for stationary periods by Beaufort wind force from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

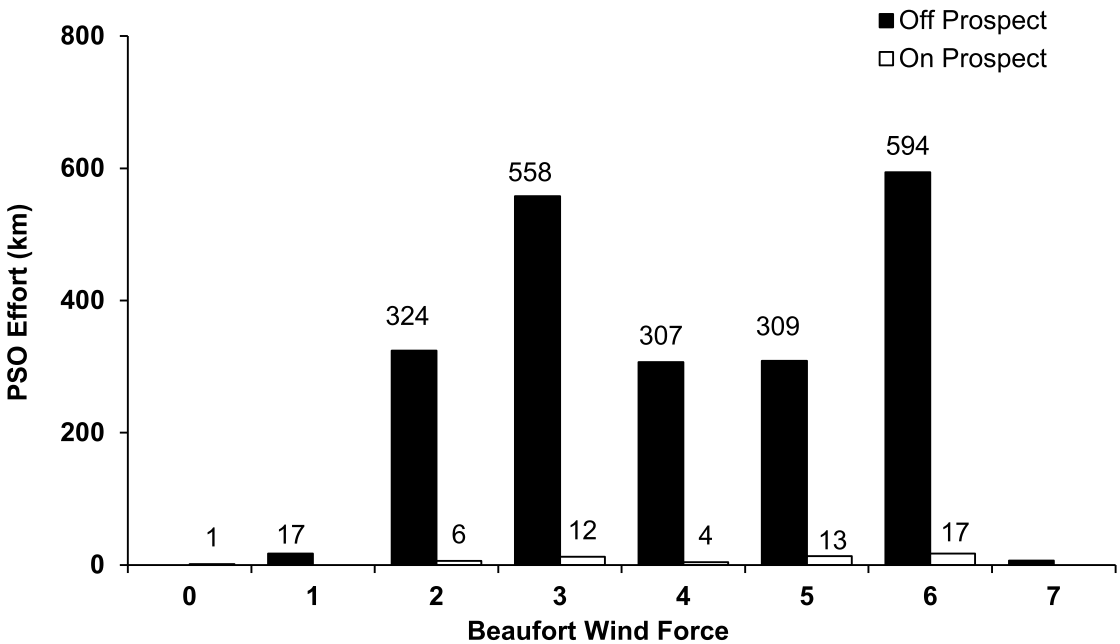

FIGURE 6.4. PSO observation effort (km) for moving periods by Beaufort wind force from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

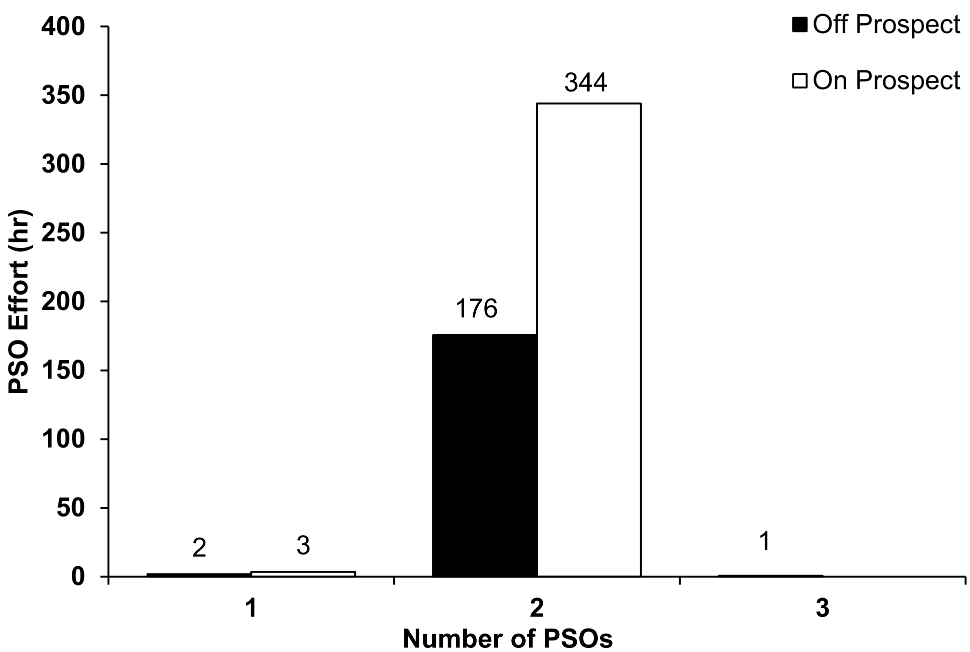

FIGURE 6.5. PSO observation effort (h) for stationary periods by number of PSOs from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

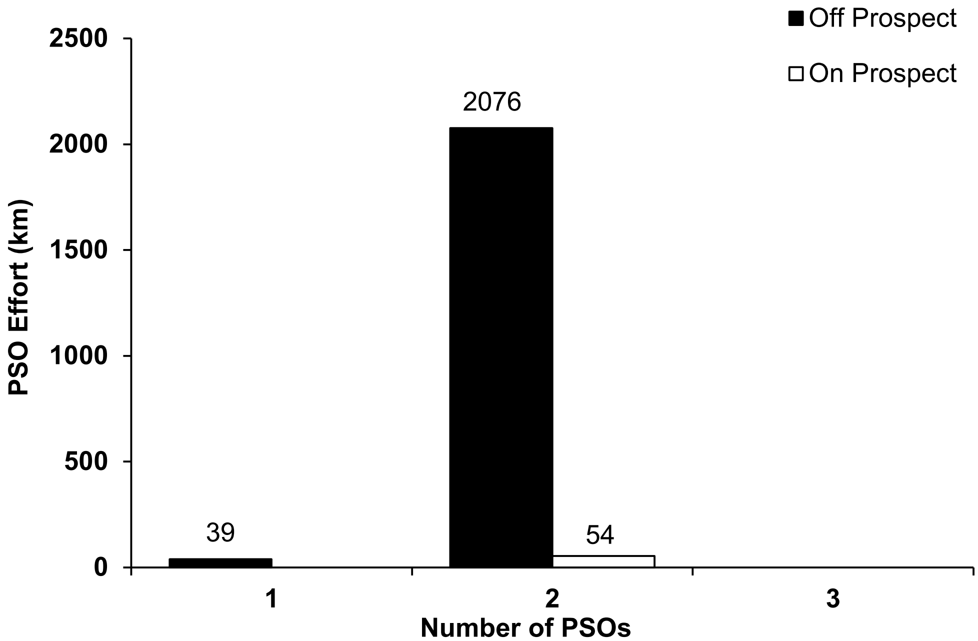

FIGURE 6.6. PSO observation effort (km) for moving periods by number of PSOs from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Observer Effort by Vessel Activity

The three activities recorded by PSOs on the *Nordica* included "dynamic positioning", or the use of dynamic positioning thrusters to stay in a single location, "idle", describing a neutral activity while engines are on, and "general vessel activities", which usually describes vessel transit or a transitional period between other activities. Most observer effort from the *Nordica* while stationary on prospect occurred during periods using dynamic positioning (93%; Figure 6.7). In contrast, most of observer effort from the *Nordica* while stationary off prospect was during "idle" activity. The low amount of effort during "general vessel activities" while stationary is due to the common use of this code to describe vessel transit, which is by definition not a stationary activity. Similarly, most observer effort from the *Nordica* while moving occurred while the vessel was engaged in "general vessel activities", typically transit, and no observer effort while moving was coded as dynamic positioning, which is typically a stationary activity (Figure 6.8).

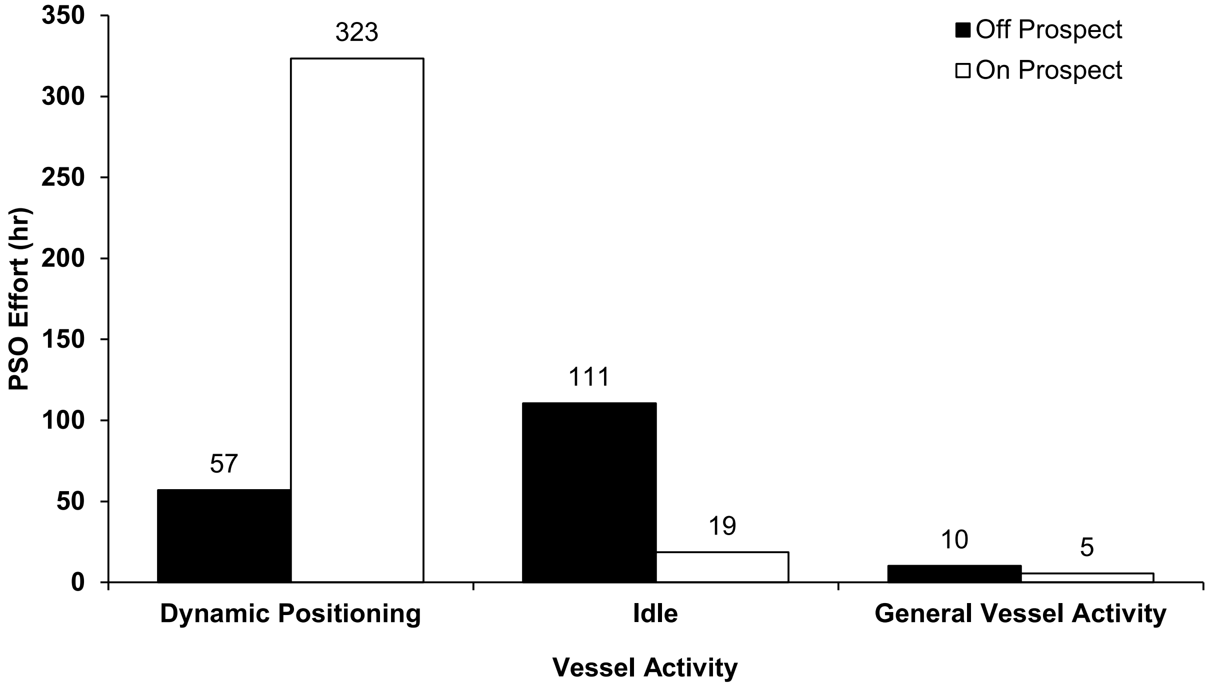

FIGURE 6.7. PSO observation effort (h) for stationary periods by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

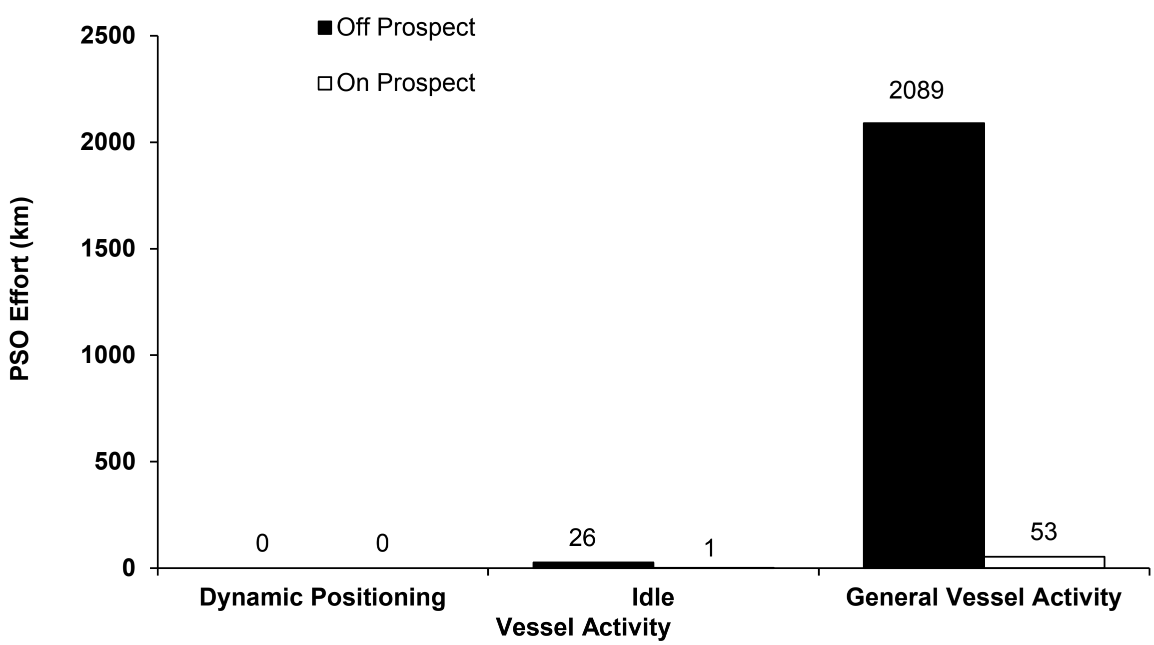

FIGURE 6.8. PSO observation effort (km) for moving periods by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Marine Mammal Sightings

During the Shell equipment retrieval operations, PSOs observed a total of 49 sightings of 58 marine mammals from the *Nordica*. Details of each marine mammal sighting observed in the survey area are available in Appendix I. The sighting data below are presented in four species groups: cetaceans, seals, polar bears, and Pacific walruses.

Cetacean Sightings

PSOs recorded 4 sightings of 4 cetaceans from the *Nordica* (Table 6.1). All of the cetaceans were observed while the *Nordica* was off the project site engaged in general vessel activities. A humpback whale sighting occurred in transit to the prospect (Figure 6.9). Two gray whale sightings and an unidentified mysticete whale sighting (likely a gray whale) occurred at the crew change location offshore of Barrow. The location of these sightings has been a known feeding area for gray whales since 2007 (LGL 2013).

TABLE 6.1. Number of cetacean sightings (number of individuals) from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Species	Sightings (Individuals)
Cetaceans	
Gray whale	2 (2)
Humpback whale	1 (1)
Unidentified mysticete whale	1 (1)
Total Cetaceans	***4 (4)***

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 F) 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 – Three cetacean sightings which met data analysis criteria occurred in Bf 3, Bf 4, and Bf 5. The limited sample size does not allow for meaningful comparison across a full range of Beaufort wind force conditions.

Cetacean Sighting Rates by Number of PSOs – The three cetacean sightings that met the data analysis criteria all occurred when two PSOs were on watch; however there was very little effort with one or three PSOs on watch (Figure 6.5). This limited sample size does not allow for meaningful comparison of number of PSOs on watch.

Cetacean Sighting Rates by Vessel Activity – The three cetacean sightings all occurred while the *Nordica* was idle. This limited sample size does not allow for any comparison among vessel activities.

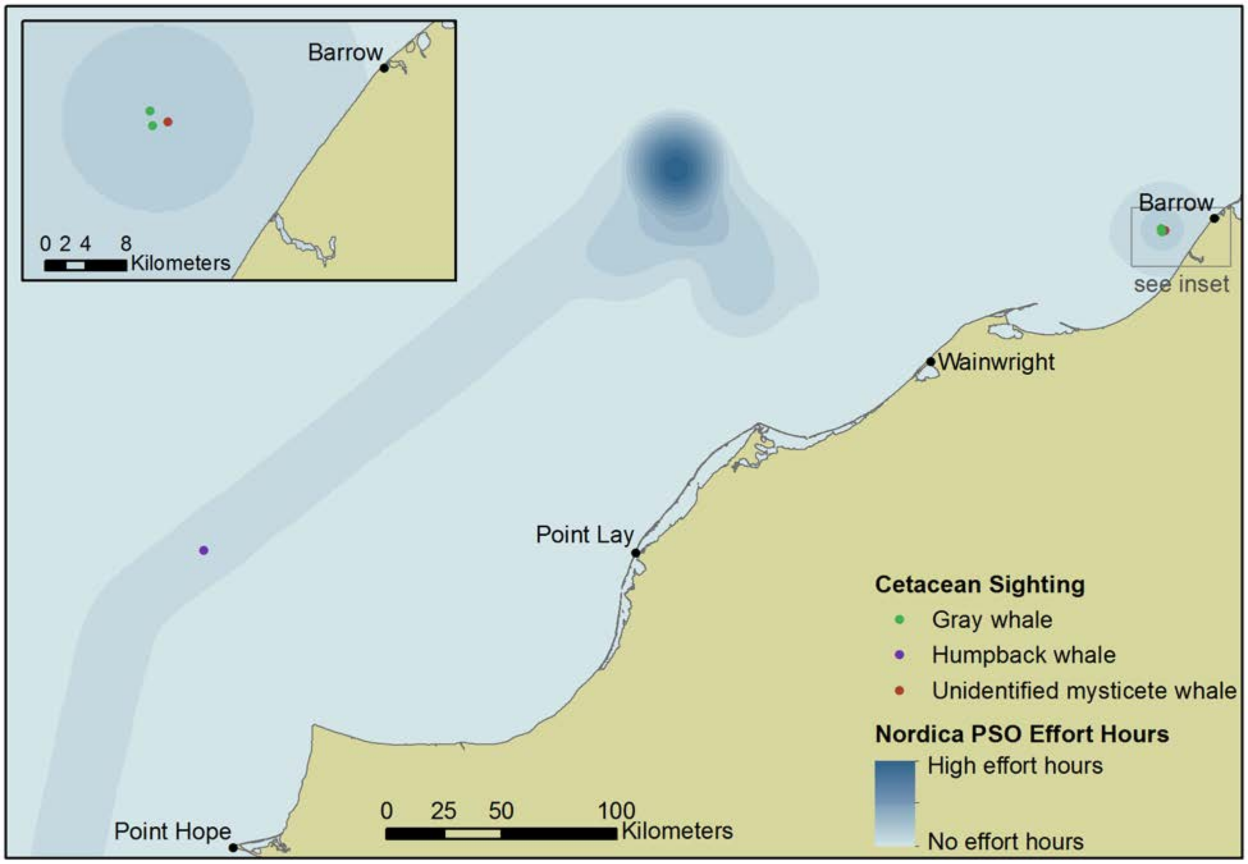

FIGURE 6.9. Location of cetacean sightings and effort from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Seal Sightings

There were 39 seal sightings of 41 individuals by PSOs on the *Nordica* (Table 6.2). Twenty eight of these sightings occurred during operations when the *Nordica* was engaged in dynamic positioning at the well site. The majority of seal sightings were identified to species (~62%; Table 6.2). The majority of seal sightings off propect occurred while the *Nordica* was in standby due to heavy ice concentration at the well site (Figure 6.10).

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 F) and the sightings that occurred during those periods. PSOs spent similar amounts of time (Figure 6.1) on prospect and off prospect, but had much greater km of effort off prospect (Figure 6.2). While on prospect, activities were mostly stationary. Given that on prospect sightings were from a stationary vessel, sighting rates were calculated in terms of hours rather than km of effort.

Seal Sighting Rates by Beaufort Wind Force – Seal sighting rates from the *Nordica* were greatest during periods of Bf two and three; however, there was limited PSO effort during all conditions except during periods of Bf three while on prospect (Fig. 6.11).

TABLE 6.2. Number of seal sightings (number of individuals) from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Species	Sightings (Individuals)
Seals	
Bearded seal	12 (13)
Ringed seal	3 (8)
Spotted seal	9 (9)
Unidentified pinniped	1 (2)
Unidentified seal	17 (17)
Total Seals	***39 (41)***

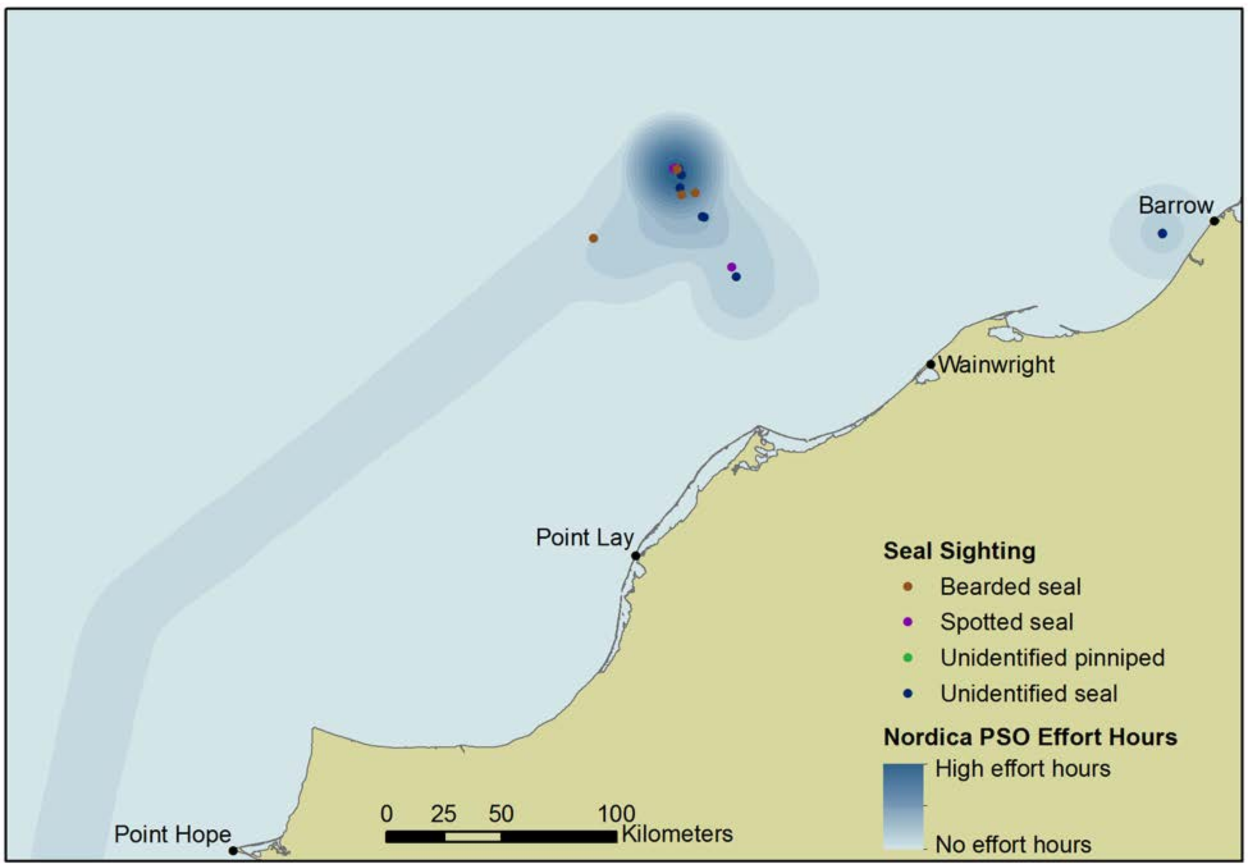

FIGURE 6.10. Locations of seal sightings and effort from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

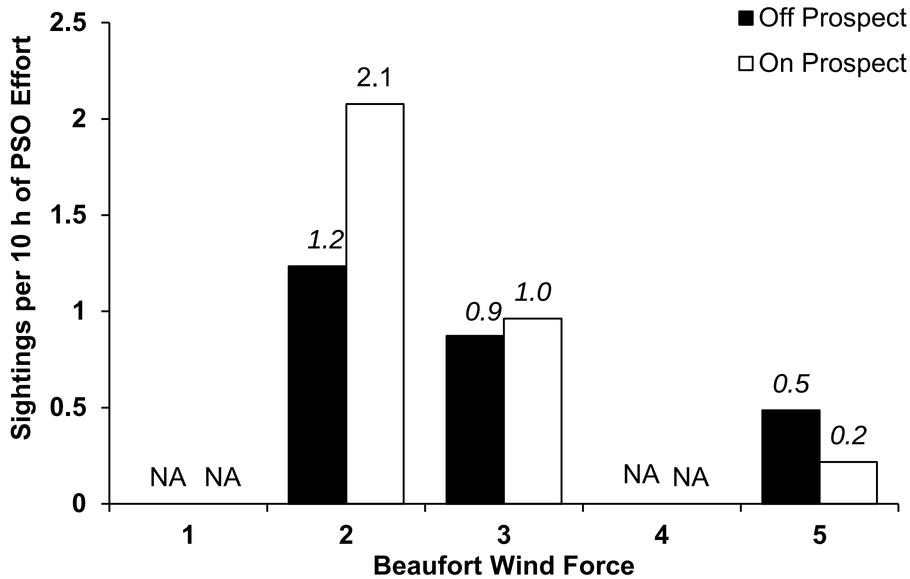

FIGURE 6.11. Seal sighting rates by Beaufort wind force from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. NA indicates insufficient effort in the category to calculate a sighting rate. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort within the category.

***Seal Sighting Rates by Number of PSOs* –** The seal sightings that met the data analysis criteria all occurred when two PSOs were on watch; however there was very little effort with one or three PSOs on watch (Figure 6.5). This limited sample size does not allow for meaningful comparison of number of PSOs on watch.

Seal Sighting Rates by Vessel Activity – The seal sighting rates were very similar for all off prospect activities, and seals were only observed on prospect during periods when the *Nordica* was using dynamic positioning (Figure 6.12). Similar sightings rates may indicate that vessel activity has little effect on sighting rate, however the limited sample size does not allow for meaningful comparison between vessel activities on and off prospect.

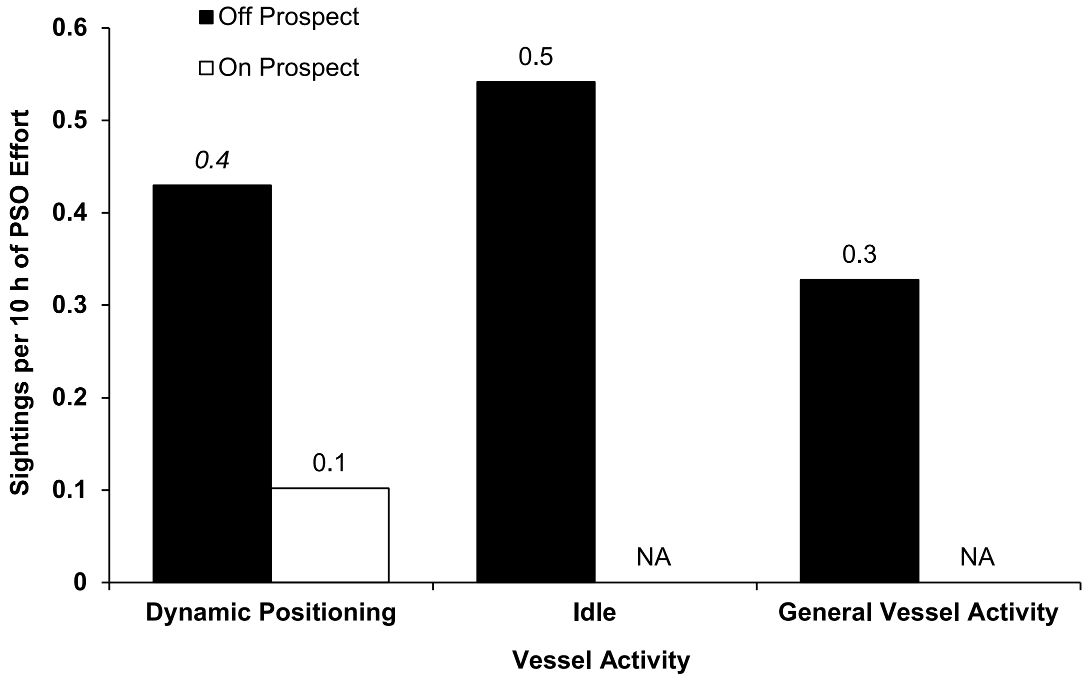

FIGURE 6.12. Seal sighting rates by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Italicized numbers indicate that the sighting rate may not be reliable due to limited observation effort within the category.

Polar Bear Sightings

There were 3 sightings of 5 polar bears by PSOs on the *Nordica* (Table 6.3). Two polar bear sightings were observed on ice while the *Nordica* was off site due to heavy concentration of ice at the well site (Figure 6.13); the third sighting was observed swimming in the water during operations at the well site. All polar bears were sighted within a one week period at the end of Aug.

TABLE 6.3. Number of polar bear sightings (number of individuals) from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Species	Sightings (Individuals)
Polar Bear	3 (5)

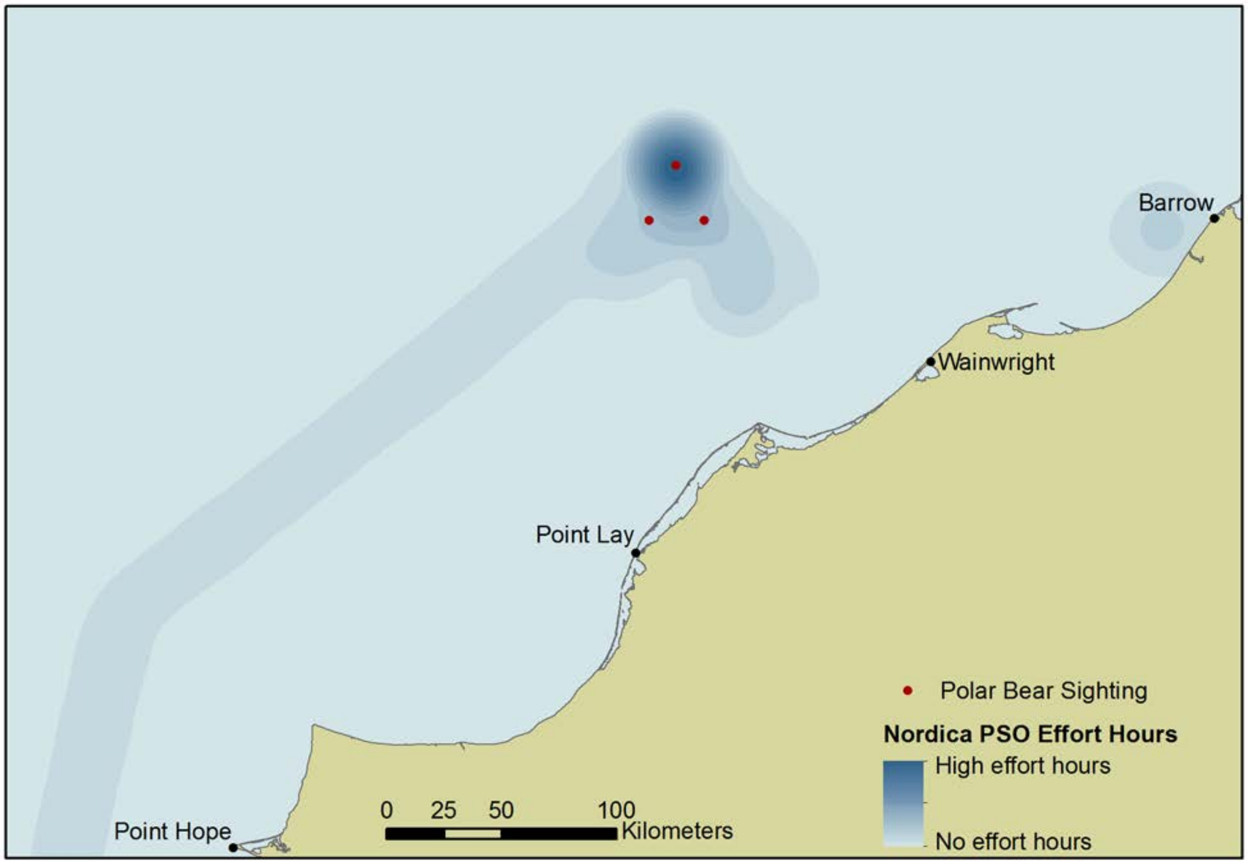

FIGURE 6.13. Location of polar bear sightings and effort from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

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 F) and the sightings that occurred during those periods.

Polar Bear Sighting Rates by Beaufort Wind Force – The polar bear sightings that met the data analysis criteria all occurred during periods of Bf 2.

Polar Bear Sighting Rates by Number of PSOs – The polar bear sightings that met the data analysis criteria all occurred when two PSOs were on watch; however there was very little effort with one or three PSOs on watch (Figure 6.5). This limited sample size does not allow for meaningful comparison among numbers of PSOs on watch.

Polar Bear Sighting Rates by Vessel Activity – The polar bear sightings that met the data analysis criteria were only sighted by PSOs on the *Nordica* during transit activity off prospect.

Pacific Walrus Sightings

There were 3 Pacific walrus sightings of 8 individuals by PSOs on the *Nordica* (Table 6.4). All of the walruses were seen on ice. Two sightings occurred while the vessel was in standby off the prospect area due to the presence of ice, and one sighting of six individuals was observed while the *Nordica* was in standby on the prospect (Figure 6.14). All three sightings occurred between 21 Aug and 15 Aug, presumably due to the presence of ice over the project area.

TABLE 6.4. Number of Pacific Walrus sightings (number of individuals) from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Species	Sightings (Individuals)
Pacific walrus	3 (8)

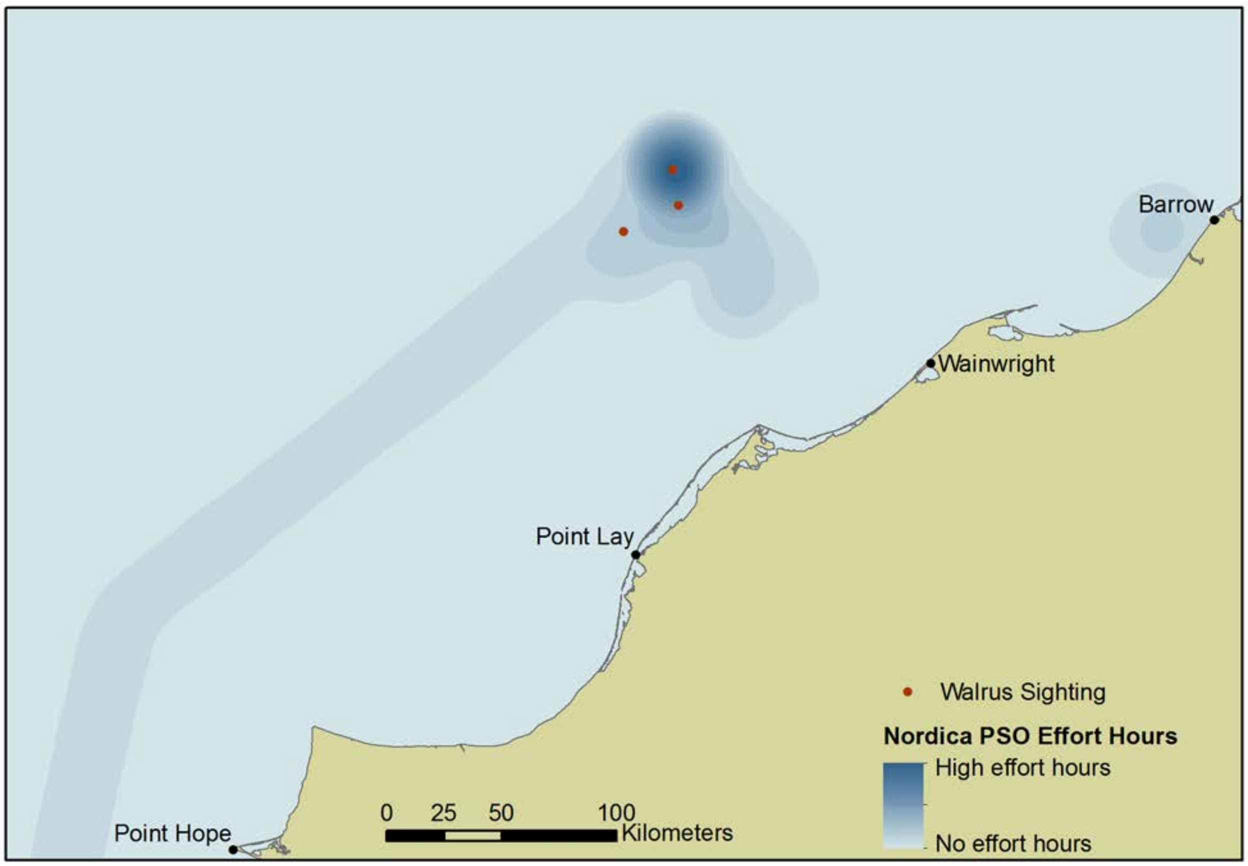

FIGURE 6.14. Locations of walrus sightings and effort from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

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 F) and the sightings that occurred during those periods.

Pacific Walrus Sighting Rates by Beaufort Wind Force – Two walrus sightings that met the data analysis criteria were sighted during Bf 2 and Bf 3. No meaningful comparison can be made since the number of different wind force conditions in which sightings walrus were encountered was limited..

Pacific Walrus Sighting Rates by Number of PSOs – The walrus sightings that met the data analysis criteria all occurred when two PSOs were on watch; however there was very little effort with one or three PSOs on watch (Figure 6.5). This limited sample size does not allow for meaningful comparison among numbers of PSOs on watch.

Pacific Walrus Sighting Rates by Vessel Activity – Of the two walruses that met the data analysis criteria, both were sighted while the *Nordica* was engaged in general vessel activities on and off the prospect.

Unidentified Marine Mammal Sightings

The *Nordica* had 20 unidentified sightings that were either too brief, too distant, or occurred during periods of low visibility to accurately identify to species (Table 6.5). Details of each unidentified marine mammal sighting in the survey area are available in Appendix I. The following materials provide the likely species assignments for unidentified sightings based on comments written by the observer at the time of the sightings. Sightings with little or no additional diagnostic information recorded by the PSO remain classified here as unidentified sightings.

TABLE 6.5. Number of unidentified marine mammal sightings from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Species	Sightings (Individuals)
Unidentified Marine Mammals	
Unidentified mysticete whale	1 (1)
Unidentified pinniped	1 (2)
Unidentified seal	17 (17)
Total Seals	***19 (20)***

Cetaceans – There was insufficient additional information observed by the PSO to assign a likely species to the unidentified mysticete whale sighting. The PSO only observed blows and a dark colored fluke, but recorded no description of the blow or fluke shape.

Pinnipeds – Of the 18 unidentified pinnipeds and seals, 6 could be estimated to species using the descriptions provided at the time of the sighting. Details such as the size of the pinniped, pattern and color of the pelage, the presence or absence of tusks, and the shape of the face led to the designation of three bearded seals and three spotted seals. The remaining 12 sightings of pinnipeds did not contain enough additional information in the comments field to assign a likely species.

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. The PSOs' primary duty was to implement mitigation rather than collect extensive behavioral data. Relevant data collected included initial sighting distance, 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. We present data from two different vessel activity periods: dynamic positioning during operations and general vessel activities. Although both activity periods create continuous sound, only sounds produced by the *Nordica* during periods of dynamic positioning during operations were considered for authorized "takes by harassment" for continuous sound levels ≥120 dB (rms; See Chapter 1 for more information). The low numbers of observations during stationary periods near the well site for cetaceans, seals, polar bears, and Pacific walruses were insufficient to perform statistical analyses for behavior and distribution between vessel activity periods.

Cetaceans

<u>Cetacean Initial Sighting Distance and Distribution</u>

The comparison of initial sighting distances of cetaceans between different operations periods is usually made only with sightings that occurred during periods of effort that met the criteria for being able to reliably detect cetaceans (See Chapter 4 and Appendix F). Cetacean sightings which met the data analysis criteria were only observed during periods of general vessel activities, so no comparison across vessel activities could be made (Figure 6.15). Cetaceans were initially sighted at an average distance of 1813 m (~5948 ft) from the *Nordica*.

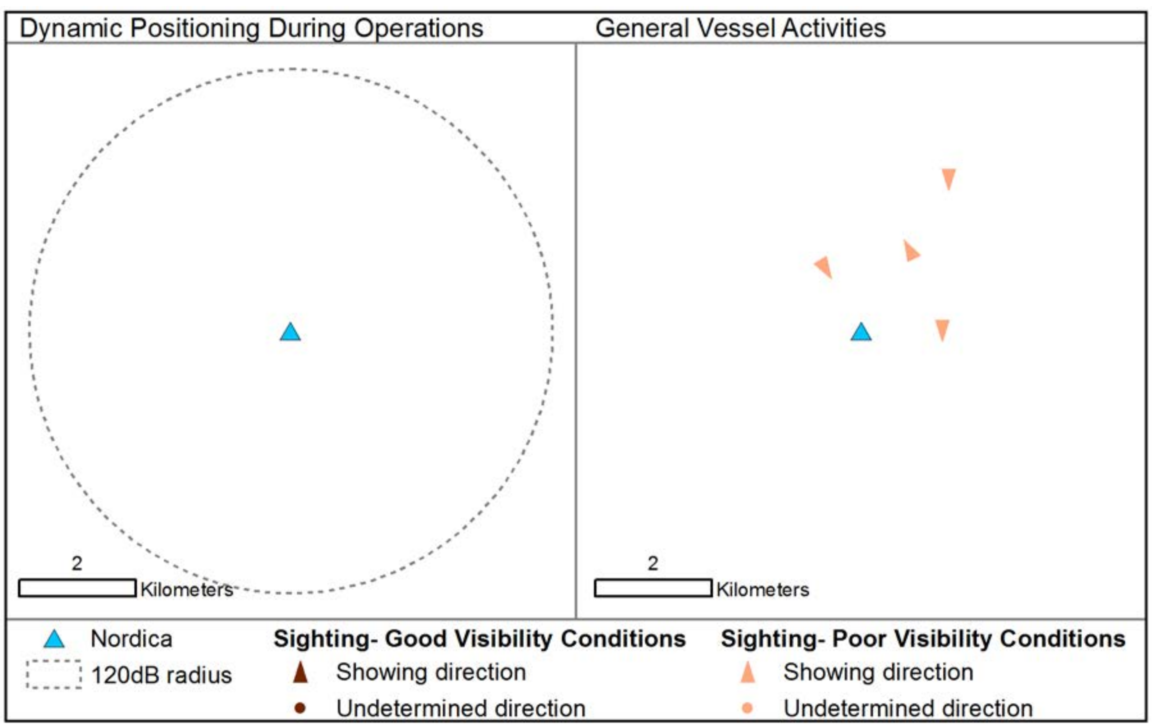

FIGURE 6.15. Distance and direction of initial cetacean sightings by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Arrows indicate direction of animal movement.

Cetacean Closest Point of Approach

The mean closest points of approach of cetaceans were calculated using only the sightings that occurred during periods of effort that met the criteria for being able to detect seals (See Chapter 4). Since no cetaceans were sighted while the vessel was conducting operations using dynamic positioning, comparison between vessel activities was not possible (Table 6.6). The mean CPA of the three cetaceans observed in good visibility conditions was 1666 m (~ 5466 ft). Cetaceans were observed from the *Nordica* as close as 600 m (~1968 ft) and as far as 3000 m (~9842 ft).

TABLE 6.6. Comparison of mean polar bear CPA distances by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Dynamic Positioning during Operations	--	--	--	--
General Vessel Activities	1666	1222	600-3000	***3***
Total	***1666***	***1222***	***600-3000***	***3***

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

Cetacean Movement

Of the four cetacean sightings on the *Nordica*, all four occurred while the vessel was engaged in general vessel activities away from the well site. Two sightings exhibited neutral movement towards the vessel, and two sightings swam toward the vessel.

Cetacean Initial Behavior

Of the four cetacean sightings on the *Nordica*, the observed initial behavior of three of these sightings was blow. Blow is often the most frequently recorded initial behavior as it is a highly visible sighting cue and often the first and only indication of cetacean presence. The initial behavior of the fourth whale was breach. The breaching cetacean was sighted while the Nordica was returning to the lease area after withdrawing to Dutch Harbor due to ice presence over the well site.

Cetacean Reaction Behavior

No cetaceans sighted from the *Nordica* exhibited an overt (or discernible) reaction to the vessel.

Seals

Seal Initial Sighting Distance and Distribution

The initial sighting distance of seals was calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect seals (See Chapter 4 and Appendix F). Mean initial sighting distance of seals was greater during dynamic positioning during operations (533 m; ~1749 ft) than during general vessel activities (375 m; ~1230 ft; Figure 6.16).

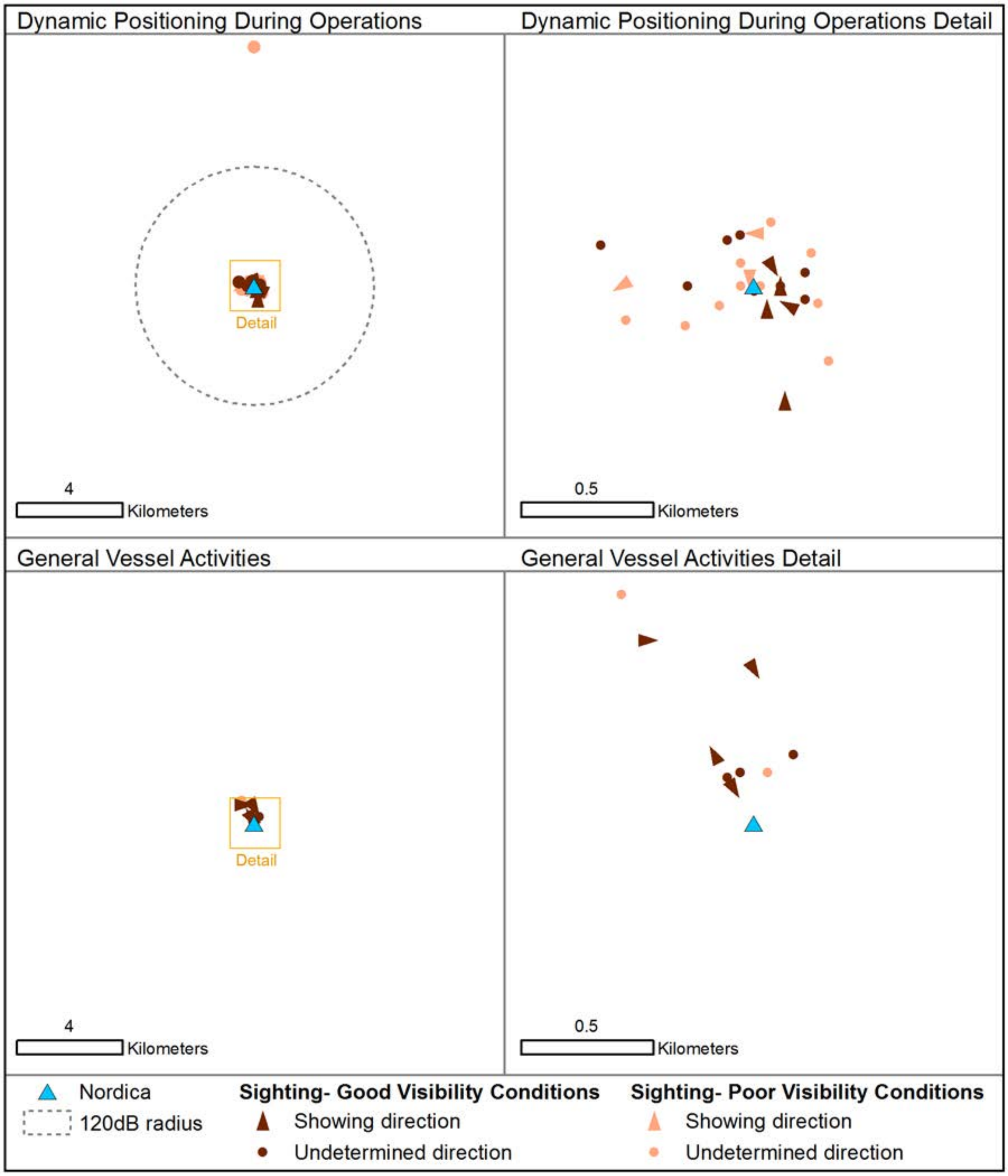

FIGURE 6.16. Distance and direction of initial seal sightings by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Arrows indicate direction of animal movement.

Seal Closest Point of Approach

The mean closest points of approach of seals were calculated using only the sightings that occurred during periods of effort that met the criteria for being able to detect seals (See Chapter 4 and Appendix F). The mean closest point of approach (CPA) for seals observed from the *Nordica* was lower during periods in which dynamic positioning was occurring (189 m; ~620 ft) than during general vessel activity periods (374 m; ~1227 ft; Table 6.7).

TABLE 6.7. Comparison of mean seal CPA distances by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Dynamic Positioning during Operations	189	148	20-600	***16***
General Vessel Activities	374	333	140-1000	***8***
Total	***250***	***236***	***20-1000***	***24***

Seal Movement

Of the 39 seal sightings observed from the *Nordica*, 28 occurred during operations when dynamic positioning was used. Of these 28 seals, 20 were observed to have no movement, and the second most common movement was swim towards (Table 6.8). During general vessel activities, movement relative to the vessel was unable to be determined in 6 cases, and swim towards was the second most common movement. More than half of the sightings did not have a determined movement relative to the vessel. PSOs on board the *Nordica* regularly observed seals floating on the surface of the water and subsequently sinking with no obvious directional movement. There was no discernible difference between seal movement relative to the *Nordica*'s vessel activity.

Seal Initial Behavior

The initial behaviors of seals observed from the *Nordica* varied considerably during operations using dynamic positioning (Table 6.9). Initial behaviors of seals observed during general vessel activities was less varied, with 8 out of 10 seal sighting behaviors recorded as look. The *Nordica* was in transit for most of general vessel activities, and the less varied behavior recorded for these sightings may be associated with shorter sighting duration typical of seal sightings during moving periods (Bisson et al. 2013).

Seal Reaction Behavior

Seals observed from the *Nordica* were most often recorded as looking at the vessel and having no observable reaction (Table 6.10). There was no discernible difference between seal reactions relative to the *Nordica*'s activity.

TABLE 6.8. Number of seal sightings within categories of movement relative to vessels by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

	Movement Relative to Vessel					
Vessel Activity	**Neutral**	**None**	**Swim Away**	**Swim Towards**	**Unknown**	***Totals***
Dynamic Positioning during Operations	3	6	1	4	14	***28***
General Vessel Activities	1	1	1	2	6	***11***
Total	***4***	***7***	***2***	***6***	***20***	***39***

TABLE 6.9. Comparison of seal behaviors by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

	Behavior								
Vessel Activity	**Dive**	**Log**	**Look**	**Mill**	**Swim**	**Thrash**	**Rest**	**Other**	***Totals***
Dynamic Positioning during Operations	2	2	9	1	12	--	2	1	***29***
General Vessel Activities	--	--	8	--	1	1	--	--	***10***
Total	***2***	***2***	***17***	***1***	***13***	***1***	***2***	***1***	***39***

TABLE 6.10. Comparison of seal reactions to the vessel by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

	Reaction			
Vessel Activity	**Increase Speed**	**Look**	**None**	***Totals***
Dynamic Positioning during Operations	--	18	10	***28***
General Vessel Activities	1	7	3	***11***
Total	***1***	***25***	***13***	***39***

Polar Bears

Polar Bear Initial Sighting Distance and Distribution

The initial sighting distance of polar bears was calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect bears (See Chapter 4 and Appendix F). Two sightings of polar bears met the data analysis criteria: both were observed on ice and during periods of general vessel activities, so meaningful comparison across activities was not possible. The mean initial sighting distance of these sightings was 6250 m (~20,505 ft). The third polar bear was sighted both during poor visibility conditions and while swimming in the water, and had a much closer initial sighting distance (450 m; ~1476 ft; Figure 6.17).

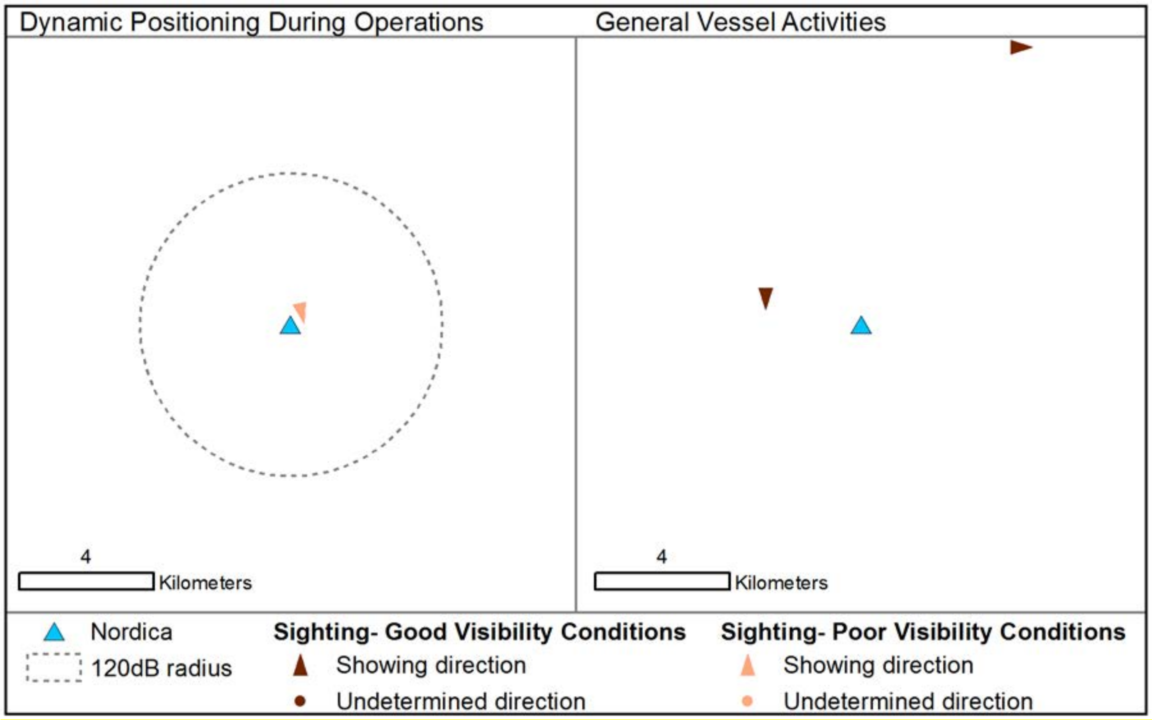

FIGURE 6.17. Distance and direction of initial polar bear sightings by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Arrows indicate direction of animal movement.

Polar Bear Closest Point of Approach

The mean closest points of approach of polar bears were calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect polar bears (See Chapter 4 and Appendix F). Both polar bears which met the analysis criteria were observed on ice. The closest sighting, a CPA of 2951 m (9681 ft), was of a sow and two cubs walking on a large ice floe (Table 6.11). The second sighting which met the analysis criteria was of a single bear, which paced along the ice edge of a medium sized floe for the duration of the sighting.

Polar Bear Movement

All three polar bear sightings exhibited neutral movement relative to the vessel. Neutral movement included occasions when the animal(s) was swimming neither towards nor away from the vessel (e.g., parallel to vessel).

Polar Bear Initial Behavior

The initial behavior for both polar bear sightings recorded during periods of general vessel activities was "walk", as both sightings were observed on ice. PSOs recorded the initial behavior of the third sighting as "swim" which was recorded while the Nordica was engaged in operations near the well site.

Polar Bear Reaction Behavior

Polar bears observed from the *Nordica* during general vessel activities exhibited no visible reaction. In the third sighting during operational activities, the reaction of the polar bear was recorded as "look."

TABLE 6.11. Comparison of mean polar bear CPA distances by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Dynamic Positioning during Operations	--	--	--	--
General Vessel Activities	5976	4277	2951-9000	**2**
Total	***5976***	***4277***	***2951-9000***	***2***

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

Pacific Walruses

Pacific Walrus Initial Sighting Distance and Distribution

The initial sighting distance of walrus was calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect walrus (See Chapter 4 and Appendix F). Both sightings which met the analysis criteria were observed on ice while the *Nordica* was off prospect due to ice concentration at the well site. Average initial sighting distance for these sightings was 5332 m (~17,493 ft). All walruses were observed "resting" on ice, and did not show any direction of movement (Figure 6.18).

Pacific Walrus Closest Point of Approach

The mean closest points of approach of Pacific walruses were calculated using only sightings that occurred during periods of effort that met the criteria for being able to reliably detect Pacific walruses (See Chapter 4 and Appendix F). All walruses were observed on ice. The closest CPA was 1954 m (~6411 ft), and PSOs requested a course alteration to maintain this distance from the sighting (See Mitigation for more information; Table 6.12). Since the two walrus sightings were a great distance from the *Nordica* to avoid disturbance, PSOs were not able to elaborate on movement, behavior, and reaction to the vessel.

Pacific Walrus Movement

All three walrus sightings exhibited no discernible movement relative to the vessel.

Pacific Walrus Initial Behavior

The initial behavior of all three walruses observed from the *Nordica* was "rest." All three walruses were observed resting on ice.

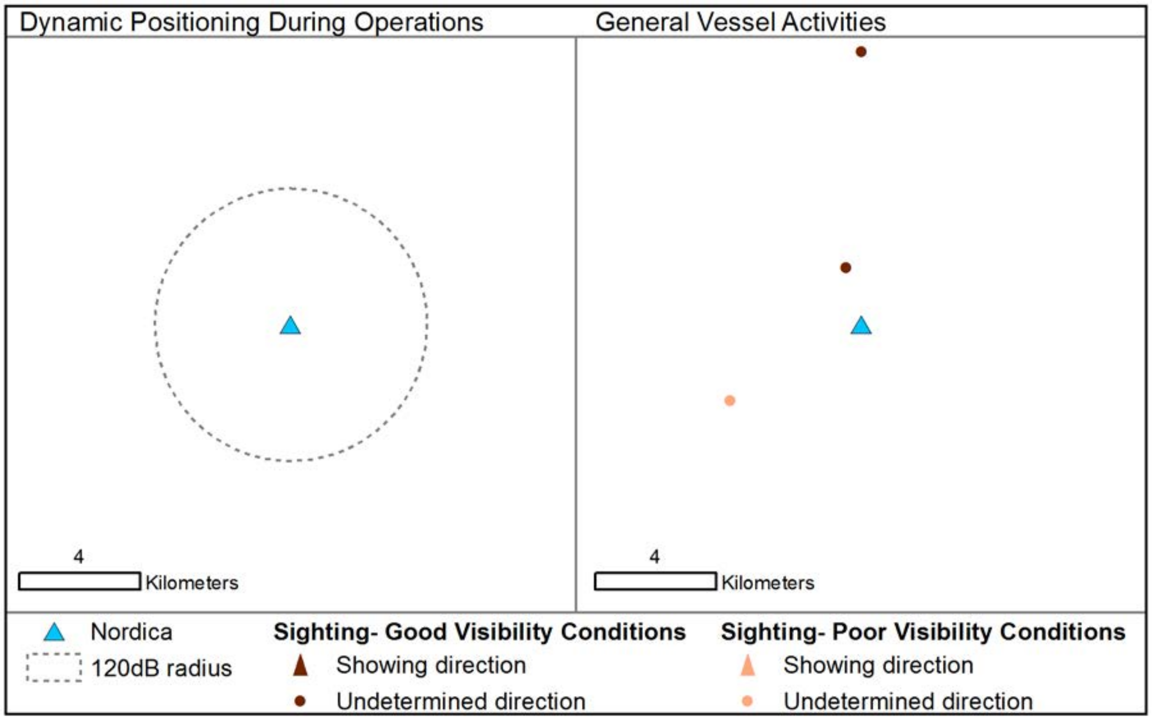

FIGURE 6.18. Distance and direction of initial walrus sightings by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Circles indicate that animals showed no observable direction of movement.

Pacific Walrus Reaction Behavior

Walruses observed from the *Nordica* exhibited no reaction the majority of the time (~66%). In the third sighting, the reaction of the walrus was recorded as "look."

TABLE 6.12. Comparison of mean walrus CPA distances by vessel activity from the *Nordica* during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Vessel Activity	Mean CPA[a] (m)	s.d.	Range (m)	*n*
Dynamic Positioning during Operations	--	--	--	**--**
General Vessel Activities	5499	5013	1954-9044	***2***
Total	***5499***	***5013***	***1954-9044***	***2***

Mitigation Measures Implemented

Safety and Disturbance Radii

Prior to completion of the sound source verification measurements, PSOs on the *Nordica* used the modeled zone of influence (ZOI) radii presented in Shell's 2013 IHA application and outline in the IHA issued by NMFS (NMFS 2013). Bottom founded recorders were present for the duration of the majority of activity over the well site (See Chapter 3), and sound levels associated with *Nordica* operational activities were determined post season.

Mitigation Actions

The *Nordica*'s proximity to ice mid-season involved significant communication between PSOs and vessel operators. Sightings information was summarized at shore-based offices in Anchorage and routinely communicated to the *Nordica* PSO crew to increase awareness of marine mammal distribution (specifically Pacific walrus distribution) within the Chukchi Sea. Walruses and polar bears hauled out on ice were detected by PSOs and the location of these animals was communicated to vessel operators and shore-based project managers, so that distances from these animals were maintained.

One general mitigation action was requested and implemented on the *Nordica* in the Chukchi Sea to maintain distance from a walrus on ice. On 21 Aug the *Nordica* was off site due to the presence of ice over the well site. PSOs observed a single Pacific walrus resting on ice 1954 m ahead of the vessel. A course alteration to maintain distance from the walrus was enacted by the vessel crew immediately. The vessel did not approach the walrus any closer than the initial sighting distance, and the reaction of the walrus to the vessel was "look."

Operations at the well site included the deployment of equipment (e.g. the ROV) off the back deck. PSOs monitored the area before deploying or retrieving equipment and worked with vessel operators to clear the area of marine mammals while work was occurring in or near the water around the vessel.

PSOs aboard the *Nordica* contacted local communication centers located in coastal Chukchi Sea villages every six hours per the Conflict Avoidance Agreement (CAA). These routine communications were designed to avoid conflicts between local subsistence users and Shell's operations. No conflicts were reported between the *Nordica* and subsistence users in 2013.

Estimated Number of Marine Mammals Present and Potentially Affected

It is often difficult to obtain meaningful estimates of "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, and situations. ***(3)*** The distance to which a received sound level (RL) reaches a specific criterion such as 190 dB, 180 dB, or 160 dB, or 120 dB re 1 μPa (rms) is variable. The RL 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 their 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 on ice.

Two methods were used to estimate the number of marine mammals exposed to continuous sound levels strong enough that they might have caused a disturbance or other potential impacts. The procedures included ***(A)*** minimum estimates based on the direct observations of marine mammals by PSOs, and ***(B)*** estimates based on polar bear, pinniped (seal and Pacific walrus) and cetacean densities obtained during this study. The actual number of individuals exposed to, and potentially impacted by, survey and vessel sounds likely was between the minimum and maximum 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 RLs at various distances from the *Nordica* while it was stationary using dynamic positioning thrusters. The NMFS required that distances to RLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for cetaceans and seals respectively. The USFWS required that distances to RLs 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 vessel while stationary using dynamic positioning indicated that sound levels at or above these thresholds were not generated (see Chapter 3 of this report for sound measurement details). Both agencies assume that disturbance to marine mammals (or zone of influence) from continuous sounds generated by the vessel while using dynamic positioning during operations may occur at RLs ≥120 dB (rms).

Estimates from Direct Observations

All sightings data 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 dynamic positioning during operations near the well site provides a minimum estimate of the number potentially affected by the continuous sounds from the vessel. 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 vessel position. 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 mid Sep.

Animals may also have avoided the area near the *Nordica* while it was engaged in dynamic positioning during operations. 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 cetaceans, pinnipeds, and polar bears may have been altered as a result of the operations.

No cetaceans or Pacific walruses were observed while the *Nordica* was engaged in dynamic positioning during operations. All four cetacean sightings occurred closer to shore than the location of operations. All walrus sightings occurred while the *Nordica* was on standby away from the well site due to ice cover on the prospect.

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

Thirty of the 41 individual seals observed from the *Nordica* were present while the vessel was engaged in dynamic positioning during operations. Of these, 28 individual seals were in the water and two seals were on ice. The two seals on ice were seen >9 km from the vessel and were not exposed to ≥120 dB (rms; Table 6.13). Closest points of approach for seals in water were between 20 and 600 m (~66 ft to ~1968 ft), and these seals were likely exposed to ≥120 dB (rms). The majority of the observed reactions of these seals to the vessel were “look” (~64%). While three of the seals remained near the stationary *Nordica* for >1 hr, the majority of the seals (20 individuals) were visible near the vessel less than 20 minutes. The mean duration for observed exposure ≥120 dB (rms) was 12 minutes.

TABLE 6.13. Number of individuals exposed to ≥120 dB (rms) while the *Nordica* was engaged in dynamic positioning during operations during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

Species Group	**Number of Individuals and Exposure Level in dB re 1µPa (rms)**			
	≥ 150	**≥ 140**	**≥ 130**	**≥ 120**
Seals	7	30	38	38
Polar Bears	0	0	1	1

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

One polar bear was seen swimming in the water while the *Nordica* was engaged in dynamic positioning during operations at the well site. The bear was seen approaching the vessel through fog. It was initially sighted at 450 m (1476 ft) and approached as close as 350 m (1148 ft) before swimming past the vessel. The observed reaction to the vessel was "look." The polar bear was observed swimming with its head above water and likely would not have experienced levels of sound comparable to marine mammals present well below the surface. This is due to the pressure release effects near the surface of the water or differences in the propagation of sounds in water and in air.

Estimates Extrapolated from Density

The number of marine mammals visually detected by PSOs likely underestimated the actual numbers that were present for reasons described above. To correct for animals that may have been present but not detected by observers, the sightings recorded during seismic and non-seismic periods along with detectability corrections $f(0)$ and $g(0)$ were used to calculate separate densities of marine mammals present during those two periods.

Marine mammal densities were calculated using data that met the analysis criteria in order to allow for meaningful comparisons (See Chapter 4 and Appendix F). Densities were based on data collected from both the *Fennica* and *Nordica* during Shell's shallow hazards and ice gouge surveys, and also during the equipment maintenance operations in the Chukchi Sea during 2013. Because there were relatively few sightings from the *Nordica* while it was stationary in dynamic positioning at the well site, and data from stationary periods that did *not* involve dynamic positioning were few, densities could not be calculated and compared between these two stationary activity states. As a result, densities calculated and used in the exposure estimates below were based only on observer effort and sightings data while the vessels were moving, and data were divided into seismic versus non-seismic periods based on the activity of the *Fennica*.

The density estimates for the Shell 2013 survey area were calculated separately by seasonal periods of 'summer' (Jul–Aug) and 'fall' (Sep) for consistency and comparison with the NMFS IHA application exposure estimates (Shell 2013). The estimated densities of marine mammals were then multiplied by the area of water ensonified (exposed to continuous sounds from the *Nordica* operating in dynamic positioning during operations at the Burger well site) to estimate the number of individual marine mammals exposed to continuous received sound levels (RLs)≥12 0 dB (rms) in each of the two seasonal periods. Density estimates from Shell's 2013 survey activities for each seasonal period are summarized in Tables 6.14 and 6.15.

TABLE 6.14. Jul–Aug densities of marine mammals in the Alaskan Chukchi Sea observed during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix F). LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively.

	No. individuals / km^2					
	Seismic			Non-seismic		
Species	**Density**	**LCL**	**UCL**	**Density**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0.000	--	--	0.002	0.001	0.006
Gray Whale	0.000	--	--	0.006	0.002	0.025
Minke Whale	0.000	--	--	0.002	0.001	0.004
Unid. Mysticete Whale	0.001	0.000	0.003	0.002	0.001	0.006
Harbor Porpoise	0.000	--	--	0.001	0.000	0.005
Unid. Whale	0.000	--	--	0.000	0.000	0.001
Total Cetaceans	***0.001***	***0.000***	***0.003***	***0.014***	***0.007***	***0.029***
Seals						
Bearded Seal	0.000	--	--	0.019	0.009	0.043
Ringed Seal	0.014	0.007	0.032	0.025	0.012	0.054
Spotted Seal	0.000	--	--	0.005	0.002	0.013
Unid. Seal	0.024	0.010	0.055	0.117	0.059	0.235
Unid. Pinniped	0.000	--	--	0.003	0.001	0.010
Total Seals	***0.038***	***0.021***	***0.071***	***0.169***	***0.102***	***0.283***
Pacific Walrus	0.014	0.005	0.038	0.003	0.001	0.010
Polar Bear*	0.000	--	--	0.007	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

TABLE 6.15. Sep densities of marine mammals in the Alaskan Chukchi Sea observed during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. Densities are corrected for *f*(0) and *g*(0) biases (see Appendix F). LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively.

	No. individuals / km^2					
	Seismic			Non-seismic		
Species	**Density**	**LCL**	**UCL**	**Density**	**LCL**	**UCL**
Cetaceans						
Gray Whale	0.000	--	--	0.001	0.000	0.006
Minke Whale	0.000	--	--	0.001	0.000	0.004
Unid. Mysticete Whale	0.000	--	--	0.002	0.000	0.012
Total Cetaceans	***0.000***	***--***	***--***	***0.005***	***0.002***	***0.013***
Seals						
Bearded Seal	0.000	--	--	0.019	0.007	0.049
Ringed Seal	0.000	--	--	0.007	0.003	0.018
Unid. Seal	0.009	0.002	0.043	0.039	0.017	0.091
Unid. Pinniped	0.006	0.001	0.034	0.007	0.002	0.023
Total Seals	***0.015***	***0.004***	***0.053***	***0.072***	***0.041***	***0.126***
Pacific Walrus	0.010	0.003	0.029	0.037	0.007	0.179

Nordica Exposure Estimates by Seasonal Periods

The area of water around the Burger well site exposed to various sound levels from *Nordica* operations in dynamic positioning during each of the two seasonal periods are shown in Table 6.16. The methodology used to estimate the areas exposed to RLs ≥120, 130, 140, and 150 dB (rms) was described in Chapter 4 and in more detail in Appendix F. See Chapter 7 for a summary of exposure estimates from the *Fennica's* seismic activities as well as those presented below from the *Nordica's* dynamic positioning system.

TABLE 6.16. Estimated areas (km^2) ensonified to various sound levels by the *Nordica* operating in dynamic position at the Burger well site during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013.

	Level of ensonification in dB re 1 µPa (rms)				
Seasonal Period	**160**	**150**	**140**	**130**	**120**
Jul - Aug	0.00	0.01	0.21	3.80	63.62
Sep	0.00	0.01	0.21	3.80	63.62

The following estimates based on density calculations assume that all mammals present were well below the surface where they were exposed to RLs at various distances as reported in Chapter 3 and summarized in Table 4.2. Some pinnipeds and cetaceans in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Also, some marine mammals may have stayed away from the *Nordica* as it was operating in dynamic positioning in an avoidance response to the associated sounds.

Cetaceans

Tables 6.17–6.19 show the estimated numbers of cetaceans that may have been exposed to dynamic positioning sounds at received levels ≥120 dB (rms) based on the density estimates in Tables 6.14 and 6.15 and the ensonified areas in Table 6.16. These estimates are based on the sum of exposures from the two seasonal periods *without* a daily multiplier. Approximately one bowhead whale, two gray whales, one minke whale, two unidentified mysticete whales, one harbor porpoise, and one identified whale were estimated to have been exposed to continuous sounds ≥120 dB (rms; Table 6.19). There was a single humpback whale observed from each vessel during 2013, however, both were recorded during periods that did not meet analysis criteria and were not captured in these density-based exposure estimates. It is possible that small numbers of humpback whales were exposed to dynamic positioning sounds ≥120 dB (rms). However, all cetacean sightings from the *Nordica* were observed away from Burger while the vessel was engaged in general vessel activities (Fig. 6.9).

Seals

Tables 6.17, 6.18, and 6.19 show the estimated numbers of seals that may have been exposed to dynamic positioning sounds at RLs ≥120 dB (rms) based on the density estimates in Tables 6.14 and 6.15 and the ensonified areas in Table 6.16. These estimates are based on the sum of exposures from the two seasonal periods *without* a daily multiplier. The total number of seals estimated to have been exposed to continuous sounds ≥120 dB (rms) is 16. Since many pinnipeds could not be identified to species by the observers, the density based estimates include 11 individual pinnipeds of unknown species.

Pacific Walruses

Tables 6.17, 6.18, and 6.19 show the estimated numbers of walruses that may have been exposed to dynamic positioning sounds at RLs ≥120 dB (rms) based on the density estimates in Tables 6.14 and 6.15 and the ensonified areas in Table 6.16. These estimates are based on the sum of exposures from the two seasonal periods *without* a daily multiplier. Density based calculations estimate that three walruses may have been exposed to continuous sounds with RLs ≥120 dB (rms) while the *Nordica* was engaged in dynamic positioning activities at the well site (6.19). All walrus sightings from the *Nordica* were of animals observed on ice while the vessel was in standby off prospect (Fig. 6.13), and these animals would not have been exposed to the same RLs as animals in the water at the same location.

Polar Bears

Tables 6.17 and 6.19 show the estimated numbers of polar bears that may have been exposed to dynamic positioning sounds at received levels ≥120 dB (rms) based on the density estimates in Tables 6.14 and the ensonified areas in Table 6.16. These estimates are based on the sum of exposures from the two seasonal periods *without* a daily multiplier. Density based calculations estimate that a single polar bear may have been exposed to continuous sounds with RLs ≥120 dB (rms) during dynamic positioning at the well site (6.19). Two of three polar bears observed during 2013 operations were on ice and polar bears typically swim with their heads above water; likely these bears would not have experienced levels of sound comparable to marine mammals present well below the surface, due to the pressure release effects near the surface of the water or differences in the propagation of sounds in water and in air.

TABLE 6.17. Estimated numbers of individual marine mammals exposed to continuous sounds ≥120 dB (rms) from dynamic positioning activities based on densities observed during seismic and non-seismic periods during Jul–Aug of Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0	--	--	1	1	1
Gray Whale	0	--	--	1	1	2
Minke Whale	0	--	--	1	1	1
Unid. Mysticete Whale	1	1	1	1	1	1
Harbor Porpoise	0	--	--	1	1	1
Unid. Whale	0	--	--	1	1	1
Total Cetaceans	***1***	***1***	***1***	***1***	***1***	***2***
Seals						
Bearded Seal	0	--	--	2	1	3
Ringed Seal	1	1	3	2	1	4
Spotted Seal	0	--	--	1	1	1
Unid. Seal	2	1	4	8	4	15
Unid. Pinniped	0	--	--	1	1	1
Total Seals	***3***	***2***	***5***	***11***	***7***	***18***
Pacific Walrus	1	1	3	1	1	1
Polar Bear*	0	--	--	1	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

TABLE 6.18. Estimated numbers of individual marine mammals exposed to continuous sounds ≥120 dB (rms) from dynamic positioning activities based on densities observed during seismic and non-seismic periods during Sep of Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Gray Whale	0	--	--	1	1	1
Minke Whale	0	--	--	1	1	1
Unid. Mysticete Whale	0	--	--	1	1	1
Total Cetaceans	***0***	***--***	***--***	***1***	***1***	***1***
Seals						
Bearded Seal	0	--	--	2	1	4
Ringed Seal	0	--	--	1	1	2
Unid. Seal	1	1	3	3	2	6
Unid. Pinniped	1	1	3	1	1	2
Total Seals	***1***	***1***	***4***	***5***	***3***	***9***
Pacific walrus	1	1	2	3	1	12

TABLE 6.19. Estimated numbers of individual marine mammals exposed to continuous sounds ≥120 dB (rms) from dynamic positioning activities based on densities observed during seismic and non-seismic periods during all of Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0	--	--	1	1	1
Gray Whale	0	--	--	1	1	2
Minke Whale	0	--	--	1	1	1
Unid. Mysticete Whale	1	1	1	1	1	2
Harbor Porpoise	0	--	--	1	1	1
Unid. Whale	0	--	--	1	1	1
Total Cetaceans	***1***	***1***	***1***	***2***	***1***	***3***
Seals						
Bearded Seal	0	--	--	3	1	6
Ringed Seal	1	1	3	3	1	5
Spotted Seal	0	--	--	1	1	1
Unid. Seal	3	1	7	10	5	21
Unid. Pinniped	1	--	--	1	1	3
Total Seals	***4***	***2***	***8***	***16***	***10***	***26***
Pacific Walrus	2	1	5	3	1	13
Polar Bear*	0	--	--	1	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

Nordica Exposure Estimates by Seasonal Periods with a Daily Multiplier

The above method considers 'turnover' of marine mammals by adding the estimated exposures of animals together from each of the two seasonal periods. It is quite possible that the turnover of animals in the survey area was greater than this, which was accounted for in an alternative exposure estimate in Shell's 2013 NMFS IHA application (Shell 2013), and is also presented below for comparison with pre-season estimates. A daily multiplier was used to sum the number of animals exposed to RLs ≥120 dB (rms) for each day that dynamic positioning was used at the Burger well site. It is likely an overestimate to assume that the entire population of marine mammals within the ≥120 dB (rms) radius would be replaced every day (i.e., a completely new set of marine mammals present on a daily basis), however, this method was used to provide an upper exposure estimate. The IHA application estimated 14 days of dynamic positioning activity at the Burger well site for each seasonal period, which resulted in multiplying the area ensonified to ≥120 dB (rms) from dynamic positioning by a total of 28 days of operations. The *Nordica* operated in dynamic positioning at the Burger well site in 2013 for only 11 days in Jul–Aug and only nine days in Sep for a total of 20 different days. The area of water around the Burger well site exposed to various sound levels from *Nordica* operations in dynamic positioning during each of the two seasonal periods times the number of days dynamic positioning occurred within each period are shown in Table 6.20. It should be noted that dynamic positioning often was used for only short periods of several hours on a given day; however, any amount of use was counted as a full day for the purpose of the following exposure estimates.

TABLE 6.20. Estimated areas (km^2) ensonified to various sound levels by the *Nordica* operating in dynamic positioning at the Burger well site during Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. These values include daily multipliers of 11 and nine for the number of days dynamic positioning was used at Burger in Jul–Aug and Sep, respectively.

	Level of ensonification in dB re 1 µPa (rms)				
Seasonal Period	**190**	**180**	**170**	**160**	**120**
Jul - Aug	0.00	0.14	2.34	41.81	699.79
Sep	0.00	0.12	1.91	34.21	572.55

Cetaceans

Tables 6.21–6.23 show the estimated numbers of cetaceans that may have been exposed to dynamic positioning sounds at received levels ≥120 dB (rms) based on the density estimates in Tables 6.14 and 6.15 and the ensonified areas considering a daily multiplier in Table 6.20. Approximately four bowhead whales, 22 gray whales, six minke whales, 13 unidentified mysticete whales, four harbor porpoises, and one unidentified whale were estimated to have been exposed to continuous sounds ≥120 dB (rms). There was a single humpback whale observed from each vessel during 2013, however, both were recorded during periods that did not meet analysis criteria and were not captured in these density-based exposure estimates. It is possible that small numbers of humpback whales were exposed to dynamic positioning sounds ≥120 dB (rms). However, all cetacean sightings from the *Nordica* were observed off prospect while the vessel was engaged in general vessel activities (Fig. 6.9).

Seals

Tables 6.21–6.23 show the estimated numbers of seals that may have been exposed to dynamic positioning sounds at received levels ≥120 dB (rms) based on the density estimates in Tables 6.14 and 6.15 and the ensonified areas considering a daily multiplier in Table 6.20. The total number of seals estimated to have been exposed to continuous sounds ≥120 dB (rms) is 169. Approximately 68% of the density based estimates of pinnipeds were of unknown species, however these are most likely to be ringed or spotted seals.

TABLE 6.21. Estimated numbers of individual marine mammals exposed to continuous sounds ≥120 dB (rms) from dynamic positioning activities based on densities observed during seismic and non-seismic periods during Jul–Aug of Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. These estimates include a daily multiplier of 11 for each day on which dynamic positioning was used at Burger during the Jul–Aug period. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0	–	–	2	1	4
Gray Whale	0	–	–	5	2	18
Minke Whale	0	–	–	2	1	3
Unid. Mysticete Whale	1	1	3	2	1	5
Harbor Porpoise	0	–	–	1	1	4
Unid. Whale	0	–	–	1	1	1
Total Cetaceans	***1***	***1***	***3***	***10***	***5***	***21***
Seals						
Bearded Seal	0	–	–	14	7	30
Ringed Seal	11	5	23	18	9	38
Spotted Seal	0	–	–	4	2	9
Unid. Seal	17	8	39	83	41	165
Unid. Pinniped	0	–	–	3	1	7
Total Seals	***27***	***15***	***50***	***119***	***72***	***198***
Pacific Walrus	10	4	27	2	1	8
Polar Bear*	0	–	–	5	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

Pacific Walruses

Tables 6.21–6.23 show the estimated numbers of walruses that may have been exposed to dynamic positioning sounds at received levels ≥120 dB (rms) based on the density estimates in Tables 6.14 and 6.15 and the ensonified areas considering a daily multiplier in Table 6.20. Density based calculations estimate that 28 walruses may have been exposed to continuous sounds with RLs ≥120 dB (rms) while the *Nordica* was engaged in dynamic positioning activities at the well site (6.23). However, all walrus sightings from the *Nordica* were of animals observed on ice while the vessel was in standby off prospect (Fig. 6.13), and these animals would not have been exposed to the same RLs as animals in the water at the same location.

Polar Bears

Tables 6.21 and 6.23 show the estimated numbers of polar bears that may have been exposed to dynamic positioning sounds at received levels ≥120 dB (rms) based on the density estimates in Tables 6.14 and the ensonified areas considering a daily multiplier in Table 6.20. Density based calculations from the estimate that five polar bears may have been exposed to continuous sounds with RLs ≥120 dB (rms) during dynamic positioning at the well site (6.23). Two of three polar bears observed during 2013 operations were on ice and polar bears typically swim with their heads above water; likely these bears would not have experienced levels of sound comparable to marine mammals present well below the surface, due to the pressure release effects near the surface of the water or differences in the propagation of sounds in water and in air.

TABLE 6.22. Estimated numbers of individual marine mammals exposed to continuous sounds ≥120 dB (rms) from dynamic positioning activities based on densities observed during seismic and non-seismic periods during Sep of Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. These estimates include a daily multiplier of nine for each day on which dynamic positioning was used at Burger during Sep. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Gray Whale	0	--	--	1	1	4
Minke Whale	0	--	--	1	1	3
Unid. Mysticete Whale	0	--	--	2	1	9
Total Cetaceans	***0***	***--***	***--***	***4***	***2***	***10***
Seals						
Bearded Seal	0	--	--	14	5	35
Ringed Seal	0	--	--	5	2	13
Unid. Seal	6	2	31	28	12	64
Unid. Pinniped	5	1	24	5	2	16
Total Seals	***11***	***3***	***37***	***51***	***29***	***89***
Pacific walrus	7	3	21	26	6	126

TABLE 6.23. Estimated numbers of individual marine mammals exposed to continuous sounds ≥120 dB (rms) from dynamic positioning activities based on densities observed during seismic and non-seismic periods during all of Shell's equipment retrieval operations, 31 Jul to 12 Sep 2013. These estimates include daily multipliers of 11 and nine to account for each day on which dynamic positioning was used at the Burger well site in Jul–Aug and Sep, respectively. LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetaceans and seals were calculated on the sum of the densities within that group, not the sum of the rounded estimates for each species.

	Estimated No. Individuals					
	Seismic			Non-seismic		
Species	**Mean**	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Cetaceans						
Bowhead Whale	0	--	--	2	1	4
Gray Whale	0	--	--	6	2	22
Minke Whale	0	--	--	2	1	6
Unid. Mysticete Whale	1	1	3	4	2	13
Harbor Porpoise	0	--	--	1	1	4
Unid. Whale	0	--	--	1	1	1
Total Cetaceans	***1***	***1***	***3***	***13***	***6***	***30***
Seals						
Bearded Seal	0	--	--	27	11	65
Ringed Seal	11	5	23	23	10	51
Spotted Seal	0	--	--	4	2	9
Unid. Seal	23	9	69	110	53	229
Unid. Pinniped	5	--	--	8	3	23
Total Seals	***38***	***18***	***87***	***169***	***100***	***286***
Pacific Walrus	17	6	47	28	6	133
Polar Bear*	0	--	--	5	NA	NA

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

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7. SUMMARY OF MARINE MAMMAL MONITORING RESULTS DURING 2013 OPERATIONS[1]

Vessel Summary

Observer Effort

PSOs aboard the *Fennica* were on watch for a total of ~ 10,705km (6651 mi; 1426 h), or 98% of all operations. PSOs aboard the *Nordica* were on watch for a total of ~2169 km (~1348 mi) while the vessels was moving and ~525 h while it was stationary. On the *Fennica,* at least one observer was on watch during 100% (~1969 km; 1223 mi; 276 h) of daylight seismic operations and two observers were on watch for ~96% (1890 km; 1175 mi; 265 h) of daylight seismic operations. At least one observer was on watch during 100% (~479 km; 298 mi; 70 h) of nighttime seismic operations and two observers were on watch for ~ 88 % (425 km; 264 mi; 62 h) of nighttime seismic operations. On the *Nordica,* at least one observer was on watch during 95% of daylight hours and during transitional hours between darkness and morning daylight, regardless of vessel activity (Figures 6.1 and 6.2). Two PSOs were on watch for ~98% (558 h) of daylight operations involving dynamic positioning and at least one PSO was on watch for ~89% (323 h) of dynamic positioning activity at the well site.

TABLE 7.1. Observer effort by vessel activity from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

PSO Monitoring Effort	*Fennica*	*Nordica*
Transit (km)	8440	2598
Seismic (km)	2448	--
Dynamic Positioning (h)	--	419

Marine Mammal Sightings

Cetacean Sightings

Over the entire season, 74 sightings of 130 mysticete whales were observed in the northeastern Chukchi Sea (Table 7.2). Approximately 95% of these sightings were observed by PSOs on the *Fennica*. Most of the cetacean sightings occurred during non-seismic activity near Barrow Canyon off the coast of Wainwright (n=56; Figure 5.5). Since 2007, gray whales have been observed by industry vessels and aerial surveys feeding in the coastal and shoal habitats of the eastern Chukchi Sea, occasionally in groups of up to ~10 individuals (LGL 2013).

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TABLE 7.2. Number of cetacean sightings (number of individuals) from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Species	*Fennica*	*Nordica*	Sightings (Individuals)
Cetaceans			
Bowhead whale	3 (13)	0 (0)	***3 (13)***
Gray whale	30 (67)	2 (2)	***32 (69)***
Harbor Porpoise	1 (1)	0 (0)	***1 (1)***
Humpback whale	1 (1)	1 (1)	***2 (2)***
Minke whale	13 (13)	0 (0)	***13 (13)***
Unidentified mysticete whale	21 (30)	1 (1)	***22 (31)***
Unidentified whale	1 (1)	0 (0)	***1 (1)***
Total Cetaceans	***70 (126)***	***4 (4)***	***74 (130)***

TABLE 7.3. Number of cetacean sightings by seismic status or vessel activity from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Vessel Activity or Seismic Status	Sightings
Fennica	
Seismic	3
Non-Seismic	67
Fennica Total	***70***
Nordica	
Dynamic Positioning during Operations	0
General Vessel Activities	4
Nordica Total	***4***

Seal Sightings

Observers on both vessels had a combined total of 300 sightings of 333 seals during the 2013 operations (Table 7.4). Most seals were sighted from the *Fennica* (86%). The majority of the sightings from both vessels were recorded as unidentified seals (~56%).

TABLE 7.4. Number of seal sightings (number of individuals) from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Species	*Fennica*	*Nordica*	Sightings (Individuals)
Seals			
Bearded seal	50 (52)	12 (13)	***62 (65)***
Ringed seal	41 (44)	3 (8)	***44 (52)***
Spotted seal	6 (16)	9 (9)	***15 (25)***
Unidentified pinniped	11 (12)	1 (2)	***12 (14)***
Unidentified seal	150 (160)	17 (17)	***167 (177)***
Total Seals	***258 (284)***	***42 (49)***	***300 (333)***

Seal Sightings by Vessel Activity – The majority of the *Fennica* PSOs' seal sightings (~92%) occurred during non-seismic activity (Table 7.5). In contrast, most of the seals sighted from the *Nordica* (~72%) occurred during periods when the ship used dynamic positioning for operations on the prospect.

TABLE 7.5. Number of seal sightings by seismic status or vessel activity from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Vessel Activity or Seismic Status	Sightings
Fennica	
Seismic	20
Non-Seismic	238
Fennica Total	***258***
Nordica	
Dynamic Positioning during Operations	28
General Vessel Activities	11
Nordica Total	***39***

Pacific Walrus Sightings

Observers aboard the *Fennica* and *Nordica* had a combined 29 sightings of 52 individual Pacific walruses during Shell's 2013 operations (Table 7.6). Most of these sightings (~89%) occurred from the *Fennica*, and a large percentage of walrus sightings recorded from the *Fennica* were observed on 22 Sep (58%). All of the walrus sightings from the *Nordica* occurred during a single week, 15 Aug to 21 Aug. Observations of Pacific walruses are probably more influenced by specific time periods during which walrus move towards the coast to potential foraging areas using shore haul outs than they are by offshore exploration activities.

Pacific Walrus Sightings by Vessel Activity – The majority of walrus sightings from the *Fennica* (~67%) occurred during periods of non-seismic activity and all of the sightings from the *Nordica* occurred during periods of general vessel activities (Figure 7.7).

TABLE 7.6. Number of Pacific walrus sightings (number of individuals) from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Species	*Fennica*	*Nordica*	Sightings (Individuals)
Pacific walrus	26 (44)	3 (8)	***29 (52)***

TABLE 7.7. Number of walrus sightings by seismic status or vessel activity from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Vessel Activity or Seismic Status	Sightings
Fennica	
Seismic	8
Non-Seismic	18
Fennica Total	***26***
Nordica	
Dynamic Positioning during Operations	0
General Vessel Activities	3
Nordica Total	***3***

Polar Bear Sightings

Polar bear sightings were only recorded by PSOs aboard the *Nordica* (Table 7.8). There were three sightings of five polar bears recorded from the *Nordica.* All polar bears were sighted within a one-week period at the end of Aug.

Polar Bear Sightings by Vessel Activity – Two polar bear sightings involved animals on ice while the *Nordica* was off site due to heavy concentration of ice at the well site; the third sighting was of an individual bear observed swimming in the water during operations at the well site (Table 7.9).

TABLE 7.8. Number of polar bear sightings (number of individuals) from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Species	*Fennica*	*Nordica*	Sightings (Individuals)
Polar Bear	0 (0)	3 (5)	***3 (5)***

TABLE 7.9. Number of polar bear sightings by seismic status or vessel activity from the *Fennica* and the *Nordica* during Shell's shallow hazards survey and equipment retrieval operations in the Chukchi Sea, 17 Jul – 28 Sep 2013.

Vessel Activity or Seismic Status	Sightings
Fennica	
Seismic	0
Non-Seismic	0
Fennica Total	***0***
Nordica	
Dynamic Positioning during Operations	1
General Vessel Activities	2
Nordica Total	***3***

Estimated Number of Marine Mammals Present and Potentially Affected

Disturbance and Safety Criteria

The NMFS required that distances to received sound levels (RLs) of ≥180 and ≥190 dB (rms) be used to implement mitigation measures for cetaceans and seals, respectively. The USFWS required that distances to RLs of 180 dB and 190 dB (rms) be used to implement mitigation measures for Pacific walruses and polar bears, respectively. Both agencies assume that disturbance to marine mammals from pulsed airgun sounds may occur at RLs ≥160 dB (rms) and disturbance from continuous sounds (e.g. from vessels using dynamic positioning) at RLs ≥120 dB (rms). Table 7.10 shows the final measured sound radii from the *Fennica's* airguns and the *Nordica* while stationary in dynamic positioning. Continuous sounds produced by the *Nordica's* dynamic positioning system did not propagate considerable distances at RLs ≥160 dB (rms; Table 7.8; see Chapter 3 for details of underwater sound measurements).

Estimates from Direct Observations

All sightings data were included in the following exposure estimates based on direct observations, regardless of whether they met the data-analysis criteria described in Chapter 4.

Cetaceans Potentially Exposed to Received Sound Levels ≥160 dB and ≥180 dB re 1 μPa (rms)

There were three unidentified cetacean sightings of five individuals observed from the *Fennica* during seismic activities while the full array was active. Four of these cetaceans occurred outside the

Fennica's ≥160 dB (rms) disturbance zone. None of these sightings occurred within the estimated ≥180 dB (rms) exclusion zone of 123 m (404 ft; Table 7.10). One unidentified mysticete whale (possible gray whale) was observed at a distance of 319 m (1047 ft), which was within the measured ≥160 dB (rms) disturbance zone for the full array of 1300 m (4265 ft; Table 7.10). This whale likely was exposed to seismic pulses ≥160 dB (rms).

No cetaceans were observed while the *Nordica* was engaged in dynamic positioning during operations at Burger.

Table 7.10. Comparison of measurements of the ≥190, 180, 160 and 120 dB (rms) distances (in m) for sound pulses from the 4-airgun, 40-in^3 array and 10-in^3 mitigation airgun deployed from *Fennica,* and of the ≥120 dB (rms) radius (in m) for continuous sounds from dynamic positioning operations from *Nordica* in the Chukchi Sea, Alaska, 2013.

	Fennica		***Nordica***
Received Level dB (rms)	**Full Airgun Array**	**Mitigation Airgun**	**Dynamic Positioning**
≥190	20	13	NA
≥180	123	127	NA
≥160	1300	400	NA
≥120	29,000	20,000	4500

Seals Potentially Exposed to Received Sound Levels ≥160 dB and ≥190 dB re 1 µPa (rms)

A total of 20 sightings of 21 individual seals were observed from the *Fennica* while airguns were operating. Seven seals were sighted while the mitigation airgun was active and 14 were observed while the full airgun array was active. All of these individuals were likely exposed to RLs ≥160 dB (rms). Two ringed seals were observed within areas where RLs were estimated to be ≥180 dB (rms); however, no seal sightings occurred within the ≥190 dB (rms) exclusion zone (123 m or 404 ft), so no mitigation measures for seals were requested.

Thirty of the 41 individual seals observed from the *Nordica* were recorded while the vessel was engaged in dynamic positioning during operations at the well site. Of these, 28 individual seals were in the water and two seals were on ice. The two seals on ice were seen >9 km (5.6 mi) from the vessel and were outside the ≥120 dB (rms) zone of influence (4.5 km or 2.8 mi; Table 7.10. The 28 individual seals in the water were within this zone of influence and likely exposed to continuous sounds ≥120 dB (rms) from the *Nordica's* dynamic positioning system.

Pacific Walruses Potentially Exposed to Received Sound Levels ≥160 dB and ≥180 dB re 1 µPa (rms)

Eight Pacific walrus sightings of eight individuals were observed from the *Fennica* while airguns were active and of these, seven walruses were observed within the ≥160 dB (rms) disturbance zone (1300 m or 4265 ft; Table 7.10) and likely exposed to RLs ≥160 dB (rms). The airgun array was shut down for a Pacific walrus approaching the ≥180 dB (rms) exclusion zone on two separate occasions, but neither of these animals was ever observed within the ≥180 dB (rms) exclusion zone (123 m or 404 ft; Table 7.10) while airguns were active. Given the conservative approach taken with the safety radii used for mitigation purposes, it is unlikely that either of the walruses were exposed to RLs ≥180 dB (rms).

No Pacific walruses were observed while the *Nordica* was engaged in dynamic positioning during operations. All walrus sightings occurred while the *Nordica* was on standby away from the well site.

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

No polar bears were observed by PSOs aboard the *Fennica*.

One polar bear was seen swimming in the water within the ≥120 dB (rms) zone of influence (4.5 km or 2.8 mi; Table 7.10) while the *Nordica* was engaged in dynamic positioning during operations at the well site. This individual was potentially exposed to continuous sounds at RLs ≥120 dB (rms), however, the polar bear was observed swimming with its head above water and likely would not have experienced levels of sound comparable to marine mammals present well below the surface.

Estimates Extrapolated from Density

Densities were calculated using data that met the analysis criteria in order to allow for meaningful comparisons (See Chapter 4 and Appendix F). The following estimates based on density calculations assumed that all mammals present were well below the surface where they were exposed to RLs at various distances as reported in Chapter 3 and summarized in Table 7.10 (and also Tables 4.1 and 4.2). Some pinnipeds and cetaceans in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Some marine mammals may also have moved away from the path of the *Fennica* as it was surveying during seismic operations or the *Nordica* as it was using its dynamic positioning system in an avoidance response to the approaching vessel, an active airgun, or dynamic positioning sounds. In the case of cetaceans and seals with higher densities during non-seismic periods compared to seismic periods, the total estimated number of exposures based on non-seismic densities represents the number of animals that would have been exposed had they not shown any avoidance of the airguns or the ship.

Table 7.11 shows the sums of density-based exposure estimates across all of Shell's 2013 survey and equipment maintenance activities compared to the number of exposures authorized in Shell's 2013 NMFS IHA. The totals include the estimated numbers of individual marine mammals exposed to either pulsed seismic sounds at received levels (RLs) ≥160 dB (rms) or continuous sounds from dynamic positioning activities at Burger ≥120 dB (rms) based on densities observed by PSOs during 2013 operations. Estimated exposures to seismic sounds ≥160 dB (rms) from the Fennica were summed from two seasonal periods: Jul–Aug and Sep (See Chapter 5, Table 5.26). Estimated exposures to dynamic positioning sounds ≥120 dB (rms) from the Nordica at Burger within each seasonal period were multiplied by the number of days dynamic positioning occurred during each period, 11 and nine for Jul–Aug and Sep, respectively, prior to summing the estimates from the two seasonal periods (See Chapter 6, Table 6.21).

Cetaceans

Based on the density estimates and the area exposed to seismic sounds ≥160 dB (rms) or continuous sounds ≥120 dB (rms) during dynamic positioning operations, ~23 individual cetaceans, mostly gray whales and unidentified mysticete whales, may have been exposed to RLs at or above these thresholds if they showed no avoidance of the operations (Table 7.11). There was a single humpback whale observed from each vessel during 2013, however, both were recorded during periods that did not meet analysis criteria and were not captured in these density-based exposure estimates. It is possible that small numbers of humpback whales were exposed to the above sound level thresholds.

Total exposure estimates for cetaceans were substantially lower than those presented in Shell's 2013 IHA application (Shell 2013) and those allowed under the IHA issued by NMFS (Appendix A). The lower estimated exposures based on the field data resulted from several factors. First, the measured distances of the 120 and 160 dB (rms) sound isopleths around the Nordica's dynamic positioning operations and the Fennica's airgun array, respectively, were much shorter than those estimated in the application materials. Additionally, dynamic positioning at Burger occurred on 20 days compared to the pre-season estimate of 28 days used in the IHA application to estimate exposures. Lastly, observed densities of cetaceans were lower than those used in the IHA application.

TABLE 7.11. Estimated numbers of individual marine mammals exposed to either pulsed seismic sounds at received levels of ≥160 dB (rms) or continuous sounds from dynamic positioning activities ≥120 dB (rms) based on densities observed during seismic and non-seismic periods during all of Shell's 2013 Chukchi Sea marine surveys and equipment maintenance operations. Estimates are compared to the number of exposures allowed under Shell's 2013 NMFS IHA (Appendix A). LCL and UCL are the 95th percentile lower confidence limits and upper confidence limits, respectively. All fractional values in the table have been rounded up to the nearest whole number. The totals for cetacean and seal species groups were calculated on the sum of the densities within that group, not the sum of the rounded up estimates for each individual species.

	Estimated No. Individuals						
	Seismic			Non-seismic			Authorized
Species	Mean	LCL	UCL	Mean	LCL	UCL	Take
Cetaceans							
Bowhead Whale	0	--	--	3	2	8	209
Gray Whale	0	--	--	10	3	39	270
Minke Whale	0	--	--	3	2	10	10
Unid. Mysticete Whale	1	1	5	6	2	22	--
Harbor Porpoise	0	--	--	2	1	7	35
Unid. Whale	0	--	--	1	1	1	--
Total Cetaceans	***1***	***1***	***5***	***23***	***11***	***53***	611
Seals							
Bearded Seal	0	--	--	46	20	111	178
Ringed Seal	19	9	40	40	18	89	5096
Spotted Seal	0	--	--	6	3	16	102
Unid. Seal	41	16	120	194	94	402	--
Unid. Pinniped	8	2	39	13	4	39	--
Total Seals	***66***	***31***	***151***	***297***	***176***	***502***	5388
Pacific Walrus	30	11	82	46	10	220	--
Polar Bear*	0	--	--	9	NA	NA	--

*Only two polar bear sightings factored into 2013 density estimates, both of which were on ice during non-seismic periods in Jul-Aug. Ice-margin monitoring effort data were insufficient to calculate a density estimate for polar bears. The Chukchi Sea ice-margin density estimate of 0.007 bears/km^2 was taken from Evans et al. 2003.

Seals

Based on the density estimates and area exposed to airgun sounds ≥160 dB (rms) during shallow hazards surveys or continuous sounds ≥120 dB (rms) during dynamic positioning operations, ~297 seals, including ~46 bearded seals, ~40 ringed seals, ~6 spotted seals, and ~194 unidentified seals may have been exposed to RLs at or above the disturbance thresholds if they showed no avoidance of the operations (Table 7.11).

These totals are substantially lower than those presented in Shell's 2013 IHA application (Shell 2013) and those allowed under the IHA issued by NMFS (Appendix A) for the same reasons noted directly above under *Cetaceans*.

Pacific Walruses

Based on the density estimates and the area exposed to seismic sounds ≥160 dB (rms) during shallow hazards surveys or continuous sounds ≥120 dB (rms) during dynamic positioning operations, ~46 Pacific walrus may have been exposed to RLs at or above these thresholds if they showed no avoidance of the operations (Table 7.11). These numbers are relatively low compared to exposure estimates from previous exploration programs, which at times appeared to coincide with areas walruses were transiting through in large numbers after ice had receded beyond the shelf break (Hartin et al. 2013). Relatively few walruses were encountered during Shell's 2013 program compared to previous exploration programs in the same areas.

Polar Bears

Approximately nine polar bears may have been exposed to seismic sounds ≥160 dB (rms) during shallow hazards surveys or continuous sounds ≥120 dB (rms) during dynamic positioning operations at Burger based on densities observed by PSOs during 2013. Two of the three polar bears seen in 2013, however, were on ice and would not have been exposed to the same RLs as those in the water.

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